Department for Transport

Centre for Connected & Autonomous Vehicles

TRL THE FUTURE OF TRANSPORT

PROJECT REPORT XPR135

Automated Passenger Services: Researching Driver Roles and Passenger Inclusivity

Final Report

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Report details

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Executive summary

Background and method

The global market for connected and autonomous vehicles is projected to reach £650 billion by 2035, with the UK poised to capture £41.7 billion of this market. Recognising the transformative potential of autonomous transport, the UK government established the Centre for Connected and Autonomous Vehicles (CCAV) in 2015 to lead innovation in this sector. With a commitment to inclusivity and accessibility, the UK aims to lead in developing an autonomous transport ecosystem that prioritises safety, efficiency, and sustainability.

This report focuses on how future automated passenger services could contribute to addressing the needs of all passengers in the absence of a driver or onboard attendant.

By acknowledging and accommodating the unique challenges faced by those with disabilities and other protected characteristics, the ultimate aim is to contribute to creating a transport network that is both inclusive and safe.

The objectives were to:

- Identify current non-driving-related roles that are carried out by drivers (for example, deploying ramps, giving information).
- Assess potential implications if these roles are not fulfilled.
- Explore alternative solutions for fulfilling these roles.

This research explored non-driving-related roles currently carried out by drivers of buses, coaches and private hire vehicles (PHV).

Through a comprehensive review of literature and engagement with stakeholders, this report aims to broaden understanding and provide recommendations for future research and implementation of inclusive automated passenger services. While limitations exist, such as reliance on existing contacts and potential oversights in identifying roles and solutions, efforts have been made to ensure a thorough approach to the research.

Overview of identified roles

The research identified 66 non-driving-related driver roles, which are classified based on five key characteristics:

- **Theme**: whether the role is related to ‘safety’, ‘physical access’, ‘providing information’, ‘service quality’, ‘general assistance’, or ‘revenue protection’. Thirty-eight roles were related to either ‘safety’ or ‘physical access’.
- **Detection vs action**: whether the role currently involves the driver detecting something or doing something. Twenty-five roles were detection roles, 41 roles were action roles.
- **All journeys vs some journeys**: whether the role is carried out in everyday operations or occurs less frequently. There was a fairly even split – 32 roles were classed as all journeys, 34 as some journeys.

- **Stage of passenger journey**: whether the role occurs before the journey, when boarding or exiting the vehicle, during the journey, at any time or outside of the journey timeframe. Boarding the vehicle is the stage where most roles occur.
- **Mode**: whether the role applies to bus, coach, private hire vehicle (PHVs) or multiple. Roles applicable to each mode were relatively evenly distributed, with 56 roles being relevant to bus, 51 roles relevant to coach, and 59 roles relevant to PHVs.

The extent to which roles can be fulfilled by alternative solutions

The technical feasibility of fulfilling the identified driver roles with alternative solutions in automated passenger services was examined. Each role was assessed based on its potential for fulfilment, leading to a four-tier rating system: ‘red’ (cannot be fulfilled), ‘orange’ (challenging to fulfil), ‘yellow’ (feasible but with challenges), and ‘green’ (feasible with relative ease).

