The impact of automated transport on disabled people: detailed methodology and findings

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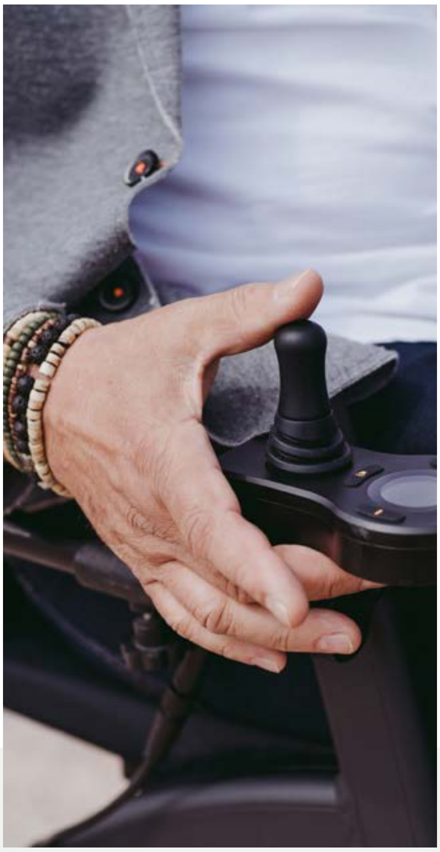

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PPR2050

TRL THE FUTURE OF TRANSPORT

RiDC Research Institute for Disabled Consumers

Report details

Project funded by:	Motability Foundation
Project/customer reference:	11226322
Copyright:	© TRL Limited
Report date:	August 2024
Report status/version:	1.0

Quality approval

Role	*Name*
Project Manager	Lucy Fuller
Technical Reviewer	George Beard

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Acknowledgments

This report was produced by TRL (Annabel Knightley, Alice Holcombe, Bharti Gupta, George Beard, Jack Hitchings, Joe Forrest) and RiDC (Eric Harris, Hayley Dawson, Indigo Ayling, Naomi Care).

The project team is grateful to Professor Matthew Campbell-Hill for his independent review and advice throughout this project, and to members of the project Advisory Group for their inputs and feedback on the work.

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Introduction

This report is a supplementary document to the 'The impact of automated transport on disabled people' Summary Report. This document provides the detailed methodology and findings for the research tasks undertaken within this project. The project was undertaken by TRL in partnership with the Research Institute for Disabled Consumers (RiDC), with funding provided by the Motability Foundation.

This research project was designed to address to following overarching objective:

> *To support the development of inclusive automated transport technologies and services by understanding the needs, perceptions, and challenges faced by disabled people.*

To achieve this primary goal, four key research questions were considered:

1. Identify the benefits of automated transport for disabled people.
2. Identify and prioritise the challenges faced by disabled people with automated transport.
3. Identify the extent to which accessibility is currently being considered in the design and development of automated transport technologies and services, including any good practice examples.
4. Identify design principles and recommended solutions to support the design, development and implementation of inclusive automated transport.

A programme of research was developed to answer these key research questions and achieve the overarching objective. This research consisted of five main tasks, each of which are detailed in full within this Technical Appendix:

- Task 1: Evidence review
- Task 2: Stakeholder engagement
- Task 3: End-user focus groups
- Task 4: End-user survey
- Task 5: Usability and accessibility trials

Firstly, the systematic evidence review (Task 1) established the current evidence base for accessibility in automated transport technologies and services. This therefore acted as a foundation for how best to design the methods applied throughout the subsequent research tasks to draw out the richest and most useful findings. The two engagements tasks that followed (Tasks 2 and 3) allowed for insight to be drawn from relevant industry, expert, and end user groups to fill any research gaps identified in Task 1, as well as helped shape the survey used within Task 4. This survey task then collected data from a wider sample of disabled people across various topics that were informed from the findings from the preceding tasks. Lastly, the series of usability and accessibility trials conducted as part of

Task 5 were able to directly evaluate the design efficacy of vehicles and services with groups of disabled people. Again, discussion guides were developed for these trials based on findings from the earlier tasks to draw out the most valuable findings.

Each chapter of this Technical Appendix details one of the research tasks, including the detailed method and in-depth findings for each. Relevant research materials (e.g. topic guides, survey questions) are also included as appendices.

Task 1: Evidence review

1.1 Evidence review: Introduction

Automation is significantly disrupting the transport sector. Various automated transport technologies are being developed, including vehicles which move people and are operated by a user (for example private automated cars); vehicles which move people but are not operated by the user (for example shuttles); and vehicles which move goods (for example delivery drones or robots). As well as improving safety and efficiency, a key driver for automation is to enable people (who might previously have been excluded) to travel or access goods or services. However, history shows that accessibility of new technology and services often slips down the agenda in favour of rapid deployment and a need to generate return on investment. For example, the lack of consideration of accessibility in electric vehicle (EV) charging station design has led to a need for expensive retrofitting which could have been avoided. Considering accessibility when technology is still in its infancy is therefore vital to ensure the same mistakes are not made again; the needs of disabled people must be considered in the development of automated transport.

In this report, the term disabled people refers to anyone who has a physical or mental impairment that has a 'substantial' and 'long-term' negative effect on their ability to do normal daily activities (GOV.UK, n.d.).This research project was developed to address this gap, by producing a robust evidence base for designers, developers, and policy makers working in automated transport, to ensure more inclusive vehicles and services are developed.

Specifically, this research seeks to address the following overarching objective:

> *To support the development of inclusive automated transport technologies and services by understanding the needs, perceptions, and challenges faced by disabled people.*

In this evidence review, we define 'automated transport' in line with Level 5 Automation as set out in the SAE Autonomy Scale (vehicles that do not need a driver to complete any of the driving tasks). We also focussed on vehicles which can transport a person, or people, rather than goods. We chose to focus on Level 5 automation as this is the stage of automation that has the greatest potential to prompt changes in vehicle design, and open up restrictions on who can operate a vehicle. Due to not having to cater for a driver, the layout of vehicles could be altered to focus more on the needs of passengers. It is therefore possible, in theory, for these vehicles to be more accessible. Level 5 may also allow for new business models which may be commercially or operationally viable due to the lack of driver.

Additionally, regarding privately-owned vehicles, it is possible that those who currently cannot drive a non-automated vehicle may be able to own/use their own private Level 5 automated vehicle.

Note that for some of the project tasks which follow this evidence review (Tasks 2-5) we will also seek to investigate privately-owned vehicles with lower levels of autonomy (Levels 3 and 4, as defined by SAE) to understand accessibility needs related to the transition moments when moving from manual to automated modes, and vice versa.

To achieve this primary goal, the following key research questions have been established:

1) What are the potential benefits of automated transport for disabled people?
2) What are the existing barriers disabled people face when interacting with current transport services?
3) What challenges will disabled people face in interacting with new automated transport technologies?
4) What examples of good practice are emerging in this area to guide future developments?

The project consists of several tasks which will be undertaken to answer these questions:

- Task 1: Evidence review – To establish the current evidence base related to accessibility in automated transport technologies and services.
- Task 2: Industry and expert engagement – To draw insight on how automated transport designers and service providers are currently considering and addressing the accessibility needs of disabled people.
- Task 3: End-user focus groups – To collect in-depth data around accessibility needs, barriers, and opportunities with automated vehicles and services.
- Task 4: End-user survey – To explore the findings drawn from Task 3 with a wider sample of disabled people.
- Task 5: Usability and accessibility trials – To evaluate the design efficacy of vehicles, services, and service interfaces.

This report details the method, findings, and conclusions from Task 1. This review highlights key insights on existing transport issues faced by disabled people, how these issues may apply to automated vehicles and services, and examples of good practice solutions which can be applied to overcome accessibility issues with future automated transport services.

1.2 Evidence review method

The evidence review took a systematic approach consisting of three main tasks: literature search, literature assessment, and in-depth review. This approach allowed for a critical appraisal of past research and a synthesis of findings from across all reviewed evidence. A summary of the evidence review process is illustrated in Figure 1. Further details about each of the three main review tasks are provided in the following subsections.

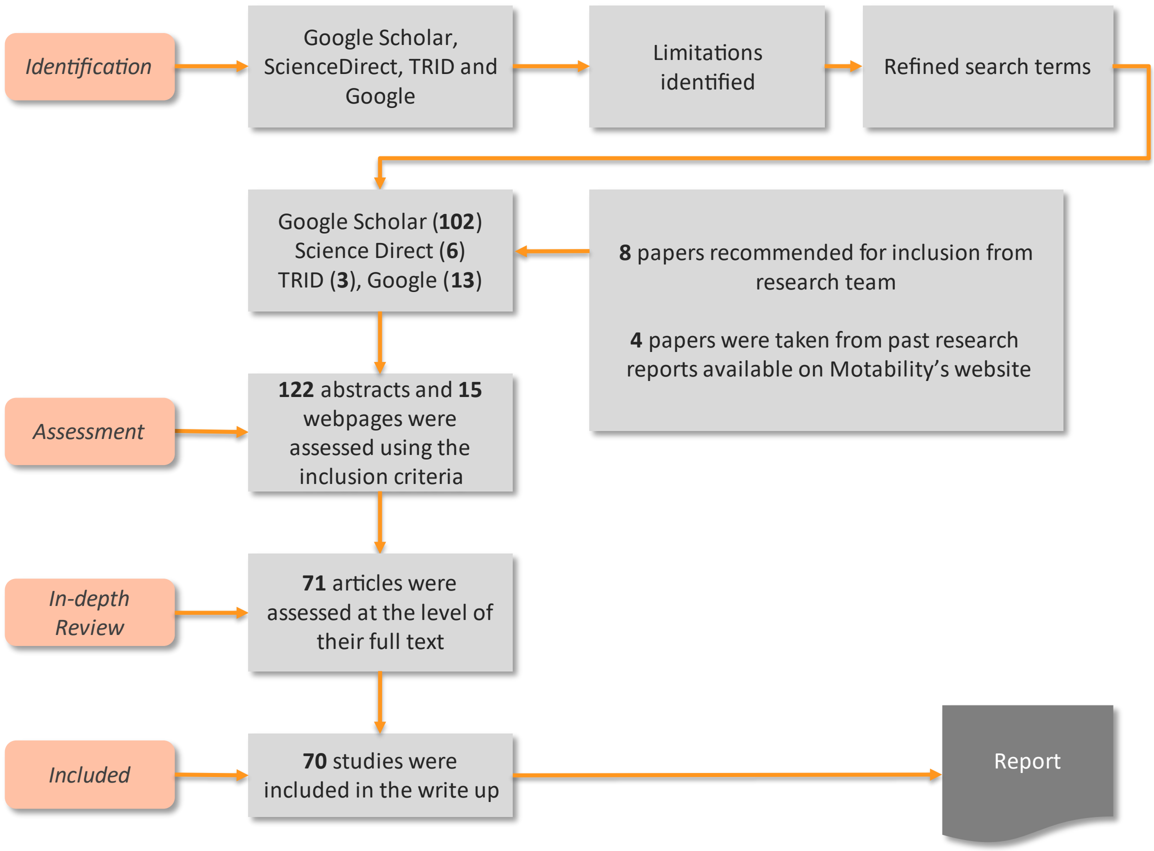

Figure 1: Flow chart depicting evidence review process

1.2.1 Literature search

An extensive list of search terms related to the research questions and topic area was generated (Figure 2). These terms covered the relevant themes which were explored by this review: disability, automation, transport, barriers, benefits, and challenges. The terms were applied across different online research databases (specifically, Google Scholar, ScienceDirect, TRID and Google) through an iterative process; each term was used in a search either individually or in conjunction with other appropriate terms. This iterative approach ensured that the search was as effective and thorough as possible at drawing out appropriate literature.

Disabled	Automation/ New Mobility	Transport	Challenges	Benefits	Interaction	Accessibility
Disab*	Automat*	Transport	Barrier	Benefit*	Interact*	Accessib*
Special-needs	Mobility as a service	Car	Obstacle	Advantage	Engage	Ease of use
Special needs	MaaS	Public transport	Challenge	Support	Connect	Access
Blind	New mobility	Van	Hindrance	Help		
Deaf	Driverless	Vehicle	Hurdle	Good practice		
Impaired	Self-driving	Road user	Drawback			
Paralysed	Self driving	Bus	Issues			
Handicap*	Technology	Taxi				
Physical disability	Autonomous	Community transport				
Emotional disability	SAE	Shared transport				
Developmental disability	Shuttle	Tram				
Sensory impaired	Pod	Train station				
Mobility impaired	Connected Vehicle	Train platform				
Mental health	Drone	Bus stop				
Impediment	Delivery drone	Rail				
Neurodivergent	Delivery robot					
Wheelchair user	CAV					
Visual impairment	AV					
Hearing impairment						
Learning disability						
Colour blindness						
partially sighted						
hard of hearing						

Figure 2: Search terms

Search results were first assessed to identify any literature that appeared relevant to the review based on the title and abstract. A total of 122 unique papers and 15 websites were identified from the search process. These items were then collated in an Excel spreadsheet for further assessment and in-depth review.

1.2.2 Literature assessment

The 122 abstracts and 15 websites were assessed using the inclusion criteria shown in Table 1. Articles needed to score a minimum of eight to be considered for full-text review. In other words, papers were excluded if they scored either:

- 1 on any of the factors, or
- Less than 3 on two or more factors.

This scoring process ensured that only the highest quality and most relevant literature was taken forward for in-depth review. Following this process, 71 articles scored well enough to justify in-depth review.

Table 1: Inclusion criteria

Criterion	Score = 1	Score = 2	Score = 3
Relevance	Not relevant to the objectives of the project	Some indirect relevance to the objectives of the review	Directly relevant to the objectives of the review (for example research which directly evaluates the role of an automated transport service for disabled groups)
Quality	Non-scientific article (for example online source, newspaper, or magazine article)	Evidence review or case study investigation	Randomised controlled trial or before and after comparison of real world data
Timeliness	Published over 10 years ago (up to 2013)	Published between 5 to 10 years ago (2014 to 2018)	Published within the past 5 years (2019 to 2023)

1.2.3 In depth review

The final shortlist of 71 articles were reviewed in full. Notes and comments made during the review were recorded in an Excel spreadsheet, with each articles occupying a row and details about the articles (including high level summaries of study purposes, methods, and findings) recorded systematically in columns. Conclusions relating to the specific research areas were drawn where possible. A discussion of these findings is provided in the following section. One article was removed due to it not being relevant, leaving a total of 70 sources included in this report.

1.3 Key findings from evidence review

The final shortlist of papers covered a range of different disabilities. Specifically, visual and physical disabilities were most represented, being covered by 27 and 22 papers respectively. Wheelchair use was covered in 15 papers. Disabilities with only a small amount of representation in the literature included cognitive disabilities with six papers, deafness with three papers, and epilepsy with one paper.

The findings from the review are summarised below in relation to the four key research questions. Each subsection opens with a summary of the key findings related to the research question. The implications of these findings are discussed in Section 1.5. The findings were analysed using a framework of journey stages. This was used to aid understanding and interpretation of user needs and barriers in relation to the key stages of making a transport journey, from start to end. Low et al (2020), Park and Chowdhury (2018) and Severs et al. (2022) have used a similar concept in their review to categorise the barriers faced by disabled people at various points in their journey when travelling. For this purpose, we have utilised the following journey stages:

- Journey planning (including information finding)
- Booking journey
- Getting to the station, stop or vehicle
- Arriving at station or stop
- Finding the correct service
- Waiting
- Boarding vehicle
- On the journey
- Alighting the vehicle
- Getting to desired destination
- Various (a catch all to cover factors which apply to multiple journey stages)

1.3.1 RQ1: Potential benefits around automation for disabled people

Key findings:

1) The main expected benefit of automated vehicles discussed in the literature is a greater degree of independence for disabled people and improved flexibility while travelling.
2) If users of fully automated vehicles are not required to hold a driving licence, this could open up access to a private vehicle for a greater number of disabled people.
3) Other benefits included decreased travel time due to private automated vehicles being able to take a more direct route than public transport.
4) If the removal of the driver enables cost savings to be passed on to passengers, this should result in cheaper travel.

The potential benefits of automation in transport highlighted in the literature related mainly to the use of private automated vehicles and private hire automated taxis, rather than public transport. The literature stated that private hire and private vehicles provide door-to-door services which can help to overcome some of the barriers that disabled people face with travelling. Public transport methods on the other hand require the user to get to and from the bus, train or tram, which often comes with its own accessibility barriers. These barriers cannot easily be overcome by automation alone as there are still the same inherent barriers in the built environment to overcome before the user gets to the vehicle.

The biggest stated perceived benefit for disabled people regarding the use of automated vehicles was increased mobility. At present, many types of disabilities such as physical and visual impairments prevent people from obtaining a driving licence, and also hinder disabled people from using public transport (Emory et al, 2022). Analysis report by the Department for Transport (2023a) suggests the barriers to transport leads to disabled adults in the UK making 28% fewer journeys than non-disabled adults. Other figures reported by the Motability Foundation suggest this ‘transport accessibility gap’ may be as large as 38%

(Motability, 2023). Irrespective of the true figure, it is clear there is a substantial difference between the travel patterns of disabled and non-disabled people. For Level 5 automated vehicles (and possibly to some extent Level 4), occupants will be unlikely to need perform any of the driving tasks, and as such there is potential that operators of these automated vehicles may not require a driving licence (Bayless and Davidson, 2019). If this does become adopted policy in future, then there would be fewer barriers for disabled people to own and use an automated vehicle (Law Commission and Scottish Law Commission, 2019).

The introduction of automated vehicles opens up a new world of transport for disabled people in terms of being able to travel around more easily (Hancock et al, 2020; Cavoli et al, 2017; Papafoti, 2020). Increased mobility for disabled people would lead to an increased level of independence and freedom (Hwang et al, 2020; Bennett et al, 2019; Sharma et al, 2023), due to a lack of a reliance on others to meet their mobility needs (Bennett et al, 2020). Automated vehicles are expected to provide opportunities for door-to-door transport (Department for Transport, 2023), eliminating many of the first and last mile challenges that disabled people currently face with getting to and from public transport stations. Increased independence would also provide disabled people with the opportunity to travel to places of employment (Brinkley et al, 2017; Martinez-Buelvas et al, 2022), leisure and social activities (Papafoti, 2020), and medical appointments (Dicianno et al, 2021). A study from the US suggests that 11.2 million medical appointments are missed each year due to transport issues. In one focus group study of visually impaired participants, 47% of participants reported that automated vehicles would help them to be more independent, and would mean they would not have to rely on others for travel (Brinkley et al, 2017). In an open-ended survey about automated vehicles, 37% of visually impaired participants also reported that they were excited about the potential for automated vehicles due to the potential for improved transport links (Bennett et al, 2020). Automated vehicles may also allow disabled people to travel without support from carers (Wu et al, 2021).

A few papers suggested alternative benefits of automated vehicles for disabled people. In particular, one focus group study asked disabled people how they perceived automated vehicles (Hwang et al, 2020). Some of the participants suggested that they would expect fully automated shared vehicles to be cheaper than non-automated private vehicles due to the removal of the operator. That said, it was also felt that it may take a while for the cost savings to be transferred to passengers through reduced ticket prices for shared transport vehicles. It was also felt that the cost of privately owned automated vehicles would take a while to decrease, due to the expected high costs of implementing the technology while it is immature. Participants also suggested that automated vehicles have the potential to be safer than non-automated vehicles, especially in terms of reducing the risk of collisions with vulnerable road users. Another focus group study with visually impaired participants found that the 18% of participants who mentioned long travel times were overwhelmingly positive about the prospect of automated vehicles, due to the perception that automated vehicles would be able to take a more direct route to destinations compared with the typically indirect routes taken on current mass public transport services (Brinkley et al, 2020b). Finally, the potential increased opportunity for people who would otherwise have been driving to engage in non-driving tasks (e.g. sleep, reading, working, etc) during a journey was mentioned as a key benefit of driverless vehicles, though this would only apply to Level 5 automation where human intervention in the driving task is not required.

In summary, the main expected benefits of automated transport discussed in the literature were improved access to transport leading to increased freedom, time savings, safety improvements and cost savings.

1.3.2 RQ2: Barriers faced by disabled people relating to non-automated transport

Key findings

1) Overall, disabled people experience a range of obstacles across different stages of the journey when travelling using public transport modes.
2) The following barriers which impact disabled people’s current use of transport were well evidenced in past research:
    a) Bus drivers’ poor attitudes towards disabled people or understanding of disabled users’ needs.
    b) Outdated information (such as bus timings, station exits, connecting journeys) in inaccessible formats (illegible font, inadequate levels of information, poor visual contrasts).
    c) Inconsistency of terminal or vehicle interior designs.
    d) Limited numbers of adapted vehicles among taxis and community transport alternatives.
    e) Poor design of road infrastructure that obstructs footpaths or hinders walking or wheeling.

Journey planning (information finding)

Advanced planning is a common feature of disabled people’s journeys (Transport for All, 2023). Planning is important for identifying step-free routes, arranging assistance and ensuring the availability of specific facilities such as toilets, charging points for mobility aids, parking, and relief areas for assistance dogs.

Access to relevant and sufficient information was noted as a major barrier to using public transport services in several pieces of literature. It was noted that the format, timeliness and amount of information available was of poor quality which meant that users were often unable to plan their journey or in some cases, were unable to make the journey entirely (Park and Chowdhury, 2018; Bennett, Vijaygopal and Kottasz, 2019a; Low, Cao, De Vos and Hickman, 2020; König, Seiler, Alčiauskaitė and Hatzakis, 2021; House of Commons Library, 2022; Park and Chowdhury, 2022; Neven and Ectors, 2023; Transport for All, 2023). For example, printed guides available at stations are often not accessible due to the use of small font sizes. The Royal National Institute of Blind People (RNIB) report (2023) noted there was overdependency on printed information available at stations – this is not only is difficult to read, but requires that individuals has to make a journey to the station in order to access a copy.

Types of information that help disabled people with journey planning include:

- Clear walking directions to/from bus stops and stations, including routes with fewest hills
- GPS services to navigate before or after the public transport journey (i.e. first and last mile).
- A single platform for viewing journey information (such as service timing; availability of lifts at the station) e.g. Mobility as a Service (MaaS).
- Information about available assistance, including information on how and where to find staff
- Walking distances within stations
- Availability and working status of lifts and escalators
- Crowding and noise levels
- Availability/location of toilets, accessible toilets, Changing Places, rest stops, relief areas for Guide Dogs, and other facilities

An inability to find sufficient and up-to-date information also hinders inexperienced travellers from attempting to make independent journeys as the uncertainty adds anxiety to the individuals’ experience of travelling (Kett, Cole and Turner, 2020; Low et al., 2020; Motability, 2020; Wu, Cao and Douma, 2021; House of Commons Library 2022; Park and Chowdhury, 2022; Neven and Ectors, 2023). The format of information available online was mostly regarded as inaccessible by individuals with visual impairments.

While it is common for disabled people to use new technology (such as real time information on buses) to look for information on transport services, the information is often not sufficient or up-to-date to be able to make an informed decision (Low et al., 2020; Motability, 2020; House of Commons Library, 2022; Orczyk, Młodystach, 2022). For example, Low et al. (2020) explored the experiences of visually impaired people using public transport in London and found that participants felt that information available on official transport provider websites was not typically in an accessible format. It was not clearly defined in these papers what features of the website were considered inaccessible, however, based on guidance by RNIB (2023) inaccessible websites could be due to font size and colours that make the information illegible for some users. It was typical for people to check multiple websites – typically run by charities and private organisations – for different types of information. Having to work through multiple websites for a complete insight adds to the burden of planning a journey.

Booking journey

Transport for All (2023) note that disabled people use a range of methods to book journeys. For buses, 65% of respondents to their survey reported having a concessionary bus pass and therefore not having a need to purchase tickets, with the remainder using mobile / contactless payment, cash, smartphone apps or buying in person. For train travel, 60% of respondents to their survey reported using digital means to book tickets. However, many also reported using non-digital means, including ticket offices (33%) and ticket vending machines (18%). Specific challenges with these in-person methods include inaccessible ticket vending machines, and lack of staffed ticket offices which means assistance is not available. Another barrier highlighted in this research was an overall inconsistency in pricing, payment methods and ticket validity, causing confusion and anxiety.

Low et al. (2020) explored the experiences of visually impaired passengers within London, and Neven and Ectors (2023) conducted qualitative research to understand the first-hand experiences of disabled people in Flanders, Belgium. In both of these cities, the main transport providers offer assistive services that users can book in advance via a website or a mobile application. The studies found that even though such services were available, the booking process was typically unsatisfactory as users felt that they were restricted by limited staff availability. Disabled people therefore felt that their freedom to travel when they wish was limited, as they need to plan in advance and are reliant on assistance being available at the time they need. Additionally, the quality of the service was rated poorly due to the waiting time to receive assistance when at the station. Waiting times could vary considerably, especially during peak and off-peak hours, due to busy or unstaffed stations, respectively.

