Accessibility Guidelines for Connected and Automated Vehicles

Contents

Acronyms

Acronym	Full Form
ADS	Automated Driving System
AI	Artificial Intelligence
AV	Automated Vehicle
CAV	Connected and Automated Vehicle
HMI	Human Machine Interface
MDI	Multi-Dimensional Mobility Index
PT	Public Transport
R&D	Research and Development
SLAM	Simultaneous Localization and Mapping
TBD	To Be Determined
TSG	The Standard Guidelines
WCAG	Web Content Accessibility Guidelines
WJG	Whole Journey Guide

Definitions

Disability-related

Definition	Meaning
Accessibility	The ability for persons with disabilities to live independently and participate fully in all aspects of life, ensuring access on an equal basis with others, to the physical environment, to transportation, to information and communications, including information and communications technologies and systems, and to other facilities and services open or provided to the public, both in urban and in rural areas.[1]
Disability	A person's visible or hidden symptoms or manifestations, including one or more of the following: a) total or partial loss of the person's bodily or mental functions b) total or partial loss of a part of the body c) the presence in the body of organisms causing disease or illness d) the presence in the body of organisms capable of causing disease or illness e) the malfunction, malformation or disfigurement of a part of the person's body f) a disorder or malfunction that results in the person learning differently from a person without the disorder or malfunction g) a disorder, illness or disease that affects a person's thought processes, perception of reality, emotions or judgment or that results in disturbed behaviour.[2]
Discrimination	The act of treating a person with disability less favourably than a person without disability in circumstances that are not materially different. The act of not making, or proposing not to make, reasonable adjustments for a person with disability where the failure to make the reasonable adjustments has, or would have, the effect that the person with disability is treated less favourably than a person without the disability.[3]

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[1] Office of the High Commissioner for Human Rights (2006)
[2] Disability Discrimination Act 1992 (2024)
[3] Disability Discrimination Act 1992 (2024)

Transport-related

Definition	Meaning
CAV	Automated vehicles can perform the entire driving task on a sustained basis without human input, either in all conditions or in specific conditions. These vehicles are equipped with an automated driving system (ADS) – that is, a combination of hardware and software capable of performing the entire driving task without human input[4]. Connected vehicles are or will soon be able to communicate with other connected vehicles, infrastructure and traffic management systems. Connected and Automated Vehicles (CAVs) are a combination of these connected and automated functions, which are expected to realise the full benefits of the technology.
Crabbing	When a vehicle can move sideways. This way, the vehicle can manoeuvre a side opening close to a platform, thereby requiring no ramp.
Last-mile connection	The final part of a journey, generally an intermediate transport to the final destination
Remote operator	A worker who is external to the vehicle and is monitoring it to provide additional assistance when necessary

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[4] Department of Infrastructure, Transport, Regional Development, Communication and the Arts (n.d.)

Introduction

Unlocking the potential and addressing challenges of CAVs for inclusive mobility

According to the World Health Organisation (2023), there are approximately 1.3 billion people that have a significant disability, which represents 16% of the world's population. People with disability are affected by at least one disability in the form of visual, auditory, sensory, mobility, speech, immunity or cognitive impairment. Compared to those without disability, people with disability find using public transport 15 times more difficult (World Health Organisation, 2023).

In Australia, there are 5.5 million people or 21.4% of the total population that have a disability (Australian Bureau of Statistics, 2022). Inaccessible public transport reduces the quality of life of people with disability as they are not able to regularly access healthcare and other basic services, work, education and social activities (Golbabaei et al., 2024). The Australian Bureau of Statistics (2022) reported that 1.9 million people with a disability in Australia experienced difficulties using public transport due to their disability.

Connected and Automated Vehicles (CAVs) have the potential to improve public transport equity. Without the requirement of drivers and with more efficient energy consumption, CAVs are predicted to reduce operational costs, which in turn could improve the availability of public transport for all. However, at the moment, many drivers provide assistance beyond what is strictly required, which is something users of CAV may miss. There may not be a driver who can answer questions, keep an eye out for people with disability or lend a helping hand. The removal of a driver or human operator also has advantages, such as providing a consistent driving experience and minimising arbitrary bias or discrimination. The high level of connectivity, sensing and computing power opens opportunities that traditional transport services are not able to provide. CAVs could be programmed to be safer, more consistent and to automatically customise its service, such as by adjusting supporting services or its style of driving to some customers. Ultimately, many people with disability have high hopes for CAVs to provide greater independence and more individualized services.

This document

This document is an overview of suggestions to ensure that CAVs are inclusive and not discriminatory. These guidelines aim to promote consensus and consistency in the vehicle design and operation of CAVs for policymakers, operators and manufacturers of CAVs by presenting the unique challenges of CAVs for people with disability while also presenting recommended solutions - from planning the trip to reaching the intended destination.

Method

These guidelines represent the best practices from guidelines around the world. The guidelines have been developed drawing from existing guidelines from the UK, USA, Canada as well as on Australian research. Many of the suggested solutions follow from the requirements under the Disability Standards Accessible Public Transport 2002 (Transport Standards). However, the guidelines are designed to encourage thinking about accessibility beyond compliance with the Transport Standards.

The development of these guidelines followed a multi-faceted research process to ensure they would be relevant, feasible and evidence based. Given the rapid advancements in CAV technology and its application in public transport, these guidelines are reflective of the most current research, standards, and stakeholder insights. We focused on the end user challenges, even if there aren't apparent solutions right now, so that these guidelines will maintain relevancy in line with future technology development.

This project builds on the previous work of the Centre of Technology Infusion and iMove Australia, 'CAVs: Barriers and opportunities for people with disability' (Van Vulpen et al., 2021). A search was conducted to analyse the existing policy landscape, relevant regulations, and literature on accessibility requirements for CAVs in public transport. This review provided a critical understanding of best practices and identified gaps in existing standards. The analysis also highlighted potential accessibility barriers associated with implementation of CAV in public transport and informed the development of the solutions raised in the guidelines.

The research and recommendations within this document have been shaped by a range of sources, including key guidelines and standards developed by institutions such as Queensland University of Technology (QUT) (Peterson et al., 2024), the University of Michigan (Klinich et al., 2022), the Mineta Transportation Institute (Riggs & Pande, 2021), and organisations such as the Canadian Standards Association (Hartman et al., 2020). Additionally, the work of Claypool et al. (2017), Ferati et al. (2018), Dicianno et al. (2021) and Golbabaei et al., (2024) played a crucial role in informing accessibility considerations.

Stakeholder engagement was undertaken to validate the feasibility and relevance of the proposed guidelines. We received online feedback from people with a disability, public transport providers and advocacy organisations. Professional networks, social media, the iMOVE website, were all used to consult with CAV manufacturers. Whilst some contact was successful, we experienced ongoing barriers to obtain timely, comprehensive feedback. The challenge in establishing and maintaining communication lines with industry, comparative to a similar project in the past, raises a concerning flag that this topic may be lower in priority for these organisations than it was previously. The industry is focusing on commercial viability. Nevertheless, the insights gained were instrumental in refining the guidelines, ensuring they address real-world accessibility challenges, and integrating additional considerations to enhance inclusivity in future CAV deployments.

By incorporating a blend of research, industry expertise, and lived experience perspectives, these guidelines offer a useful framework to support the implementation of accessible and equitable CAV-integrated public transport systems.

Feedback

We hope that this document provides useful guidance to drive innovation in the field of transport accessibility for people with disability, and in the development and operation of CAVs in the future. If you have feedback or questions please reach out to DisabilityTransport@infrastructure.gov.au.

What are Connected and Automated Vehicles?

Automated vehicles (AVs) are able to perform the entire driving task on a sustained basis without human input, either in all or specific conditions. AVs are enabled by a combination of hardware and software components that assess and react to the vehicle's environment (Department of Infrastructure, Transport, Regional Development, Communication and the Arts, n.d.). Connected vehicles are able to communicate with other connected vehicles, infrastructure and traffic management systems (Kühl & Papí, 2023). Connected and Automated Vehicles (CAVs) are a combination of these connected and automated functions, which are expected to realise the full benefits of the technology.

CAVs are expected to advance safety, efficiency, and sustainable transportation systems (Litman, 2023). This report assumes that non-connected AVs will become an exception to the rule (for example, in restricted or off-grid locations) and that automated vehicles are also connected.

Industrial CAVs, such as self-driving trucks in mining, have paved the way for public transport applications. Today, public transport CAVs can come in various modes:

- Automated shuttles are driverless buses that operate short-distance routes and are being deployed globally with around 10–12 passengers. Currently, they are tested in full-size with 30 passengers and 'platooning' configurations (Nguyen, 2019).
- Driverless trains have been used for years in London's Docklands Light Railway and more recently, Sydney's Metro. Advances in Artificial Intelligence (AI) and sensor technology are enabling their use in more complex rail networks, including monorails and metros (Singh et al., 2021).
- Automated trams are being tested in several cities in Europe and Asia to improve transit efficiency and reduce operational costs (Siemens Mobility, 2025).
- Automated taxis are available in a few American and Chinese cities (Li et al., 2022). There are plans underway for these taxis to be available in Singapore, Seoul and Dubai (Channel News Asia, 2025; Seoul Metropolitan Government, 2024; Gulf News, 2025).
- Automated pods, which have been operational for years in controlled environments like Heathrow Airport, transport 1–4 passengers over short distances (Heathrow, n.d.).
- Automated maritime vessels are being developed for both commercial and leisure purposes, including cargo ships, passenger ferries and small personal boats (Gu et al., 2020).
- Automated aerial mobility involves developing automated aerial vehicles, such as drones and air taxis (Madi & Madi, 2024). This sector is still in its early stages.

Connected and Automated Vehicle Accessibility: Guidelines

Delivering CAV transport services for all passengers requires a collaborative approach from operators, infrastructure managers and vehicle manufacturers to address a variety of challenges CAVs pose.

These guidelines focus on the end user experience and the challenges that people with disability and the elderly may face in each stage of their trip, offering solutions through each stage of the journey. These stages include:

1. Pre-journey planning

2. Pickup location

3. Find and authenticate the vehicle

4. Entering the vehicle

5. Manoeuvring within the vehicle

6. In-vehicle interactions

7. Trip progress information

8. Exiting the vehicle

9. Drop-off location and final destination

1. Pre-journey Planning

Access to information that facilitates pre-journey planning is particularly important when riding CAVs compared to traditional modes of transport, as human assistance may not be available throughout the journey.

The user's ability to find this information increases their confidence to embark on their journey and travel on public transport using CAVs.

1.1. Accessible communication and interaction

CAV public transport typically utilises digital means of communication, such as mobile applications and live information screens. While this provides opportunities to enhance accessibility for people with disability, it also poses challenges for people who are unfamiliar with these modalities.

Pre-Journey Planning

What could this look like?

Follow the digital guidelines

- For transport that requires a digital interface, people with various disabilities may find it difficult to provide personal details such as name and contact information into a website or mobile application.

- Challenges may include menus and interfaces that are difficult to navigate for some people with disability and/or do not meet the accessibility standards of the Web Content Accessibility Guidelines (WCAG 2.2).

- Websites and interfaces that are designed to be accessible may still contain certain features that unintentionally hinder access for some users. The WCAG 2.2 provides a series of requirements that meet different levels of accessibility. Aiming for the highest requirement (AAA) will ensure that the best experience is provided for all users.

Have non-digital options

- For people who are unable to use or access digital means of communication due to various reasons (including high cost of devices, lack of skill, intellectual capacity or memory issues), other options should be available. These options may include control button access to remote operators or using a phone to book journeys.

Resist the temptation of advertising

- Due to the widespread use of digital screens, operators may be inclined to use these screens for other non-essential communications such as advertising. However, this can distract and overwhelm some people with disability, which may cause them to miss the information that they need. Therefore, advertising should be limited or non-existent on digital communications throughout the journey.

1.2. Familiarisation with CAV modalities

All passengers will need to familiarise themselves with CAVs as new modes of transportation. This is particularly important for people with disability, where accessibility requirements can lead to increased anxiety if the user is not familiar with the vehicle design. Familiarisation involves users becoming aware of the differences between automated vehicles and vehicles with drivers, as well as understanding how CAVs operate and whether the vehicle is accessible to them.