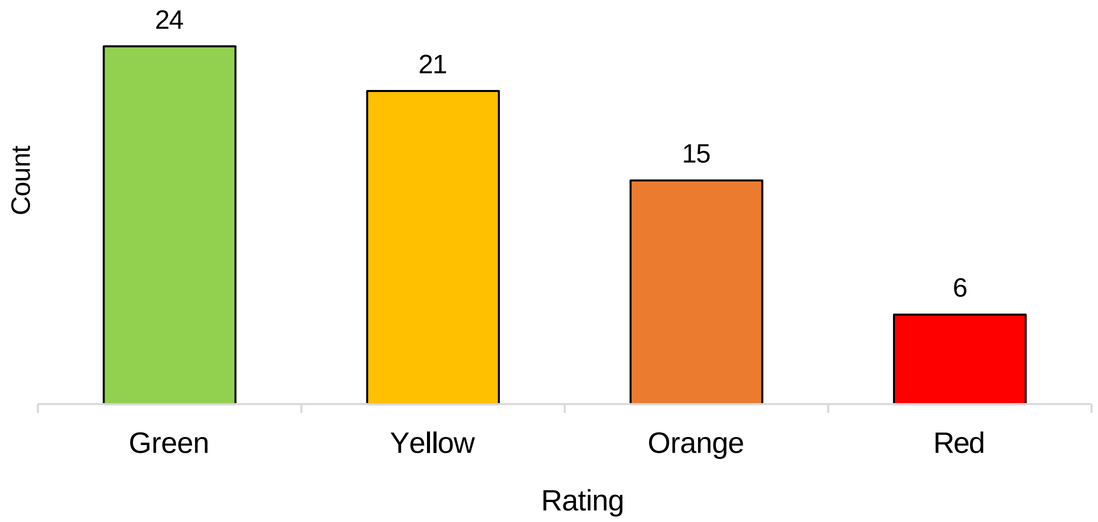

Figure 1: Distribution of role ratings across the four tiers

The majority of roles were rated as ‘green’ (36%) or ‘yellow’ (32%), suggesting that they can be fulfilled by alternative solutions. However, a notable proportion of roles were rated as ‘orange’ (23%) or ‘red’ (9%), signifying challenges in finding alternative solutions for these roles. This included roles such as:

- Preventing the vehicle being over-capacity
- Helping a passenger get into and out of the vehicle with their mobility aids
- Recognising external or passenger issues where the vehicle needs to stop
- Ensuring wheelchairs are secured properly before pulling away
- Acting as a friendly face
- Recognising and addressing medical emergencies

Some of the roles are challenging to fulfil because they rely on judgement and interpretation – humans are able to pick up on nuance that computers may struggle with. Other roles are challenging because they require physical intervention or enforcement of rules.

Most of the 'orange' or 'red' roles related to safety or physical access to the vehicle, which means that the associated risk of not fulfilling these roles is high. At the extreme end, non-fulfilment of the roles may result in passengers not being able to travel at all or result in passenger injury. Some of these roles were also categorised as all journeys, which implies that these roles would occur when operating the service.

Conclusion

Out of 66 roles identified, 21 were deemed challenging to fulfil without a driver or onboard attendant in terms of technical feasibility, with six roles rated as very challenging ('red') and 15 as challenging ('orange'). For some roles, there are risks if the role is not fulfilled, such as lack of enforcement. In other cases, passengers may not be able to board/alight the services successfully.

1 Introduction

This section outlines the background to the project, relevant definitions, the objectives and scope of the work, the method employed, and the limitations.

1.1 Background

Estimates suggest that the global market for connected and autonomous vehicles will be £650 billion in 2035, with 6.4% being captured by the UK market (£41.7 billion)[1]. This growth trajectory highlights the significant potential and opportunities presented by autonomous transport technologies in reshaping the future of mobility. The UK stands at the forefront of the autonomous transport market and has embraced a forward-thinking stance towards integrating autonomous vehicles into its transport network. The nation aims to lead the way in pioneering an autonomous transport ecosystem that revolutionises mobility while enhancing safety, accessibility, efficiency, and sustainability.

The Centre for Connected and Autonomous Vehicles (CCAV) was established by the government in 2015 and serves as a pivotal hub, bringing together a range of stakeholders and bodies. CCAV collaborate with technology developers, manufacturers, academia and local governments to test and develop policy that helps build upon UK capabilities and supply chains in the automated vehicle space. Embedded within CCAV's mission is a commitment to ensuring that the benefits of mobility innovation are accessible to all corners of the UK and all segments of society. This principle, included as one of the nine principles from the 'Future of Mobility: Urban Strategy'[2], aligns closely with the government's overarching Inclusive Transport Strategy which emphasises equal access to transport for people with disabilities.

Over recent years, transport has become more accessible, with autonomous passenger services holding promise for benefitting those with protected characteristics by enhancing independence and accessibility. As technology continues to evolve, there are opportunities to design and develop transport services to prioritise inclusivity.

According to the Equality Act 2010 it is against the law to discriminate against anyone on the grounds of disability, age, being pregnant or on maternity leave, gender reassignment, being married or in a civil partnership, race including colour, nationality, ethnic or national origin, religion or belief, sex, and sexual orientation.

Approximately 16 million people in the UK (24% of the population) report having a disability in 2021/22[3] and make 25% fewer trips than non-disabled adults[4]. This group includes vision impairment, deaf or hard of hearing, mobility impairment, learning disabilities, and mental health conditions. This group intersects with the ageing population, comprising 38% of the populace, who are more likely to have mobility impairments, who may encounter a myriad of barriers such as service provision issues, accessibility, proximity to interchanges, and safety concerns [5]. Approximately 1.5 million people in the UK (2.16% of adults) have a learning disability[6], and they may encounter challenges such as understanding information and social cues. Moreover, with 8 million individuals in the UK suffering with anxiety disorders[7], factors like unpredictability, crowded environments and safety concerns pose significant stressors.

Vulnerable cohorts such as women and girls, children, ethnic minorities and LGBTQ+ individuals tend to face elevated risks of harassment or mistreatment during travel. Recognising and addressing the unique needs and challenges faced by these diverse group encourages a more inclusive and sustainable transport network.