A common theme in the literature was that there are often limited accessible options available via private transport services (such as private taxi, rideshare). Some papers reported that participants felt that they had limited options to travel using these services and had to plan far in advance to ensure availability of an accessible vehicle (if the service provider had one at all) (Tabattanon, Sandhu and D'Souza, 2019; Hwang, et al., 2020; Kett, Cole and Turner, 2020; Remillard, Campbell, Koon and Rogers, 2022; Leonard Cheshire, 2023). Service providers of private transport in USA are not obligated to have a minimum number of wheelchair accessible vehicles in their fleets; this therefore contributes to limited suitable options for disabled people, specifically for wheelchair users (Bayless and Davidson, 2019; Hwang, et al., 2020; Remillard et al., 2022).

Getting to the station, stop or vehicle

Past research has identified a number of critical issues related to the built environment which impede the ability of disabled people to access transport. These include:

- A lack of footways (Tennakoon et al., 2020; Neven and Ectors, 2023).
- Poorly maintained footways (such as uneven surfaces; cobbles; undetectable kerbs) (Park and Chowdhury, 2018; Tennakoon et al., 2020; Unsworth, So, Chua, Gudimetla & Naweed, 2021; Park and Chowdhury, 2022; Transport for All, 2023).).
- A lack of consistent design of stations such as handrails and tactile paving at stations (Low et al., 2020; Neven and Ectors, 2023).
- A lack of ramps for wheelchair access, or ramps which are too steep (Tennakoon et al., 2020; Park and Chowdhury, 2022).
- Obstruction of footpaths caused by construction works (Park and Chowdhury, 2022). Note that Chapter 8 of the Traffic Signs Manual for Road Works (Department for Transport, 2009) specifies that a minimum of one metre width is required for

pedestrian footways during construction works to ensure that the routes are more accessible to disabled people.

- Alternative routes during construction work not being accessible (for example, Plastic walkways around construction sites) (Park and Chowdhury, 2018; Park and Chowdhury, 2022).
- Long distances between the origin or destination and the stop / station (Park and Chowdhury, 2018; Tennakoon et al., 2020).
- Lack of accessible parking at stations, leading to long walking distances (Transport for All, 2023).

Unmarked crossings, inaudible traffic signals and out-of-order or dimly lit streetlamps (Wu, Cao and Douma, 2021; Park and Chowdhury, 2022) were reported as issues which reduce disabled people's feelings of safety when travelling on footways, and thus are considered a barrier to their access to transport.

As described above, many disabled people rely on information available on the internet to plan their journey. If the information does not inform them of blocked roads and footpaths due to roadworks, they may not confidently be able to navigate the remainder of the journey or they may need to rely on other pedestrians to find their way. This impacts their overall journey experience and adds unnecessary burden.

Arriving at station or stop, finding the correct service, and waiting

Arriving at the station or stop, finding the right service after arrival, and waiting at the station or stop were sometimes talked about in the literature as one combined journey stage. Thus, while certain barriers were primarily experienced by some individuals in one particular stage, they were also described as overlapping across the three journey stages. For this reason, the barriers experienced in these three journey stages have been grouped together in this section.

Generally, most disabled people found that outdated information at bus stops prevented them from finding the right service, and outdated signs and announcements at train stations added confusion and hindered their ability to navigate the station properly (Wu, Cao and Douma, 2021; Orczyk and Młodystach, 2022, Transport for All, 2023). Visually impaired users rely heavily on audio announcements made in stations and reported that noisy stations also prevent them from hearing announcement messages clearly (Orczyk and Młodystach, 2022; Młodystach, Orczyk and Tomaszewski, 2023). The placement of signage was also considered inaccessible in some cases; for example, by being too high and hence difficult to read (Britain Thinks, 2020; Unsworth et al., 2021; RNIB, 2023).

At bus stops, real-time information on bus timings presented in visual format on illuminated panels can be difficult to read for those with partial or residual eyesight. It is also not typically accompanied with an audio announcement meaning the information is not readily available for visually impaired people.

König, Seiler, Alčiauskaitė and Hatzakis (2021) conducted semi-structured interviews with disabled people and a social media content analysis to identify barriers with public transport across seven European cities. They found that while there are new technologies and accessibility solutions such as elevators, screen readers or audio announcements on buses in place, often they were not used properly or were not working. This was also supported by other work conducted by Bayless and Davidson (2019), Park and Chowdhury (2022), and Bennett, Vijaygopal and Kottasz (2019a).

Low et al. (2020) also noted that the lack of consistency in the layout and design of terminals across the train network made some users feel vulnerable and unsafe when travelling to new stations. Visually impaired people navigate on their journeys using mental maps hence inconsistent layouts or journeys to new stations comes with a lot of uncertainty, making them feel anxious and affecting their ability to have a smooth journey on trains.

Wheelchair users have said that bus stops are too small and hence do not lend space for wheelchair or mobility aid users (Kett, Cole and Turner, 2020; Tennakoon et al., 2020; Neven and Ectors, 2023). In addition to small bus stops, bus stops without shelters were said to be especially problematic when it rains, hence making the experience of using public transport negative.

For some disabled people, staff assistance is required; 30% of respondents to a survey conducted by Transport for All (2023) said that when assistance is on hand and delivered promptly, train travel is much more accessible.

Boarding vehicle

The literature highlighted two key issues faced by various disability groups and another experienced by wheelchair and mobility aid users, specifically, when boarding a public transport vehicle.

Bus drivers' lack of awareness about different user needs and poor attitudes towards disabled passengers were highlighted by multiple papers conducted in various countries as a factor that discourages these users to travel using public transport modes, especially by bus (Park and Chowdhury, 2018; Bennett, Vijaygopal and Kottasz, 2019a; Britain Thinks, 2020; Hwang, et al., 2020; Kett, Cole and Turner, 2020; Motability, 2020; Odame, Abane and Amenumey, 2020; Tennakoon et al., 2020; König et al., 2021; Wu, Cao and Douma, 2021; Orczyk and Młodystach, 2022; Park and Chowdhury, 2022; Remillard et al., 2022; Transport for All, 2023). On the other hand, the Public Service Vehicle Accessibility Regulations (PSVAR, 2000) and UK Equality Act 2010 specify that the bus driver should provide reasonable assistance to disabled people with boarding and alighting (Department for Transport, 2000 and Marson et al, 2021 respectively). An accessibility audit conducted by Bus Users UK (2023) captured changes and updates made by operators across 40 regions in Great Britain since their previous accessibility audit in 2022. The audit highlighted that about 4%-7% of staff from responding operators had not received any training in disability awareness/assistance training, or the Mental Health First Aid training. It was noted that when bus drivers were able to support disabled users appropriately, their overall journey experience was said to have improved considerably.

Similarly, Leonard Cheshire (2023) explored how journeys on taxis and private hire vehicles can be made accessible. They reported that many disabled people had faced discrimination and stigma by taxi or private hire drivers or operators. Some respondents had also been refused service because of their disability despite it being unlawful to refuse service on that basis (Taxis and Private Hire Vehicles (Disabled Persons) Act, 2022). Under the Equality Act 2012, taxi and Private Hire Vehicle (PHV) drivers in UK must accept the carriage of disabled passengers and assistance dogs, must provide them with appropriate assistance, and not charge them more than other passengers for the same service, unless the driver has an exemption certificate.

Park and Chowdhury (2022) conducted a literature review of barriers for disabled people on public transport and noted that mobility and visually impaired people preferred seats near the door or entry of the vehicles and close to the driver as this limited their need to move about the vehicle to find a seat. The location of a seat near the entrance and the driver made these users feel safe on their journey. Vehicles that varied from this design were seen as a challenge to board (Kett, Cole and Turner, 2020; Low et al., 2020).

It has been highlighted that traversing the gap between the kerb or ground into a vehicle can be difficult for individuals with mobility issues (Tabattanon & D'Souza, 2021; Unsworth et al., 2021). This can be supported through the use of boarding ramps. The PSVAR (2000) states that all regulated public service vehicles (for example, buses) should be fitted with at least one boarding lift or ramp, with the ramp slope not greater than seven degrees. However, this applies to all new public service vehicles (buses and coaches) introduced since 31 December 2000, suggesting that older buses still in service may not meet this requirement. As of August 2022, over one third of full-size (with a capacity exceeding 22 passengers) local buses are low floor vehicles and over 90% of the London fleet consists of low floor vehicles (Department for Transport, 2022). Some buses such as those used for rail replacement bus services and home-to-school transport are not fully compliant with the PSVAR 2000. They are supported with a letter of exemption to allow operators to continue providing services while requiring their main fleet to be compliant with the existing legal obligations (House of Commons Library, 2022).

Disabled participants in one study noted that ramps on buses sometimes fail due to technical faults; this prevents them from boarding or alighting the vehicle and therefore the service becomes inaccessible (Velho, 2019). Other recent studies have shown that participants were unable to access buses because they were not fitted with a boarding lift or ramp. Such instances extend the overall travel time for wheelchair or mobility aid users as if they are unable to board the bus they need they then have to wait for another bus; this causes considerable inconvenience and delay (Velho, 2019; Cordts, Cotton, Qu and Bush, 2021; König et al., 2021; Wu, Cao and Douma, 2021).

According to the PSVAR (2000), all public bus services should be fitted with at least one wheelchair space. The Bus Users UK (2023) accessibility audit showed that 48% of the respondents had created more space to manoeuvre wheelchairs and 44% had made space for an additional wheelchair. These figures suggest that most buses are designed with at least one dedicated space for wheelchairs. In instances where there is already a wheelchair user on board, this can create a first come, first served system (Remillard et al, 2022; Unsworth et al., 2021), with wheelchair users waiting at the bus stop having to forgo the bus and wait for the next service (which in some cases will be a long wait). These issues can be further compounded by narrow entrances and access corridors, and insufficient space for wheelchair manoeuvrability within vehicles that may be difficult for mobility-impaired individuals to traverse unsupported (Unsworth et al., 2021). These obstacles add burden on the user, requiring them to plan more time in their journeys and reducing the ability to make spontaneous journeys (Hwang, et al., 2020).

The above supports other findings about conflict around the priority spaces on board vehicles (Velho, 2019; Transport for All, 2023). Having access to priority areas and seats can often be especially challenging for those with less visible impairments. In 2017, a legal precedent was set requiring operators to adopt a policy of wheelchair users taking priority in the space. The issue of motion sickness when facing backwards was also highlighted. Velho (2019) noted that there was quite often conflict between whether a wheelchair space was used by a wheelchair user, or those with pushchairs – with some wheelchair users waiting up to 45 minutes to get on a bus with an available wheelchair space).

Easy access onto trains is also not always guaranteed. According to Transport for All (2023), while a quarter of stations are step-free from street to platform, only 2% of stations have level boarding. This means that those using wheelchairs and mobility scooters are unable to board independently at all stations, instead being restricted to travelling from stations that have staff to deploy a manual boarding ramp within staffed hours. The risk of having mobility aids caught in the gap between the train and the platform was also identified as an issue.

On the journey

While on board the vehicle, passengers with visual impairments typically rely on audio announcements made on the bus or train to know when their stop is arriving and be prepared to alight the service (Low et al., 2020). As mentioned above, visually impaired people also prefer to be seated near the driver – this allows the driver to inform the passenger when their desired stop has arrived. Poor auditory announcements, poor driver attitude, or a lack of seats near the driver ultimately result in a negative experience for the visually impaired user as it limits their ability to travel independently and may add uncertainty about arriving their destination. For those who are Deaf or hard of hearing, having to face away from the board displaying the next stop can create additional barriers to accessing information (Transport for All, 2023). As of 2021, 45% of buses across Great Britain provided audio-visual information (House of Commons Library, 2022). Currently there are no regulations in the UK requiring the provision of audio-visual information to passengers on the bus. The National Bus Strategy and the National Disability Strategy plan to introduce guidance and specifications on what type of information should be provided and how it should it be provided (House of Commons Library, 2022).

Wheelchair users, who have limited space to park themselves in the vehicle, and neurodivergent users find overcrowded vehicles difficult. Limited spaces, or invasion of personal space on crowded public transport can be overstimulating and thus induce anxiety among this group (Hwang, et al., 2020; Dicianno et al. 2021; König et al., 2021; Transport for All, 2023).

Finally, the literature highlighted that some disabled people experience negative attitudes and discriminatory behaviour from staff and other passengers (Transport for All, 2023).

Alighting the vehicle

There were fewer unique challenges noted in the literature relating to alighting the vehicle. The location of stop buttons was cited by one paper as an issue (Transport for All, 2023), with a suggestion for these to be placed at more user-friendly locations, for example at lower levels and within reach of all seats. It is likely that issues relating to boarding the vehicle, such as the availability of a ramp, will be relevant at this stage of the journey as well.

1.3.3 RQ3: Potential barriers faced by disabled people relating to automated transport

Key findings:

1) The following barriers were noted in past research as potential barriers to disabled people's use of automated transport:
    a) Booking and finding the required vehicle.
    b) Boarding and exiting the vehicle.
    c) Ensuring that wheelchair users are secured in position.
    d) Interacting with the human-machine interface.
    e) Safety concerns due to no driver on board.
    f) Confirming the correct location and orienting in the correct direction.
2) Similar to the existing barriers in transport, most of the studies involved people with visual or mobility impairment and other disabled people, such as those with hearing or cognitive impairments were underrepresented.
3) Barriers reported in the literature were concentrated on the stages of boarding the vehicle, on the journey and alighting. This may be because these are the elements of the journey that are most clearly defined, and other journey stages may depend on individual operating models, which may not yet be fully developed.
4) Barriers were more prevalent for shared automated transport, due to a greater emphasis on sharing the vehicle with other passengers, assessing where the vehicle is to board, and a lack of bespoke personalisation of the vehicle to people's needs.

Perceptions of automated vehicles

Some literature highlighted that there are different levels of willingness to ride in an automated vehicle depending on type of impairment. For example, Kassens-Noor et al (2021) found that survey respondents with visual impairment were statistically significantly more likely to be willing to ride in automated buses than non-disabled respondents, but those with mobility impairments were less likely to be willing to use automated vehicles than non-disabled respondents.

Some respondents expressed concern over safety, both in terms of lack of trust in the safety of the technology itself and in relation to what would happen if they needed assistance or had a medical emergency. These results demonstrate that some disabled people may not see benefits in automated vehicles, which may impact their willingness to use them in the first place (Kassens-Noor et al, 2020).

This latter point is also supported by Papafoti's (2020) study which asked a small sample of over 55-year-olds about their attitudes towards automated vehicles. Beyond the concerns around safety in the vehicle, this sample also raised doubts in the current technology's ability to provide a reliable service that would actually meet their travel needs. Even among those in Papafoti's sample that showed some willingness to use an automated vehicle service, there was some feeling that such services simply are not needed.

Finding the vehicle

For disabled people, although the prospect of automated vehicles comes with many potential benefits, there are also some potential pitfalls. Although few studies considered the process of booking transport via an automated vehicle, it is likely that the same barriers would occur as in public transport methods. Visually impaired users in one focus group study were concerned that the vehicle would not know where they were, and that this would make finding the vehicle difficult (Etminani-Ghasrodashti et al, 2021).

Boarding vehicle

Access and egress to the vehicle is another key consideration for both automated and non-automated vehicles (Hancock et al, 2020; Bayless and Davidson, 2019; Unsworth et al., 2021); in particular mobility impaired users have noted needing easy access from ground level to the level of the vehicle (for example, via a ramp – preferably in the centre of the vehicle to speed up boarding time (Tabattanon et al, 2019)) and a large amount of floor space to manoeuvre around the vehicle (Tabattanon and D'Souza, 2021). While this exists in some public transport methods (for example buses), trains currently require an external operator to deploy a wheelchair ramp, and there are no ramp systems that currently exist in standard cars, suggesting that this remains a key barrier to public transport methods with no staff members on board.

On the journey

Once on board the vehicle, the lack of a driver presents new obstacles for disabled people. For example, wheelchair restraint systems have been suggested by the disabled community for automated vehicles, to ensure that users can secure their wheelchair when travelling (Bayless and Davison, 2019). However, as noted by Klinich et al (2022c), many wheelchair users cannot secure their wheelchair to a restraint system by themselves, with the application of the fastening device typically conducted by a caregiver. However, a requirement to travel with a caregiver during every journey would reduce independence for the disabled traveller.

The lack of a driver within automated vehicles also has alternative ramifications in terms of safety. A current barrier of automated vehicles is that the vehicle may not know how to cope with medical emergencies for a disabled person (Hancock et al, 2020). For example, assuming the automated vehicle can identify that a person has had a seizure, one focus group study of eight epileptic participants pondered the question of what should happen next (Sultan and Thomas, 2020). Note however that even amongst disabled users, a consensus as to whether the vehicle should come to a safe stop or continue its journey was not arrived at, suggesting that this remains a barrier that will require addressing through further research. For this reason, some disabled participants suggested that an operator would still be required in an automated vehicle, in order that the best solution could be arrived at in each scenario (Etminani-Ghasrodashti et al, 2021).

In one workshop-based study of participants with protected characteristics (for example disability and mental health issues), disabled people also suggested that an onboard operator would be useful in order to prevent any antisocial behaviour towards vulnerable road users such as theft and assault (Severs et al, 2022). In fact, a third of participants surveyed reported that they would want to have a driver on board the vehicle in order to feel safe (Cordts et al, 2021). These results suggest that the lack of an onboard operator may be a barrier dissuading disabled participants from considering riding on an automated vehicle.

Automated vehicles will require a human-machine interface (HMI) for the human to inform the vehicle of where they would like to be picked up, where they would like to travel to, and to communicate any other requirements before or within the journey. It is crucial that the HMI is designed correctly to ensure disabled users are able to easily interact with the vehicle. In particular, an HMI which only involves one type of input method (such as requiring the user to add the location via a touchscreen without a screen reader) would be discriminatory, and would likely create a barrier for visually impaired users, for example (Brinkley et al, 2017). Likewise, HMIs which are reliant on speech input would create a barrier for those with speech impairments or auditory impairments, for example (Brinkley et al, 2020a). HMI must instead offer multiple input methods in order to cater for different needs (Riggs and Pande, 2022). Smartphone apps may be a good solution if they can be designed appropriately (Brinkley et al, 2020a).

Some disabled participants reported that not knowing where the vehicle currently was whilst they were in the vehicle was another potential barrier. Participants reported that the addition of situational awareness information would help to ensure that they were more at ease during transit (Brinkley et al, 2020b). Regarding use of a privately owned automated vehicle, which would likely be an electric vehicle, another study suggested that the lack of auditory information (for example regarding the current charge status or tyre pressures of the vehicle) would be a barrier to visually impaired people using and maintaining their vehicle (Brinkley et al, 2020a; Bayless and Davidson, 2019). In a shared automated vehicle, a lack of auditory information noting that the chosen destination is approaching may also be a significant barrier (Bayless and Davidson, 2019).

Alighting the vehicle

After the disabled user has arrived at their destination, a new set of barriers affect visually impaired participants during the process of disembarking. In particular, during a focus group study of visually impaired participants, one user suggested that the automated vehicle should be able to verify that they are at the correct destination so that they knew that they could get off (Brinkley et al, 2017). On the other hand, the suggestion of how the vehicle would verify the location was not mentioned. As such, this is a particular barrier as visually impaired people will not be able to confirm that they are at the correct destination.

After confirming that they were in the correct location, the next barrier is an inability to orient themselves in the correct direction. Whereas current public transport and paratransit methods have drivers who can orient visually impaired users in the correct direction, automated vehicles may not have any operators or additional passengers who would be able to help in this scenario. Indeed, many focus groups of visually impaired people have suggested that this an especially big problem (for example Bayless and Davidson, 2019). Once oriented, the automated vehicle will also need to ensure that the route from the vehicle to the destination does not contain a multitude of obstacles (Bayless and Davidson, 2019). In particular, the goal of getting from the vehicle to their onward destination was viewed by many visually impaired participants as a significant challenge (Brinkley et al, 2020b).

External interaction with vulnerable road users

Finally, the external interaction between automated vehicles and disabled people is also a barrier. Non-automated cars have a driver who can communicate with other road users e.g. who may wish to cross the road etc, automated vehicles will ideally need a system for external communication too, so that the vehicle can indicate its intentions, particularly to vulnerable road users. Importantly, since automated vehicles are likely to be electric, on the whole, this may make them harder to detect, especially for blind and visually impaired people who rely more heavily on audio cues to assess the surrounding environment (Brinkley et al, 2017; Azizi Soldouz, 2020; Department for Transport, 2023b). While there is new regulation that ensures that electric vehicles must be fitted with acoustic sound systems (Department for Transport, 2019), this is only mandatory up to 12mph. In all there are a multitude of barriers that are expected for disabled users when automated vehicles come to the market.

1.3.4 RQ4: Examples of good practice solutions in automated transport to overcome accessibility issues

Key findings:

1) Overall, there was a greater focus in the literature on barriers to transport for disabled people, with less information on what solutions should be implemented to overcome those barriers. Nevertheless, the following suggestions were made:
    a) Ensuring that the built environment is accessible for those with disabilities.
    b) Ensuring ramps and aisles are built to accessible (e.g. PSVAR) specifications.
    c) Automated restraint systems for wheelchairs.
    d) Ensuring the human-machine interface uses a combination of input methods.
    e) Ensuring that there is a method to provide information to passengers to ensure the user understands where they are on the journey.
    f) Multi-modal information (i.e. audio cues and visual information) provided by the automated vehicle when they are communicating externally with other road users (i.e. to denote that they are giving way to a person at a junction).

g) Suggestions for effective regulation, including the transfer of current regulation to automated transport, avoiding “one-size-fits-all” regulation, the introduction of permits for operators to prove they have considered accessibility and the generation of codes of practice which could be used alongside regulation.

h) The employment of co-design and testing with a variety of user groups during the design process.

Many of the papers included in the review suggested that automated vehicles should be accessible to ensure that disabled people are not excluded. However, many of these papers did not state how exactly this was to be achieved.

An exception was a series of reports from the Law Commission and Scottish Law Commission (2019, 2020, 2023) which outlined responses to a consultation with the charitable sector and industry about how to ensure accessibility of automated vehicles. These mainly focused on approach to regulation and guidance for the sector. Key points are:

- Ensuring that the same principles of existing regulation around transport (e.g., PSVAR) is maintained in relation to automated transport. Whilst there is acknowledgement that the existing regulations are useful, it was highlighted that there is opportunity to go beyond these to further define best practice in the automated transport sector.
- The suggestion that guidelines or codes of practice could be used alongside regulation to suggest good practice, given that these may be more flexible to change or adjust as knowledge and technology evolves.
- Acknowledgement that it will be important to avoid ‘one-size fits all’ regulation for vehicles, or impose inappropriate technical and operational requirements which could hinder the development of automated transport. For example, consultees suggested that a dual approach could be taken which may involve ensuring that sufficient adapted vehicles are available alongside non-adapted vehicles.
- The suggestion that operators of automated vehicle passenger services should apply for a permit before operation, with the granting of permits contingent on the operator meeting certain criteria around meeting the needs of older and disabled passengers.
- The recommendation that an accessibility advisory panel is established to assist in granting of permits and the development of national minimum accessibility standards for automated transport passenger services. This panel should be made up of those with a variety of visible and non-visible disabilities.
- The suggestion that co-design and testing with a variety of user groups should be an important step of any operator or developer’s design process.

Consultees also mentioned the desire for a database of potential scenarios, to aid organisations to generate engineering solutions (Law Commission and Scottish Law Commission, 2022).

These Law Commission papers set out 12 accessibility outcomes that automated transport services should meet:

- Outcome 1: Information about services and the booking process should be accessible
- Outcome 2: Passengers must be able to board and alight the vehicle
- Outcome 3: Passengers must be safe and reasonably comfortable during the journey
- Outcome 4: There must be suitable provision for wheelchair users and priority seats
- Outcome 5: Providing a reliable service and support in the event of disruption
- Outcome 6: Passengers should have accessible information about their journey and the available facilities
- Outcome 7: Disabled passengers should be able to communicate with transport staff
- Outcome 8: Accessibility awareness training for transport staff
- Outcome 9: Travel training for disabled users
- Outcome 10: Mitigating the risk of anti-social and discriminatory behaviour
- Outcome 11: The right to travel with an assistance dog
- Outcome 12: Suitable provision should be made for carers accompanying disabled passengers

Beyond these detailed examples provided by the Law Commission papers, a few other papers highlighted the need for designing automated vehicles with accessibility needs in mind from the outset (Papafoti, 2020; Tabattanon et al, 2020), with particular emphasis being given to the importance of co-designing with user groups and collaboration across the industry (Sundararajan, Yousuf, Omay, Steinfeld & Owens, 2019).

Specific suggestions for infrastructure and design of vehicles from papers are summarised below.