<u>What could this look like?</u>

Providing instructions for CAV use to passengers

- Following CAV introduction and roll out, it is likely that people with disability will not be familiar with the new mode of transport. As a result, they may lack the knowledge they need to use and operate the vehicle. This includes opening the doors, setting the drop-off location, finding the vehicle exits or positioning themselves at boarding points. Information that guides passengers in using and operating the vehicle should be provided in advance.

Conveying information about the journey when planning

- For CAVs that follow a non-linear or demand-responsive route, information about the route and journey will need to be communicated to users. In situations where the service cannot be booked and has flexibility in its pickup locations, this information will need to be conveyed to the users before the journey begins, and at the pickup location. Methods for communication will need to be in a variety of formats (e.g. visual and audio), ensuring the information provided is fully accessible to people with disability.

Mobility and orientation training

- CAVs will have a different orientation and design when compared to current modes of public transport. This may create anxiety and confusion for people with disability as they learn to navigate this new mode of transport. Operators and providers of CAVs for public transport should provide accessible, free mobility and orientation training for people with disability to ensure that they can confidently and independently board and operate the CAV.

- Training options that include in person sessions is relevant to many people with disability who require practise with the physical modality in order to feel confident with the system.

Communicate accessibility features

- People with disability have highlighted the importance of knowing the availability of accessibility features ahead of their journey. Questions they may have include: 'Will there be a ramp?', 'Will there be space for my guide dog?' or 'Will there be a way to secure my

wheelchair?'. Providing information about the accessibility features in advance allows people to make informed decisions about their journey and travel with confidence.

1.3. Seeking assistance

Providing assistance to passengers throughout the whole journey will still be required despite the lack of drivers, stewards or other humans on board.

While the availability of assistance is relevant throughout the entire journey, addressing and informing people about the availability of assistance in the planning phase allows for preparation.

<u>What could this look like?</u>

Making sure assistance is available

- The operator has a duty of care for CAV passengers, despite the absence of a driver. This involves providing assistance in unforeseen circumstances, such as falls or passenger disputes. The lack of available and immediate assistance poses a risk. The solution could lie in new service models, including remote monitoring using CCTV cameras, ambulant assistance teams, and service agreements with commercial entities along the route where the vehicle is operating. Thorough industry consultation and planning will be needed to develop a minimum service level agreement.

- The inability to interact with staff throughout the stages of the journey can create a sense of anxiety and confusion. Customer service throughout the whole journey will therefore be necessary to provide high-quality user experiences. Remote assistance should be easily requested through an accessible button or phone that is consistent in design and placement, such as emergency help buttons in vehicles, or those in elevators or carpark boom gates.

- During the initial implementation of CAVs it is recommended that these vehicles include an onboard staff to assist users and explain the functions of the vehicle, as people will be unfamiliar with the new technology.

Pre-booking of assistance

- Users should be able to indicate a need for assistance in advance so that the operator can organise this in time.

Training staff on how to interact with people with disability

- Challenges may arise from barriers with staff being unable to communicate with users with different means of communication, such as Auslan or assistive technologies. Training staff to interact with users through multiple means of communication will allow them to effectively assist more passengers with disability.

Creating an emergency plan that provides users with information on who to contact

- In the case of an emergency, some passengers with disability would like to know beforehand what happens and who to contact. Allowing passengers to access specific emergency plans for people with disability will help provide reassurance.

- Training should be available for remote operators, public safety officials and personnel to effectively support people with disability in emergency situations.

1.4. Booking: Destination, vehicle type and seat

Many people with disability need to plan their journey in advance. This includes planning their route, accessing accessibility information for different parts of their journey and booking their preferred seat. CAVs can provide opportunities for users to book trips and priority seats in advance.

<u>What could this look like?</u>

Allow destination setting in advance

- Setting the destination in a potentially busy vehicle causes stress for many people with disability. The vehicle and service may be adapted to allow passengers to set their destination in advance. This will need to be implemented in conjunction with other features such as smart tickets or other kinds of passenger verification methods (see below).

Accurate information regarding stops/stations and terminals

- The accessibility of pick-up locations may be reduced if they are unfamiliar to the user. Providing accurate, clear and precise information in advance regarding the CAV pick-up location allows users to make any changes if necessary and allows them to plan out their personal route to the meeting spot.

Booking the right type of vehicle

- Without prior knowledge of the type of vehicle booked, issues may arise surrounding the size, loading of mobility devices, and other vehicle-specific problems that can prevent the user from boarding the vehicle. Providing information or instructions in advance regarding the type of vehicle and orientation at the pick-up location may help users effectively plan their journey. This may also include information about lifts, ramps and other means of entering the vehicle.

- Provide real-time data on the availability of accessible CAVs so that users can book these vehicles when needed.

- Smart vehicles will have the functionality of adjusting services for the passenger by communicating with them prior to boarding. For example, indicating that a wheelchair user is attempting to board will allow the vehicle to prepare and start the boarding process by extending the ramp. Many other opportunities based on an automated exchange of data with the vehicle are available to customise and cater to individual user needs.

Allow seat booking

- The connected nature of CAVs ensures that appropriate seating will be available for people with disability. Users may feel secure knowing which seats they have been allocated to or are available prior to entering a shared CAV. The Transport Standards require operators and providers to ensure passengers with disabilities can book seats that are located in parts of a public transport vehicle that are appropriate for their travelling needs. This will ensure users are able to take public transport with guaranteed accessible seats.

Provide real-time information

- Service disruptions and missed connections between services can significantly impact people with disability. Providing real-time vehicle and trip information, or alternative route solutions equips users with the necessary information to minimise interruptions along their journey.

Provide information about patronage in vehicle

- Provide information about the number of people, and for instance if another wheelchair user or guide dog is already in the vehicle. This allows people with disability to consider whether suitable seats or necessary accessibility features in the vehicle will be available.

Reduce or remove the impact of changes and delays

- The connected and intelligent nature of CAVs has the potential to reduce the occurrence of delays and trip modifications. Operators should consider demand-responsive models and seamless intermodal connectivity, especially for people with disability.

Prevent disruptions altering the accessibility of the journey

- Replacement vehicles should have the same accessibility requirements as the originally booked vehicle. Any changes to the pick-up and drop-off locations should also be reflected in the new vehicle.
- Predictable response times for how long it will take a vehicle to get to the user will remove the likelihood of disruptions to the service.

Ticketing is a customisation opportunity

The transport experience of people with disability can be significantly improved by understanding their unique requirements. Operators can anticipate individual accessibility needs if they are notified in advance. For example, if a person who uses a wheelchair books a service, a ramp can be efficiently deployed.

What could this look like?

Accessible use of user data for logging in

- People with disability often have to provide the same information about their accessibility needs every time they travel. Being able to set up an account or a common booking option that stores this information would improve the travel experience for people with disability. The account can be set up in advance of travelling, with assistance from another person if necessary, such as a carer or staff.

Pre-payment

- Pre-payment can potentially help avoid misunderstandings and difficult situations for people with disability at public transport stations.

Various means of payments

- For passengers who have difficulties with standard fare payment systems, operators and providers should offer other forms of payment that meets equivalent access principles.

Providing other means of payment such as physical payments at a station or phone call payments allows users to have more options to engage with CAVs.

Provisions for carers, children, or assistance animals and concession payments

- In order to ensure that passengers who require assistance or additional travel companions, including children, parents, assistance animal and carers have equivalent access to the services, concession payments will need to be implemented correctly. Concession ticketholders need to be accounted for when implementing a pre-payment system. A companion should also be included in the fares and bookings to reduce anxiety of passengers requiring assistance, or passengers with young children.

Disability benefits are accepted by the app or web interface

- An improved user experience may be delivered by confirming that concession cards and other disability benefits work for pre-payment. This may include an option for a code to be entered or a card to be uploaded when applying payment, which ensures that disability concessions are applied.

Safely and securely using user data

- Improper protection of user data may result in a variety of privacy issues. Ensuring that data is used and treated according to relevant legal standards that are accepted in the industry will help mitigate these issues. Privacy management and consent is required for this information to be securely managed and stored. This process should also be accessible and easy for people with disability to complete.

Avoid blanket consents

- People with disability may be hesitant to provide personal information due to the discrimination they may experience based on disability. Therefore, allowing people to give situational consent based on a trip or travel period can suit people with disability better.

2. Pickup Location

A key benefit of specific CAV models is their ability to pick up or drop off users from any location. These CAVs may for instance be deployed as a last mile connection or as self-driving taxis. This would be beneficial for many people with disability to whom getting to and from other modes of public transport is a challenge. However, this may also present challenges. Ramps and platforms for demand responsive CAVs will need to adapt to a range of environments. The questions passengers may have for example are: 'Will the pickup location be accessible?', 'Will I be able to enter the vehicle without assistance?' or 'Will I be able to access any form of assistance if I need it?'.

Pickup Location

2.1. Communication of pickup location

Pickup locations for CAVs may include train stations or suburban roads. For every mode of CAV, users will need different ways to find their pickup location.

What could this look like?

Provide precise location data

- Kerb side pickups may occur at any location. Users will need an adequate amount of information about the pickup location prior to boarding.

- Providing specific navigation instructions will help the user arrive at the exact pickup location or at the entrance points for transport hubs.

Let users know that they are at the right location

- Providing users with information that allows them to determine their correct location through a mobile application or accessible signage at a standing post.

- Reassure users by using a mobile application or a landmark such as bus stops to notify them that the vehicle is currently on its way when they arrive at the pickup location. This notification will need to come in multiple accessible forms, such as audio announcements and accurate 'time till arrival' boards.

2.2. Arrive and manoeuvre around the pickup location

With the absence of human assistance, users will need to independently navigate around a transport hub or a busy sidewalk. This could be challenging for people with disability.

<u>What could this look like?</u>

Accessible ways to travel to the pickup location

- Especially when utilising demand-responsive models that have variable routes and pick up points, the CAV could choose a pickup location that is free of barriers for the passengers, particularly if the CAV is made aware of the passenger's accessibility needs. The information provided to the CAV system by the user regarding their accessibility requirements may also allow the system to suggest accessible routes to the pickup location. An example of this is if a location requires using stairs with no alternative options, the pickup location should be changed by the system to a more accessible location for passengers that use mobility devices.

- Default locations suggested by the system should be accessible for all types of disabilities. This includes ensuring disability parking options and accessible loading zones are located around the pickup location.

- Obstacles along the route such as nature strips, bike lanes, rubbish bins and uneven terrain should be identified and accounted for when choosing the pickup location.

Pickup location is unsafe

- Pickup locations should not be positioned at intersections, railway crossings or other potentially hazardous locations. Pickup locations should be on flat and stable surfaces. If the user requests an unsafe pickup location, nearby safer locations should be recommended.

2.3. Seek assistance/interact with staff at pickup location

For public transport, there are many challenges that would typically be solved with human assistance. CAVs will need to compensate for this by providing transport experiences that do not require assistance or provide users with sufficient remote assistance.

<u>What could this look like?</u>

Staff should always be available

- In situations such as passenger disputes or falls, the operator may need to provide assistance through a roaming team or contracts with local companies. (This may be required for in-vehicle incidents too, see chapter 6).

- Despite the availability of good information and communication, a user may still need to ask for assistance and interact with a person, for example, in an emergency. In a transport hub, designated help zones such as those found at some train stations can be set up to allow a user to speak to a person.

- Other means of seeking assistance for less urgent matters should be available when using CAVs, such as automated chat bots, automated hotlines or a phone line dedicated to people with disability, including interpreter, teletypewriter and relay services.

2.4. Prepare to board

Prior to boarding the vehicle, passengers need to prepare by correctly positioning themselves at the boarding point. People with disability may require additional time to travel to the vehicle or a specific location for boarding, and they may be concerned that the vehicle will not wait for them. Additionally, the waiting area and boarding point needs to be safe.

<u>What could this look like?</u>

Recognise passengers that want to board

- CAVs must account for the additional time that people with disability may require to travel to the CAV and prepare themselves for boarding. Applications are available to provide interaction with the vehicle, as opposed to a driver. The vehicle may stop if a user sends a notification that they are nearby the pickup location.