1.2 Objectives

CCAV commissioned TRL to conduct this research. This report provides an overview of identified non-driving-related roles and potential alternative solutions pertinent to ensuring the inclusivity of future automated passenger services. It aims to outline the types of roles that may or may not be feasible at this moment in time without a driver on-board, offering descriptions of their characteristics and associated risks, along with considerations for future developments.

Ultimately, the research addresses the following research questions:

1. What are the current non-driving-related roles and duties of drivers?
2. What are the potential implications if these roles are not fulfilled?
3. What alternative solutions could be implemented in the absence of a human driver to ensure the continued inclusivity of automated passenger services?

1.2.1 Definitions and scope

The term 'automated passenger service' (APS) refers to a service carrying passengers in road vehicles which are designed or adapted to travel autonomously[8]. As APS technology is still under development, trials involving new technologies will likely be necessary for some time.

This research explored non-driving-related roles currently carried out by drivers of buses, coaches and private hire vehicles (PHV).

For the purpose of this project, the concept of non-driving-related roles covers both specific responsibilities and more nuanced, informal roles. Firstly, it encompasses the specific duties undertaken by drivers of on-road public transport vehicles to deliver an inclusive passenger service – for example deploying ramps and lowering vehicle suspension. Additionally, it includes informal, less tangible roles such as answering questions and being a figure of authority.

The following are out of scope:

- Driver roles and duties related to the dynamic driving task, such as steering, accelerating, braking, and monitoring the road environment are excluded.
- Roles related to non-passenger facing driver duties (e.g. vehicle checks).
- Roles related to journey stages outside of the immediate journey timeframe where a passenger would be in contact with a driver (e.g. booking).

The next section outlines how we conducted the research.

1.3 Method

The sections below set out the method employed with regard to the evidence review and stakeholder research to answer the research questions.

A detailed method is provided in Appendix A.

1.3.1 Evidence review

An evidence review was conducted to identify the literature around driver roles and duties in ensuring services are inclusive for all, and information about alternative solutions in the absence of a driver in an autonomous passenger service.

The first strand consisted of reviewing papers identified by CCAV and revisiting papers which had been reviewed for a related project TRL were also conducting in parallel. We reviewed the abstracts of the 32 papers sent to us by CCAV and 20 papers from the parallel project, to assess their relevance to the present project. We included eight of the papers sent from CCAV and 20 of the papers from the parallel project in the full review.

The second strand consisted of reviewing peer-reviewed articles and grey literature. Search terms were created in collaboration with CCAV to answer each research question. Boolean operators were used to combine these search term themes to ensure the review was precise and displayed relevant results.

Of the 64 sourced articles, 17 were excluded due to lack of relevance, quality or timeliness, and 47 were reviewed in full. These 47 papers were selected for review based on receiving the highest scored on the inclusion criteria and having been deemed of relevance to answering the research questions.

Following the review of peer-reviewed articles, we conducted a review of grey literature to ensure coverage of driver duties which may have been recorded more informally. We used a selection of search terms from within our search term themes (i.e. one search string was “bus driver duties disabled people”), which were entered into Google.

A full list of the resources reviewed can be found in Appendix B.

1.3.2 Stakeholder research

Virtual roundtables and interviews were conducted to fill the gaps identified in the evidence review and collect additional driver roles and potential alternative solutions. A topic guide was developed to aid conversation, included in Appendix C.

1.3.2.1 Roundtables

Two virtual roundtables were carried out in February 2024, one with transport operators and one with accessibility and safety organisations. A total of 33 stakeholders from 24 organisations were contacted to participate in a roundtable discussion. In total, 14 stakeholders from 11 organisations took part in the roundtables. Stakeholders were sent an information sheet and pre-read material including the summary of the evidence review findings in advance of the session. Stakeholders were asked to review the material and come to the roundtable prepared to discuss driver roles and potential solutions. Notes were taken during the sessions and insights were captured directly into a spreadsheet that has fed into the final list of non-driving-related roles and potential alternative solutions.

1.3.2.2 Interviews

Ten online interviews were conducted to engage with stakeholders who expressed a preference to be consulted in a more confidential setting, to follow-up with stakeholders who could not attend the roundtable session, to gather additional detail from those who had attended a roundtable, or to gather insight from stakeholders from organisations who do not directly fit in the above-mentioned roundtable groups. This included representatives from the Department for Transport, automotive manufacturers and technology providers.