Getting to the station, stop or vehicle

A key finding is that disabled people (and especially those with mobility or visual difficulties) often find the built environment difficult to navigate due to obstacles (for example cracks in the pavement), and the environment not being designed or managed with disabled people in mind. Automated vehicles will not solve these problems in their own right; disabled users may still face challenges with travelling to/from an automated transport service due to the built environment not being accessible (Hwang and Kim, 2023). Since the built environment is so fundamental to accessibility, use of automated vehicles may remain limited for disabled people unless these issues are addressed (Kuzio, 2021). It has been suggested that any regulation should cover the infrastructure adjustments and requirements that will be needed to operate automated transport services in an inclusive way (Law Commission, 2020).

Boarding the vehicle

In the literature, the importance of providing a ramp for both wheelchair and mobility-impaired users to ensure safe and easy access to vehicles was raised (Hwang et al, 2020). The PSVAR (PSVAR, 2000) prescribes a mandatory requirement for ramps on all new buses, and sets specific minimum requirements regarding the design of those ramps. In particular, ramps must have a safe working load of no less than 300kg, be at least 80cm wide and have an angle of no more than 20 degrees. The regulation also gives a number of other set dimensions for features such as the size of wheelchair spaces.

A low vehicle floor bed is beneficial to reduce the step up from the ground and to allow for a shallower ramp gradient. Frizziero et al (2023) highlight that it may be beneficial to carefully consider the position of any engines or equivalent in the vehicle, to ensure they do not make the floor bed higher than necessary. This has also been supported by Unsworth et al. (2021).

Edge guards are critical for ramps to ensure that wheelchairs do not fall off the side of the ramp while in use (Tabattanon et al, 2021). It was also noted that ramps should be able to be operated manually in case of power failures (Klinich, 2022a). One paper noted the findings from two studies that suggested that ramps should be placed in the middle of the vehicle rather than at the front to reduce boarding times, although it was not revealed as to why this would affect boarding times (Tabattanon and Sandhu, 2019). Ramp angles of around five degrees have also been suggested as being easily traversable by most individuals (Unsworth et al., 2021). The use of handrails at passenger doorways ensures that those with mobility impairments can more easily enter the vehicle (Klinich et al, 2022a). Handrails should continue inside the vehicle to ensure that mobility impaired users can make their way around the vehicle without fear of falling (Severs et al, 2022). Aisle widths are recommended to be at least 86.4cm, with at least a 137.2cm diameter circle required for wheelchair spaces (Klinich et al, 2022a). Extra legroom was also suggested as important for disabled users, in order to provide extra space for those who are unable to fully bend their legs (Cordts et al, 2021), for those who need to store assistive devices (Tabattanon et al, 2019) or for those who require space for an assistance dog (Severs et al, 2022). Note that some of these values given during the review were at odds with those given through the regulation. For instance, while Klinich et al (2022a) suggested that aisle widths were at least 86.4cm, the PSVAR only states that gangways should not be less than 75cm wide (PSVAR, 2000). This suggests that a review may be needed to assess the minimum requirements for many of the features on board automated transport.

A key barrier for wheelchair users discussed in the literature is a lack of a restraint system that can be automatically secured. Although automated wheelchair restraint systems were not mentioned by many papers, two articles outlined a concept for a novel design of an automated wheelchair restraint system. Both designs were operated using a button system to avoid the need for an external operator. One of the designs requires the use of an electromechanical system involving two horizontal arms locking the wheelchair into position with one button press (Tabattanon et al, 2021). The other design requires the use of universal design hooks which connect to the wheelchair with one button press, while another button press allows the seatbelt to be lowered or raised (Klinich et al, 2022b). Crash tests were performed with this latter design, which showed that a centre airbag is also required to ensure that wheelchair users are not injured in a collision. This research shows that an automated wheelchair restraint system is possible and these or similar designs could be used for future automated vehicles in order that wheelchair users can use automated vehicles by themselves.

On the journey

Some good practice suggestions around the Human Machine Interface (HMI) were also identified in the literature. In particular, it was suggested than HMI should have a variety of sensory inputs to ensure that all participants can interact with the vehicle, including audio, visual and tactile interfaces (Riggs and Pande, 2022; Bayless and Davidson, 2019). Brinkley et al (2019) conducted a real world test of an HMI including both a graphical and a voice activated human-machine interface (i.e. the operator could either speak into, or type on the tablet interface to ask the vehicle to drive to a destination) in a perceived automated vehicle (i.e. the vehicle was being driven, but the driver was hidden, so it seemed that the vehicle was being driven in automated vehicle). The results showed that the usability of the system was rated as excellent by many visually impaired participants, suggesting that the addition of a second input method (speech) as well as a visual interface was key. On the other hand, at least one of the participants scored the system as poor, suggesting that even though accessibility needs had been considered, not all participants had a perfect experience with the system (Brinkley et al, 2019).

Another paper (Frizziero et al, 2023), suggested that any screens inside vehicles should be tilt adjustable, allowing it to be utilised standing up or sitting down, whether that be in a seat or in a wheelchair.

While the HMI inside the vehicle is important, many papers have suggested the need for alternative means of interacting with automated vehicles via smartphones. Dicianno et al (2021) note that many ridesharing service smartphone applications are currently designed to be accessible for disabled people (such as the apps being compatible with screen readers). The current booking systems that ridesharing applications use could be considered as best practice for ensuring accessibility with automated vehicle booking systems (Etminani-Ghasrodashti et al, 2021). A focus group study of visually impaired participants found that many of the participants already found their phones accessible and would prefer the use of their personal phone to interact with the vehicle, rather than being reliant on an HMI within the vehicle (Brinkley et al, 2017). On a similar note, one technology developer suggested that instead of a push-button to request a stop, this same function could be served by the passenger using a handheld device (Law Commission and Scottish Law Commission, 2020).

Smartphone applications also need to be designed to be usable for those who are cognitively impaired (Lisinska et al, 2022). Many papers were identified which proposed that any vehicle control system must be designed with an intuitive layout (for example Riggs and Pande, 2022). This will also help older adults who are less familiar with smartphone technology, ensuring there were fewer barriers for mass usership (Brinkley et al, 2017). Although not everyone has a smartphone, the potential to use a phone to interact with an automated vehicle via a simple application as well as also using an in-vehicle HMI ensures that disabled users should find it easier to operate the vehicle as they can choose the method that is easiest for them.

In-vehicle HMI must provide the user with full situational awareness of the status of their journey. This means providing the passengers with a clear understanding of where they are throughout the journey and when they have reached their destination. This is particularly crucial for visually-impaired passengers. In one focus group study of 38 visually impaired participants, 45% suggested that it would be important for the HMI to provide real time information on journey status – akin to the level of information a non-visually impaired passenger would be able to ascertain by looking outside (Brinkley et al, 2017). Participants in the Brinkley (2019) study rated the human-machine interface of the vehicle as 6.55 out of 7 in terms of being helpful in making them aware of their surroundings (note that this average fell between mostly agree and strongly agree). This suggests that the addition of real time information would be helpful in order to ensure that visually impaired participants are aware of their surroundings whilst in an automated vehicle.

External communication with vulnerable road users

Although most of the articles found during this review investigated how disabled road users would be affected by travelling in an automated vehicle, a few papers investigated how disabled road users would want an AV to communicate with them if they were walking, wheeling or cycling on the same stretch of road. In a virtual reality experiment assessing preferences for automated vehicle messaging, researchers found that when automated vehicles are giving way to pedestrians, visually impaired participants preferred to have a longer message with verification that pedestrians can cross the road such as “I am stopping, you can cross” rather than just “I am stopping”. (Colley et al, 2020). In addition, participants with vision and cognitive impairments and those with learning disabilities preferred a combination of cues (such as visual and auditory) rather than auditory cues alone to note that a vehicle was coming to a halt. Importantly, while visual cues alone were as useful as the combined set of cues in some cases, the use of a combination of cues that a vehicle is about to give way was suggested in order for those who could not hear or see to be able to identify that the vehicle is coming to a halt (Haimerl et al, 2022). These findings suggest that external interaction should be conducted via a combination of communication techniques, in order to ensure that all disabled people can understand the message. Finally, this interaction should be tested with disabled participants, to ensure that they are included in the design process, and are not an afterthought (Colley et al, 2019).

1.4 Reflection on existing literature and evidence gaps

1.4.1 Opportunities for disabled people regarding automation

In terms of the opportunities for automation to address disabled people’s barriers to transport, the greatest benefit of automated vehicles is the potential for disabled people to have a **greater amount of freedom whilst travelling**. This is due to the potential for disabled people who are unable to drive to own a private automated vehicle. This type of vehicle would save people the extra time needed to travel on public transport, reduce reliance on others for their transport needs, and may reduce the impact of barriers in the built environment due to a greater likelihood of undertaking door-to-door travel. This would have the greatest impact for disabled people if there are no requirements for users of automated vehicles to hold a driving licence. Other benefits stated in the literature around shared automated vehicles included perceived decreased travel time and potential for cheaper travel due to more efficient and cost-effective services. Although not stated in the literature, it is hypothesised that automated vehicles also have the potential to bring benefits in the form of more accessible vehicle designs, due to not having to designate space for the driving task.

1.4.2 Types of automated transport described in the literature

The literature in this review mainly referred to automated vehicles as a whole category, rather than referring to specific types of automated transport (for example private automated vehicles and shuttles). This is likely because the technology is still evolving and the specific types of automated vehicles that will exist in the future is still unknown.

This lack of precision around specific types of automated transport meant that potential barriers related to automation tended to be quite generic, and it is unlikely that all types of barriers were identified.

The types of automated vehicles used in the future will have a bearing on the number of potential barriers to use. For example, barriers to use of private automated vehicles may include interactions with digital human-machine interfaces and interior adaptions to suit mobility devices such as wheelchairs, whereas barriers to use of shared automated transport such as shuttles will likely include additional issues regarding navigation, boarding and alighting, payment, interior seating and space, and communication with operators.

We suggest distinguishing between:

- Vehicles that you would traditionally operate yourself (if they were not automated), e.g., privately-owned vehicles or car club vehicles
- Vehicles you travel in as a passenger, e.g., taxis, shuttles, buses, trains, community transport

Through the later stages of this research project, we will endeavour to differentiate between different automated vehicle types and refine the list of barriers and recommendations which are relevant to each.

1.4.3 Prevalent barriers relating to non-automated transport

It was notable that disabled people experience obstacles across all stages of the journey from journey planning to arriving at their destination.

The barriers identified from the literature are listed against each journey stage in Table 2. We classified each of the barriers using the Individual-Social-Material (ISM) model (Southerton et al., 2011 as cited on Scottish Government, 2013). The ISM model states that factors that influence people’s behaviours can be classified as Individual, Social, and Material, and factors need to be considered within those contexts in order to design effective interventions for behaviour change. Perspectives held by an individual that affect their choices and behaviours are known as Individual factors. Social factors are understood as shared beliefs amongst groups that influence how groups of individuals behave, such as social norms that are influenced by people's networks, relationships, and affiliated organisations. Finally, Material factors are environmental factors, which both constrain and shape behaviour – this can be tangible things such as infrastructure or technologies and intangible things like regulations and schedules. In Table 2 each barrier has been coded to indicate the ISM category it falls in – Individual (I), Social (S), and Material (M).

The majority of the barriers identified in the literature were categorized as 'Material' barriers, suggesting that past research has primarily identified environmental factors as the key obstacles to disabled people's travel. This aligns with the Social Model of Disability which states that it is the environment which disables an individual's ability to do certain things, rather than being a product of the individual's inherent ability to do it (Scottish Government, 2013). A few barriers identified in the literature fell into the 'Social' category where they related to interactions with drivers or other passengers. Very few fell into the 'Individual' category, although it should be acknowledged that poor experiences when travelling may lead to a loss of confidence in travelling in the future.

Key barriers that were well-evidenced in the literature included:

- Drivers' poor attitudes or understanding of user needs (S).
- Outdated information (such as bus timings, station exits, connecting journeys) in inaccessible format (such as font size, amount of information, visual information on illuminated panels) (M).
- Inconsistency of terminal or vehicle interior design (M).
- Limited numbers of adapted vehicles among private transport services and community transport alternatives (M).
- Poor design of road infrastructure that obstruct footpaths or hinder walking or wheeling (M).

This evidence review showed that even though guidance and requirements are in place (e.g., the PSVAR, Traffic Signs Manual for Road Works), these are not always adhered to. For example, the legal requirement to provide reasonable assistance to disabled people on bus services is evidently not upheld by all drivers, as past research has highlighted poor bus driver's attitudes and lack of awareness on how to help disabled people as one of the prominent barriers. Similarly, there have been complaints about inaccessible pathways during construction works, despite a requirement for pedestrian footways to remain at a minimum width of one metre. It suggests that while there might be official guidelines in place, these are not necessarily comprehensive enough to meet the needs of users, or being implemented or monitored sufficiently.

1.4.4 Types of disabilities covered in the literature

The vast majority of the evidence reviewed related to visual and physical impairments. The barriers described by physically impaired people were typically related to the built environment and physical features such as terminal layouts, bus stop space, spaces within vehicles, and quality of footpath. In contrast, visually impaired people mentioned barriers mainly relating to presentation or provision of information, with some mention of quality of footpaths. These barriers all fall under the ‘material’ category as outline above.

There was far less evidence surrounding other impairments, such as hearing and cognitive impairments. This could be for a variety of reasons. First, it is possible that some groups of disabled people have been less represented in the research due to potential additional ethical considerations needed; for example, establishing consent from those with cognitive impairments. Another consideration for underrepresentation of people with cognitive impairments and learning disabilities in the literature could be based on an assumption that they are less likely to travel independently, and that the presence of a carer would reduce the barriers faced.

It is recommended that the groups of disabled users who were not represented in the reviewed literature (in particular those with autism and other mental health difficulties, as well as those with epilepsy, speech and hearing difficulties) are included in further research. It’s highly likely that there are other barriers which have not been formally documented due to a lack of research into these groups.

Of the evidence that was identified and reviewed, **there was limited research relating to accessibility needs from the perspective of a disabled driver**. Instead, the majority of the literature focused on the accessibility needs of disabled passengers. Hence, the literature mostly covers obstacles faced by users taking public or shared transport modes, specifically buses, trains, rideshare, and taxis. This highlights a knowledge gap on the perspectives of disabled drivers, since most of the research identified was focussed on the needs of disabled passengers.

1.4.5 Comparing existing barriers in transport to potential barriers in automated transport

In the literature reviewed, barriers relating to non-automated transport were noted against all stages of the journey, whereas for literature specifically focussed on automated transport, barriers were largely discussed in relation to boarding the vehicle, while on the journey, and when alighting the vehicle. It is possible that barriers in journey planning and booking journeys may not be evidenced in the current literature because those services did not exist at the time when those studies were conducted, and were therefore too abstract to evaluate. However, it is likely that barriers relating to these stages will continue to exist in relation to automated transport, as automating the vehicle is unlikely to solve these specific issues by default. **Barriers in journey planning and booking journeys relating to non-automated transport, such as an inaccessible format of information or limited service options, could continue to be an obstacle in automated transport if they are not addressed**.

1.4.6 Limited information on how to make automated transport accessible

Many of the papers found during this review **did not fully investigate how to make automated vehicles accessible for disabled people.** For example, while many papers considered the prospect of a wheelchair restraint system, many of these articles failed to note that many users would be unable to operate these devices themselves, and only two papers described an automated wheelchair restraint system.

Many of the papers stated that automated vehicles should be designed to be accessible for disabled people. Yet many of these papers **revealed no details of quite how such a change would be achieved.**

A notable exception was in the area of regulation, where there have been recommendations around creating codes of practice, implementing permits to be awarded to operators when accessibility requirements have been met, and suggesting the use of co-design and testing of prototypes.

Overall, while some research has investigated accessibility requirements for disabled people, a greater emphasis is required to assess how to ensure that automated vehicles are accessible for all disabled people.

It was notable that there are gaps in the literature in terms of good practice recommendations for how disabled people will book vehicles, ensure that they identify and board the right vehicle, how AVs will stop safety concerns when travelling without a driver and how the vehicle will orient the passenger when they get to the correct stop.

Table 2: Barriers faced by disabled people at each journey stage, as identified in the literature

Journey stage	Existing transport issues faced by disabled people (I = Individual, S = Social, M = Material)	Potential barriers for disabled people on automated vehicles and services
Journey planning (info finding)	Lack of knowledge and experience travelling alone adds anxiety to and prevents individuals from making independent journeys. (I) Format of information is not accessible. (M) Uncertainty about routes, schedules, walking distances, crowding levels and facilities. (M) No single platform for all information. (M) Poor public transport options in rural areas. (M)	None noted in literature
Booking journey	Limited accessible private hire vehicles available for booking. (M) Limited services available on paratransit options. (M) Having to pay more for a journey due to need to travel with a carer. (M) Inconsistency in required payment methods, ticket validity and pricing. (M) Difficulty arranging assistance. (M/S)	None noted in literature
Getting to the station, stop or vehicle	Poor design of physical infrastructure on footpaths (e.g., dropped kerbs, tactile paving, construction works blocking pavement). (M) Lack of step-free routes. (M) Long walking distance. (M) Bikes / scooters being ridden on pavements. (S)	None noted in literature

Journey stage	Existing transport issues faced by disabled people (I = Individual, S = Social, M = Material)	Potential barriers for disabled people on automated vehicles and services
Arriving at station or stop	Limited stops or stations that are designed to accommodate wheelchair user or mobility aid user. (M) The process of booking assistance or adapted service at stations is poor. (M) Lack of disabled parking. (M)	None noted in literature
Finding the correct service	Lack of consistency across the terminals makes: it harder to navigate the terminal. (M) users feel insecure or fearful for personal safety. (I) Technologies and accessibility solutions that are supposed to make public transport more accessible are often not used properly, or are broken (for example elevators, escalators, screen readers or audio announcements on buses). (M)	Working out where the automated vehicle is, and which automated vehicle to get on. (M)
Waiting	Paratransit options are unreliable (for example often late). (M) Lack of shelters at bus stops. (M) Insufficient space at bus stops for wheelchair users. (M) Lack of facilities (e.g. toilets, waiting areas with heating, relief areas for assistance dogs) available, or in working order (M) Inaccessible ticket vending machines. (M) Lack of staff available to help with purchase of tickets. (S) Lack of real-time information. (M)	None noted in literature

Journey stage	Existing transport issues faced by disabled people (I = Individual, S = Social, M = Material)	Potential barriers for disabled people on automated vehicles and services
Boarding vehicle	Lack of step free access onto vehicle, including mechanical faults with ramps. (M) Drivers not 'kneeling' vehicles or deploying ramps correctly. (S) Having to wait for a bus that will enable them to board / have space for their mobility aids. (M) Risk of mobility aids being caught in gaps. (M) Narrow entranceways and access corridors, and a lack of insufficient space to manoeuvre a wheelchair or other mobility aids. (M) Difficulties communicating directly with the drivers or when paying the fare in the ticket window. (S)	How will wheelchairs be secured with no human on board? (M) Lack of space inside for wheelchairs, guide dogs, canes. (M) Lack of standardised seating means visually impaired users may struggle to work out where everything is positioned. (M) Fixed seating means a lack of layout options for all user types i.e. those who need extra legroom or space for a wheelchair. (M)
On the journey	Priority seating not available / not clearly defined / not given up by others (M/S) Few seats that are aptly positioned for disabled people. (M) Overcrowding is a practical barrier with limited space reserved for wheelchair users.and persons with mental health issues may experience sensory overstimulation or invasion of personal space in crowded vehicles. (M) Lack of real-time information/ inaccessible information / broken screens or announcements. (M) Negative attitudes from staff and other passengers. (S) Motion sickness from sitting facing backwards. (M)	Fear of what happens in an emergency with no human on board? (S) Fears of safety due to no driver present to stop assault. (S) Lack of real time communication as to where the vehicle currently is. (M)

Journey stage	Existing transport issues faced by disabled people (I = Individual, S = Social, M = Material)	Potential barriers for disabled people on automated vehicles and services
Alighting the vehicle	Placement of stop buttons / intercoms not user-friendly. (M) Lack of step free access off of vehicle, including mechanical faults with ramps. (M) Drivers not 'kneeling' vehicles or deploying ramps correctly. (S)	None noted in literature
Getting to desired destination	Poor design of physical infrastructure on footpaths. (M)	Difficulty orienting once the visually impaired person has exited the vehicle, with no operator to guide them. (M) Confirming that the disabled person has arrived at the correct location when they get to the destination. (M) Dropping off the disabled person at a location with no obstacles around the vehicle (street layout). (M) Visually impaired person unable to tell the automated vehicle the specific place where they want the vehicle to park. (M)

Journey stage	Existing transport issues faced by disabled people (I = Individual, S = Social, M = Material)	Potential barriers for disabled people on automated vehicles and services
Various	None noted in literature	Difficulties interacting with the human-machine interface to tell the vehicle where to go or be told where to get off. (M) Difficulties getting into and out of the vehicle for mobility or visually impaired people. (M) Vehicle is less able to externally communicate with disabled people (i.e. the automated vehicle cannot wave a hand to tell a disabled person to go). (S) Controls (i.e. to stop the vehicle) may be hard to reach. (M) Lack of trust in the automated vehicles. (I) AVs being electric will mean they are harder to detect by those with visual impairments. (S)

1.5 Conclusions from evidence review and implications for future research

The primary objective of this review was to understand the barriers relating to transport faced by disabled people and the potential barriers and benefits associated with automated transport. The review also sought to identify good practices and solutions to overcome accessibility needs for automated transport users.

This review has shown that:

- Disabled people experience obstacles across all stages of the journey when using non-automated transport. This is likely to be similar for automated transport. However, in the literature, potential barriers relating to automated transport focused mainly on boarding the vehicle, experience while on the journey, and alighting the vehicle. It is likely that there are gaps related to other journey stages. **Future research should consider potential barriers at all stages of the journey using automated transport.**
- The majority of the barriers identified in the literature relating to non-automated transport were categorised as 'Material' barriers (in line with the ISM model), suggesting that primarily factors in the external environment are the most impactful. **This is likely to be the same for automated transport, and so these are factors that should be prioritised to enable accessibility – although social factors should also be considered.**
- The vast majority of the evidence reviewed related to visual and physical impairments. There was far less evidence surrounding other impairments, such as hearing and cognitive impairments. **It is recommended that these groups of disabled users who were not represented in the present review (in particular those with autism and other mental health difficulties, as well as those with speech and hearing difficulties) are included in further research.**
- There is a lack of precision in the language used to describe automated transport, meaning that potential barriers to using automated transport are generic and not comprehensively noted. **During the coming research it will be important to differentiate between different automated vehicle types and refine the list of barriers and recommendations for each.**
- Many of the papers found during this review did not fully investigate how to make automated vehicles accessible for disabled people. Whilst some referred to guidelines for existing non-automated transport, **there is a need for more thinking to be done on practical recommendations for ensuring automated transport is accessible.**

Task 2: Stakeholder engagement

2.1 Stakeholder engagement method

Interviews were conducted with representatives from three different types of organisations: Disability Organisations, Technology Providers and Transport Operators. The objective of the interviews was to understand the perspectives of these various stakeholders in terms of the challenges and opportunities automated transport brings for disabled people, how much current focus is being given to accessibility in the development of automated transport, and what can be done to improve accessibility in the future. The three types of organisations were selected in order to capture a range of perspectives:

- **Disability Organisations** – to inform us of the challenges that disabled people currently face with public transport, how these could be resolved in automated vehicles, and the benefits that automated vehicles could offer. We aimed to recruit a diverse selection of disability groups. Some of the organisations were represented by a person with lived experience of a certain disability (i.e., Disabled People's Organisation (DPO)) while others were non-users-led disability charities.
- **Technology Providers** – i.e. organisations involved in the design and development of automated transport and associated technologies, to inform us of the extent to which accessibility is currently being considered and any challenges in developing accessible automated transport.
- **Transport Operators** - to inform us of the extent to which accessibility is considered in current transport services and any challenges with delivering an automated (or non-automated) service that is accessible for disabled people. We aimed to include operators of a range of transport types including bus, train and taxi, as well as those involved in automated transport trials.

We contacted 27 Disability Organisations, 24 Technology Providers and 24 Transport Operators via email asking them if they would be willing to take part in a 30–45-minute online interview. We sent out reminder emails where we had not received a response within a few days of sending out the initial email.

A total of 28 stakeholders took part in the interviews, covering six Disability Organisations, 11 Technology Providers and 11 Transport Operators. Whilst we aimed to cover a broad cross-section of organisations, it should be noted that due to the relatively small sample size the findings from these interviews should not be assumed to be representative of the whole sector.