Program in safety

- Safety issues may arise when users need to be lifted into a vehicle, especially if they need to navigate to a loading zone that is also a parking spot for other CAVs. Due to the connected nature of CAVs, a range of safe loading zones can be stored and shared to other vehicles for safety purposes. CAVs can also notify other vehicles if there are issues with the pickup locations to avoid them in the future. While loading a passenger, a CAV may communicate with other CAVs to avoid them entering the loading zone during this time.

- The loading zone should provide sufficient circulation space for a CAV and a user's mobility device. Appropriate kerb cut is needed at pickup locations for wheelchair or mobility scooter users to allow them to be lifted at road level.

Communicating to people outside the vehicle what the CAV is doing

- In the absence of a driver, users outside the vehicle need to be able to understand what activity a CAV will be undertaking to ensure they remain safe. CAVs can communicate arriving, halting and departure. Alerting external users of oncoming vehicles through different multimodal signals, such as lights and sounds, ensures their safety.

- Users inside the vehicle can be alerted if they are in a potentially dangerous situation, such as accidentally opening a door into oncoming traffic.

- Manufacturers should consider how this can be done without creating too much noise or alarms, for instance by using universal 'white noise' sounds.

- The alert signals and communication methods used by the CAV need to be accessible to people with disability when they are inside and outside the vehicle.

3. Find and Authenticate the Vehicle

It can be a challenge for people with disability to identify the correct vehicle for their destination amidst the many vehicles on the road, particularly for users with vision impairments. As such, making sure the automated systems can send the vehicle's location and destination to users, and that users are able to authenticate the vehicle, are critical functions. These systems and authentication processes should be accessible for people with disability.

Find and Authenticate the Vehicle

3.1. Recognise that the vehicle has arrived

For people with visual or auditory disability, or for those who have yet to arrive at the pickup location, there should be ways to identify that the vehicle has arrived. In addition, they should be able to locate key areas of the vehicle, such as ramps and doors.

What could this look like?

Incorporating accurate wayfinding solutions

- Integrate vehicles with digital wayfinding solutions such as GPS locators connected to an application or user interface, haptic vibration interfaces or audio directional indicators. These solutions ensure that the vehicle, its doors, and the front and rear areas of the vehicle can be found.

3.2. Recognise the correct vehicle and hailing

Many people with disability struggle to identify their vehicle. Even in current transport hubs, identifying the correct bus, tram or train for their destination can be a challenge. These issues can become more prevalent when human assistance is not available. It is therefore especially important to develop ways for individual CAVs to become recognisable to users.

What could this look like?

Making the right vehicle stand out to the user

- Ensure that the correct vehicle for the user stands out by using an application to provide real-time location data. External identifiers on the vehicle, such as route codes, vehicle numbers and audible announcements can also assist the user in identifying their vehicle.

- Existing robo-taxi services allow users to input 2-character codes on a coloured display that is customisable by users for colourblind support. They also allow the user to prompt the vehicle to honk or play a melody. Evolving these features to create further accessibility options would help grow the service.

- Alternate means for locating or identifying specific vehicles, such as unique tactile and visual interfaces and auditory beacons must be available for people with disability. These options should also stand out in the surrounding environment, but not cause overstimulation to other users.

Understanding users hailing

- CAVs that do not stop at all locations will need to detect that a user is waiting for the vehicle at the pickup location. Digital solutions such as mobile applications may allow passengers to notify the vehicle they are waiting to be picked up. For passengers that cannot use these solutions, visual detection may be implemented on the CAVs as well as on the platforms to recognise users and the different types of hailing, including standing and raising a hand.

3.3. Vehicle-passenger verification

For vehicle services that require booking or tickets, passengers need to be verified. Common means of verifications, such as 'tap on' cards, are not always accessible to people with disability. As the next generation of transport, CAVs could consider having multiple accessible options for this part of the service.

What could this look like?

Use more than one verification interface

- Standardising the interface and its location will remove the uncertainty of passenger verification. A card-based system linked to an account like a Myki (Victorian public transport card), or cards used by deaf-blind people can be effective and require minimal cognitive demand. However, reach can be an accessibility issue for users with an upper body disability.

- Providing more than one verification method, such as biometrics, tokens, voice or phone recognition may be considered. Setting up and utilising verification methods for the user should be accessible before travelling.

- Entering a code to both verify the vehicle and authenticate the user is common among robo-taxis and app-based vehicle booking services. The interface to input the verification code, such as a mobile application or keypad in the vehicle, should have multiple input options (as above) and be accessible for people with disability. CAV operators and providers should refer to WCAG to ensure accessibility of these interfaces.

4. Entering the Vehicle

Entering a vehicle presents many challenges that are currently solved through human assistance, including communications regarding hazards, doors, and deployment of ramps. While CAVs have the ability to automate many functions that may otherwise require human assistance, such as ramp deployment and opening doors, other issues such as preventing overcrowding and alerting to hazards need to be considered.

Entering the Vehicle

4.1. Proceed from pickup location into the vehicle

Most CAVs have capabilities to provide easy entry by crabbing, kneeling or allowing flush platforms. However, obstacles such as height differences between surfaces can still exist once the vehicle has arrived at the pickup location. Boarding the vehicle with these obstacles can be dangerous if the user is not informed of these potential barriers.

What could this look like?

*Utilise accessibility ramps or lift*s

- If level platform access cannot be assured, automated ramps or lifts must be available on the vehicle. Lifts and ramps need to cater to a variety of assistive vehicles (size-wise and capacity-wise) and should not introduce new risks to the user or other passengers.

- The end of the ramp should flare out to allow entry and exit to be at an angle that is safe for users in a variety of mobility devices.

*User*s should be given warning of any potential hazards on the outside of the vehicle

- When approaching the vehicle and attempting to get on board, some users will be vulnerable to hazards in the surrounding environment, such as other vehicles or bicycles passing by the entry or exit points. Methods that alert users to these hazards include light-based warning displays and auditory signalling.

4.2. Open doors

Users will likely interact with the doors initially when boarding the vehicle. Ensuring this interaction is easy for passengers with disability will increase the accessibility of the service.

<u>What could this look like?</u>

Implement automatic doors

- Automatic doors are preferred for users with disability to board the vehicle. However, there is a chance of causing injury if the doors close on the user. Ensuring that users have enough time to get through the doors can be achieved by methods including door release through an app, sensors on the vehicle interior that detect users entering the vehicle and cameras connected to a remote operator.

- Using sideways opening doors removes a lot of complications regarding additional space needed within the vehicle for and inward swinging door, or potentially opening an outwards swinging door into a bike lane or pedestrian traffic

- Doors opening, doors closing information and ideally door is open, and door is closed indications.

- Low-contrast colours on doors can be difficult for users with vision impairments to detect. Increasing contrast using bright and distinct colours increases the visibility of the doors.

- For users with visual or auditory needs , additional cues are needed to indicate that the vehicle has been unlocked for boarding. Light up displays and clicking noises are current frequently used signals. Tactile alert systems through infrastructure or a personal device such as haptic feedback or tactile paving could be implemented to aid accessibility.

Implement accessibility features for non-automatic doors

- If the doors do not automatically open, the door weight and height need to be considered to allow users to access the doors, such as through a button. This button needs to be accessible, visually differentiated from other features, have a tactile code (such as braille) and potentially have sound or vibration. Door control through an application or using voice control are solutions that are available.

- Ensuring that a CAV alerts the user before opening its doors is important. Other options such as tactile interface or built-up tactile infrastructure may be implemented beyond audible signalling alone. The vehicle can also use sensors to detect the location of the users and ensure that the doors do not open into them.

4.3. Getting onto the vehicle

People with disability also encounter a range of accessibility barriers while boarding, such as additional time requirements, unavailable seats and limited space in the vehicle. These barriers also need to be considered when implementing a CAV transport service.

<u>What could this look like?</u>

People with disability may require more time to get onto the vehicle and secure a seat

- If the vehicle starts moving before the user is seated, it presents a risk of falls. To prevent this, the vehicle should not move until the passenger is ready. This would be determined by the remote operator or human machine interface, even if more time is required. Vehicle or

remote operators can be notified that it is safe to depart through methods such as cameras within the vehicle that are monitored by a remote operator, sensors on seats and vehicle release triggered by an application.

<u>Prevent vehicle overcrowding</u>

- Crowded vehicles can be a problem for people with disability, as they may require seating or additional room to navigate in the vehicle. Providing a pre-booking option allows seats in the vehicle to be reserved in advance, and the number of people allowed on the vehicle can be capped to prevent overcrowding.

5. In the Vehicle

People with disability need to be able to navigate within the vehicle to find a comfortable place to sit or park their mobility device and stow their luggage. Each of these processes have their own challenges, ranging from restraining a wide variety of mobility devices with different requirements, to including spaces near accessible seating for an assistance animal. While some of these solutions exist within the public transport sector, implementing them within CAVs will be particularly important to compensate for the lack of a driver being available to provide assistance.

In the Vehicle

5.1. Navigate to seat/standing area

Moving inside the vehicle is a potentially confusing or hazardous environment if the users are not supported or are unfamiliar with the CAV model. If no human assistance is available, designing vehicles to reduce these challenges is critical in accommodating the uptake of people with disability using these services.

<u>What could this look like?</u>

Instructions for new users

- In vehicles that still have a steering wheel and clutches, instructing passengers to 'let the vehicle do the driving' and not touch the controls are common. These instructions should be provided in multiple formats for accessibility and safety of all. With smart tickets, it can be established whether a user is new to the modality.

Accessibility features to assist in navigating

- For users with impaired vision, navigating through a vehicle can be a confusing experience as there is limited information available from their surroundings to direct them to their seat. Providing a braille or tactile trail, or LED lights or high contrast pathway may assist users to find key features such as seating and help them navigate around obstacles.

Implement supportive infrastructure

- Many people with disability require supportive infrastructure such as handrails. These should be positioned in easily accessible locations that are consistent across different makes and models. For example, at the door or leading to and around accessible seats. They should also be used frequently in modes where users are allowed to stand to increase their stability.

Standardise the position of priority seats

- The location of accessible seating varies across different modes of public transport. However, the seats are mostly found at the front of the vehicle. For new vehicles, having a consistent location for accessible seating will provide users with a sense of consistency throughout their journey.

Reduce the vertical distance from loading surface

- When users who require mobility devices are lifted or loaded into a vehicle, it is crucial to reduce or eliminate the distance from the loading surface to the vehicle floor. This reduces the risk of falls and injuries.

5.2. Sit on the seat

Once a suitable seat has been found, users must be able to safely and comfortably sit down. This process presents many potential challenges for people with disability, including accessible seating not being vacated when advised, and users safely lowering themselves into the seat.

<u>What could this look like?</u>

Include handrails near the seating

- Users with restricted lower body movement often require additional assistance to get into their seats. Handrails should therefore be positioned next to seats to assist users with lowering themselves into the seats.

Seat design

- Seats that provide support (that are curved) are preferred over seats that are flat, as slightly curved seats reduce physical effort to stay upright in curves.

Seat direction

- The ability for the user to adjust the direction that the seats face could allow for customisation, especially for users travelling with a carer and require face to face communication, while still allowing users the choice to face forward.

Remote operator intervention for accessible seating

- If a passenger refuses to give up accessible seating for a person with disability, the remote operator can intervene by microphone. Requiring passengers to pre-book their seats can help to address this issue.

5.3. Passenger secures themselves

There are many ways in which users can restrain themselves on public transport, and it is an important step to increase the safety of the service. Ensuring CAVs have universal, sufficient restraint systems that are easy to use, and providing information to users regarding the operation of the restraint system, help to maintain the safety of these services.

<u>What could this look like?</u>

Reduce the physical effort of restraint systems

- Current restraint systems often require physical effort from the operator to safely secure the user. Restraint systems that do not require significant effort from the user, such as restraints that are automatic or manual with low effort, will reduce the need for assistance when securing themselves.

Creating a universal securement system

- Currently, mobility device restraints are not universal as there are many different types of mobility devices. Most of these devices are designed to require different types of restraints. This may cause issues when designing a universal restraint system for accessible vehicles. Roll-in securement is currently being trialled in the public transport industry and works effectively as a possible automated solution. Consideration should be given to adopting a suitable industry standard among both mobility device and CAV manufacturers. As the world of disability technology evolves, new restraint systems may become more applicable.

Providing information about the restraint process

- Many users may feel intimidated by restraint systems. Providing education and training about the restraint process in advance may alleviate some concern. Additionally, having information displayed in multiple accessible formats within the vehicle gives users the knowledge they need to operate the system.

5.4. Locate space for luggage, assistive devices or assistance animals

Since there will be limited space available in many CAVs, the placement and configuration of storage is an important factor to consider for many users. Ensuring storage space is easy to identify and located within reach of seating areas will improve accessibility for people with disability. There should also be additional space near accessible seating for mobility devices and assistance animals.

<u>What could this look like?</u>

Increasing accessibility of storage areas

- Introducing an automated system that lifts or rotates items will create more opportunities for storage space and help secure personal items to prevent possible theft. This system could use the same or similar methods as the authentication for the CAV to lock the items so they can only be retrieved by the owner.

- Storage accessibility can be achieved in different ways. Placing storage spaces lower to the ground or on the ground increases the accessibility for users with physical limitations. Placing these storage spaces next to allocated seating ensures that users can access their belongings while the vehicle is moving, along with minimising the need to move around the vehicle while it is potentially crowded.

- Storage locations should be marked with a unique tactile surface and high contrast colour to be easily identified by users with low vision.

- Segmented storage areas for larger cargo such as mobility aids, luggage or groceries should be provided. This could work similarly to a plane, where you are able to check-in some luggage and take some with you onboard. This maximises space onboard the vehicle, while giving users the choice about which items to keep with them.

Provide space for assistance animals and assistive devices

- Areas around accessible seating must include enough space for service animals and other additional assistive devices.

- Using high contrast marking and a unique tactile surface around the accessible seating area and the additional space for assistance animals will assist people with low vision in locating these areas.

6. In-vehicle Interactions

Many functions of CAVs will require the user to interact with different parts of the vehicle. Many of the challenges around these interactions can be solved with human assistance, such as requesting a driver to stop at the next stop. However, with the absence of human assistance, there needs to be new automated or remote solutions for these problems, such as a remote operator.

In-Vehicle Interaction

6.1. Pay for ticket as an onboard payment

With the implementation of new modes of transport, such as robo-taxis and shuttles, understanding how to pay for each individual form of transport may become a confusing task for people with disability.

What could this look like?

Frictionless payment

- There are currently many different payment systems available onboard public transport services across Australia. This causes confusion for many users and can result in them being unprepared for their journey. Being able to use the same pass or ticket across metro, regional and interstate travel would alleviate this concern.

- Being able to use a card payment such as debit or credit cards would reduce the barrier of travelling with multiple public transport cards and keeping all of them topped up.

- Automatic ticketing and payment may provide great flexibility and accessibility for people with disability.

6.2. Set/change destination

Most CAVs allow passengers to set their destination in the vehicle through a digital touch screen. However, this excludes people with disability who are unable to use a touch screen. There are many ways to increase the accessibility of a digital interface or provide other options to set or change the destination.

<u>What could this look like?</u>

Set destination prior to boarding

- Users that are unable to use a digital display should be provided with the option to use their own personal devices or public HMIs to set the destination.

Simplified designs while the vehicle is preparing to move or stop

- As the vehicle is moving, tasks required from users within the vehicle, such as moving around or modifying location, can potentially become more hazardous. Having a simplified design with no menus and limited operations allows accessibility for more users.

Implement accessibility features in the human-machine interface

- People with limited reading ability may struggle with a text-based interface. Including optional visual sign language displays or read aloud options that are built into the system allows those users to use the system.

- Many fonts are harder for people with learning disabilities or vision impairments, such as dyslexia or Irlen's syndrome. Using an accessible font increase the readability of the displays for these users.

- Animations and other moving graphics can be overwhelming and overstimulating for some users. Avoiding animations or allowing an option to disable them during the initial engagement with the system removes unnecessary stimuli.

- Accessibility features for users with limited vision should be made available. These features may include high contrast displays that separate text from the background, default font in a large size on text-based displays and the option of changing font size.

- The option to connect a refreshable braille keyboard to a display should be made available to allow users who use braille rather than a touch screen to input details.

- It may be difficult to locate the displays within the vehicle. This could be addressed by having a consistent and universal location for visual displays or interfaces across different models and modes of transport. The location of these displays should be close to accessible seating.

Reduce privacy issues associated with voice control and auditory systems

- Many emerging technologies use voice controls to avoid touch screens or to make adjustments within the vehicle. However, there are potential privacy concerns that can arise when using this system, particularly involving other passengers overhearing an exact destination as it is being set. Just like a good driver would highlight a stop and address the passenger, audible outputs in CAVs could announce a particular user's destination, such as addresses. Allowing connectivity with auditory assistance devices such as hearing loops, or other communication forms with personal devices also reduces privacy concerns.

6.3. Request stop

For vehicles that don't have a driver, the mechanism to request a stop should be accessible to all users, and in the case of a malfunction, there should be several fallback options to prevent users from being trapped in the vehicle waiting for it to stop.

What could this look like?

Button/control are positioned in a way that is accessible

- Similarly to current public transport systems, the stop buttons need be within reach from a variety of positions. With the implementation of screens and digital displays, this is even more important. Ensuring that the buttons and interfaces can be reached from a seated position increases the accessibility.

- Continuing to include braille on buttons, which has already been implemented in current public transport systems, increases the accessibility of the service.

Alternate methods of stopping the vehicle

- If an issue occurs while the vehicle is in operation and it prevents the user from being able to use the button, alternate methods to end the journey need to be implemented. Being able to stop the vehicle using a mobile device allows the user to still halt the vehicle if all the buttons or interfaces onboard the vehicle stop working. Additionally, a remote operator should be able to stop the vehicle and call for a replacement.

6.4. Emergency situations

An emergency button located on the vehicle enables the user to communicate that there is a problem without human assistance onboard. Similar to the stop button discussed in section 6.3, an emergency button and/or selection on an interface needs to be placed in an accessible location and follow the same accessibility requirements. Additionally, due to the more electronic nature of automated vehicles, manual fail safes need to be implemented in case of emergency.

What could this look like?

External communication

- When an emergency occurs, the vehicle needs to inform other road users of the situation to ensure that they are given sufficient space and access to it. This could include signalling using lights, audible announcements and exterior signage on the vehicle to convey information, including audio signalling to notify others that the vehicle is going to do something.

- The connected nature of CAVs can allow it to communicate directly with other connected vehicles, making sure that they are given plenty of time to react.

- Emergency contacts and care facilities can also be notified when needed.

*Emergency procedures, m*anual overrides and backup generators

- The vehicle needs to be able to manage potential emergency situations safely. This would include processes to not only avoid emergency situations, but also deal with emergency situations safely if they do occur. This could include retreating to a safe position, redirecting itself to a medical facility or continuing to its original destination.

- During a crash, many vehicles lose function to its powered components such as sliding doors or automated restraints. Failsafe redundancies should be available, and passengers should be informed if manual activation is required, for instance to open doors.

- Manual overrides for restraints and doors are particularly important as not having them can cause users to become trapped within the vehicle after an emergency.

Emergency plans are easily accessible

- Having no access to the emergency evacuation plans of the vehicle may cause panic and distress amongst users as they may be unaware of what to do in an emergency. Plans should be clearly displayed within the vehicle in a variety of accessible formats.

- Users should be able to prepare ahead of time. Emergency plans should be accessible online in an easy and convenient location. Operators and providers should refer to WCAG to ensure accessibility of these webpages

- Emergency plans should also be available offline, either via mail or physical request at major transport hubs.

6.5. Seek assistance/interact with remote staff while on the vehicle

During the journey, users may have questions about the vehicle or journey. They may also want to be able to reach a staff member or automated service. In situations that would have previously required human interactions, such as a medical emergency, procedures need to be put in place to allow for the user's safety to be prioritised, and for the correct services to be called out to the vehicle.

What could this look like?

Provide the necessary training to staff

- Training should be provided for remote assistants regarding disability responsiveness.

- It may not be feasible to expect remote operators to be able to fluently communicate in sign language, but adequate interpreting services should be available. Using a program through the human machine interface that can understand and translate Auslan for staff and is able to return the staff's response in Auslan or in transcript form to reduce the communication barrier.

Summoning an assistant to the vehicle

- In the case of an emergency, there may be times when a human assistant is required. Having an emergency button or control within the vehicle to summon an assistant to the vehicle through the remote operator may provide better support while travelling. This button should be located near accessible seating to improve accessibility.

- In the case of more populated CAVs, or those that are larger in size, it could become difficult to access an emergency button within the vehicle. Allowing a personal device to request an assistant provides an alternative method where a button is not easy to access.

- Where a user is unable to summon someone to assist them due to a medical emergency or the partial loss of system function, assistants monitoring the vehicle should be able to identify the situation and contact the relevant department to assist.

- Current Robo-taxi services have cameras and microphones within the vehicle, these are only turned on during ingress, egress and if something goes wrong in the vehicle, such as if a seatbelt is removed or the steering wheel is touched. These also signal to the remote operator that something has occurred within the vehicle. Evolving this system for other types of vehicles will help keep people safe during the transit.

6.6. Settle any passenger disputes

Passenger disputes are mostly solved by intervention from either a driver or public transport officers. However, without a person present on the vehicle, there may be fears surrounding the lack of intervention and support. This is particularly the case when it comes to people with disability accessing priority seating and finding space for assistance animals that are occupied by other passengers.

What could this look like?

Remote operator to intervene in intrapersonal issues

- Due to the absence of staff members on the vehicles, there may not be anyone to solve intrapersonal issues or arguments between users of the service. A remote attendant may supervise the interior of multiple vehicles at the same time. They should be able to communicate to users within the vehicle and contact police, public transport officers or other relevant authoritative bodies when required.

Make use of prebooking options

- Pre-booking accessible seating gives users assurance that there will be a seat for them on the vehicle. In the case that someone is occupying the accessibility seat without booking it prior to the trip, the remote operator can intervene.

- Some users do not want to be on a vehicle with assistance animals due to allergies or experiences in the past. Some users require assistance animals and there are a limited number of circumstances when a person with disability who has an assistance animal may be refused access to public transport. Prebooking options for people who do not want to be on a vehicle with an assistance animal could prevent any intrapersonal issues from occurring. Increasing vehicle frequency on a route also reduces the impact of a delay caused by not being on a vehicle with an assistance animal.

6.7. Travel safely and comfortably

Creating a safe and comfortable environment within the vehicle can be done through a variety of means. Making accommodations in the design of transport services can help prioritise the comfort and safety of people with disability.

What could this look like?

Limiting functions that inflict high G-forces

- Current modes of public transport often jolt the user during periods of sudden braking and accelerating or when traveling at high speeds. This is an issue particularly for users who have balance issues. CAVs can travel at controlled speeds to maintain a reasonable G-force, and even adapt these if it is known that a frail passenger is on board. As more vehicles become part of a connected network, it will reduce the likelihood of suddenly requiring braking when equipped with information about the vehicles ahead.

Reduce unnecessary stimuli

- There is a risk that CAV technology and customisation may include unnecessary stimuli which can be potentially overwhelming for some users. To reduce this risk, unnecessary stimuli from within the vehicle can be reduced or removed, including not playing music and reducing any animations on display monitors.

- Like the vehicle interior, the external environment also has the potential to be overwhelming. Tinted windows reduce some external stimulation and increases user privacy.

Headrests for wheelchair users

- It is important to protect and support the head and neck of wheelchair users throughout the journey. Providing head protection, such as headrests at wheelchair stations or accessible seating, will assist in supporting the user's neck. An adjustable headrest that users can raise up and down, or adjusts automatically, may be implemented for further user customisation.