We developed a topic guide for the interviews to guide the discussion and ensure consistency between interviewers. Questions were tailored according to the stakeholder group. The following topics were covered:

- existing barriers to non-automated transport faced by disabled people
- potential barriers disabled people may face with automated transport

- the potential benefits of automated transport for disabled people
- to what extent is accessibility being considered in the development of automated transport vehicles and services
- examples of good practice for delivering accessible automated transport

Interviews took place between November 2023 and January 2024 on Microsoft Teams and were audio and video recorded with interviewees' consent. In most cases, two researchers took part in each interview, with one leading the discussion and the other taking notes.

To analyse the data, we collated responses to each question area from the topic guide and used thematic analysis to analyse the data related to each question.

In this report we have listed findings under 4 topics:

- Potential benefits of automation for disabled people.
- Potential challenges disabled people may face interacting with automated transport, including the needs that they would have regarding automated transport.
- Accessibility considerations made in the design and development of automated transport
- Summary: What examples of good practice are emerging in this area?

Quotations are presented anonymously throughout the report, with the corresponding letter indicating the type of organisation the quote links to (D – Disability Organisations; T – Technology Provider; O – (Transport) Operator), and the letter indicating the participant number.

2.2 Key findings from stakeholder engagement

2.2.1 Stakeholder views on potential benefits of automation for disabled people

Stakeholders noted four key areas where automation could bring particular benefits for disabled people. First, automated public transport could eventually lead to cheaper running costs for Public Transport Operators, due to the potential removal of the need for a human driver. This may allow cost savings to be passed on to customers, making the service more cost competitive and appealing to customers.

Second, Transport Operators suggested that some bus routes that were not currently financially viable (and had therefore stopped running) may become financially viable with an automated service. The reintroduction or expansion of bus routes would open up a greater number of choices for public transport users, allowing them to reach areas where there may not have been able to previously.

Third, automation may enable Public Transport Operators to offer a better level of service for travellers with the same number of staff members present on the vehicle, as effectively the staff member previously responsible for driving could switch to a customer service / steward role and provide assistance during the journey, as required.

Fourth, private automated vehicles were viewed as bringing particular advantages for disabled people. In particular, a private automated vehicle would provide door-to-door transport which is, typically, not possible with public transport. The vehicle can also be set up to the bespoke needs of each individual traveller. One stakeholder suggested that a private automated vehicle would avoid the pressure some disabled passengers feel to board and alight public transport vehicles quickly, to avoid incident or delay. It was raised that disabled travellers may perceive themselves to be a burden on other passengers if they require longer to board or alight the vehicle, as they may prevent other travellers getting to their destination as quickly. If a disabled person has a private automated vehicle however, they can take as long as they want to board and alight without the fear of being judged.

2.2.2 Stakeholder views on potential challenges disabled people may face interacting with automated transport

Disability Organisations and Transport Operators noted multiple challenges that different disabled groups could face with automated transport. Many of these were barriers that disabled people already face with non-automated transport, which are likely to apply to automated transport as well. The existing barriers were identified and discussed in detail in the evidence review conducted before this stakeholder engagement. Further potential barriers related specifically to automated transport and would not apply to non-automated transport. These barriers are discussed in the following sections. They are structured around six key needs that should be met in order to provide an accessible service. These needs were identified through analysis of the stakeholder interviews:

- The need for clear, timely, and accessible information – both before the journey and when on the journey.
- The need for physical access on and off the vehicle.
- The need for immediate and effective assistance to be provided when something goes wrong.
- The need to feel comfortable and safe on the vehicle.
- The need for affordable services.
- The need to establish trust in automated transport solutions.

2.2.2.1 The need for clear, timely, and accessible information – both before the journey and when on the journey

Interviewees stated that access to clear and reliable information, both before and during the journey, was important to help travellers plan their journey and be informed about their current whereabouts, thus enabling them to travel with greater confidence and independence.

Disabled people rely on various sources of information such as tactile, audible, or visual messages to orientate themselves and navigate to and through public transport stops, hubs, and interchanges.

Some interviewees indicated that current public transport options typically lack the provision of information in suitable formats. While there are physical signs, mobile apps, websites, and text alert services that transport providers have adopted, Disability Organisations said that disabled people often find them difficult to use or that the information is not in accessible formats. There is a risk that this will also be the case in relation to automated transport.

Interviewees described the need for information in different formats:

- **Tactile signage:** Tactile signage, such as braille or raised symbols, helps individuals with visual impairments to navigate unfamiliar environments independently. A lack of tactile signage can make it challenging for them to locate essential facilities, platforms, and exits.
- **Aural information:** Audio cues, such as announcements, provide important information about schedules, changes, and upcoming stops – this is particularly useful for people with visual impairments who cannot access updates on visual boards. The Disability Organisations that we spoke to mentioned that apps like *Be My Eyes* and *Aira* which can guide blind and visually impaired people around stations and platforms. The lack of audio information also caused barriers to disabled people on the journey.

  "[With toilet doors on trains] There's nothing that says 'locked'. You just have to trust, you can't hear anything. I've pressed what I thought was a lock and then people have been able to open it [the toilet door]." (D2)

- **Visual information:** Interviewees highlighted that while current transport hubs have visual signage in place (e.g. information boards and displays), not all of them are accessible to users. Information conveyed through colour contrasts, clear fonts, and familiar symbols assist individuals in wayfinding and understanding their surroundings. Visual signage serves as a substitute for auditory announcements for individuals with hearing impairments. A lack of, or poorly designed, visual information may lead to confusion and difficulty in planning their next move.

When introducing automated public transport services, it will be important to ensure that information is provided in accessible formats to instil confidence and allow independent travel by disabled people so that they do not have to rely on assistance from drivers or other members of staff on their journey. This includes information provided in advance of a journey (information about the service, the facilities onboard the vehicle and at the station, and directions to navigate the stations), and also real-time information about service changes or disruptions during the journey.

In particular, Disability Organisations stated that disabled people face challenges when booking transport or purchasing a ticket through automated ticket machines. It was stated that there is no consistency in the interface of these machines, and the accessibility of these machines could vary, with many machines relying on visual information only (such as a screen) to buy a ticket. If physical tickets are a requirement for automated vehicles, this challenge will need to be addressed.

Automated private vehicles also need to consider how to incorporate all necessary information using appropriate formats (tactile, audio, and visual) within the vehicle to keep the passengers informed about the journey; this is especially important for automated services where there is no driver and no other member of staff onboard.

2.2.2.2 The need for physical access on and off the vehicle

A key challenge anticipated with automated public transport services is around ensuring passengers with mobility challenges are able to easily board and disembark vehicles. For example, a lack of step free access at bus stops, stations and platforms means that disabled people currently struggle to access some public transport vehicles independently, and are often reliant on assistance from drivers or other members of staff (e.g. to deploy ramps). This is likely to continue to be a challenge with automated transport services, but could in fact be made worse where services are operated without a driver or other member of staff available.

In the case of trains, some Disability Organisations noted that older stations predating current accessibility regulations continue to pose challenges for disabled people to navigate. These structures sometimes have limitations on the extent to which they can be modified or improved due to planning restrictions. In some cases, new infrastructure (such as lifts, ramps, and step free access) is built around existing structures and if the original building design cannot accommodate the structural upgrade, then it limits how accessible the stations can be made. This will continue to be a challenge if automated vehicles use this same historic infrastructure.

One interviewee reported that some bus stops are not accessible (i.e., because there is a lack of step free access) which means that it is possible for a user in a wheelchair to alight at the bus stop and then end up stranded due to steps being the only way off the bus stop. Another interviewee noted that as a starting point any automated bus or train service should provide information (e.g. on their website or app) in an accessible form which clearly notes which stops are accessible for that service so that users can understand whether they are able to get to their destination before they set off.

> *"We need an inventory of which stops are accessible, [which] will help passengers with disabilities plan their journeys properly from end to end, rather than getting to their destination, getting off an accessible bus and finding they are stranded and don't have a suitable route from that bus stop" (O3)*

Currently one way this challenge is addressed is through the use of staff assistance. Many of the Disability Organisations that we spoke to highlighted the crucial role that station staff and drivers play in assisting disabled people to board and disembark public transport and in private hire vehicles. This can involve the use of a dedicated assistance service, where travellers can book assistance for journeys, most notably train journeys, in advance. Whilst this service can be of great value to disabled people, interviewees reported some challenges, including having to arrive a significant time before departure, and booked assistance not arriving. These issues could continue in relation to automated transport, and would need to be addressed to enable an effective assistance service. Aside from a dedicated assistance service, drivers offer assistance through deployment of ramps, or helping passengers into the vehicle, and so alternative means of providing this support in the absence of a driver or other member of staff will need to be developed.

Interviewees expressed concern about the potential lack of a staff member on board automated vehicles and how this would impact passengers' ability to board and alight. While there were assumptions that accessible features such as automated ramp extensions would be included in automated vehicles, interviewees were concerned about how users would be informed about the existence and functionality of these features, how to operate them and what would happen if things went wrong (e.g. ramps becoming stuck during deployment). Interviewees recalled instances where automated ramps in existing public transport services have become stuck, and the driver has had to manually override the deployment. Going forwards, there is a need to plan for how such situations would be resolved if the technology malfunctions without a staff member in the immediate vicinity.

There is also a need to improve the functionality of this technology to reduce instances of malfunction in the first place. This includes aligning new automated vehicle models with existing infrastructure or ensuring that the infrastructure around public transport is updated to accommodate automated transport. For example, if ramps are going to be deployed automatically, either the technology needs to be flexible (i.e. with the ramps being able to reach different bus stop heights) or the infrastructure needs to be adapted (i.e. all bus stops meeting a certain design standard).

2.2.2.3 The need for immediate and effective assistance to be provided when something goes wrong

A strong theme emerging from the interviews in relation to anticipated challenges with automated transport services related to the need for assistance if things go wrong. Inevitably there will be times when things do not go to plan (e.g. delays and emergencies). The interviewees noted that the passengers onboard automated transport services would want reassurance that there will be some form of assistance in these situations. On buses, the driver is currently the main source of assistance for passengers, and the interviewees noted that a lack of a driver on automated buses may lead to both inadequate management of, and inadequate responses to emergencies. In particular, interviewees thought that any driverless service may not be able to spot emergencies (such as a fire) to know the appropriate course of action. This may lead to higher levels of passenger anxiety due to a lack of reassurance that any emergencies would be addressed swiftly.

> *"If you didn't have personnel on board, what would be the issues … if you physically needed assistance to get onto a vehicle or off a vehicle, we had one incidence where the vehicle had to be evacuated because of a situation. Again, what would happen if you didn't have assistance on board?" (O11)*

The challenge of communicating during emergencies, especially for disabled people with communication difficulties was raised by many Disability Organisations. It was also suggested that disabled passengers would be apprehensive about relying on other passengers to provide assistance or seeking appropriate support from the service operator on their behalf. This raises questions about the protocols and options available to individuals in case of unexpected situations or crises.

There were assumptions that automated transport services, like current transport services, would likely have features such as intercoms to communicate with the relevant operators during an emergency. However, a reliance on intercom features raised concerns with some Disability Organisation, especially for those with hearing or speech impairments. There are text-to-speech features in some devices designed as an accessibility aid that attempt to bridge the communication gap between computers and humans. However, the effectiveness of these devices may be compromised in scenarios for those with speech impairments or distinct accents who may not be accurately understood. This limits an intercoms' usability, impacting the ability of disabled people to effectively convey their needs to the automated vehicles in the absence of a human operator.

One common suggestion in the short term was for automated vehicles to retain a staff member on board to provide assistance in case of any emergencies. This was suggested as a temporary solution to help passengers transition from the current services (vehicles with drivers) to automated vehicles (driverless vehicles) in the future.

There is also uncertainty surrounding liability and insurance in the event of accidents involving automated vehicles. This applies to both privately owned and public transport vehicles.

2.2.2.4 The need to feel comfortable and safe on the vehicle.

Interviewees spoke about challenges that disabled passengers may experience when on board the vehicle. Specifically, they highlighted situations involving conflicts with other passengers, such as someone occupying a designated space for disabled individuals. There were concerns about managing such situations without the presence of a driver or staff member on board. One suggestion included providing more priority spaces to accommodate wheelchairs or pushchairs, in order to avoid conflict in the first place. There may be an opportunity to add more priority spaces as there is flexibility around the design of automated vehicles. Overall, interviewees expressed uncertainty around how conflict would be managed in automated vehicles in the absence of a driver or other member of staff. This could therefore have a negative impact on passengers' perceived and actual safety on board automated services.

In current public transport services, members of staff (e.g. the driver) are considered as the main means by which conflicts can be deterred or managed. Drivers are also considered to be a critical source of reassurance for passengers that they will reach their destination safely, are seen as authority figures, and as someone who may be able to provide a more 'personal touch' to people's journeys. All of these things can contribute to passenger feelings of safety and comfort; thus there could be negative impacts of running automated services in the absence of a driver or other members of staff unless this gap is filled by other means.

> *"The biggest one will be losing the 'personal touch'. Losing the ability to offer that unique/personal service – can nervous/anxious passengers receive the reassurance they need around the service without a driver?" (O7)*

2.2.2.5 The need for affordable services

Disability Organisations highlighted financial barriers that prevent disabled users from using current transport services. Some disabled people have a low income or receive benefits. Although it was suggested that automated public transport could eventually lead to cheaper prices for passengers (which was noted in Section 1.3.1), public transport can continue to be a challenge for disabled people due to the above-mentioned barriers (i.e., poor assistance services, physical barriers, lack of provision of information in accessible formats).

Private transport, while more convenient, is typically more expensive for disabled people. This contributes to the disparity that disabled people face in being able to travel independently. Private automated vehicles are expected to be more expensive than current private vehicles because of their technological novelty. Disabled people already perceive transport costs as a barrier to travelling, hence Disability Organisations raised concerns that the introduction of private automated vehicles could further exacerbate existing affordability barriers.

> *"And the affordability as well - Whether people can access, for example, a personally owned vehicle and the cost of it being adapted, that's a barrier and that could potentially be unaffordable for people." (O8)*

2.2.2.6 The need to establish trust in automated transport solutions

Disability Organisations suggested that poor experience with inaccessible features and services on current transport services would likely foster mistrust and anxiety when contemplating the use of automated transport in the future. An underlying mistrust in new technology and in Transport Operators may prevent disabled people from using automated vehicles, even if the system is fully accessible. Therefore, to establish trust in automated public transport it is imperative to show disabled people that automated public transport options are accessible and will overcome the expected and perceived barriers. One suggestion was to let disabled users "try out" an automated vehicle to give them first-hand experience that their perceived barriers can be addressed with assistive technologies on automated vehicles.

> *"So we work with various disability charities on various projects like confidence building. We work with individuals who perhaps have only recently got a disability, it's not something they've had all their life and so they need a bit of support, so we do confidence building with them." (O5)*

2.2.3 Accessibility considerations made in the design and development of automated transport

This section outlines findings from the interviews with Transport Operators and Technology Developers in terms of how much they are currently considering accessibility in automated vehicle design and operation.

Interviewees representing Transport Operators and Technology Developers were supportive of the goal of designing accessible transport vehicles and systems. They reflected that designing an accessible automated transport system has the potential to benefit everyone, as making services accessible to a diverse range of individuals should contribute to an overall improvement in access and service quality for all.

Some Technology Developers reflected that current public transport systems appear to prioritise the movement of people rather than the quality of their experience, and there is an opportunity to change this. Interviewees felt that it is crucial to not treat disabled individuals as an afterthought in the design and implementation of automated transport services. Recognising the importance of inclusivity from the outset will ensure that the needs of all passengers, including those with disabilities, are considered integral to the overall design and functionality of the service.

Some interviewees were excited by the opportunity to explore new form factors of vehicles which could overcome some of the current barriers around accessibility, although many had not yet started developing new form factors.

Overall, there was a positive attitude towards making automated vehicles accessible. Below we set out what appears to be happening in practice, on the basis of what interviewees told us, and some complexities that were raised by interviewees.

2.2.3.1 Involvement of disabled people in design and development process

Many of the interviewees noted that disabled users should be considered during the process of designing the vehicles so that important accessibility aspects are not missed out. This was viewed as paramount by those representing disabled groups. The following activities were identified as being currently being employed by Transport Operators to help their services become more accessible:

1) Talking to disabled users about past journeys which had not been accessible, and seeking to understand how they could be improved in future.
    a) Some Operators and Technology Developers reported doing this through deliberative research with disabled people.
    b) One Operator said they engage with individuals who have lodged complaints to gain deeper insight into issues related to the accessibility of their service.
    c) One Operator said they engage disabled user groups through regular open days where passengers and drivers can have two-way communication regarding barriers, challenges and solutions.
2) Inviting disabled people to test different vehicle designs to understand what works best, what does not work well, and how it can be improved to be accessible.

2.2.3.2 Prioritisation of accessibility

Some Technology Developers stated that they were currently focussed on ensuring that the basic functionality of the automated driving technology is working, with plans to place more focus on customer experience and the automated transport service later in the development process. This suggests that accessibility may be viewed as an afterthought by some companies, which could result in automated vehicles not meeting the needs of all users.

> *"From the OEM perspective… if we're talking about something that can be done within the vehicle by means of screen or sound or HMI, Human machine Interface, it's almost like a secondary layer – it's a different kind of problem, but it's a problem that you can tackle closer to the production, the big challenge from my perspective is more about the fundamental definition of how will the vehicle look like, and how it will go around the city." (T5)*

One Technology Developer felt that it was mainly the operator's role to consider the user experience. In contrast, an operator noted that, from their perspective, accessibility starts with the design of the vehicle. They felt it was important for Technology Developers and vehicle manufacturers to have certain accessibility features on their checklist in the design phase, although they acknowledged that there were challenges in providing some features due to cost pressures. This suggests a potential lack of coordination between Technology Developers and Transport Operators regarding their roles in ensuring accessibility on automated transport services. There is therefore a risk of inadequate attention being given to the needs of disabled users.

2.2.3.3 Innovation around alternatives to drivers

As discussed previously, Disability Organisations and some operators expressed concerns around the lack of driver on automated transport services, and the impact that could have on running an inclusive service. Technology providers were also aware of this. Some Transport Operators reported that they are considering alternative options for covering the non-driving related duties of a driver once that driver is removed.

Features raised by interviewees included intercom systems that allow communication between passengers and system supervisors at an HQ, internal cameras to monitor passengers' status and handle emergency situations and audio systems to give announcements and updates on journey information, warnings to passengers, etc. One technology provider indicated that there is currently little work being carried out on potential human-machine interfaces for automated vehicles – highlighting a potential future gap - but it was also noted that there may be on-going work that has not yet been shared in the public domain for commercial reasons.

It was notable that all interviewees viewed some of these features as a poorer method of getting assistance than having a driver. This is because they do not enable instant responses, and generally provide a lower level of support than a human driver would be able to. Therefore, some Transport Operators and Disability Organisations proposed having a dedicated member of staff on board automated bus services to ensure adequate support was provided for all passengers.

> *"I think staff on buses will always be required because when there's an emergency - it's a bit like the whole conductor on train argument. Oh yes, the train can go perfectly well without it, but what happens when it doesn't work? What happens if there's an accident? What happens if, if, if…" (D3)*

Currently, automated vehicle trials require a safety driver - as mandated by legislation - but many interviewees suggested that a staff member may also be required when automated transport services move beyond trials and into commercial deployment. Some interviewees felt that having a dedicated customer-service staff member could in fact be an advantage over current models. While a bus driver has to compete with the multiple demands of driving a bus and supporting passengers, a customer service staff member would be able to give their full attention to the customers' needs.

On the other hand, some stakeholders perceived that a staff member onboard a bus in addition to the driverless vehicle technology would not be viable from an economic perspective. In particular, one participant noted how a large coach company which had tried to introduce a deluxe coach service with a host had stopped these services due to the sheer cost of employing a host or hostess. Possibly, the cost advantages that could be gained from automation (see Section 1.3.1) may be negated by use of an on-board staff member.

Table 3 provides a list of solutions suggested by stakeholders to overcome challenges in the absence of a driver.

Table 3: Suggestions to overcome challenges relating absence of a driver

Challenges related to having no driver on-board	Potential solutions
Inability to identify which passengers require a boarding/alighting ramp.	An automated ramp deploying at each stop.
No one in authority to direct passengers during emergencies.	An intercom system to enable passengers to talk to a supervisor at HQ.
Inability to ensure that passengers behave on board the bus.	CCTV cameras watching the passengers.
The bus not being able to arrive at an appropriate location to deploy the automated ramp safely (due to other vehicles being parked in the bus stop). Note that this can be overcome on current public transport due to the possibility of a manual ramp deployment by the driver.	Greater enforcement around bus stops to stop other vehicles parking in the stops.
Lack of access to information and support.	An information system onboard (i.e. a human machine interface via a digital concierge or avatar) who can answer questions regarding the service.

2.2.3.4 Challenges and complexities when considering accessibility

Interviewees spoke about several challenges and complexities associated with the design and operation of accessible transport services:

- They felt that it is challenging to design a one-size fits all solution due to the diversity in user needs.
- There is currently little guidance around how to ensure a high-level of accessibility for automated vehicles.
- Inconsistency in the external environment makes it challenging to roll-out automated vehicles in the first place.

It is challenging to design a one-size fits all solution

Whilst respondents recognised that designing a vehicle to be accessible would benefit all users, some of the Technology Developers felt that achieving a one-size-fits-all solution may not be possible in practice. They suggested that this is because there are a wide variety of disabilities and user needs, each with different (and sometimes conflicting) requirements.

> *“Every OEM work to guidelines, rules, regulations so…you can design a product around it where you know exactly what it's going to be used for. With the accessibility you got such a breadth requirement and it's not defined, that's the issue.” (T8)*

Some pointed to cost-related factors – in that creating such a vehicle would be very expensive to develop. Participants reflected that the need for accessible vehicles can be in conflict with commercial priorities.

> *"So the reason that none of these public transport services enable these systems for disabled people now is because the cost is too much pressure to such a small volume of people. And I don't know what the numbers are, but I bet you it's less than 1% of people need disabled access." (T9)*

In contrast, some interviewees felt there was an opportunity to offer a variety of vehicles designed to meet differing needs. For example, automated vehicles could result in more frequent services, and so vehicles with different levels of accessibility could be run on these routes – allowing the user to select which vehicle suits their needs the best.

> *"Also, because it's a private right and it's an on-demand system and you're booking your vehicle, you can actually prebook a suitable vehicle" (T10)*

In the case of privately-owned automated vehicles, some interviewees felt that a one-size-fits-all vehicle would not be appropriate as not all individuals would require all accessibility features, and some may not be willing to pay a higher price for features they do not need. One interviewee felt that a more realistic target would be to design vehicles that meet the needs of the majority of the users, with the option to convert the vehicle for others.

Finally, it was shared that conversion companies, who convert vehicles to make them accessible on behalf of vehicle OEMs, do not always publicise their methods of altering a vehicle to make it more accessible, due to commercial sensitivity. This prevents OEMs from making progress on producing accessible vehicles on their own terms.

When these findings were shared with the project Advisory Group, there was concern about the resistance of striving for a one size fits all solution. While it was acknowledged that it is challenging to meet all needs, stakeholders raised that there are risks with relying on different vehicles to meet different needs. If different choices are offered, customers need to be able to exercise this choice easily, and be able to access the vehicle they require. There is a risk that even if the appropriate vehicles exist in the fleet, the surrounding system used to order that vehicle may not be fit-for-purpose – for example, there may be long wait times for the appropriate vehicle, or it may cost more – which may mean the service is not inclusive.

It was stated that challenges around one-size-fits-all vehicles should not dilute the ambition to develop a holistic solution.

There is currently little guidance around how to ensure a high-level of accessibility for automated vehicles

Technology developers noted that there is a lack of specific guidance for creating accessible automated vehicles. The National Technical Specification Notices - Persons with Reduced Mobility (NTSN-PRM) and PSVAR regulations were referenced, which cover requirements for non-automated trains and buses, respectively, but it was felt these were not sufficient for automated transport services as this regulation does not cover how vehicles will be made accessible without a driver on board. For example, the PSVAR does not cover how disabled people will be assisted onto a bus without a driver present. This means that Technology Developers are currently not legally required to consider accessibility in the development of automated vehicles, other than these two pieces of regulation that do not consider the particular automated features of buses and trains (e.g. how a disabled person will be assisted without a driver). A lack of guidance also introduces the risk of developing inconsistent levels of accessibility on different models of vehicles.

Interviewees felt that accessibility regulations for existing non-automated vehicles (i.e. those above) are useful in driving minimum standards for accessibility. Across interviews, there was a perception that the current regulations on accessibility in vehicles would be the starting point for regulations around automated transport. One transport Operator suggested that specific accessibility standards should be written into local transport authority contracts to lead the industry to produce more accessible vehicles.

Technology developers felt that a minimum design standard taking into account the needs of all disabled users would be valuable. Some interviewees made a suggestion for a rating system similar to the New Car Assessment Programme (e.g. EURO NCAP), which is a voluntary car safety performance assessment programme with several levels of rating. They felt that having a similar voluntary programme could prompt manufacturers to consider accessibility further. Achieving a high rating would provide a point of differentiation from competitors, increasing appeal to consumers and increasing chances of securing public procurement contracts.

Inconsistency in the external environment makes it challenging to roll-out automated vehicles

While the design of the vehicle is a key factor for ensuring accessible it is not the only piece of the puzzle. In general, many interviewees suggested that automated vehicles will require an environment that is as standardised as possible to operate safely. This would include there being fewer non-automated vehicles on the road, and more consistent road layouts, bus stops and kerb heights. However, this would require a complete re-think of the transport system and infrastructure that can be costly and time consuming – which many interviewees felt was a barrier to the roll-out of automated vehicles in the first place.

2.3 Conclusions from stakeholder engagement: What examples of good practice are emerging in this area?

There were few examples of current good practice related to accessibility of automated vehicles. This is likely due to the technology being in its infancy.

Boarding automated vehicles and providing accessible information were the most common topics discussed by interviewees. Much of the technology in these areas (e.g. automated ramps, intercoms) is under development, and so there does not appear to be much in the way of demonstrable good practice currently.

Some Operators and Technology Providers had implemented features to improve accessibility of current non-automated transport services which could be translated across to automated vehicles. Examples included:

- Automatic ramp deployment.
- Considering colour schemes with brand materials that are more accessible to those with vision impairments (O10).
- Audio announcements that increase in volume when there are more passengers on the vehicle, to adjust for background noise (O9).
- Adding a second wheelchair space onto the bus. (Blackpool Transport)
- Display screens positioned to be viewable from the wheelchair-priority bay on vehicles (O1).
- Research on wireless charging of electric vehicles to remove the need to lift and plug in a cable (T2).
- Anti-slip flooring to reduce injuries and improve stability (T4).
- Emergency buttons placed at lower heights to be accessible to those sitting or in wheelchairs (T4).
- Systems to allow passengers to flag that they have specific needs in advance of travel.

These features did not seem to be consistently implemented across vehicles and operators.

There was also some evidence of research taking place which may lead to advancements in accessibility in both non-automated and automated transport:

- Research into boarding/alighting from a vehicle among the elderly (T7).
- Research into facial / voice recognition technology to reduce the number of functions required to start a private vehicle, and to interpret the stress/ wellness levels of passengers (T7).
- Research on brain-to-vehicle communication, via sensors placed on the head (T1).

As discussed previously, there was also some evidence of organisations engaging with disabled users to gather feedback and improve their services.

Overall, we can conclude that the organisations we consulted clearly see the benefit of making automated transport accessible, and some had already taken steps to consider how this may be done. However, there did not appear to be a consistent or comprehensive approach to making automated transport accessible across the different stakeholder groups, and further work is needed to establish suitable guidance, standards and regulations to improve accessibility in future.

Task 3: End-user focus groups

3.1 Focus group: Introduction

Three focus groups with disabled people from the RiDC panel were held in January 2024. The RiDC pan-disability panel is a group of over 4,000 disabled and older people across the UK who are interested in helping to make services and products more accessible and inclusive. Some more information about the panel can be found at www.ridc.org.uk.

The focus groups explored the potential benefits of automated transport for disabled consumers and the accessibility requirements disabled consumers would need to be addressed for them to use automated transport.

In the focus groups, participants were asked to consider both private vehicles (vehicles that you would traditionally drive yourself) and shared vehicles (vehicles that you would ride in as a passenger). Participants were encouraged to discuss topics in the following areas:

- the benefits of fully automated vehicles,
- the access requirements of automated vehicles, and
- perspectives on safety

Focus Groups: Key Findings

- For disabled consumers, the main benefit of automated transport came from the sense of independence that could be gained from private automated vehicles. Participants wanted to travel independently and thought that automated vehicles could be a “game changer”.
- Many participants felt that, even if a private vehicle was fully automated, they would not be able to benefit because they could not drive. This is because some participants had impairments, such as visual impairments, that prohibited them from driving. There was a concern that expectations could be raised when, in reality, they were unlikely to see the full benefits.
- The safety of automated vehicles continued to be a concern throughout the focus groups. Some participants were unwilling to use them at all, whereas others would only use them once it had been established that they were safe.
- Participants highlighted that all aspects of owning a private automated vehicle needed to be accessible for them if they were going to be able to use them. This included charging the vehicle, communicating with the vehicle, maintaining it and being able to park.
- Overall, there was a greater reluctance to use shared automated vehicles compared with private ones. Participants emphasised the need for human assistance on shared vehicles to ensure safe boarding and alighting. Participants wanted a human conductor to be present in case of an emergency.

3.2 Methodology: Focus Groups

16 people from the RiDC panel took part in a series of three virtual 90-minute focus groups.

Participants were selected based on their demographic profile. They were then sent a short survey to indicate whether they were willing and available to take part in the focus groups. Panel members were selected who had disabilities in different impairment categories (sensory, cognitive and physical). The focus groups were organised by impairment grouping, with the first one including those with sensory impairments, the second including those with cognitive impairments and the final one including those with physical impairments.

It’s important to note that most participants have one or more disabilities and in interpreting results, researchers looked at the nature and context of the insight rather than the group participants were allocated to.

The focus groups included people from a range of locations across the UK, including a range of people from urban, suburban and rural locations. Participants were also asked if they used a private vehicle and whether it was adapted.

Demographics

The majority of participants had more than one impairment. 12 participants had a sensory impairment, 10 had a cognitive impairment and 11 had a physical impairment. In terms of gender, 9 of the participants were male and 7 were female. In terms of ethnicity, 2 participants were Asian/British Asian, 4 were Black/African/Caribbean/Black British, 1 was from Mixed/Multiple Ethnic Groups, 7 were White British/Irish/Other and 1 participant selected Other.

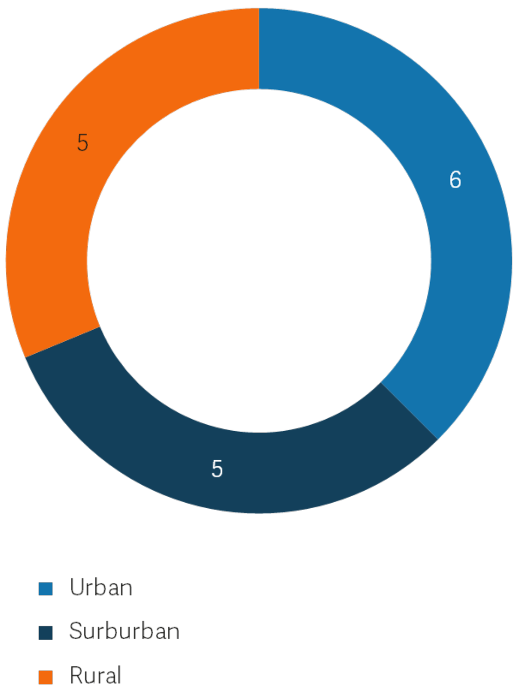

Figure 3: Community types included in the focus groups

Additionally, recruitment included a focus on whether participants lived in an urban, suburban, or rural area (see Figure 3). 6 participants lived in an urban area, 5 in a suburban area and 5 in a rural area. Participants were also asked whether they had access to private transport (see Figure 4). 6 drove an un-adapted vehicle, 3 drove an adapted vehicle, 6 were driven by someone else and 1 person did not use a private vehicle.

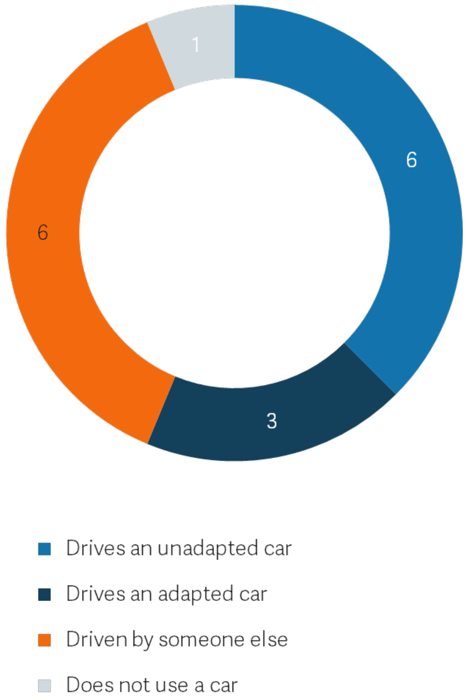

Figure 4: Private vehicle use in the focus groups

3.3 Focus Group: Findings

3.3.1 Perceptions of automated transport: Benefits

Participants were asked to consider the benefit of automated transport more broadly before considering the customer journey. They considered what they thought would be the benefits in a more abstract sense. Three clear themes emerged: independence, excitement and enjoyment, and safety.

3.3.1.1 Independence

A key benefit of private automated transport was the potential to improve independence for disabled people.

> *"I think the initial feeling is…if this was available and fully no intervention required from a human driver, this could be a game changer for anyone with a visual impairment who, you know, can't get an adapted vehicle pre the concept of reliable automation."*

This theme was particularly apparent for participants who were currently restricted from driving because of their impairments. Those with visual impairments said they were often reliant on friends or family, or public transport, to get where they needed to go. For them, private automated vehicles presented an opportunity to allow them to go where they wanted on their own.

> *"The number one thing for me personally is independence because I rely mostly on my mother to help, you know, to take me places or public transport, and sometimes you do want to be able to go to places on your own."*

3.3.1.2 Excitement and Enjoyment

For a handful of participants, the excitement of automated private transport was a benefit in and of itself. They were fascinated by the technology and were keen to be able to try it for themselves.

> *"I would still find it a draw. I would find it fascinating and I love the idea of it actually, I can't see us ever owning one, but having part ownership or part use or whatever when I needed it on a timetable. I mean, whatever, I would grab it with both arms."*

Others enjoyed the thought of being able to relax while on journeys.

> *"My benefit would be that I didn't have to think about what I'm doing. I can just sit back and relax and read a book, let the car take me."*

3.3.1.3 Improved safety

Finally, a few participants expressed the view that automated transport would be safer than vehicles operated by human drivers.

> *"It reduces like the human error element. So, for example, not so much error but error of judgment. So, like drunk drivers, things like, for example, sleepy drivers, anything like that and the accidents caused by that."*

3.3.2 Perceptions of automated transport: Barriers to Access

Participants also explored the barriers that may prevent them from accessing automated transport. The two key themes that emerged were safety concerns and legislative barriers.

3.3.2.1 Safety Concerns

Participants were asked to consider the safety of automated vehicles. In the focus groups perceptions of safety appeared to be polarised. Some participants considered improved safety to be a benefit of automated vehicles, whereas many voiced that concerns about safety would prevent them from using an automated vehicle.

Many participants were concerned about the safety of automated vehicles. Some were unwilling to try automated transport until there was evidence that they were safe. Participants were aware of reports of accidents and other safety failures that made them wary of trying automated transport.

> *"I've seen cases where they've been trying automated vehicles and there's been accidents and people have, they've all stopped in the middle of nowhere…So we seem at the moment to be a long way off getting a foolproof system."*

In some cases, the concern for the safety of automated vehicles became a barrier to considering any benefits for disabled people. This was despite being asked to consider the benefits, assuming automated vehicles were safe.

> *"However, as much as that sounds amazing and brilliant. I would be, I would still be concerned about the prospects of, of an accident occurring."*

These concerns resulted in the sentiment that some participants would be willing to try automated transport, but not yet. This concern was less evident for participants who already used automated transport, such as those in London who already used the Docklands Light Railway (DLR).

3.3.2.2 Legislative Barriers

Some participants also raised that, despite the potential benefits, many of them felt that private automated transport would not be made available to them because they were not legally allowed to drive.

Some were concerned that, unfairly, expectations could be raised for disabled people before legislative frameworks were understood.

> *"I will never be able to legally operate a vehicle on the road, you see."*
>
> *"Sometimes I get very worried about these research projects because they raise expectations for disabled people…they come up with a brilliant idea and then when we get to legislative frameworks, that's when all things start catching up with people and reality hits home."*

For others, it was felt that disabled people who were unable to drive because of their impairments should not be allowed to drive automated private vehicles.

> *"I think it should be that if you cannot get a driving license, you should not be allowed to get behind the wheel because even though it's autonomous, there are going to be times where a driver has got to take over the controls of the vehicle."*

3.3.3 During the Journey: Boarding

Participants were then taken through the customer journey to consider what access barriers they might face when using automated transport. Three themes emerged: lack of assistance, wheelchair access and ramps, and boarding safely.

3.3.3.1 Lack of Assistance

A primary concern for participants when considering boarding shared automated vehicles was the lack of human assistance. Some participants relied on human assistance to find their seats or to get relevant information about their journey. Without that assistance, they felt they would be unable to use shared automated vehicles.

> *"If you're going on these automated shared vehicles and the wheelchair has to be tied down, who does that for you?"*

> *"If it's going autonomous, you would still need to rely on public contact. You would because if, for instance, you're in a wheelchair or mobility scooter or anything like that and the ramp stops working, then you need help to get off..."*

3.3.3.2 Wheelchair Access and Ramps

Participants, particularly wheelchair users, were concerned about their ability to board the vehicle. Wheelchair users and mobility scooter users required a ramp to access the vehicle and they required the ramp to align with the pavement.

> *"Where there would be perhaps a ramp on a bus at the moment is whether there would be an automated, you know, sort of ramp to enable people to get out with wheelchairs from the vehicle if they were still sitting in their wheelchair. And…there may be a facility where the vehicle's gonna stop, but if it doesn't line up properly, then, you know, that could be a problem or if it stops, I'm aware there's a very high, drop down to the pavement or the curb…you've got to be able to cater for a wide variety of circumstances"*

Additionally, wheelchair users needed the correct doors for boarding and alighting shared automated vehicles to open automatically, and they needed room in the vehicle to manoeuvre their wheelchairs.

3.3.3.3 Boarding Safely

Finally, some participants raised concerns that the vehicle would not know when they had safely reached their seat.

> *"Will it wait until I sit down? What are the rules and regulations if you have these vehicles? Because if it's allowed to travel with people stood up, then that's more of a manifest problem rather than a detection problem if it does set off without you safely seated."*

3.3.4 Alighting and Maintenance

Towards the end of the focus group, participants explored alighting automated transport. Spontaneously, many participants raised the issue of maintaining privately owned automated vehicles. Two themes emerged: becoming stranded, and fuel, charging and parking.

3.3.4.1 Becoming Stranded

For private automated vehicles, there was the additional concern that disabled people may become stranded if something went wrong or in the event the vehicle went the wrong way.

> *"If it suddenly breaks down or something goes wrong, you could be left stranded, and particularly if you're disabled, that would be incredibly difficult to cope with."*

"And you end up somewhere you don't really want to be, and it happens all the time, and you're talking about a network that's been going for years. So, this is why when you're talking about the automatic car, I think a lot more thought needs to go into it."

3.3.4.2 Fuel, Charging and Parking

A significant concern was how disabled people would manage to put in fuel, charge or park an automated vehicle. Many participants were unable to do these tasks independently. As a result, there was a concern that this would prevent disabled people from using private automated vehicles.

"I think charging or petrol or whatever these vehicles run on because you have to get out of the vehicle and locate the pump and the whole process can be quite difficult, especially if you know, it's your first time experiencing that…. So how would this car know where to locate these charging points or petrol stations? And how will it instruct me on how to do that? Will I have to learn it myself, like in a safe environment and just remember how to, because I don't have that same capital, that same experience as a driver of a normal car would have."

Another consideration was how a private automated vehicle would find an accessible parking spot. Additionally, participants with visual impairments were unsure how they would find a parking spot if they could not see one.

"And then things like parking. Again, I'm assuming it's gonna find you a vacant spot, but is it gonna necessarily find you an accessible parking spot? Like how is that gonna help you in terms of accessibility again."

Finally, participants were concerned that they would struggle to maintain their vehicles. This included maintaining tyre pressure, putting in oil and ensuring the vehicle was kept clean. Participants noted that if they were able to drive vehicles independently, they would also need to be able to look after the vehicles.

3.3.5 Shared versus private automated transport

Overall, there is a greater reluctance to use shared automated vehicles than private automated vehicles from participants. The primary concerns were:

- A lack of safety from other passengers
- A lack of human support in the event of a medical emergency or accident

In the focus groups there was a concern that riding in a shared automated vehicle without human support could be dangerous for disabled people. Participants felt that they were more vulnerable because they were more likely to experience medical emergencies and less able to defend themselves from other passengers.

"If I fall, and it's happened [before], then if there's nobody there whatsoever apart from this blob of metal, the best it can do is to call emergency services. I've got a button for that, or I've got a phone for that. But if I'm unconscious, I haven't"

> *"If something went wrong, there's a human there who, who's sort of in charge and can help… human connection for me is vital from both the logistics as well as safety…If anything, I'd be much better off getting on a normal bus."*

> *"So, you know, if you haven't got anybody like a conductor or a bus driver on there to intervene and protect…then you're on your own."*

Participants were more likely to view private automated vehicles in a positive light. For private automated vehicles, the primary concerns were:

- Wayfinding and knowing the vehicle would arrive at the correct location
- That their location data would be collected or that they would be monitored
- Being unable to communicate with the vehicle

> *"They would be using some form of AI they would be learning as they go. Presumably, they're sharing that data with a central company…So where does privacy come into it? Because you're potentially signing up for all of your journeys to be recorded and monitored and shared to a central company."*

> *"Google Maps…you've only got to get a bad signal and the map's gone. And I remember trying to go to a party only recently just before Christmas and I couldn't get a signal. I couldn't find my way to the party. I had to go back home…So there's all those type of things, you know, that that can weigh into the equation of, of automation."*

> *"How would you stop the vehicle? Would, could it be by voice control?"*

3.4 Focus Group: Conclusion

The focus groups provided insights into the needs and preferences of disabled people when considering automated transport. The participants were clear that for them to be able to use automated transport they needed the entire process of accessing such transport to be accessible. This did not just include accessing the vehicles, but also included considering legislative barriers, maintenance of vehicles, and being able to communicate effectively with the vehicle. For shared automated vehicles, it also meant understanding that some disabled people require human assistance to be able to board, alight and safely access their seat. Additionally, for some, there was a need to have human assistance in the event of an emergency or to prevent harassment from the general public.

The participants had mixed feelings about the benefits of automated transport for disabled people. In general, there was a belief that automated transport, particularly privately owned vehicles, would be a game changer for disabled people. Participants voiced that it would give them more independence and freedom, particularly in cases where driving was not possible or restricted due to impairment. However, many were concerned that the benefits would not be fully realised unless the needs of disabled people were explicitly considered in the design of vehicles and in legislation and policy.

Task 4: End-user survey

4.1 Survey: Overview

Informed from the preceding focus group work, we scripted a survey which was sent to the RiDC panel. The RiDC pan-disability panel is a group of over 4,000 disabled and older people across the UK who are interested in helping to make services and products more accessible and inclusive. Some more information about the panel can be found at www.ridc.org.uk. The survey aimed to gather a better understanding of what the barriers and opportunities relating to automated vehicles might be.

After asking a few questions about the respondents' private and public travel habits, the survey followed a typical customer journey from planning and booking a ticket through to boarding, travelling, and alighting. There were 32 core questions which took on average between 15 to 20 minutes to complete. The survey was open for two weeks between 29th February and 14th March 2024 and received 906 responses, of which 808 were complete and used in the quantitative analysis.

4.2 Survey: About the respondents

4.2.1 Disability

Details of the demographics of the respondents can be seen in Appendix B . These show the survey respondents to be a largely representative sample to ONS data (UK data taken from Family Resources Survey 118/19) by 'Gender'. However, 'Age' is slightly under-represented within the below 35 years old categories (7% compared to 16%; note that the Family Resources Survey categorise age from 15 to 24 years old, as opposed to 18 to 24 years old in the RiDC panel) and 'Disability' is over-represented in the Physical category (92% compared to 72%) and Sensory category (46% compared to 18%).

It should be noted that approximately three quarters of disabled people on the RiDC panel have more than one disability.

70% of respondents reported having some form of sensory difficulty, which may be due to being neurodivergent or having a mental health condition, when travelling by private or public transport. The most prevalent difficulty recorded concerned 'having difficulty managing crowds' (74%).

4.2.2 Vehicle ownership and driving

44% of respondents lease their vehicle with a further 27% owning their vehicles. Two thirds of respondents (65%) said they drive their vehicle whilst the other one third have someone else drive it for them such as a personal assistant, family member or carer. 69% of respondents have a full or provisional driving licence and 15% were disqualified on medical grounds.

4.2.3 Public transport

The older our respondents were, the less likely they were to use public transport. This was particularly the case for people with a physical impairment. We also saw less use of public transport in rural areas, compared to urban or suburban areas, which might be due to reduced public transport infrastructure in rural areas.

4.2.4 Assistance

40% of respondents required some form of assistance from another person when using a vehicle, getting on or off, or during the journey itself.

Many of the respondents have assistive technology or devices to help with getting on and off their vehicles or adaptations to help with driving their vehicles.

70% of respondents reported having some form of sensory difficulty when travelling by private or public transport. The most prevalent of these related to difficulty in managing crowded environments (74%).

4.3 Survey: Findings

4.3.1 Challenges

Respondents were asked to think about their needs and to consider what the important things were to get right for both shared and private automated vehicles. Options were provided which were informed by the previous focus group work, with the respondents being able to select as many options as they felt applied to their needs.

These questions were framed in four sections relating to the customer journey for shared automated vehicles:

1. What you would need to know before starting a journey
2. When booking or paying for a journey
3. When getting on a shared automated vehicle
4. When onboard a shared automated vehicle

And in two sections for private automated vehicles:

1. When boarding
2. When onboard

In both cases, later in the survey, respondents were presented with all the options they had previously selected and asked to select the three most important ones that were essential to get right.

We also asked if there was anything about getting off the vehicle which might present different challenges to getting on the vehicle and provided an open text box to capture what these might be.

4.3.2 Shared automated vehicles

Figure 5 shows a bar graph of the number of responses to each of the options provided in the four sections. We have abridged the full option descriptions for display purposes. The full descriptions can be seen in Appendix C.

Each option was selected by at least 300 respondents (37% of respondents) apart from ‘Guide or assistance dog space’ which can be explained by the smaller number of respondents who have these assistance animals.

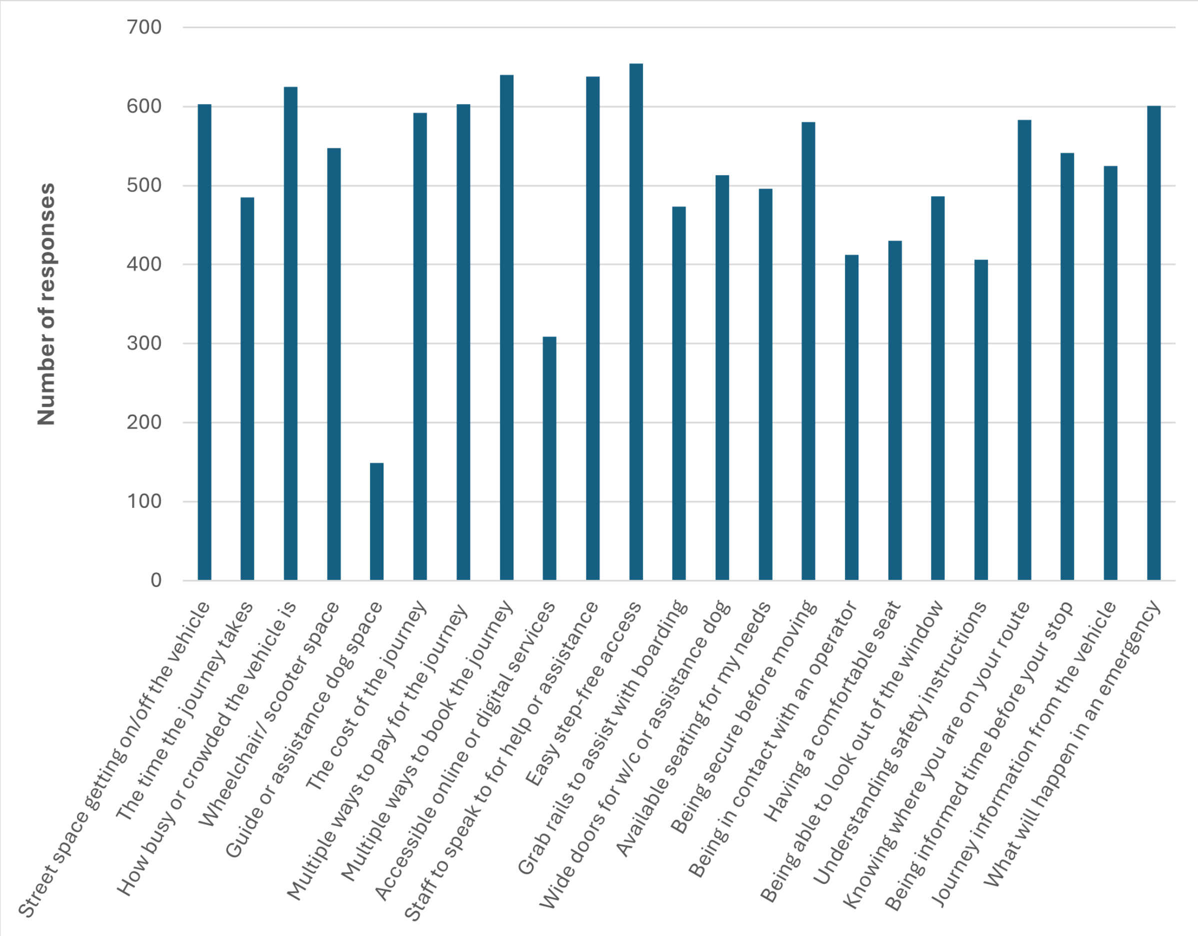

Figure 5: ‘Which of the following would be important to you and your needs?’ for shared automated vehicles

When the respondents were asked to select ‘the three most important things that are essential to get right’ from the complete list of their previously selected options we get the graph shown in Figure 6. This was done to help prioritise the most important options for people across all disability groups. The options have been colour coded to represent the different stages of the customer journey (Before, Booking, Getting on, During journey).