Options for charging assistive devices

- Many assistive devices, including hearing aids, refreshable braille displays or personalised mobile phones, currently require charging, particularly on longer journeys. Providing secure outlets that users can access and use for charging small personal devices on CAVs helps users to feel secure when equipped with their critical devices.

- On long distance journeys, there is the possibility that powered mobility devices may run out of power. Providing mobility device charging stations on conveyances travelling long distances, such as trains, coaches and planes, allows users to travel longer distances and reduces anxiety related to the battery charge.

Safe options for user recovery if they fall

- If a user falls, they will need time to right themselves, or may need assistance. Making sure that passengers are safe and have stability during this time is critical to them being able to use the service. When an accident occurs, either the vehicle or the remote operator should stop the vehicle at the side of the road or somewhere safe. If the user is struggling following the fall, then the remote operator should contact the relevant department to provide appropriate assistance.

7. Trip Progress Information

Anticipating the time to exit the vehicle can be a major source of stress for people with disability. As CAVs will not have a human driver to alert passengers they are at their destination, automated vehicles will need to provide information about the trip progress. The implementation of navigation technology would allow users to track their location throughout their journey, as well as view any changes or disruptions to the journey.

Trip Progress Information

7.1. View the current location of vehicle

Within the current landscape of public transport, precise vehicle tracking must be done through external applications such as mobile phone GPS. The connected nature of CAVs allows this information to be used within the vehicle to accurately display the location of the users along their journey. Ensuring that this information is conveyed in a variety of formats is needed to satisfy the accessibility requirements of the service.

What could this look like?

Present information about location

- Without accurate and reliable updates about the current location and route progress of the vehicle, users can potentially become confused or anxious about getting lost along their journey. This is especially important for people with disability, who may require additional assistance surrounding wayfinding. As the vehicle is aware of all of its surroundings and positionings, CAVs have the opportunity to provide more detailed information about the trip progress throughout the entire duration of the vehicle journey.

Provide alternatives for audible or visual signalling

- Using a variety of mediums for communication, including visual screens, auditory announcements, Bluetooth connectivity to hearing aids and phones, or optional refreshable braille displays will assist in catering to a wider range of accessibility needs.

- Some users may not be able to access public information displays. This can be mitigated by integrating compatibility with personal devices while onboard the vehicle, allowing users to receive information on their device which is customised to their personal needs.

Ensure line of sight to visual information is always uninhibited

- If other users are stationed in areas that block access to visual points of information, it may be difficult to see what is being communicated. This is particularly an issue for users with disability who may struggle to re-orient or manoeuvre themselves. Visual information displays should be elevated and angled to be visible from all accessible seating and most other seating locations. They should also be positioned at multiple points around the vehicle.

7.2. View extra travel changes/disruption

Changes to the vehicle route can increase anxiety and cause some users to become disoriented, especially if they are not aware of the changes or any travel time added to the journey. CAVs have the opportunity to reduce anxiety and disorientation by providing more insightful and accurate information about how the changes will affect the user. This information should be communicated to users in accessible formats.

<u>What could this look like?</u>

Minimise trip delays/changes

- With a limited number of accessible vehicles available, people with disability may have to wait significantly longer than other users for a vehicle that caters to their needs. This is particularly the case when a specific vehicle is delayed or cancelled. Increasing the number of accessible vehicles on the road reduces the likelihood and impact of these delays.

- CAV's also have the opportunity to communicate delays and organise alternative routes which could reduce the occurrence of delays and interruptions to trips.

Clearly convey information about route changes/delays

- If information about route changes or delays is inaccessible to people with disability, it can lead to them missing crucial information that impacts their journey. These changes should be conveyed through a variety of accessible mediums, including visual screens, auditory announcements and personal devices.

Consistent communication methods across all vehicles

- Inconsistent communication across different vehicles can create confusion and anxiety, particularly among people with disability who may struggle to quickly adapt to unexpected differences. Standardised communication methods should be used with an emphasis on accessibility by accommodating for auditory, visual, and tactile requirements.

8. Exiting the Vehicle

While many of the challenges outlined in chapter 4 apply to both entering and exiting the vehicle such as the requirements around doors, ramps and lifts, there are some unique challenges to users leaving the vehicle. As this is the last stage, users should be able to remove any restraints and navigate their way out of the vehicle safely, with all their belongings.
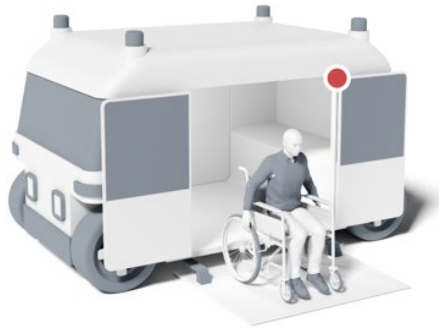
Exiting the Vehicle

8.1. Departing the vehicle

As mentioned in chapter 4, a user may require assistance from a ramp or lift when exiting the vehicle. However, there are additional challenges that arise when exiting the vehicle as the user may exit into a hazardous situation, such as oncoming traffic or a cycle lane. It is also important that the vehicle can notify the user when exiting at a terminal destination so that they can prepare to get off.

What could this look like?

Positioning for lifts and ramps before departure

- Positioning the ramps should occur before users attempt to get off the vehicle. This can be synced up to the opening of doors to ensure the safety of the passengers.

User will need warning if there are any potential hazards on the outside of the vehicle

- Users are often vulnerable to hazards when exiting the vehicle using ramps or lifts. This vulnerability can be reduced by the vehicle warning users about potential hazards, such as traffic, before attempting to alight.

Reduce pressure from other users

- Other users may pressure people with disability to get off the vehicle faster. If the presence of a person with disability is known, through a smart ticket or AI recognition, passengers could be informed to wait until that person has left the vehicle.

Inform users if this is the end destination of the service

- The vehicle should clarify if a stop is interim or terminal through multiple communication methods, including visual and auditory.

8.2. Send the vehicle on

Ensuring that the vehicle does not begin to move while in a potentially dangerous location is important for all modes of CAV.

<u>What could this look like?</u>

User is able to send off the vehicle on their own

- To ensure that the person with disability has sufficient time to alight the vehicle, the CAV should provide the option for the user to send the vehicle on through an app or otherwise.

- In some situations, users may have multiple pieces of luggage which cannot be unloaded off the vehicle in one trip. For these types of vehicles, it is critical for the vehicle to wait until the user sends it off to ensure that users are ready before the vehicle departs.

Indication of departing

- The users should have fully cleared the area before the vehicle begins to move to alleviate possible safety concerns. Before starting to move, the vehicle should provide a number of indicators including sound and lights to indicate that it will start to move.

Lost items

- If a user forgets an item on a vehicle, there should be a way for users to retrieve it. This could be achieved by an on-board camera that can detect missing items and inform remote operators. If smart ticketing is active and the user has consented to being contacted, the person can be informed.

9. Drop-off Location and Final Destination

Upon leaving the vehicle, the journey does not end for a user, until they reach their final destination. This involves either finding their preferred building or location after departing or finding a connecting vehicle. This part of the journey involves navigating the drop-off location, which could be a transport hub or the kerb side. Many of these challenges are covered in chapter 2 which discusses the pickup location. As a result, this chapter explores the challenges unique to the drop off location.

Drop-off Location and
Final Destination

9.1 Locate the final destination and identify path from drop-off location

Without the assistance of a driver, people with disability may struggle to navigate the unfamiliar surrounding environment outside the vehicle. This may leave users feeling disoriented and lost, particularly if their disability makes navigation more difficult. Automated vehicles thereby need to provide information about the environment outside of the vehicle and the location of the user with regards to their final destination.

<u>What could this look like?</u>

Arrive at the preferred place within drop-off location

> Many current services do not account for the exact location when arriving at the drop-off location. For people with disability, this can cause issues if they are too far away but there is a closer drop off point, the route to their final destination isn't accessible, the drop off is on the wrong side of the road, or they are unable to navigate to their desired destination. Specific information about the drop-off points such as bike lanes, footpaths or the side of road should be clearly communicated to the user.

Provide orientation assistance as the vehicle arrives at the destination

- People with disability may require additional time or information when arriving at the drop-off location to orient themselves towards their final destination or the next phase of their journey. CAVs could provide vehicle orientation information in various formats upon arriving at the user's destination, similar to the auditory outputs of some existing navigation applications such as, "Your destination is across the street on your left."

Multiple vehicle trips

- Moving between multiple vehicles during a journey can be challenging, especially if a user misses a connecting vehicle. While there is still a possibility that users may miss their connecting vehicles, CAVs have unique opportunities in terms of communication with other vehicles that could help prevent major delays, especially in demand responsive scenarios.

What could this look like?

Minimise disruptions for connecting vehicles

- If a part of the trip is delayed or interrupted, users may miss connecting vehicles throughout the stages of their journey. This problem may be compounded for people with disability, who may require extra time to transfer from one vehicle to another. The connected nature of CAVs can enable the communication of disruptions ahead of time, and may limit the impact of delays or interruptions where alternate vehicles may be organised.

Innovation Opportunities: Further Research and Development

Most research and development (R&D) for CAVs is conducted in-house by the companies that are developing these services. However, in recent years, there has been an increase in academic research surrounding the impact of CAVs on the lives of people with disability and others.

Access to public transport is critical for people to participate fully in the community and the economy. Many people use public transport to travel to work or study, connect them to family, friends and their community, or help them access support and services, such as healthcare and education.

CAVs provide the opportunity to help facilitate transport services which would otherwise not be viable. For example, by increasing service frequency throughout the day or allowing passengers to access these services outside of normal public transport operating hours (Dianin et al., 2021). Additionally, CAVs have the potential to increase the availability of transport in remote areas that do not have regular transportation services (Nahmias-Biran et al., 2021).

CAVs also provide an opportunity to improve the availability and accessibility of transport for people with disability.

The purpose of this chapter is to provide an overview of research into the challenges that people with disability face, and to present promising technological innovation areas that provide solutions to these challenges. This chapter also identifies areas for further R&D to ensure inclusive CAVs.

Adoption of Connected and Automated Vehicles by People with Disability

People with disability have high hopes for CAVs, but also reservations. This section summarizes the studies that have tested the adoption of CAVs among people with disability.

A systematic review of CAV services for people with disability and others by Dicianno et al. (2021) addressed the gap in the literature at the time, with the few included papers addressing different disability and impairment types. Barriers to accessible CAV services were identified, including the interior design of CAVs. Many vehicles lacked the dedicated space for wheelchairs and other assistive or mobility devices, featured non-standardised seating configurations or locations and were made inaccessible due to crowds from other passengers. The study recommended that future studies should develop accessible designs tailored to each user group's needs and preferences across the entire travel journey. Prospective experimental studies of higher quality that include participation from people with disability need to be undertaken to effectively evaluate outcomes of accessible CAV technology.

Key areas of attention

Reports published by La Trobe University and the Queensland University of Technology have presented the latest findings on the use of CAVs by people with disability. La Trobe University's Centre for Technology Infusion in collaboration with the Department of Infrastructure, Transport, Regional Development and Communications have conducted research on the barriers and opportunities for people with disability regarding CAVs as part of the iMOVE project (Van Vulpen et al., 2021). The report

found challenges for people with disability and opportunities for improvement in the four main areas of vehicle design, monitoring and direct assistance, operations and human machine interface.

The Queensland University of Technology and the Queensland Government Department of Transport and Main Roads identified design principles for an accessible CAV that caters to users with varying needs as part of a three-year research program (Peterson et al., 2024). The key principles that guided the design included communication (face-to-face communication, human-computer interaction, environment communication), stress (emotional stress throughout the journey), safety (risks and safe practices when interacting with vehicles and infrastructure), interface (human interaction with digital or physical elements) and independence of people with disability (how it is facilitated and where it is compromised). Design opportunities were prioritised for seating, restraints, configurability, controls and storage. These opportunities need to consider the design principles of anthropometrics, visibility, wayfinding and route navigation, stewards or attendants or assistance through automation. Additionally, it was found that infrastructure, barriers, risks, regulation and cost were the key limiting factors for the implementation of accessible CAV design, and its success relied on how these factors were managed.