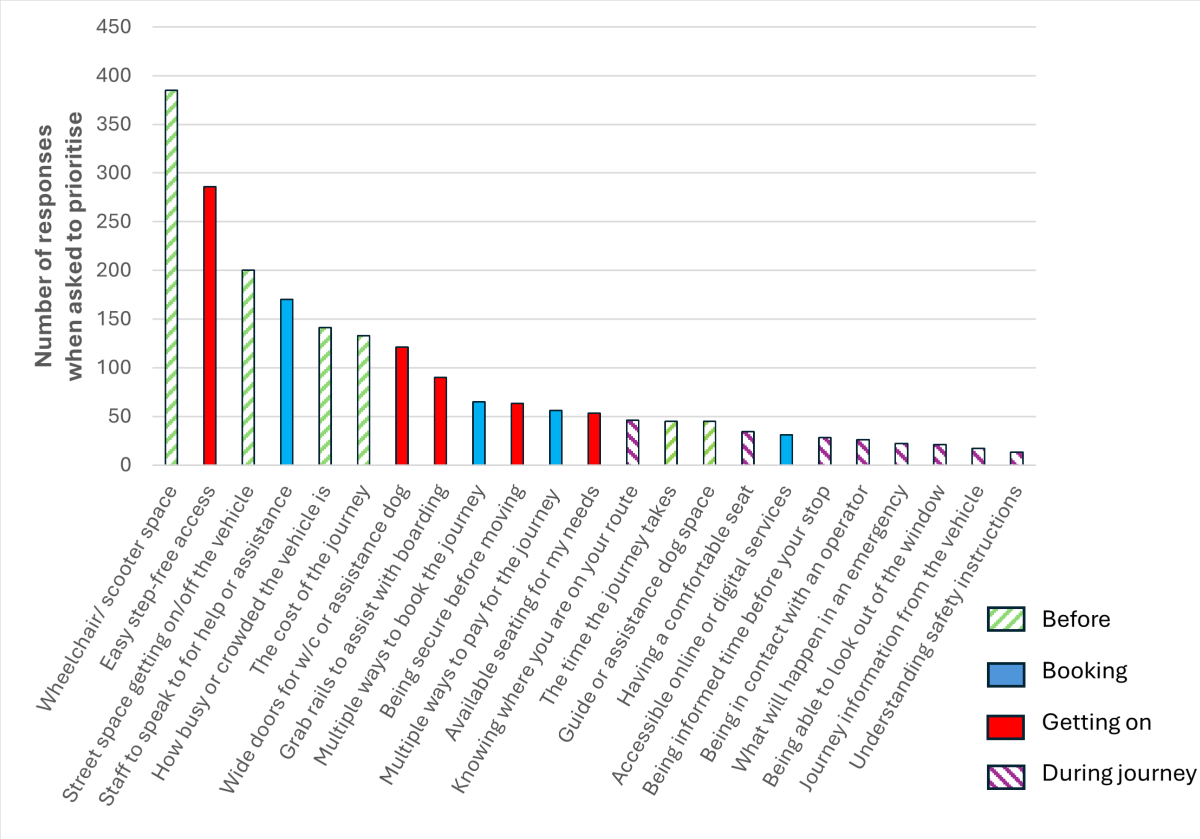

Figure 6: Priority choices for shared automated vehicles.

A note of caution should be made here not to over interpret the results in Figure 6. Many difficulties experienced by disabled people when travelling on public transport cannot be easily overcome and often become barriers to travel. This is demonstrated by the even spread of selected options in Figure 5.

A further calculation was made to show how many respondents selected the same choice as before when asked to prioritise and select only three. This is displayed as a percentage of the number of people who originally selected that option and reflects the strength of feeling the respondents had for each of the options selected, see Figure 7.

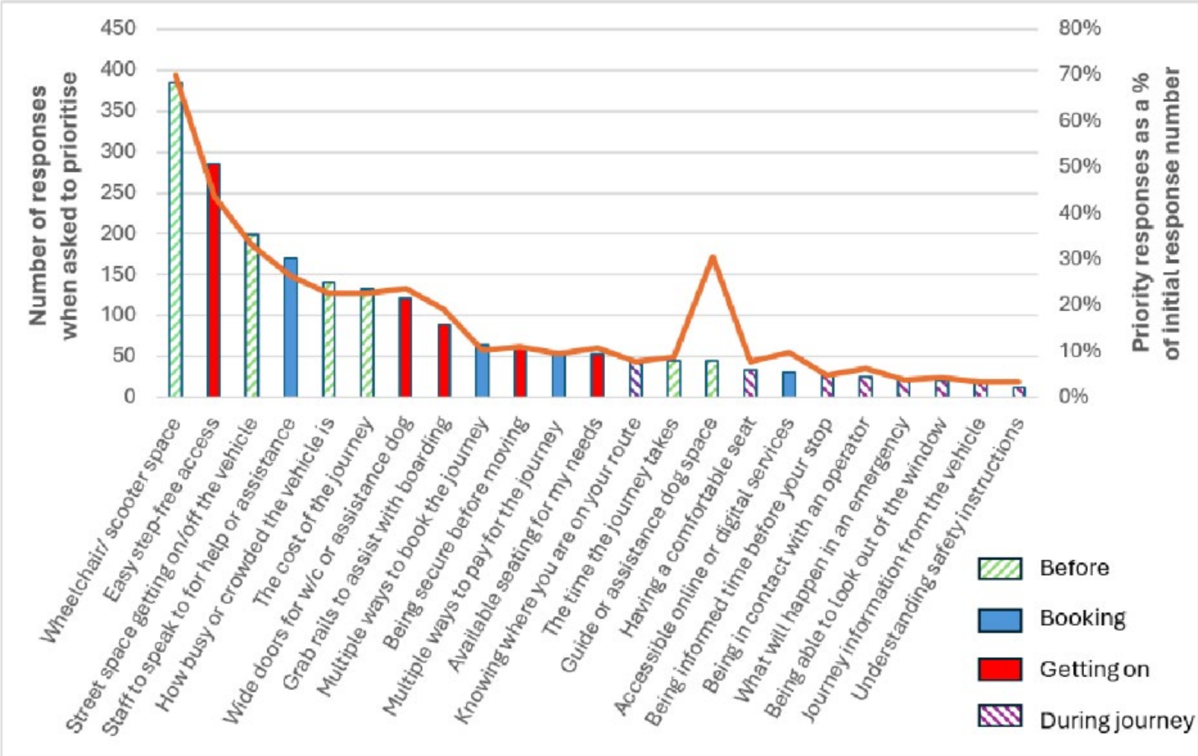

Figure 7: Strength of feeling of prioritised choices for shared automated vehicles

This largely follows the values of the prioritised selections. The exception to this is seen in the number of respondents who selected ‘Guide or assistance dog space’ which shows a greater proportion of respondents who selected this option also prioritised it. This would place it as the 4th most important thing to get right for people who have guide or assistance dogs.

4.3.2.1 Planning and booking a journey.

The options most prioritised by the respondents, were in the survey section which asked about the importance of what people would need to know **before** starting a journey. This suggests that these options are barriers and of particular importance which could prevent people from travelling. The need to know about wheelchair or scooter space on a shared vehicle is aligned with having a large representation from people with physical disabilities (92%).

Whilst **booking** a journey, the need for being able to speak to staff for help with assistance was prioritised, whereas having accessible online or digital services was considered less important. This is reflected in the comments collected in the open text box.

> *“Having staff to speak to who actually understand that all disabled people are different, and we might all have different needs.”*
>
> *“This point is difficult as over 90% of the Internet is not screen reader friendly or have [no] audio readback. Deafblind people are excluded as they are… ‘Internet disabled’ due to costs of equipment.”*

4.3.2.2 Boarding & alighting

The physical transfer from one place to another is where many people, especially those with physical disabilities, need the greatest support. The requirement for easy step-free access, provided by level boarding or an automatic ramp was frequently mentioned. The point of transfer, or gateway onto and off the vehicle, is a critical area for disabled people as indicated by the next prioritised boarding feature, i.e., 'Wide enough doors for wheelchairs and assistance dogs.'

Getting to/from, and the availability of, suitable seating (disabled seating or wheelchair space), was also a concern for many respondents. The need for room to manoeuvre wheelchairs and mobility scooters to a secure place was highlighted, as well as the importance of grab rails whilst boarding.

> *"Wide enough aisles and room to manoeuvre the wheelchair into a position that is out of the way for other vehicle users, then being able to have the wheelchair and myself secured BEFORE continuing on my journey."*

Similar concerns about boarding were echoed in respect to alighting, with the addition of having enough notification time to exit the vehicle.

> *"When you are getting on, the vehicle waits for you to board. Getting off (specifically getting up from the seat) can be slow/difficult. There needs to be sufficient time at the stop without having to think you need to start getting up when the vehicle is moving."*

4.3.2.3 During the journey

All the concerns recorded in the 'during the journey' section had significant response numbers i.e., between 400 to 600. However, when asking the respondents to prioritise their selections, the 'during the journey' concerns were the least frequently chosen options. This is probably because the other concerns are more of a barrier to access whereas the 'during the journey' concerns assume that access is achieved.

This should not detract from the importance the respondents gave to factors impacting this stage of the journey. Both 'knowing what will happen in an emergency' and 'knowing where you are on the route', received high response rates, 601 and 583 respectively.

> *"Knowing there are backup systems that will allow me to exit the vehicle if the main power goes out, or some other emergency."*
>
> *"Informative screen showing where you are and times of when each stop happens."*

4.3.3 Privately owned automated vehicles

A similar approach to that used in the shared automated vehicles section of the survey was taken when asking respondents about their views on privately owned automated vehicles. However, instead of asking questions that covered four stages of the journey, (before, booking, getting on, during), the privately owned questions covered two stages (getting on, during).

Figure 8 shows the selected concerns which are important to respondents to have recorded mostly between 300 and 600 responses (37%, 74%), with three exceptions of 'A wheelchair hoist', 'Space for guide/ assistance dog' and 'Vehicle designed to assist transfer to your seat'.

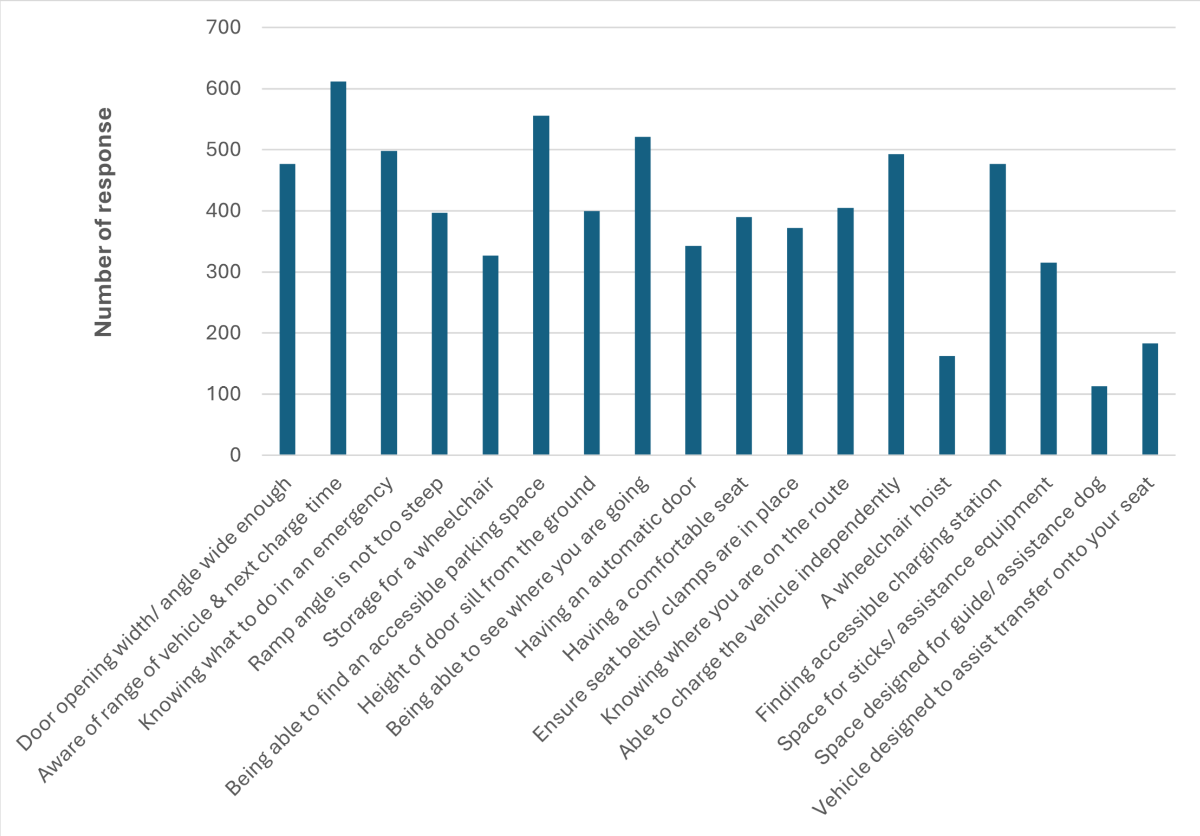

Figure 8: 'Which of the following would be important to you and your needs?' for privately owned automated vehicles

Figure 9 shows the results from respondents when asked to select 'the three most important things that are essential to get right' from the list of their previously selected options.

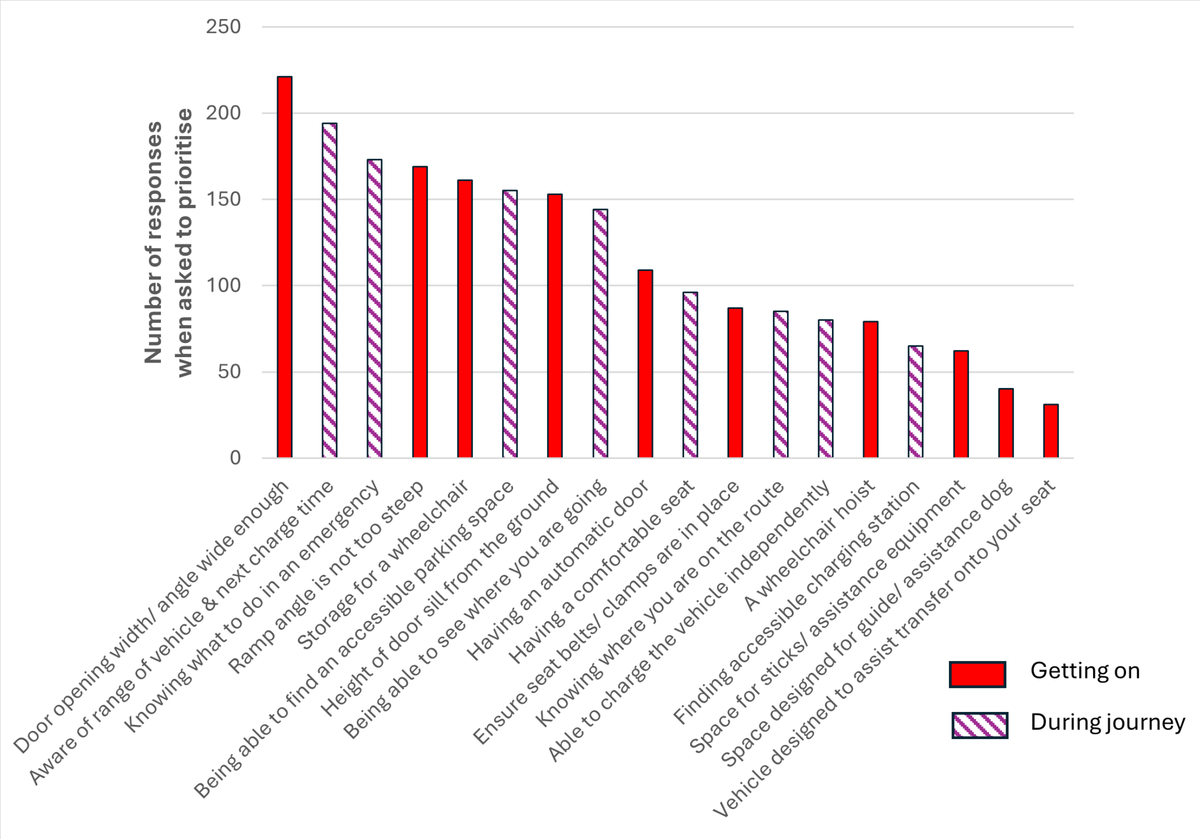

Figure 9: Priority choices for privately owned automated vehicles.

However, in Figure 10 we see the three choices in Figure 8 which had the least amount of responses (a wheelchair hoist, space designed for assistance dog, and vehicle designed to assist transfer onto your seat) all record a high 'strength of feeling' which would order these choices as more important for those people who selected them. For example, if a person needs a wheelchair hoist, it is a necessity, not a nice to have, for independent travel.

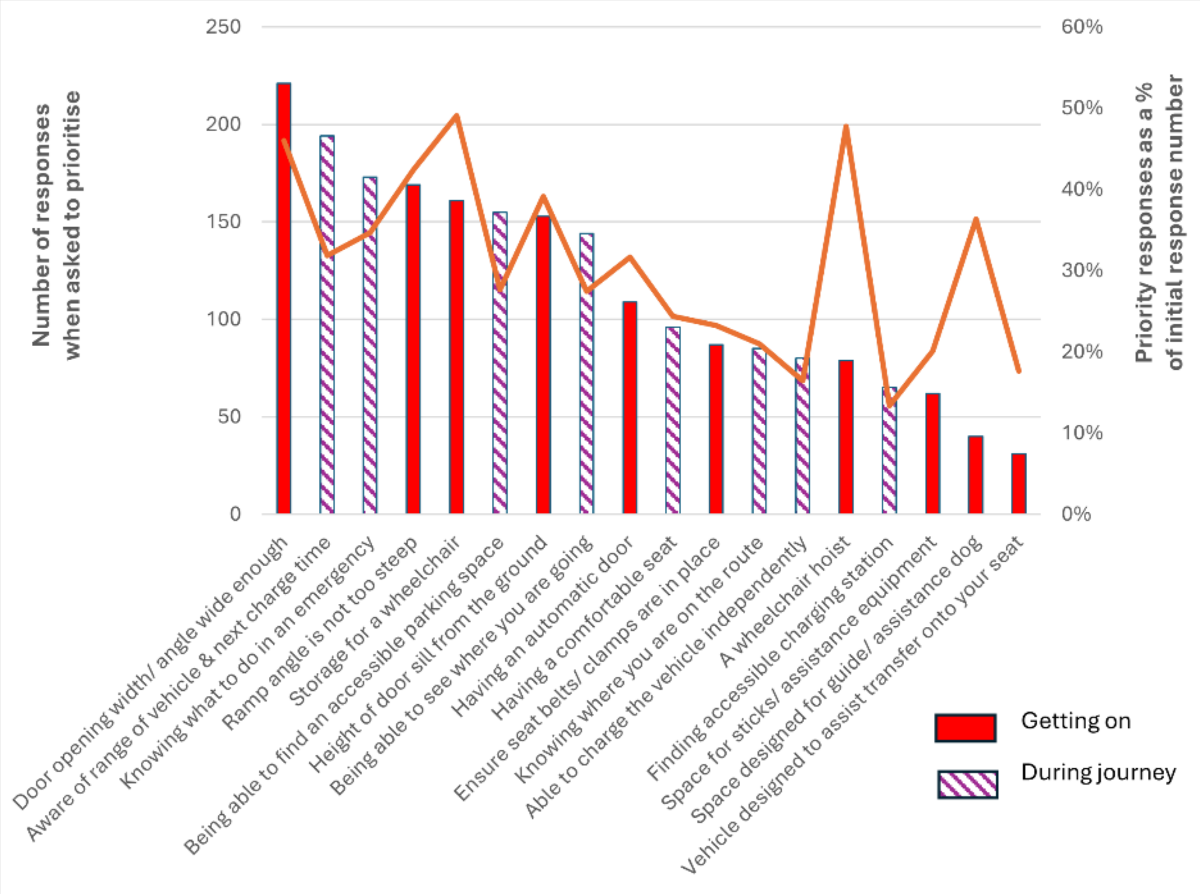

Figure 10: Strength of feeling of prioritised choices for privately owned automated vehicles

4.3.2.4 Boarding and alighting

As with shared automated vehicles, the point of entry to the vehicle was cited as a priority to get right with the 'Door opening width/angle is wide enough' option being selected the most. Although the option of 'a wheelchair hoist' was further down the list of priorities, for those people who selected this, it had the second highest proportion of responses (circa 50% of those who indicated it was important also selected it as one of the priority choices). The importance of accommodating assistance aids used to enable everyday mobility such as wheelchairs, scooters, guide/ assistance dogs and sticks/ assistance equipment is underlined by their increased proportionate response rates.

When looking at the qualitative open-ended responses to alighting privately owned vehicles, the pavement environment was highlighted with features such as space to manoeuvre wheelchairs, the presence of drop curbs, and a lack of obstructions all being important.

> *"With being disabled, getting on/off taxis is incredibly difficult already. Black cabs are horrendous to get in and of already. Better designed vehicles would be vital whether they are autonomous or not! But step free or automatic ramps would help. Knowing the drop off/pick areas are safe and not overcrowded so that disabled can take our time getting in/out. We need time and space to exit travel and being hurried raises*

the risks of falling/anxiety/not wanting to even try… It's tough and different for people with all sorts of disabilities and challenges."

4.3.2.5 During the journey

The worry of running out of fuel and being stranded or being caught in an emergency featured highly when respondents were asked to prioritise their concerns. The other 'during the journey' concerns were reasonably and evenly distributed.

> *"On the way information systems would be useful such as the ability to ask the navigation (at any point in the journey) to immediately re-route to go to the nearest accessible toilet facility and park at the nearest place to it."*

> *"Knowing exact limitations of automated vehicle like, will it find a gas station or charge point by itself, who is going to fuel it, how will we pay for that. Will there be staff at charge point or gas station to assist in fuelling up."*

4.3.4 Opportunities (potential benefits)

After providing an explanation of what the various levels of vehicle automation mean (see Appendix D) we asked respondents what they thought the benefits might be of private and shared automated vehicles. We carried out a thematic analysis of all the responses to these questions; the results are presented in a word cloud below which highlights the key themes that emerged.

For **private automated vehicles (n=829),** the perceived benefits reported emphasised the opportunity for an increase of personal independence and improved opportunities for disabled people.

Figure 11: Word cloud of Q3.3, 'What do you think the benefits might be for disabled people riding in a fully automated private vehicle?'

A further theme emerged concerning the potential to have an increased range to their travel plans which can currently be curtailed by tiredness or the stress of driving.

> *"If a disabled driver struggles to use the steering wheel an autonomous car could help greatly with proper lane/road positioning. It could also help with correct speed and braking control. It could be that driving is very tiring for the disabled person, an autonomous car would take away the stress allowing them to visit family no longer within driving reach."*

> *"Liberation-to be able to wheel into a car without the stress of initial positioning and subsequent quite intense concentration levels required for manual control operation would be amazing. This would lead to journeys for pleasure rather than necessity. Independence - not having to rely on partners/carers so heavily for travel would be a source of relief to both parties. Work benefits - I have Multiple Sclerosis and travelled widely in the UK with my work progressing from walking stick to wheelchair over a ten-year period. An automated vehicle would undoubtedly have extended my working life."*

The same question was asked about **fully automated shared vehicles (n= 720).** Many respondents said there would be no benefits for disabled people. One reason for this related to the high level of assistance required which is usually provided by the driver when boarding and alighting the vehicle. There was also concern about the automation adapting to the variety of needs of disabled people

> *"No benefits at all. A human being driver should ring my doorbell or phone on my adapted landline telephone and be present to collect me from front door to the vehicle and from the vehicle to assist me to inside the destination venue. It is*

essential to have verbal communication with a human being drive and not a hi-tech machine which has no idea or understanding of the people with either visual and/or auditory dual sensory loss."