User adoption

With regards to CAV acceptance, research has mostly focused on the opinions of the general population, resulting in a lack of understanding of other user groups with different mobility and communication needs. To solve this issue, Miller et al. (2022) surveyed 300 participants in Singapore through 53 focus group discussions to understand how specific user groups such as the blind, people with low vision, deaf and hard of hearing, mobility aid users, individuals with autism and their caregivers, older individuals and families with young children perceive shared CAVs. Most participants were optimistic towards the potential integration of AVs in public transport but prioritised the need for increased safety and reliability of CAV services (Miller et al., 2022). The most important factors that influenced CAV acceptance were the ease of boarding and alighting the CAV, the availability of onboard safety features and ability to communicate in real-time through a live intercom, the availability of auditory and visual cues in the interior and exterior of the vehicle and a consistent universal interior design. Overall, including a variety of user groups during the experimental test stages of CAVs will likely improve the readiness of those groups to accept CAV technology once introduced.

A recent study by Classen et al. (2023) tested the acceptance of people with disability by involving 42 individuals with disabilities before and after exposure to an automatic test shuttle in downtown Gainesville, Florida, USA. The study found that their perceptions of CAVs were positively enhanced following exposure. Individuals had greater intention to use CAVs with a greater acceptance of CAVs and fewer perceived barriers when compared to baseline. Like the study by Miller et al. (2022), these results suggest that people with disability will be more likely to adopt this technology with increased optimism if they are exposed to it and are included in the testing stages during the development of CAVs. Moreover, the study recommended the installation of handrails on shuttle ramps for safe entry and egress, assistance during on-boarding and off-boarding including carrying personal items, designated areas for the storage of heavy items such as oxygen cylinders, clear signs and messaging inside the shuttle in various formats such as auditory, visual and/or haptic, availability of more flexible route options and innovative business models for mobility vulnerable populations (Classen et al., 2023).

Consistent framework

From the above studies, there is a noticeable lack of a consistent framework for assessing accessibility of CAVs for people with disability.

One recent methodology was developed in Europe for the Transport Innovation for Persons with disabilities needs Satisfaction (TRIPS) project - a four-year EU-funded Horizon 2020 research project focusing on making public transport and shared services more accessible for people with disability and older people. One of the outcomes of the TRIPS project was a multi-dimensional mobility index (MDI), a new tool co-designed with people with disability to evaluate the accessibility of existing public transport. The MDI measures the gap that a user must overcome to have easy access to transportation systems (Repetto et al., 2022). This MDI could be considered by operators to become a global benchmarking tool.

The implementation of the MDI is envisaged as a mobile application which enables users to send their feedback while travelling. This information is then sent to a web dashboard which automatically analyses and visualises the results of audits from users. The MDI collates detailed user feedback data so that it can be used for monitoring and planning access to urban mobility. The MDI is designed around six key parameters: travel time, comfort, affordability, safety, convenience, and autonomy as shown in Figure 1.

Figure 1

Six key metrics of the Multi-Dimensional Mobility Index (MDI)
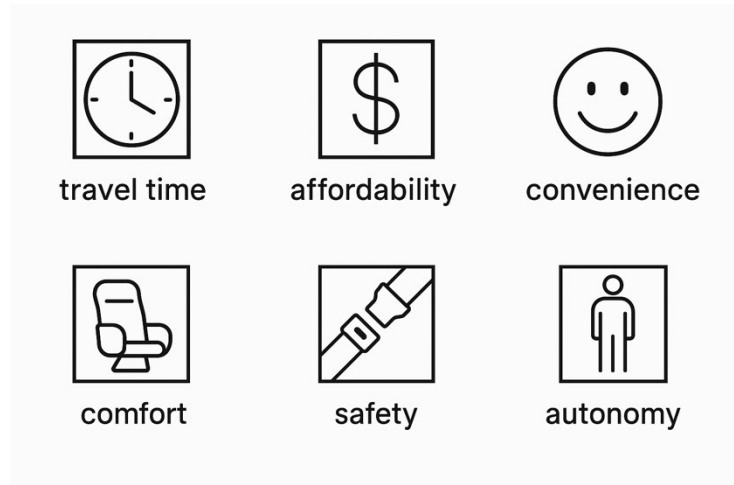
Note: Based on "Developing the multi-dimensional mobility divide index (MDI) as a methodology to assess the accessibility level of public transport systems." Repetto et al. (2022).

Promising Research and Development Opportunities

These guidelines suggest the minimum requirements and opportunities to maximize the accessibility of CAVs for people with disability. With the current state of technology and through further research and development, significant enhancements can be achieved.

The changing mobility landscape provides fertile ground for assistive technologies to make a difference. Assistive products encompass a broad variety of products that cater to a large variety of disabilities. Increasingly, these products are produced with electronic components which make them smart, connected, and often automated.

We reviewed numerous technologies that can help improve the accessibility of public transport for people with disability and grouped solutions into five categories. For each category, we provide examples.

Robotics and automation

To provide a fully independent journey, innovations should focus on making human assistance redundant through robotics and automation. Robotic systems can assist passengers with boarding by lifting and securing wheelchairs into vehicles. Additionally, robots can help transfer passengers between platforms and vehicles by providing automated ramps, conveyor systems or robotic arms. Automated assistive devices such as buckle fastening and release along with universal wheelchair "clamps" can ensure a safe and secure ride for individuals with mobility challenges. The University of Michigan Transportation Research Institute in collaboration with May Mobility installed a wheelchair docking system according to the specifications of the universal docking interface geometry, allowing any wheelchair with compatible hardware attachment to safely and independently be secured in the vehicle (Klinch et al., 2022). In the project, a prototype of the Automated Wheelchair Tiedown and Occupant Restraint System was adapted in an electric vehicle to emulate a shared CAV. A lift was installed on the vehicle to board wheelchair users. An automated donning arm was designed to be placed in the vicinity of the driver's seat to lock the arm and seatbelt in place before travel. The securement system was evaluated by 12 volunteers who are wheelchair users and indicated that they would prefer a ramp instead of a lift to enter the vehicle. All participants successfully docked their wheelchair in the trials but had issues routing the shoulder belt and securing it. Further studies should address the challenges reported by the users to develop better designs for future deployment across CAVs.

Artificial intelligence

Good drivers pay attention and respond to their observations outside and inside the vehicle. Artificial intelligence (AI) is an area that should be developed to compensate for the absence of a human driver and to deliver new features. AI can be used to provide personalised assistance for passengers travelling in CAVs by recognising and adapting to their specific needs. Through advanced sensors, computer vision and machine learning, AI systems can analyse passenger behaviour, physical condition, and preferences to offer support inside and outside the vehicle. For example, AI can detect if a passenger needs assistance with boarding, or automatically adjust the vehicle's speed, temperature or seating according to the passenger. AI can also recognise alarming situations such as a fall or dispute among passengers to help alert a remote operator. An example of an AI-based system is the in-cabin monitoring system that was developed recently by Mishra et al. (2022) to ensure the safety and security of passengers in CAVs. The system consisted of cameras monitoring the in-cabin area with an onboard device that has AI installed for the identification of objects and events. An appropriate database was also created to support other research projects focusing on monitoring higher-level AVs. The database includes a collection of top-view images of real-life scenarios inside the cabin with detected objects categorised as passengers, children, pets, harmful objects, food and drinks, smoking items and electronic devices or other belongings. The tiny-yolo AI model was chosen for the system after comparing the performance and accuracy of other popular algorithms including R-CNN. This demonstrates the ability of AI cameras in this system to detect abnormal or potentially hazardous situations in CAVs and alert remote operators of the situation. In-cabin monitoring systems like this may benefit from further research to extend this to the operational design domain for fully automated vehicles in the future.

Communication and information

Emerging communication and information technologies have the potential to outperform human communication and current information systems. Technology that caters to people with communication challenges is a fast-developing research area. For individuals with visual impairments, text-to-speech systems and screen readers provide real-time updates, while audio-based navigation guides help them navigate their surroundings. Haptic feedback devices, such as vibrating wearables or smart gloves, deliver tactile signals to alert passengers about important information like stop announcements or changes in the journey. Real-time captioning or visual displays can relay information through text, ensuring accessibility to updates and notifications. More assistive technology devices are connected. Similarly to the hearing aid, these technologies offer new ways to keep people with disability informed. AI cameras can also recognize when a passenger has difficulty communicating and provide alternative methods of interaction, like voice commands or gesture recognition.

A recent study by Ranjbar et al. (2022) found that vibrotactile guidance along with information provided in the form of visual, auditory or tactile, allowed users with hearing or vision impairments to independently travel using CAVs. The Ready-Ride and Ready-Move vibrotactile aids communicate with the user through information transmitted in short or long pulses or a combination of both. The commands (arrived/start, turn left, turn right, interrupt/queue and stop) were coded as short or long vibrations through the vibrators placed on each wrist or hand. This allowed users to receive the information they need to assist them on their journey, including before the trip when identifying the correct vehicle, during the trip to identify the right seat and after the trip when finding their final destination. Although users reported the aids to be helpful, it was suggested that vibrations should be delivered in different intensities depending on the type of information sent. Particularly, potentially dangerous situations should alert the user by intense vibrations. The aids were also limited by the amount of information and number of haptic codes sent as the users would need to memorise them. As participants were only able to receive information, future research in this field should look at how these users could control the vehicle through commands such as changing the final destination while considering their unique needs. Additionally, communication aids should be designed to cater to the diverse needs of people with disability and their type of disability, as well as the degree of functional impairment.

Human machine interface

Human machine interface (HMI) systems enable users to interact with vehicles and other ***devices through intuitive and personalized interfaces, ensuring accessibility for people with various disabilities. The current touch display that is present in many CAVs presents a significant accessibility barrier, but there are solutions. For example, voice-activated controls allow passengers with mobility impairments to adjust settings, request information, or control features like climate and lighting. For individuals with visual or hearing impairments, HMI systems can use tactile feedback, or vibrations to communicate essential updates. Gesture-based control interfaces allow users to control the vehicle's features through simple hand movements. Several technologies can also facilitate smart ticketing ('Be in, be out') which can be highly beneficial for people with disability. For example, a smart token with short range connectivity provides ticketing information but also conveys the intended destination to the vehicle, and any special needs that the passenger may have.***

One study co-designed an inclusive mobile application with people with disability to allow them to interact and use CAVs without needing additional assistance (Martelaro et al., 2022). The needs of these individuals before the ride, boarding the vehicle, during the ride and after the ride were considered while designing the app. The app interfaces allow users to have full control over their trip by firstly requesting a suitable vehicle based on their user profile, which lists their accessibility requirements. They are then able to select a specific route to their final destination and find a safe, accessible pick-up location. There are several methods that help users identify their vehicle, such as by flashing the vehicle lights or honking the horn. Once they have boarded the vehicle by sending commands to the vehicle to open a specific door or deploy a ramp, they can then verify that they are ready to depart. During the ride, information is provided about the ride to help users keep track of their trip and in-vehicle or climate controls may be adjusted for their comfort. Additionally, emergency actions are provided in case they need help or there are issues with the vehicle. Once they have reached their final destination, they are able to identify a safe drop off point and exit the vehicle by opening a door or deploying a ramp when they are ready to leave and end the ride. The app enables users to have situational awareness through a 360-degree camera, along with information on local landmarks and alerts sent to users about obstacles during pickup or drop-off.

Navigation

Current navigation technologies, such as those enhanced by Simultaneous Localization and Mapping (SLAM) and other positioning systems, can significantly benefit people with disabilities when finding and accessing CAVs. These systems can guide individuals through complex environments, such as busy transit stations or parking lots. This ensures that they can locate the nearest accessible vehicle with ease. Real-time navigation updates can provide information on the availability of CAVs, route changes and when and where to board. This information helps passengers with visual or mobility impairments to navigate more independently. For example, apps can provide step-by-step directions with audio cues for users with low vision or integrate with smart canes or other assistive devices to offer tactile feedback. This allows passengers to confidently and efficiently reach their destination.

Inside a vehicle, SLAM technology can help orient users by creating a real-time map of the interior space. It can assist in identifying and highlighting key features like empty seats, buttons and doors, thereby enhancing the passenger experience for those with disabilities. SLAM can guide users with low vision to available seats or provide real-time updates about where specific features, like the emergency button or grab rails, are located. This can be integrated with other assistive technologies, such as audio or haptic feedback to make the journey more accessible and user-friendly. An example of a novel assistive navigation app is the Autonomous Vehicle Assistant (AVA), developed from the United States Department of Transportation Inclusive Design Challenge for people with visual impairments (Fink et al., 2023). Assistive navigation and obstacle avoidance capabilities using computer vision allows users to request accessible rides and be safely guided to their vehicle. The app also allows users to create profiles to communicate their accessibility needs to the vehicle and personalise their visual, multisensory user interface. GPS is used to determine the user's location and with the open-source OpenStreetMap database, feedback can be provided through visual, auditory or haptic modes. User testing revealed that although there was a 90% success rate for travel-to-transit using the app for assistance, the speed of instructions given by AVA was difficult for users to quickly process. Specific user training by orientation and mobility experts, and integration of the AVA software on existing user hardware, can help with its future implementation. The positive feedback from users indicate that future studies should expand upon this to provide navigation assistance throughout the whole trip.

Conclusion

Overall, most recent literature regarding the accessibility of CAVs have agreed that CAVs have the potential to improve the quality of life for all people including people with disability. However, there are still significant reservations and challenges that need to be addressed for people with disability. Although the rise in interest for CAVs and people with disability in transport research is encouraging, that momentum needs to translate into practical solutions, many of which are suggested in these guidelines. Further R&D is required to provide full independence for people with disability across the entire travel journey.

Working in Partnership with People with Disability

CAV transport operators and providers should actively collaborate with affected stakeholder groups, including people with disability and their advocates, government and industry.

Engaging with affected stakeholder groups ensures operators and providers understand potential issues and opportunities. It also assists with making informed decisions that take whole-of-journey accessibility into consideration.

The Australian Government Department of Social Services worked with people with disability to develop the *Good Practice Guidelines for Engaging with People with Disability*. The guidelines are designed to help people working in the government, private and not-for-profit sector respectfully and effectively engage with people with disability. The guidelines are based on five key principles.

1. Build mutual respect: Engage people with disability early, intentionally, respectfully, and continuously, and use their contributions effectively.
2. Take responsibility: Create and maintain experiences, activities, spaces, and processes that are inclusive of people with disability.
3. Meet people where they are at: Design engagements that can adapt to people with disability, rather than asking people with disability to adapt to your engagement.
4. Prioritise safety and trust: Be transparent, take concerns seriously, and be an ally.
5. Close the loop: Once your engagement or project is complete, follow-up with people with disability and tell them about the impact their contributions made.

For more information on the guidelines, visit https://www.disabilitygateway.gov.au/good-practice-guidelines

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Appendix 1 – References to Transport Standards and Guidelines

The table below outlines relevant references within the Transport Standards and related Guidelines (current as of March 2025). While these documents should be used to inform the design and implementation of CAVs, the unique and innovative nature of CAVs will require additional considerations and measures to ensure they are accessible for people with disability.

The documents referred to are as follows:

- Transport Standards – The Disability Standards Accessible Public Transport 2002. Further information is available at https://www.legislation.gov.au/F2005B01059/latest/text
- Guidelines – Disability Standards for Accessible Public Transport 2002 Guidelines. Further information is available at https://www.legislation.gov.au/F2005B01059/asmade/2002-08-15/supportingmaterial1/original/pdf
- Reforms – The announced reforms for the Disability Standards for Accessible Public Transport 2002. Further information is available at https://www.infrastructure.gov.au/infrastructure-transport-vehicles/transport-accessibility/reform-disability-standards-accessible-public-transport-2002-transport-standards
- The Whole Journey Guide (WJG) – A guide for thinking beyond compliance to create accessible public transport journeys. Further information is available at https://www.infrastructure.gov.au/infrastructure-transport-vehicles/transport-accessibility/whole-journey-guide/whole-journey-guide-thinking-beyond-compliance-create-accessible-public-transport-journeys
- *Web Content Accessibility Guidelines (WCAG) 2.2* (World Wide Web Consortium (W3C) 2024) are a set of recommendations developed by the World Wide Web Consortium (W3C) to make web content more accessible to a wider range of people with disability. WCAG 2.2 extends Web Content Accessibility Guidelines 2.1, which was published as a W3C Recommendation June 2018.

Pre-journey planning

What could this look like?	Transport Standards Reference	WJG Reference
1.1. Accessible communication and interaction	Guidelines 4.3 Accessible formats, data, apps and technology Reforms Regulatory (TSG) Stage 1-7 (website accessibility) Regulatory (TSG) Stage 2-22 (mobile web systems)	3.1.7 Address Web Content Accessibility Guidelines (WCAG)
1.2. Familiarisation with CAV modalities	Transport Standards 27.1 Access to information about transport services Guidelines 1.18 Explaining and understanding networks 1.25 Education	3.1.1 Providing a richer set of information/data in journey planning tools 3.2.1 Transparent information about accessing stops/stations/terminals 3.6.2 Journey planning tools 3.3.3 Real time information

	1.26 Publicity Reforms Regulatory stage 2-5 (Better communication of accessibility features)	
1.3. Seeking assistance	Guidelines • 33.3 Direct assistance 33.8 Provision of direct access 37.1 Attitude of staff 37.2 Orientation and education programs 37.3 Customer service programs Reforms Regulatory (WJG & TSG) Stage 1-1	3.1.5 Customer service to cover the whole journey 3.7.1 Disruption management planning
1.4. Booking: Destination, vehicle type and seat	Transport Standards 8.8 Notification by passenger of need for boarding device 27.1 Access to information about transport services Guidelines 1.18 Explaining and understanding networks 1.26 Publicity 28.1 Notice of passenger's requirements Reforms Regulatory (TSG) Stage 1-7 (website accessibility) Non regulatory stage 2-7 (real time communication) Regulatory (TSG) Stage 2-22 (mobile web systems) Regulatory (Guidelines) Stage 2-55 (appropriate seats on booked services)	3.1.1 Providing a richer set of information/data in journey planning tools 3.1.7 Address Web Content Accessibility Guidelines (WCAG) 3.3.3 Real time information 3.6.2 Journey planning tools

1.4. Book trip/set destination	Transport Standards 27.1 Access to information about transport services Guidelines 1.18 Explaining and understanding networks 1.26 Publicity Reforms Regulatory (TSG) Stage 1-7 (website accessibility) Regulatory (Guidelines) Stage 1-55 (appropriate seats on booked services) Regulatory stage 2-5 (Better communication of accessibility features) Non regulatory stage 2-7 (real time communication) Regulatory (TSG) Stage 2-22(mobile web systems) Regulatory (Guidelines) Stage 2-55 (appropriate seats on booked services)	3.1.1 Providing a richer set of information/data in journey planning tools 3.3.3 Real time information 3.6.2 Journey planning tools
1.5. Ticketing is a customisation opportunity	Transport Standards • 25.2 Fare payment and ticket validation systems Guidelines • 1.24 Carers, assistants and assistance animals Reforms Regulatory (TSG) Stage 1-5 (digital information screens) Non-Regulatory (WJG) Stage 2-2 (equivalent access) • Regulatory (WJG & STG) Stage 2-23 (accessible fare system elements) • Regulatory (TSG)-Stage 2-29 (location of fare systems)	WJG 3.3.8: Ticketing

Pickup location

What could this look like?	Transport Standards Reference	WJG Reference
1.1. Communication of pickup location	Transport Standards 8.4 Hail-and-ride services 27.1 Access to information about transport services Reforms • Regulatory (WJG & TSG) -Stage 1-7	3.3.5 Drop off/pick up points

2.2. Arrive and manoeuvre around the pickup location	Transport Standards 8.1 Boarding points and kerbs Guidelines 2.1 Access Paths- General 7.2 Formats for providing information Reforms Regulatory (WJG or TSG, TBD) Stage 1-15 (passenger loading zones) • Regulatory (WJG) Stage 1-14 (tactile ground surface indicators) • Regulatory (WJG) Stage 2- 11 (print size and format) • Regulatory (WJG) Stage 2- 13-17 (letter height, contract, brail and tactile lettering) • Regulatory (TSG) Stage 2-14 (location of signs) • Regulatory (WJG & STG) Stage 2-46 (Bus, tram and light rail boarding points on infrastructure) • Regulatory (WJG & STG) Stage 2-49 (accessible passenger loading zones on-street) • Regulatory (WJG & STG) Stage 2-50 (accessible parking spaces)	3.2.4 Precinct planning and coordination • 3.1.2 Provide information in a range of formats • 3.2.2 Pathway quality • 3.2.3 Obstructions • 3.3.5 Drop off/pick up points • 3.4.2 Audible announcements • 3.5.4 Vertical transportation • 3.7.6 Acoustic environment
2.3. Seek assistance/interact with staff at pickup location	Guidelines 33.10 Assistance during boarding and alighting Division 33.3 Direct assistance Reforms Regulatory (WJG & TSG) Stage 1-1 (staff training and communication)	3.1.5 Customer service to cover the whole journey 3.3.6 Customer service
2.4. Prepare to board	Transport Standards 8.4 Hail-and-ride services Guidelines 7.2 Formats for providing information Reforms Regulatory (WJG) Stage 1-14 Regulatory (WJG) Stage 2- 11 (print size and format) Regulatory (WJG) Stage 2- 13-17 (letter height, contract, brail and tactile lettering) Regulatory (WJG & STG) Stage 2-49 (accessible passenger loading zones on-street) Non regulatory stage 2-56 (conveyance dwell times at stops)	3.1.2 Provide information in a range of formats 3.3.2 Amenity considerations

Find the vehicle

What could this look like?	Transport Standards Reference	WJG Reference
3.1. Recognise the vehicle has arrived	Reforms Regulatory stage 1-13 (wayfinding) Regulatory (TSG) Stage 2-14 (location of signs)	3.4.2 Audible announcements 3.5.2 Wayfinding
3.2. Recognise the correct vehicle and hailing	Reforms Regulatory stage 1-13 (wayfinding)	3.2.4 Precinct planning and coordination 3.5.2 Wayfinding
3.3. Vehicle confirms the passenger is correct	Transport Standards 27.4 Access to information about location Reforms Regulatory (TSG) Stage 2-2 (equivalent access) Regulatory (TSG) Stage 2-14 (location of signs) Regulatory (TSG) Stage 2-21 (ICT procurement)	3.1.6 More consistency within the public transport system 3.3.1 Consistency 3.4.2 Audible announcements 3.8.5 Security matters

Entering the vehicle

What could this look like?	Transport Standards Reference	WJG Reference
4.1. Proceed from pickup location into the vehicle	Transport Standards 6.3 Minimum allowable width 8.2 When boarding devices must be provided 13.1 Compliance with Australian Standard — premises and infrastructure Guidelines Part 6- Ramps Reforms Regulatory (n/a) Stage 1-6 (lifts) Regulatory (WJG & STG) Stage 2-40 (Portable boarding ramp edge barriers)	3.2.3 Obstructions 3.4.1 Limit the need for assistance
4.2. Open doors	Transport Standards 12.3 Weight activated doors and sensors 12.4 Clear opening of doorways 12.5 Vertical height of doorways 12.6 Automatic or power-assisted doors Guidelines 12.2 Activation of doors 12.4 Accessible taxis	2.2 Universal design considerations 3.4.2 Audible announcements 3.7.6 Acoustic environment

4.3. Getting on the vehicle	Reforms Non regulatory stage 2-56 (conveyance dwell times at stops) Stage 2-55 (Appropriate seats on booked services	