Figure 12: Word cloud of Q3.4, 'What do you think the benefits might be for disabled people riding in a fully automated shared vehicle?'

A possible increase in independence was discussed but caveated by the current problems disabled people face when travelling on public transport such as space being available when onboard, smooth access on and off, and the behaviour of other passengers.

"Freedom to get out! But only if fully accessible and affordable. It would also depend on space inside if it was shared with able bodied people. Even today disabled spaces are often taken by the able bodied and confrontation can often happen. A totally automated vehicle would not have anyone to intervene if this situation occurred."

Many of the responses to these questions about the possible benefits of automated vehicles pointed out the complexities disabled people face when wanting to travel somewhere. An example of this is explained in the following quote.

"For someone like myself this would honestly open up a world of independence. I suffer from arthritis and drive with hand controls as I have a coded licence. If my arms flare, I simply can't go out without a PA driving for me. Also, I take a lot of controlled medication like diazepam. If I take it, I can't drive which often leaves me house bound for months sometimes. For my husband who has autism and bipolar disorder he will not use public transport as he doesn't talk to people. He has arthritis and is unable to walk far. He can't learn to drive with his disability and medication which again leaves him house bound. Having the opportunity to get a car with nobody to talk to or bother with is his idea of heaven. He would be able to use it and not worry about his huge mental health problems and explaining he doesn't want to talk to people etc and give him real independence. My only concern is he wouldn't

> *use it if it was like a bus where other people could just use it too so a private car would be the only way I would consider it for his mental health needs as it's no different to using a bus really. I can't see any financial assets to running this service for our needs."*

4.3.5 Semi-automated vehicles (Level 3 or Level 4)

Semi-automated vehicles can in certain situations require some level of intervention by the person in charge and were viewed with a level of mistrust. There was a lack of belief that the technology would not fail and an added concern of not being able to take control when prompted, see Figure 13. Additionally, there was concern over licensing arrangements for these levels of vehicle, as one respondent noted.

> *"Whilst my concerns have a basis about being disabled, there are general* ***concerns about being in charge of a vehicle and then swapping back to semi-automated control****. It would have to include sounds, visual and maybe even technology to alert disabled people when the car is in charge and when to get ready to change to automated control and vice-versa.*
>
> *I also feel that the* ***licensing*** *around semi-automated vehicles will have to be very specific and careful, for people with disabilities. Medication needs and impairments will have to be carefully considered when looking at a hybrid version because the changing of controlling the car to and from automated aspects would have to be obvious and ensure sensory issues are taken into control.*
>
> *The technology would also have to take into account* ***how much notice is needed by each individual driver*** *and their situation. I'm not sure I'd want to have a semi-automated vehicle until I could try it in a safe environment and be able to see it in use?"*

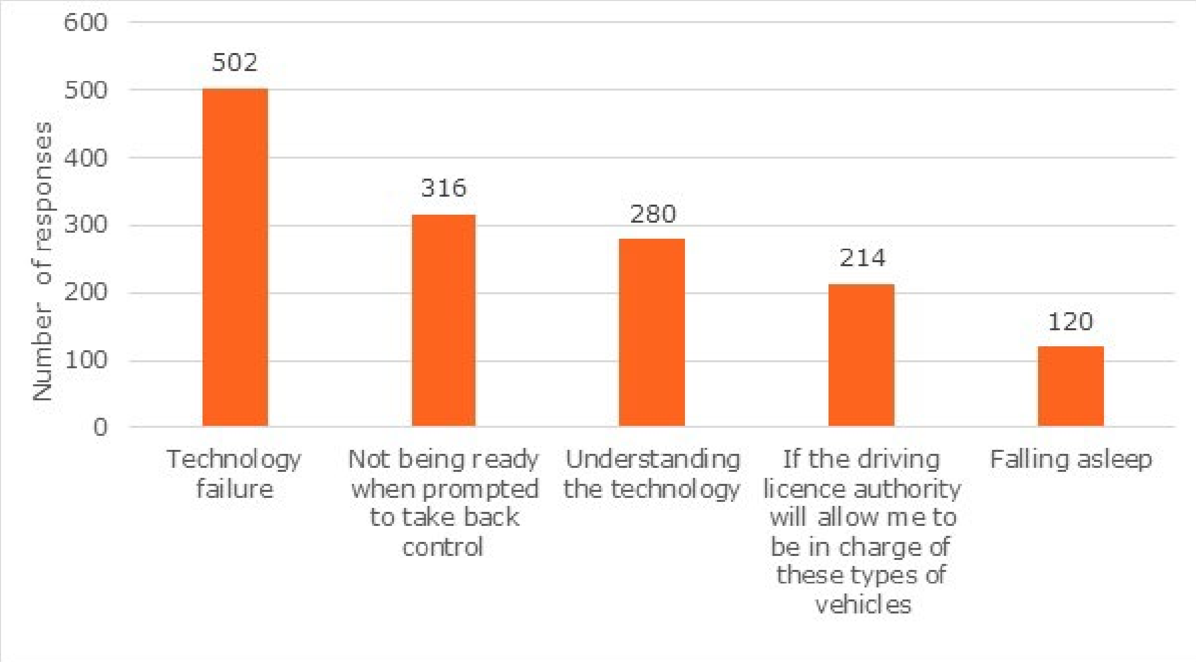

Figure 13: 'What are the most important things that are essential to get right for semi-automated vehicles for you and your needs?'

4.3.6 Willingness to ride in, and preference for automated vehicles

When respondents were asked about their willingness to ride in an automated vehicle, there was a preference for private automated vehicles with 37% of respondents saying they were very willing to ride in a private automated vehicle as opposed to only 20% willing to ride in a shared automated vehicle (see Figure 14).

Men were slightly more willing than women to ride in automated vehicles – both shared and private (see Table 4). Additionally, respondents with cognitive impairments favoured fully automated over semi-automated vehicles the most (44%).

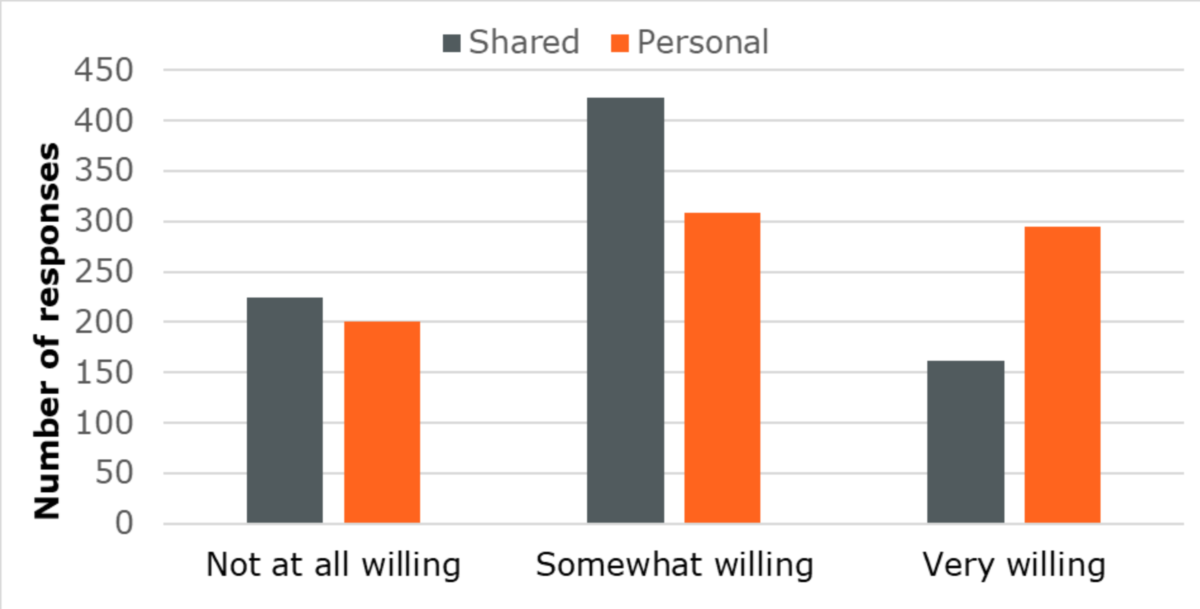

Figure 14: Q7.2 and 7.3, Willingness to ride in automated vehicles (Shared n=808, Private n= 802)

Table 4: 'Somewhat' and 'very' willing to ride in automated vehicles

AV Type	Male	Female
Shared	77%	69%
Private	81%	71%

4.3.7 The use of biometric monitoring whilst using automated vehicles

There is potential for biometric data to enable greatly enhanced and personalised services for customers. This would clearly need to be balanced against the concerns around data privacy and security. We were interested in the level of acceptance respondents might have for the inclusion of these systems in automated vehicles.

57% of respondents said they were extremely or somewhat comfortable with the use of biometric monitoring whist riding in automated vehicles. Whereas just over a quarter (26%) said they would be somewhat or extremely uncomfortable with the use of biometric monitoring.

There was little variation across different demographic categories except for a slightly greater acceptance of biometric monitoring amongst men, respondents who are 75 or older and those with cognitive Impairments.

4.4 Survey: Conclusion

Currently many disabled people need assistance of one sort or other whilst travelling on either privately owned or public transport. This can take the form of assistance from another person when boarding or alighting a vehicle, or having devices or technology adaptations that assist with the journey such as, hoists, driving controls, heating aids, WAVs etc.

40% of all respondents said they require assistance from another person when getting in and out of a vehicle whilst 18% said need assistance during a journey, such as driving adaptations, contingencies for emergencies, and rest breaks.

In addition to this 70% of respondents said they experience some form of sensory difficulty when travelling by private or public transport. Three quarters (74%) of those respondents said they experience difficulty managing in crowed environments.

The main perceived benefit of both private and shared automated vehicles is independence. Another benefit raised was the potential for an increase in the range of travel which can be otherwise curtailed by health concerns. The impact of increased independence and a greater range of travel might well improve access to work, education and social opportunities.

In understanding the concerns that disabled people have when considering using automated vehicles in the future, the message was clear. The needs of people with different disabilities can, and often are, specific to that disability. A person with an assistance dog will need a space for that dog when travelling on a shared automated vehicle, and a person with wheelchair will need to secure or store wheelchair when travelling. Without these concerns being met they can quickly become barriers to travel and not inconveniences to be navigated around.

The planning stages before travelling on shared automated vehicles are seen as particularly important to disabled people. This is consistent with needing to prevent being presented with barriers such as unmanageable boarding and alighting pavement environments.

The successful introduction of inclusive shared automated vehicles would need to understand why older people are less likely to use public transport as well as to address the barriers and concerns raised in the survey.

Although there was a greater acceptance of privately owned automated vehicles the route towards achieving this, through the design of semi-automated vehicles, was seen as problematic for disabled people.

Task 5: Usability and accessibility trials

5.1 Background

This research project's fifth and final task was to conduct two usability trials exploring the accessibility of automated vehicles with disabled people. One trial involved research participants riding on the CAVForth bus – an automated single-decker commuter Stagecoach service operated in Edinburgh. The second trial involved research participants exploring a static automated minibus, located at TRL headquarters in Crowthorne, Berkshire. Both trials had the following research questions:

1. What are the common accessibility barriers for disabled consumers when using a shared automated vehicle?
2. Do perceptions of accessibility barriers change after familiarity with an automated vehicle? If so, what accessibility barriers are raised after familiarity?
3. Are disabled people more willing to use an automated vehicle after they have had personal experience of riding one? If so, what concerns or barriers (if any) remain?
4. What are the vehicle and operational requirements that automated transport must deliver to realise benefits?

5.2 CAVForth Automated bus trial: Methodology

The first usability trial was conducted over two days in Edinburgh, Scotland. Ten disabled participants were recruited to take part. We ensured the sample of participants was as representative of the disabled community as possible and included people with a variety of different access needs, age ranges and genders.

Table 5: Breakdown of participants

Participant	Impairment(s)	Gender	Age
1	Mobility, social and behavioural, non-visible health conditions, stamina	Non-binary	27
2	Hearing, vision	Woman	34
3	Mobility, dexterity	Man	59
4	Mental ill health, vision	Man	52
5	Mobility, hearing, vision, non-visible, getting older	Woman	66
6	Mobility	Woman	66
7	Mobility, communication, social and behavioural, dexterity, getting older	Woman	55
8	Mobility, communication, non-visible	Woman	44
9	Appearance, mobility, dexterity, mental ill health, non-visible	Man	32
10	Mobility, vision	Man	54

During the trial, participants rode the CAVForth AB1 automated bus as part of its usual commuter service. The automated bus, operated by Stagecoach, uses Fusion automated technology to operate independently of a human driver. To comply with current legal regulations, a 'safety driver' is present in the driver's cab and is trained to take over the driving of the vehicle when necessary. During this trial, the safety driver was manually driving the bus due to system updates taking place at the time. However, the experience for on-board passengers was identical to when the bus was in automated mode. The bus also operates with a second member of staff present, the 'captain', whose role is to provide practical assistance, take payment for the journey fare and provide reassurance to the public.

The participants took a round trip onboard the bus as it travelled from Edinburgh Park Station to the Ferrytoll Park & Ride in Fife and back again. The journey took approximately one hour to complete. Three researchers accompanied the participants throughout the journey, discussing their experiences of the bus with them in real time. Participants were also invited to complete a paper survey whilst on board, where they could write about their experiences on the bus. After the bus ride, participants took part in an in-person debrief session where they discussed the accessibility of the bus journey and their perspectives on automated vehicles.

Audio recordings were made during the debrief sessions and during key conversations that took place on the bus. The researchers also took notes throughout the sessions. With the consent of the participants, researchers also took photographs during the bus trials and encouraged participants to do the same, with some participants also recording videos. All of the recordings were transcribed, and along with the notes of the researchers and the paper survey responses, the data was combined to give an overview of the trial. This data was then analysed together, and the results are presented below.

We carried out a thematic analysis of the usability trial. Each theme is presented here, along with participants' suggestions and recommendations to ensure future automated vehicles are as accessible and inclusive as possible.

5.3 CAVForth Automated bus trial: Findings

5.3.1 Accessibility barriers of shared automated vehicles

5.3.1.1 Potential lack of staff presence

The presence of onboard staff was a significant enabler which made the journey on the automated bus accessible for many of the participants. There was fear that without the bus 'captain', or at least a safety driver present, the bus would not be usable for some disabled people.

The bus captain was a role put in place by Stagecoach to overcome some of the public's trepidation about riding in an automated vehicle. Our participants highlighted that their presence made the journey more accessible than a standard bus, where the bus driver is preoccupied with the task of driving and, therefore, less able to provide individualised assistance and support.

Participants described some of the benefits of the onboard staff as being the following:

- **Passengers could purchase their tickets at their seat**
  This removed the pressure participants felt on previous bus journeys around queueing or holding up the line. It allowed more time for passengers to sort payments, which was easier when seated, as well as time to ask any questions about the destination, length of journey, and stops. As one participant noted, ‘Really good that [the ticket] was paid for once seated. Relieved the usual anxiety of not having enough time to sit down before the bus moves.’
- **Staff could assist with boarding and welcoming passengers onto the bus.**
  Having one staff member in charge of driving and one in charge of customer support and well-being meant participants felt less rushed when boarding and alighting from the bus. The captain was responsible for setting down the manual boarding ramp and ensuring everyone had gotten to their seats before the bus moved off.

  When asked what they would need in place to feel confident when boarding an automated bus, one participant wrote, ‘assistance from stagecoach staff was very good… [I would like] staff always on the vehicle for getting on and off the bus, this is very important for wheelchair users’. Another participant simply wrote, ‘A human!’
- **Staff were there to answer questions and provide support.**
  For disabled participants, especially those with visual impairments or who were less confident travelling, having staff to answer questions was especially important. Participants wanted a staff member present to answer questions such as “When is my stop?” and “Where do I go when I get off the bus?”.
- **The staff were informed and provided reassurance about automated technology.**
  Many of the participants were very curious to understand how the technology worked and what safety features it had. Having a knowledgeable and reassuring captain on board was seen as a benefit. As one person commented, ‘[the staff] were excellent at answering all my questions.’
- **Staff presence provided added security and safety for disabled travellers.**
  Participants told us about the different experiences of intimidation, discrimination and hate crimes they had experienced from other members of the public when travelling on public transport. For some, this meant they no longer felt safe travelling on buses at all. For one participant, the experience related to their use of a mobility aid and the conflict of space within the wheelchair priority area. For another, they had experienced harassment due to being transgender and expressed fear that, as a disabled person with a mobility impairment, they wouldn’t be able to defend themself if attacked. In this context, onboard staff was seen as necessary to protect travellers and ensure they could travel more safely. As one person summarised, ‘The presence of a human made such a big difference.’

During the on-board journey, participants discussed with the captain what would happen in the event of an emergency. Participants were not satisfied by the captain's suggestion of panic buttons on the bus in lieu of onboard staff. One person questioned how long it would take staff to arrive, especially in the case of being harassed by other passengers. She said that staff would need to be stationed at each bus stop for her to feel safe.

5.3.1.2 Lack of audiovisual and digital information

An automated bus without advanced audiovisual technology, such as onboard visual information screens and audio announcements, was a significant barrier for disabled participants.

The bus did not have any display screens informing passengers of where the bus was going, the journey route or the next stop. It did, however, have an LED display of the date and time on the ceiling above the aisle to the rear of the driver's cabin. However, this was turned off during the second journey. The bus also did not have any audio announcements other than the bell noise that rang when the 'stop' button was pressed. There was a different noise when the 'stop' button was pressed from the wheelchair user space, indicating to the driver that ramp assistance may be necessary. Even in automated mode, the captain was required to deploy the ramp manually.

For the deaf and blind participants, the lack of audiovisual information would prevent them from travelling independently, especially if there was not a captain in place to provide equivalent information. Participants also noted that, since some of the hopes of an automated bus were that it might provide them with more independence, having to rely on others for this information was disappointing.

One participant who was using a powered wheelchair commented on the further issue caused by the design of the wheelchair space, necessitating that a wheelchair user face backwards throughout their journey. He was not able to see upcoming destinations out the window or see a forward-facing display screen, had there been one. He highlighted the importance of having a backwards-facing display screen or designing the wheelchair space so it was safe to sit facing forward. The latter was his preference due to the nausea that travelling backwards can create. He said, '[the] wheelchair space was facing the rear of the bus, making it very difficult to see where you are on the journey.'

Participants noted the importance of information being presented appropriately – for example, at a suitable volume and not muffled – and reliably – for example, the information being accurate and in sync with times and stops. As one person said, 'more information is better than a lack of information.'

One participant also commented on how there wasn't any information onboard about how much the bus tickets would cost, and the captain was not forthcoming about explaining the payment process. As someone with a neurological condition, the participant found this confusing and stressful, even when accompanied by her personal assistant. She explained how, because the staff interactions weren't what she was used to and there wasn't enough information about how it all worked, it led to 'a bit of a wobble'. A range of solutions to suit different needs would be necessary to ensure everyone had access to information in a way that suited them.

As well as onboard audiovisual information, some participants said that they would have liked to have information available during the planning and booking stage about the busyness of the service and the availability of seats, particularly the accessible seats and wheelchair space. Participants discussed the benefit of an accessible app which could provide this information. One participant using a small mobility scooter had difficulty manoeuvring into the wheelchair space due to the space available in the aisle and the positioning of railings. This would have been even more difficult had there been a pram in the allocated pram space opposite. Participants mentioned the frustration of only having one wheelchair space available on most buses. Providing information in advance as to whether this space was free was not seen as a solution to this issue, but something that would still be of benefit.

5.3.1.3 Barriers to accessible boarding and alighting

Accessible boarding and alighting were key considerations for many of the participants. The bus required staff to operate the manual boarding ramp. Participants found this useful but highlighted the issues it would present if no staff were present. Ambulatory participants who had mobility impairments valued the opportunity to use the ramp rather than be expected to step up or down from the bus entrance. For the powerchair user, the ramp was accessible, however for the mobility scooter user, there were issues with the ramp and the turning space and manoeuvrability within the cab.

5.3.1.4 Barriers from surrounding infrastructure

There were also a lot of issues raised around the surrounding infrastructure required to access the bus service. There was no screen that provided live updates of the service at the bus stop, and no auditory information was provided on upcoming, arriving, and departing services. Though plenty of benches were close to the bus stop, it was mentioned that these were a necessity and 'leaning posts' should never be considered an alternative to a bench or seating. Participants didn't all notice the seating next to the bus stop, which suggests that clear colours and signs may also have been of benefit. The bus stop pole (which had the board showing the service and times) was also positioned directly in the middle of the pavement, which made it difficult for some participants to board the bus from the pavement.

5.3.1.5 Perception changes after familiarisation

Before riding on the automated bus, participants had mixed perceptions about the experience. Some were excited, saying, 'This is like a spaceship!', while others were more cautious, asking, 'What if things go wrong?'

Overall, there were some feelings of disappointment after riding the bus. Participants hoped that a bus with new automated technology would also include technology to improve accessibility. However, as one participant commented, it 'just felt like being on a normal bus'.

5.3.2 Vehicle and operational requirements for independence

Below is a list of requirements suggested by disabled participants regarding what they would like to be put in place as standard in future automated vehicles.

- Audiovisual journey information onboard the vehicle.
- An app which provides live service updates and journey planning information.
- An onboard captain to give assistance and support to passengers.
- An automatic boarding ramp for wheelchair users and those with mobility impairments where the step up into the bus is too high.
- An ability for the bus to ‘kneel’ (lowering the suspension) for boarding and alighting.
- Ergonomic seating with increasing padding and legroom.
- Flexible seating arrangements to accommodate various needs.
- Larger wheelchair spaces with proper securement and a separate dedicated space for pushchairs.
- Handrails and support beams must be in useful places, especially for assisting in boarding the bus.
- Ensuring vertical support beams do not reduce the turning circle for wheelchair and mobility scooter users.
- Consistent positioning of the stop buttons across different buses and consistent use of braille ‘S’ on the button itself.
- Louder and clearer bell to inform passengers that their pressing of the ‘stop’ button has been registered.
- A place to hang or place walking sticks and crutches when seated.

5.3.3 Summary

From the first usability trial, participants felt more research was necessary in order to properly actualise the potential benefits of automated vehicles for disabled people. As one participant summarised, ‘Information at this time is limited. A great deal of imagination is required to imagine total autonomy as there is a driver operating the bus. Future observations are necessary.’

5.4 Static minibus trial: Methodology

The second usability trial took place at TRL’s office in Crowthorne, Berkshire. The objective of this trial was to further understand the perspectives of disabled people in terms of the accessibility of automated transport. An automated minibus, provided by the company Fusion, remained static in the car park and participants were asked to examine it and think about whether it was accessible for them. Eleven participants with a range of sensory, cognitive and mobility impairments joined us across a morning session and an afternoon session. Once participants had explored the minibus, we ran a 45-minute debrief session to talk about the participants’ experience of the vehicle, whether they thought it was accessible for them and their needs, and what they would need to feel comfortable travelling on automated transport.

Table 6: Breakdown of participants

Participant	Impairment(s)	Gender	Age
1	Sight, cognitive	Woman	17
2	Mobility	Woman	57
3	Mobility	Man	60
4	Mobility	Woman	53
5	Mobility	Woman	57
6	Mobility, hearing	Woman	44
7	Cognitive, mobility	Man	47
8	Mobility, dexterity	Man	70
9	Cognitive	Woman	36
10	Mobility, dexterity	Woman	46
11	Mobility, dexterity	Man	36

We carried out a thematic analysis of the usability trials and have presented each theme along with participants’ suggestions and recommendations to ensure an accessible automated bus.

5.5 Static minibus trial: Findings

5.5.1 Ramp

When boarding the bus all participants used the ramp to walk or wheel onto the bus. On the day of the trial, the ramp had to be deployed manually, which raised the following question: “How would someone indicate that they need the ramp to be deployed if there is no staff on board?” Typically, participants said they would make eye-contact with the driver to confirm that the driver has seen them and then the driver will deploy the ramp to allow them to board the bus. Participants wanted to know how the vehicle would detect a wheelchair or mobility scooter user waiting at the bus stop. One participant suggested that there should be a way to indicate to people waiting at the bus stop whether the wheelchair space is available or not. Perhaps this could be done using an indicator on the exterior of the bus, preferably at eye-level for wheelchair/mobility scooter users. Other participants liked this suggestion.