5. Manoeuvring within the vehicle

What could this look like?	Transport Standards Reference	WJG Reference
5.1. Navigate to seat/standing area	Guidelines 31 Priority 31.1- Location of priority seats Reforms Regulatory (TSG) Stage 1-3 Regulatory stage 2-15 (braille specifications) Non regulatory stage 2-56 (conveyance dwell times at stops)	3.4.3 Vehicle fleet consistency
5.2. Sit on the seat	Transport Standards 31.2 Information to be provided about vacating priority seating Guidelines 31.2 Vacating priority seats Reforms Regulatory (TSG) Stage 1-3 (priority seating)	3.4.3 Vehicle fleet consistency
5.3. Passenger secures themselves	Guidelines 1.22 Safety 9.5 Active and passive restraining system 9.6 Active restraining systems 9.7 Passive restraining systems Reforms Non-Regulatory (WJG & TSG) Stage 2-53 (passive restraints) Non-Regulatory (WJG & TSG) Stage 2-54 (active restraints	
5.4. Locate space for luggage, assistive devices or service animals	Transport Standards 28.3 Location of carers, assistants and service animals Guidelines 1.24 Carers, assistants and service animals 30.2 Disability aids to be cabin or accompanied luggage 30.3 Entitlement to baggage allowance 30.4 Transport of disability aid on same conveyance as passenger 30.5 Assistance to stow or retrieve mobility aid	

In-vehicle interactions

What could this look like?	Transport Standards Reference	WJG Reference
6.1. Pay for ticket if onboard payment	Transport Standards 25.2 Fare payment and ticket validation systems	WJG 3.3.8: Ticketing
6.2. Set/change destination	Transport Standards 17.5 Electronic notices Guidelines 7.2 Formats for providing information Reforms Regulatory (TSG) Stage 2-21 (ICT procurement) Regulatory (WJG) Stage 1-16 (provision of information in multiple formats) Regulatory (WJG) Stage 2- 11 (print size and format) Regulatory (WJG) Stage 2- 13-17 (letter height, contract, brail and tactile lettering)	3.8.5 Security matters 3.1.2 Provide information in a range of formats
6.3. Request stop	Transport Standards 21.3 Location of passenger-operated controls for opening and locking doors 21.4 Signal devices for conveyances that stop on request	
6.4. Emergency situations	Transport Standards 19.1 Emergency warning systems Reforms Regulatory stage 1-11 (emergency egress)	
6.5. Seek assistance/interact with remote staff while on the vehicle	Transport Standards 27.2 Direct assistance to be provided 33.8 Provision of direct access 33.11 Assistance while travelling Guidelines 33.8 Provision of direct access Reforms Regulatory (WJG & TSG) Stage 1-1 (staff training and communication)	3.1.5 Customer service to cover the whole journey 3.4.5 Driver and staff training and passenger awareness 3.4.7 Passenger communications
6.6. Settle any passenger disputes	Transport Standards 31.2 Information to be provided about vacating priority seating Guidelines 31.2 Vacating priority seats	
6.7 Travel safely and comfortably	Guidelines 1.22 Safety 1.19 Orientation and motion 9.7 Passive restraining systems	3.8.1 Supporting the journey

	Reforms Non-Regulatory (WJG & TSG) Stage 2-53 (passive restraints)	

Trip progress information

What could this look like?	Transport Standards Reference	WJG Reference

7.1. View the current location of vehicle	Transport Standards
	27.4 Access to information about location
	
	Guidelines
	27.2 Formats for providing information
	
	Reforms
	Regulatory (WJG) Stage 1-16 (provision of information in multiple formats)
	Regulatory (TSG) Stage 2-2 (equivalent access)
	Non regulatory stage 2-7 (real time communication)
	    • Regulatory (TSG) Stage 2-14 (location of signs)
		3.4.2 Audible announcements
		3.5.2 Wayfinding
		    •

7.2. View extra travel changes/disruption	Reforms Regulatory (WJG) Stage 1-8 (Communication during service disruption)	3.4.7 Passenger communication 3.7.1 Disruption management planning 3.7.2 Communication 3.7.3 Help/meeting point

Exiting the vehicle

What could this look like?	Transport Standards Reference	WJG Reference
8.1. Departing the vehicle	Transport Standards 6.3 Minimum allowable width 8.2 When boarding devices must be provided 13.1 Compliance with Australian Standard — premises and infrastructure Guidelines Part 6 Ramps 2.1 Unhindered passage • 30.5 Assistance to stow or retrieve mobility aid Reforms Regulatory (n/a) Stage 1-6 (lifts) Regulatory (WJG & STG) Stage 2-40 (Portable boarding ramp edge barriers)	

8.2. Send the vehicle on	Guidelines 30.5 Assistance to stow or retrieve mobility aid 30.2 Disability aids to be cabin or accompanied luggage Reforms Non regulatory stage 2-56 (conveyance dwell times at stops)	

Drop-off location and final destination

What could this look like?	Transport Standards Reference	WJG Reference
9.1. Locate final destination and identify path from drop off location	Transport Standards 27.2 Direct assistance to be provided 27.4 Access to information Guidelines 37.2 Orientation and education programs 37.3 Customer service programs Reforms Regulatory stage 1-13 (wayfinding) Non regulatory stage 2-7 (real time communication)	3.1.5 Customer service to cover the whole journey 3.3.3 Real time information 3.3.6 Customer service 3.5.2 Wayfinding
Multiple vehicle trips	Reforms Regulatory stage 1-13 (wayfinding) Non regulatory stage 2-56 (conveyance dwell times at stops)	3.5.2 Wayfinding

Appendix 2 – Global Vehicle Specification Standards

Existing vehicle specifications vary internationally, and many countries have their own standards. Below we provide vehicle specifications, which, if followed, will ensure that the vehicle meets the specifications of a broad range of countries.

We have reviewed international accessible public transport standards to identify a 'Globally Accepted Value', which creates a benchmark that ensures vehicles meeting this standard are accepted across all international regulations. This includes legislation in Australia (Standards Australia, 2010; DITRDCA, 2022; DIRTDCA 2022; Federal Register of Legislation, 2022; DITRDCA 2002; Commercial Vehicle Compliance 2022), Canada (Standards Council of Canada, 2010; Government of Canada), the U.S. (US Access Board, 2022; US Access board 2016), Europe (ECMT, 2006), the UK (UK Government, 2022), Japan (MoLITT, 2006), and Singapore (Singapore Building and Construction Authority, 2019).

Please note that these are excerpts we believe can be helpful. For comprehensive lists of standards, please refer to the source documents.

Vehicle Aspect	Specifications: (This value indicates acceptance in other countries)	Source
Doors (external and internal)	Mobility vehicle doorways - width = 870mm, access depth = 1508mm. Area = 1.31m2	QUT
	Globally Accepted Value: Doorway for clear opening: 850mm (w) Manoeuvring area for sliding door: 1200mm (w) x 1350mm (d)	Singapore accessibility standards Europe accessibility standards
Allocated space	Allocated spaces for those with accessibility needs should be 900mm wide x 1350mm deep. The height for the standing person should be 2300mm, and 1410mm for wheelchair users.	Australian accessibility Standard 9.4.2
	At least one allocated space must be provided in each bus with less than 33 fixed seats	Australian accessibility Standard 9.4.2
Knee and toe/Foot space	To protect wheelchair users, knee and toe/foot spaces are specified as below: • Toe: 230mm(d) x 280mm(h) • Knee: from the highest to the lowest parallel height, the depth of the knee space shall decrease at a uniform rate with height. (US indicated the rate: 125 mm in depth for each 150 mm in height)	Australian accessibility Standards

Vehicle Aspect	Specifications: (This value indicates acceptance in other countries)	Source
	• Maximum vertical space (mostly located on the side of the obstacle close to the body): 205(d) x 685(h) • Maximum parallel space (on the side of the obstacle close to the floor): 280(d) x 230(h) Foot space: • Under 280 height part: 510 depth (knee 280 + toe 230) Over 280 height part: 280(d) x 230(h) and 205(d) x 685(h)	Canada accessibility standards
Manoeuvring space	This the space for a wheelchair or similar walker to complete a 180-degree rotation. This dimension is for interior spaces or flat ground. The recommended space is 1700mm (w)d 2070mm (d).	Australian accessibility Standards Canada accessibility standards
Reach range	Reach range means the range of heights that a wheelchair user's hands can reach. The 'depth' refers to the depth of the obstacle from the outside to the wall. The height data for this depth, refers to the highest height that the wheelchair user can reach when facing the obstacle, that is, the reach depth. Some areas also declare the grab depth (the highest height that can grab an item), which is usually 10mm less than the reach depth. • Forward: 400 – 1200 mm • Maximum forward obstructed: from its surface to 1100mm for 600mm depth objects • Sideward: 380 – 1220mm • Maximum sideward obstructed: from its surface to 1170mm for 600mm depth objects.	Australian accessibility Standards Canada accessibility standards America accessibility standards
Aisles	Aisles should be at least 914 mm wide	University of Michigan
	Tactile paths (TGSI) Contrast=30-60%+	QUT
Lighting	The standard for light level varies according to the location. • Path (include stair and ramp): 150 lux • Countertop: 250 lux • General display: 200-300 lux • Control part: 150 – 200 lux or 100 from itself	Australian accessibility Standards Canada accessibility Standards

Vehicle Aspect	Specifications: (This value indicates acceptance in other countries)	Source
		Europe accessibility Standards
Viewing range	The wheelchair user's field of view. When installing the seats, it is necessary to consider that the passengers in the rear row have sufficient visibility. The recommended range is 800-1400mm (h)	Singapore accessibility Standards
Visual characters	The recommended character size or height depending on the horizontal viewing distance. See Australian accessibility standards for the minimum letter height corresponding to the viewing distance.	Australian accessibility Standards
Signage	This refers to where the signage should be installed and the internal elements (graphics, tactile characters, braille, etc.). • Height: centreline at 1500 • With obscured: >2600 • Raised letter: 1 – 1.5 • Character high: 16-50 • Pictogram high: 150 (cannot specify a range for all countries)	Singapore accessibility Standards Canada accessibility Standards
Handrails	Luminance contrast = 30%+ contrast to with surrounding surfaces	QUT
	Handrail diameter falls within a 30-40mm range	AS1428. 1 (2009) Clause 12 (b)
	The global accepted values handrails are; • Diameter: 32-45 mm • Extended: >305mm long • Located height: 865-900mm (665-700mm for extra shorter one) • Clearance between wall and handrail: 60-70mm (cannot specify a range for all countries)	American accessibility Standards Europe accessibility Standards
Active Listening systems	Sound level requirements for hearing enhancing systems can ensure they will still be able to be heard above ambient sound, • Sound pressure level -110-118 dB	American accessibility Standards

Vehicle Aspect	Specifications: (This value indicates acceptance in other countries)	Source
	• Signal-to-Noise Ratio -18 dB • Peak clipping level - ≤18 dB	
Warning system	For visible alarms, Australia stipulates that the flashing frequency should be about 1 Hz. For audible alarms, Australia stipulates 'except that level shall exceed by 15 dB(A) the noisiest background sound pressure level averaged over a period of 60 s, and the level shall not be less than 75 dB(A)'(Design for access and mobility Part 2, 2010).	Australian accessibility standards
Wheelchair Stations	The wheelchair stations should fit within a 1524 mm diameter circle of clear space	University of Michigan
Light level		
Technical Requirements around Wheelchair tiedown and occupant restraint systems		AS/NZS 10542.1:2009
Ramps	Limit the difference between the floor and entry surfaces to achieve ramp slopes with a grading less than or equal to 1:8	Steinfield et al, 2020
	Ramp slope to road is 4.8 (1:12) degrees or less	University of Michigan
Landing	The landing at the top or bottom of the ramp should have the following specifications: • Wide; at least as wide as the path • Landing between the path/ramp/stair: >1700 long • Landing at top or button of ramp/stair: >1500 long	Canada accessibility Standards
Step/stair	These standards do not distinguish between outside and inside the vehicle. The globally accepted value: Riser height: 150mm Tread depth: 300mm Extend noise: ≤25	Singapore accessibility Standards
Controller or device	This is a general standard for operation part, such as force required or position; • Clear floor area: 900mm(w) x 1350(mmd) • Height: 700mm – 1200mm • Auto-door control height: 900mm – 1100mm • Force: ≤19.5 N	Australia accessibility Standards Canada accessibility Standards

Vehicle Aspect	Specifications: (This value indicates acceptance in other countries)	Source
Stop request button	• Located height: 900 – 1100mm • Diameter: >25mm (cannot specify a range for all countries below)	Australia accessibility Standards