One participant mentioned the benefits of having a manual ramp:

> "*The manual ramp is really good – it never breaks down. I think when they put in the automatic ramp, they need to make sure the manual ramp is still there. It's a design challenge, but if the automatic ramp doesn't work, someone can help and pull it out.*"

Most participants found that the ramp was too steep. Some wheelchair users felt more comfortable alighting the bus backwards as they didn't feel safe alighting facing forwards. It's worth noting that the ramp was deployed to the ground. In practice, it's designed to be deployed on the pavement which would make the gradient less steep. However, we were unable to test this during the trial.

Some participants told us:

> "*Today was more difficult than a real-life situation because the ramp was too steep. 99% of my experience of getting on a bus is through the centre door, so it's different. I had to do quite a lot of manoeuvring to get into the wheelchair space.*"

> "*My normal way of getting off a bus is front-facing […] I preferred to go backwards because the ramp was steep. It was a choice to go backwards.*"

Participants discussed the need for bumpers on the side of the ramp. A bumper ensures that a wheelchair or mobility scooter does not derail while moving up or down the ramp, even if it is not properly aligned at the start.

5.5.2 Emergency exit

Participants liked that there was an emergency exit door towards the back of the bus. However, wheelchair and mobility scooter users commented that the space around the door is too narrow for them to manoeuvre. Some participants suggested that the door to the vehicle would be better placed at the back (i.e., double doors), or it could be moved to the middle of the vehicle – such as the middle doors on some buses in London. Benefits to having the door at the back include potentially allowing for a wider ramp which would make people with bigger wheelchairs or mobility scooters feel safer when boarding and alighting. Alternatively, having the door in the middle of the side of the bus could potentially allow for more space for wheelchair/mobility scooter users to manoeuvre into the designated space.

5.5.3 Wheelchair space

All participants who used a wheelchair reported that the wheelchair space was too small. Most of the participants experienced difficulty when moving into the space due to the lack of space available in the aisle and the proximity of the front row seat. Participants observed that the seat in front of the wheelchair space and the wheelchair space could not be used at the same time. Some suggestions were made to make the front row seat a flip seat to allow for more space.

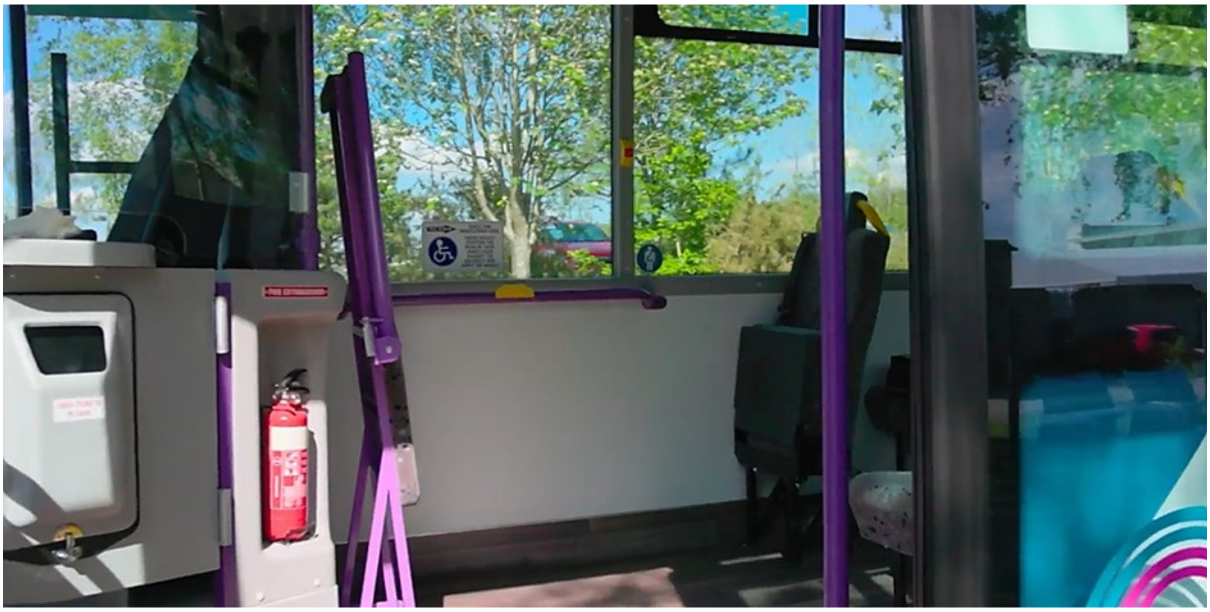

Figure 15: Image of the wheelchair space on the minibus

Addressing the lack of space in the wheelchair area, one participant suggested that there could be a separate wheelchair space and pushchair space. They explained that on occasion, people using pushchairs refuse to move out of the wheelchair space and the bus drivers need to intervene. In an automated vehicle without a driver present, having two separate spaces might reduce any conflict issues between passengers. Participants were keen on having access to a wheelchair space large enough so that two wheelchair or mobility scooter users can travel together.

The stop button in the wheelchair space is positioned on a horizontal grab rail. Most of the participants who used a wheelchair were worried about knocking the button with their arm. One participant mentioned that ideally there would be two buttons in front of the wheelchair space: one that can be pushed down as a standard button, and one that can be pushed sideways so that people with poor dexterity can use them with ease. Participants told us:

> *"It's right where you'd go to rest your elbow."*

> *"I've seen before they have a long bar that you can tap, so that people who don't have manual dexterity, they can use it."*

5.5.4 Seating

Participants liked the seatbelts and felt that they were secure. However, some participants observed that the seats were too narrow. While they said that the seats were generally comfortable to sit in, they felt there was not enough space for people to store their bags or mobility aids (e.g., crutches) or for larger people. Two participants suggested that there could be a way of clipping their crutches onto the back of the seat in front of them to stop them from moving or falling during the journey and allow passengers to travel hands-free.

Figure 16: Image of a row of seats on the minibus

Some participants wanted to have more space:

> *"I did find the seats claustrophobic."*
>
> *"It needs more space. The seats are tiny. If you're a slightly plumper lady, how are you going to sit on the seat?"*

One participant suggested that the wide aisle space was used for bigger seats:

> *"I think with all the space in the middle, you could make more girth for the seats."*

Another suggested that the rows of seats require more space between them too:

> *"I've got a 32 inch inside leg and when I sat in it my knees went straight into the back of the [seat in front]."*

Figure 17: Close-up image of a seat and seatbelt on the minibus

One participant, who was previously involved in a car accident and experienced whiplash, expressed concerns about the headrest. She felt it was very hard and could likely cause more damage than protection in the event of a sudden halt. Normally, she carries a cushion to support her head and neck on public transport. She strongly recommended for the hard headrest to be replaced with a softer one for improved safety and support:

> *"In terms of its internal design, I wouldn't be able to sit in those seats. The headrests, which are rock hard, not covered in any material, and too low, I would be in a panic sitting on that and uncomfortable as I'd have to have my cushion."*

One participant explained that they prefer minimal contact with others as they find it difficult or awkward to communicate with others:

> *"I liked the single seats because than I don't have to ask someone if I can get out. […] I normally stand on buses so that I don't need to ask ,'Can I get out?' because I don't want to have to ask someone."*

Another participant made a suggestion for flexible seating:

> *"I'd suggest flexible seating that can be moved easily, for example, on a coach they can take seats out to put seats in and it actually just takes 5 minutes, the driver can do it as one person. So, if you did have a safety driver, they could move the seating to allow for more wheelchairs to come on if that's what's needed. So, it's really adaptability and using the newer technologies to try and overcome some of the issues where it's a space for able-bodied and disabled people, and also the range of disabilities."*

5.5.5 Moving around the minibus

Participants felt as though they had enough room to move around the bus and positively commented on the wide aisles. Wheelchair users could move down the aisle if they needed to, but the issue still remains with there not being enough room towards the back of the bus for wheelchair users to use the emergency exit. One participant said:

> *"It was kind of copied from Dial-A-Ride, but did they ask whether Dial-A-Ride was actually that suitable? Because that's the worst thing to try to get on."*

Another said:

> *"I found the aisles to be wider than what they are on a standard London bus."*

5.5.6 Stop buttons

In addition to the stop button in the wheelchair area being placed in a hard-to-reach position, participants using the seating struggled to reach the stop buttons. They felt that the buttons were not conveniently placed as some passengers would have to move across another passenger to reach the buttons. Some participants suggested that each row of seats has a stop button, or that every seat has a stop button on the back of the headrests. Some participants also found the stop button stiff and difficult to press. They commented on them being harder than what they've previously experienced on a standard bus. A participant explained:

> *"I immediately noticed that for the stop button you have to reach across a person and you'd be right in their face."*

Another participant said that they'd find it awkward to reach over people:

> *"The stop buttons were all on the side, so you have to reach over someone which I'd find awkward."*

One visually impaired participant who uses braille also noted that the raised dots for the 'S' on the stop buttons were incorrectly spaced, meaning it was hard to read it as an 'S'. She said this could lead to confusion and misunderstanding, especially when travelling on a new vehicle.

5.5.7 Audiovisual information

Participants commented on two aspects of audiovisual information, which we have labelled as internal and external information.

In terms of internal audiovisual information, participants who used the wheelchair area noticed that they didn't have access to the information screen because it was placed above their head. The people sitting in the front row could not see the screen with ease either as they needed to lift their heads up very high. There was only one information screen on the bus, and it was felt that there should be multiple screens on different sides of the bus, and one at the back of the bus so that a wheelchair user could access it. It was also noted that any visual information must be accompanied with audio information so that blind or visually impaired people can access the information.

Regarding external audiovisual information, one participant felt that the colour of the bus could be brighter or made more obvious. They observed that the colours of the bus could easily be mistaken for a generic vehicle. One person told us:

> *"If I were to book a seat on the service and it arrives at the pick up point, I would not be sure this is the autonomous bus. How would I know this is it, especially if it was not manned?"*

A bright colour such as pink (similar to the one used on First Bus buses) was suggested:

> *"It would be particularly good for someone who is partially sighted to detect the bus coming from afar."*

5.5.8 Independence

Many participants voiced the importance of independence and were keen to see automated vehicles being used for a variety of purposes, not only to help people get to and from medical appointments:

> *"I don't want the bus to only be able to take me to hospital. I want it to take me to town, maybe I want to go swimming, or to the pub, meet friends. I want it to have that whole purpose, rather than being yet again it's only for the medical side of disability. There's a lot more to somebody than just that part of their life. […] It could give so much freedom and independence to people."*

Some participants welcomed the use of automated transport for different purposes, but were concerned about the lack of space on board if it were to cater for medical appointments:

> *"Hearing about the fact that it might have different purposes also divides my feeling. If it was meant to be just a hop on hop off bus to give access to shops and getting around, and it's to take a mix of disabled and non-disabled people, it might be more suitable. If it's to be hospital transport, the way it's set up is absolutely impossible because you've got to have a lot more space."*

5.5.9 Safety, reliability and trust

Some participants were concerned about the safety and reliability of riding in an automated vehicle:

> *"When I saw that the bus was on wheels and that it was going to be on the road, it made me nervous. I could imagine quite happily going on an automated vehicle on rails. […] It looks perfectly safe. But when I see this vehicle with nobody controlling it, yes, it does worry me."*

One participant touched on the trust aspect of automated vehicles:

> *"For me it's a mindset thing of trusting the bus to go where it should go when there's no driver. It's a bit weird that you're putting trust in it. It's more of a confidence thing for me."*

We asked the participants ‘What needs to be put in place as standard to ensure that disabled people are able to use shared automated vehicles?’ Some participants touched on the importance of having a human conductor always available on the bus:

> *“The most important thing I think is that you have to have somebody on board. The hardest thing for any company to handle disability is that we all have different needs. So what you could do, I might not be able to do. That’s the hardest thing. It’s almost impossible to accommodate every single need. But if somebody’s on that bus, they could help [someone] to a chair, they could help [someone] to get up the ramp, they could help [someone] carry their bag. It would allow that person to discreetly help, rather than asking ‘Can I have some help?’”*

And others suggested that there is always someone available even if it’s to support remotely:

> *“To have someone you can talk to even on the other end of a line, who’s always there and monitoring, and who can intervene when you need help. Things do go wrong and you don’t always know what it’s going to be. There needs to be a human brain there that understands flexibility.”*

One participant touched on the use of technology outside of the vehicle:

> *“An App telling you when the vehicle will arrive, how many people are on board and how many seats are available, and if there are wheelchair spaces. Everyone will see it coming on their phone, this will help with a range of disabilities, and will help you know if you can travel safely.”*

5.5.10 Summary

The main themes that came out of the second usability trial are:

- The importance of accessibility on the bus, including having enough space, the positioning of seats, buttons and screens to allow for a comfortable journey.
- The use of shared automated transport being for more than just health appointments. People want to be able to have independence and go to the supermarket, town centre, meet friends, and do sports.
- Being able to trust automated transport and the importance of a human to cater to a wide range of accessibility needs.

5.6 Usability trials: Conclusion

The usability trials explored the accessibility of automated vehicles with disabled people across two different locations with two different vehicles. In the first trial, participants rode on a live automated single-decker bus service during its usual commuter service, and in the second trial, participants explored a static automated minibus at a test centre. However, despite these differences, the disabled participants had similar perspectives when it came to their hopes and concerns for automated vehicles in the future.

The standards for shared vehicle design need updating and improving to ensure future automated vehicles meet the accessibility needs of disabled travellers. Participants talked about wanting consistency in vehicle design, better designed and more spacious wheelchair spaces, more ergonomic seating, and improved grab bar and stop button placement. In addition to this, accessible audiovisual information provided to a high standard was seen as essential for all. The disabled people we spoke to were excited by the prospect of shared automated vehicles coming together with improved accessibility and usability in public transport provision. For the participants, this was where some of the hopes for shared automated vehicles lay.

Safety and emergency planning are high priorities for disabled people when using shared automated vehicles. After familiarising themselves with the vehicles, participants still had significant concerns about their ability to use them independently and questions about what would happen if something went wrong. Participants discussed issues such as the breaking of an automatic ramp, fears around no safety driver being present and the impact of experiencing negative public attitudes and behaviours when travelling. Current suggestions, such as onboard panic buttons, did little to ease concerns, and there was a feeling that it may take a longer time for disabled people to feel confident travelling independently via shared automated vehicles and that more work will be needed in this area.

The presence of a human, whether on board or even available virtually, was seen as essential for the future of accessible shared automated vehicles. The disabled participants in both trials discussed the necessary access assistance that only a person can provide. Whether that is making eye contact with the driver when they come to the bus stop, so they know to put out the ramp or providing information on where and when to get off, onboard staff currently provide assistance which hasn't yet been replicated by technology. However, as the 'Captain' on board the CAVForth bus noted, when you allow the bus to drive itself, you free up the bus staff to focus on customer service and do so better than before. It may be possible for personalised service provision, and therefore accessibility, to improve through developing new roles for onboard staff.

Finally, the trials found that if designed right, shared automated vehicles could increase disabled people's independence. The disabled people we spoke to wanted the opportunity to travel by themselves whenever they wanted to and for whatever reason. They didn't want to travel only for medical appointments; instead, the participants talked about trips to the shops and trips to see their friends. The future roll-out of new shared automated vehicles is an opportunity to improve surrounding infrastructure, vehicle design, and safety so that more disabled people can travel without barriers.

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Appendix A Summary of barriers related to both non-automated and automated transport for disabled people

The following table shows a summary of the barriers related to both non-automated and automated transport for disabled people found in this study. These are broken down into the journey stages.

Journey stage	Barriers faced by disabled people in relation to non-automated transport	Potential barriers for disabled people in relation to automated transport
Journey planning (info finding)	A lack of knowledge and experience travelling alone adds anxiety and prevents individuals from making independent journeys. Uncertainty about routes and wheelchair facilities. A lack of real time information for the vehicles. Available information is out of date. Current private hire vehicles are expensive. Poor public transport options in rural areas.	The same barriers as those relating to non-automated transport.
Booking journey	Many private hire vehicles not taking an assistance dog. Automated ticket machines not providing enough or clear information about purchasing tickets, or do not have accessible features. Not knowing whether a wheelchair space will be available. Difficulty arranging assistance.	The same barriers as those relating to non-automated transport.

Journey stage	Barriers faced by disabled people in relation to non-automated transport	Potential barriers for disabled people in relation to automated transport
Getting to the station, stop or vehicle	Poor design of physical infrastructure on footpaths (e.g., dropped kerbs, tactile paving, construction works blocking pavement). A lack of step-free routes. Long walking distance. Bikes / scooters being ridden on pavements.	The same barriers as those relating to non-automated transport.
Arriving at station or stop	The process of booking assistance or adapted service at stations is poor. Booked assistance is not available for disabled people. Limited stops or stations that are designed to accommodate wheelchair user or mobility aid user. A lack of disabled parking.	The same barriers as those relating to non-automated transport.
Finding the correct service	Finding the correct platform, bus, or private hire vehicle. A lack of consistency across the terminals makes it harder to navigate the terminal, and users feel insecure or fearful for personal safety. Technologies and accessibility solutions that are supposed to make public transport more accessible are often not used properly, or are broken (for example elevators, escalators, screen readers or audio announcements on buses).	The same barriers as those relating to non-automated transport.

Journey stage	Barriers faced by disabled people in relation to non-automated transport	Potential barriers for disabled people in relation to automated transport
Waiting	Unreliable waiting times for paratransit options. A lack of shelters at bus stops. Insufficient space at bus stops for wheelchair users. A lack of facilities (e.g. toilets, waiting areas with heating, relief areas for assistance dogs) available, or in working order. A lack of real-time information.	The same barriers as those relating to non-automated transport.
Boarding vehicle	A lack of step free access onto vehicle, including mechanical faults with ramps. Having to wait for a bus that will enable them to board / have space for their mobility aids. A lack of available assistance to board a vehicle. Narrow entranceways or access corridors, or insufficient space to manoeuvre a wheelchair or other mobility aids. Refusing services by not allowing guide dogs onboard. Negative/unhelpful attitudes from driver.	The same barriers as those relating to non-automated transport, plus: Unlocking a private hire vehicle. Automatic ramps not deploying correctly. Being unsure if the vehicle recognises that they wish to board. The vehicle moving off before the passenger is seated/ stable.

Journey stage	Barriers faced by disabled people in relation to non-automated transport	Potential barriers for disabled people in relation to automated transport
On the journey	Negative attitudes from staff and other passengers. Priority seating not available / not clearly defined / not given up by others. Few seats that are aptly positioned for disabled people to see key information or alight easily. Sensory overload due to colour contrasts on the vehicle. A lack of real-time information/ inaccessible information / broken screens or announcements. A lack of accessible facilities (i.e. toilets) on board (e.g., on trains and coaches). Charging points not placed within easy reach of disabled spaces.	The same barriers as those relating to non-automated transport, plus: Passengers unaware of what to do in emergencies. Passengers unable to ask for assistance.
Alighting the vehicle	Placement of stop buttons / intercoms not user-friendly. A lack of step free access off the vehicle. Negative attitudes from staff and other passengers. Lack of step free access off of vehicle, including mechanical faults with ramps.	The same barriers as those relating to non-automated transport, plus: Locking a private hire vehicle. Automatic ramps not deploying correctly. Being unsure if the vehicle recognises that they wish to alight. The vehicle not giving passengers sufficient time to disembark.

Journey stage	Barriers faced by disabled people in relation to non-automated transport	Potential barriers for disabled people in relation to automated transport
Getting to desired destination	Poor design of physical infrastructure on footpaths (e.g., dropped kerbs, tactile paving, construction works blocking pavement). A lack of step-free routes. Long walking distance. Bikes / scooters being ridden on pavements.	The same barriers as those relating to non-automated transport, plus: Difficulty orienting once passenger has exited the vehicle, with no staff member to guide them (particularly relevant for those with vision impairments).

Appendix B Survey respondent demographic information

Table 7: Breakdown of age of survey respondents

Age	n	%
18-24	11	1%
25-34	44	6%
35-44	85	11%
45-54	125	16%
55-64	232	29%
65-74	201	26%
75+	90	11%
Total	788	100%

Table 8: Breakdown of gender of survey respondents

Gender	n	%
Female	445	55%
Male	354	44%
Other	7	1%
Prefer not to say	5	1%
Total	679	100%

Table 9: Breakdown of impairment types of survey respondents

5	n	%
Physical	743	92%
Sensory	375	46%
Cognition	260	32%

Table 10: Breakdown of location type of survey respondents

Where people live	n	%
Urban	257	32%
Suburban	358	44%

Rural	193	24%
Total	808	100%

Table 11: Breakdown of driving licence ownership of survey respondents

Driving licence	n	%
Yes (full)	537	67%
Yes (provisional)	18	2%
No (disqualified – medical)	117	15%
No	89	11%
Something else	47	6%
Total	808	100%

Table 12: Breakdown of vehicle ownership of survey respondents

Vehicle ownership	n	%
I own	63	27%
I lease	102	44%
Carer / family owns	36	16%
Something else	29	13%
Total	230	100%

Table 13: Breakdown of driving behaviour of survey respondents

Who drives	n	%
I drive	148	65%
Someone else drives (carer, PA, family member)	81	35%
Total	229	100%

Appendix C Detailed options for survey question

Full descriptions of options presented to survey respondents for shared automated vehicles.

Before starting a journey

Q4.2: Think about what you would need to know before starting your journey in a shared automated vehicle. Which of the following would be important to you and your needs?

- What the street space is like where you get on and off the vehicle
- The time the journey takes
- How busy or crowded the vehicle is
- Whether there is a wheelchair or scooter space
- Whether there is space for a guide or assistance dog
- The cost of the journey

Booking or paying

Q4.3: When booking or paying for a shared automated vehicle ride, what would be the important things to get right for you and your needs?

- Having multiple ways to pay for the journey (for example cash and contactless card)
- Having multiple ways to book the journey (for example, turn-up and street hailing, online and over the phone)
- Online or digital services being accessible for use with assistive technology (such as a screen reader)
- Having staff who you can speak to if you need help or assistance

Boarding

Q4.4: When getting on a shared automated vehicle, what would be the important things to get right for you and your needs?

- Easy step-free access (such as level boarding or an automatic ramp)
- Grab rails to assist with boarding
- Wide enough doors for wheelchair and assistance dog
- Available seating for my needs
- Being secure before moving

During the journey

Q4.5: When onboard a shared automated vehicle, what would be the important things to get right for you and your needs?

- Being in contact with an operator
- Having a comfortable seat

- Being able to look out of the window
- Understanding safety instructions
- Knowing where you are on your route
- Being informed about the time before your stop
- Knowing how to find out information about the journey from the vehicle, if I need to
- Knowing what will happen if there is an emergency

Full descriptions of options presented to survey respondents for privately owned automated vehicles.

Boarding

Q5.2: When boarding a privately owned fully automated vehicle, what would be the most important things to get right for you and your needs?

- Ensure door opening width/ angle is wide enough
- Having an automatic door
- Ramp angle is not too steep
- The vehicle designed to assist transfer onto your seat
- Storage for a wheelchair
- A wheelchair hoist
- Height of door sill from the ground
- Ensure seat belts/ clamps are in place
- Space designed for guide/ assistance dog
- Space for sticks/ other assistance equipment

During the journey

Q5.3: When on-board on a privately owned fully automated vehicle, what would be the most important things to get right for you and your needs?

- Knowing where you are on the route
- Having a comfortable seat
- Being able to see where you are going
- Knowing what to do in an emergency
- Being aware of how much range the vehicle has and when you need to charge it or add more fuel
- Being able to find an accessible parking space
- Being able to find an accessible petrol or charging station
- Being able to charge the vehicle or add more fuel independently

Appendix D Description of level of vehicle automation

Description given to survey respondents of what the various levels of vehicle automation mean.

In the context of automated vehicles, the UK follows the classification defined by the Society of Automotive Engineers (SAE), which outlines six levels of automation.

Here's a brief overview of levels 3 to 5:

- **Level 3 - Conditional Automation.**

  At this level, vehicles can perform certain driving tasks automatedly under specific conditions. However, human intervention may be required if the system encounters a situation, it cannot handle or if it requests the driver to take control.

- **Level 4 - High Automation.**

  Vehicles at this level can perform most driving tasks automatedly. However, there might be situations, such as extreme weather conditions or complex urban environments, where the driver may need to take control if requested by the system.

- **Level 5 - Full Automation.**

  Level 5 represents full automation, where vehicles can handle all driving tasks under all conditions without human intervention. At this level, there is no need for a steering wheel, pedals, or a human driver on board. The vehicle is fully self-driving.

In the UK, levels 4 and 5 are considered highly advanced and are still in the research and development phase.

The impact of automated transport on disabled people: detailed methodology and findings

This report is a supplement to the Summary Report of the same title, produced by TRL and RiDC. Where the Summary Report provides a greater focus on presenting key research findings and conclusions, this document provides the detailed methods for, and findings from, each of the five research tasks: evidence review, stakeholder engagement, end-user focus groups, end-user survey, and usability and accessibility trials.

PPR2050

DOI: 10.58446/lvlf3929

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