The interviews took place across February and March 2024 and lasted between 30 and 45-minutes each. 13 stakeholders from nine organisations took part in the interviews. Similarly to the roundtable discussions, notes were taken during the interviews and insights were captured directly into a spreadsheet that has fed into the final list of non-driving-related roles and potential alternative solutions.

1.3.3 Limitations

There are some limitations associated with the research which should be highlighted when discussing key findings and conclusions.

Firstly, there were some limitations with the stakeholder research. The stakeholder research was mainly conducted with stakeholders who were existing contacts of TRL and CCAV. It relied on stakeholders having availability to participate in the research. Some stakeholders were unable to attend the engagement sessions due to funding and resource pressures at the time. This may have restricted the range of perspectives gathered. Roundtable discussions also have some limitations. Participants may have been hesitant to share candid opinions, especially if they feel their remarks could be perceived negatively or reflect poorly on their organisation. This could have led to a lack of depth in the discussions and open dialogue or brainstorming creative solutions. Furthermore, there were some time restraints – not all topics were covered in each session. To counteract this, stakeholders were engaged with via email to gather their input on the topics that weren’t covered in the session.

Secondly, every effort was made to ensure the list of roles, and the identification of solutions was comprehensive – through engagement with stakeholders and desk research. However, it’s possible that some roles and solutions were overlooked, for example where potential solutions are not currently in the public domain. Additionally, new roles may present themselves as future systems and technologies become more advanced and potentially disruptive. These will also need to be considered. It is likely that the list will have to be updated going forwards.

Lastly, it must be noted that the rating of technical feasibility is subjective – it relied on a level of interpretation and judgement from the research team. Other analysts may have different judgements.

1.4 Report structure

This report is divided into an executive summary and five sections, summarised below.

- **Section 1** is this introductory section, which covered the background, objectives, and method.
- **Section 2** provides an overview of identified roles and solutions.
- **Section 3** explains the extent to which roles can be fulfilled by alternative solutions.
- **Section 4** presents the discussion element of the report, including gaps and associated risks, considerations moving forward, wider factors at play and lastly recommendations for future research.
- **Section 5** sets out the conclusion.

Appendices are provided separately.

- **Appendix A:** Detailed research method
- **Appendix B:** List of reviewed papers
- **Appendix C:** Stakeholder research topic guide
- **Appendix D:** Case studies of potential solutions

Summary of Section 1: Introduction

This work was commissioned by CCAV to understand the types of non-driving-related roles drivers play in making journeys accessible and inclusive for passengers – and therefore what needs to be considered in relation to automated passenger services where a driver may not be present.

The research objectives were:

1. What are the current non-driving-related roles and duties of drivers?
2. What are the potential implications if these roles are not fulfilled?
3. What alternative solutions could be implemented in the absence of a human driver to ensure the continued inclusivity of automated passenger services?

This research explored non-driving-related roles currently carried out by drivers of buses, coaches and private hire vehicles.

An evidence review and stakeholder research was carried out. This included two roundtables, one with transport operators and one with accessibility and safety organisations, and ten interviews, with representatives from transport operators, automotive manufacturers, technology providers and the Department for Transport.

It should be noted that although intended to be as comprehensive as possible, some roles and solutions may not have been identified in the research due to a limited number of stakeholders participating and to the fact that additional roles may emerge in the future.

The project team rated each potential solution in terms of technical feasibility. It should be noted that this rating is subjective.

2 An overview of identified roles

Through the methods outlined in the previous section, a list of driver roles and potential alternative solutions were collated. The identified roles stemmed from either the literature review, stakeholder engagement, or discussion within the research team. As new roles were identified, they were logged in a spreadsheet. The research team discussed which roles should be included or excluded based on their relevance to the project's scope. For example, some roles were excluded because they were non-passenger-facing or were driving-related tasks.

When roles seemed similar, the research team held internal workshops to discuss if they could be merged or if they were distinct based on the support that they provided passengers, or the solutions needed in the absence of a driver or onboard attendant.

Additional columns were added to the spreadsheet to note the characteristics of each role (outlined in the section below). Commentary was added on the risks associated with a role not being fulfilled, potential solutions in the absence of a driver or onboard attendant, feasibility ratings, and challenges, assumptions and design considerations related to the solutions. These were informed by the literature review and stakeholder engagement.

The spreadsheet was refined and converted into the final interactive matrix. Roles are ordered by stage of the journey, starting with roles related to identifying and boarding the vehicle, through to roles related to exiting the vehicle. Unique ID numbers are assigned to each role for easy reference. A screenshot of the interactive matrix can be seen in Figure 2 on the next page.

ID	What role does the driver currently do?	Examples of role	Theme	Action vs detection	Business as usual vs exceptional circumstanc	Stage of a passenger's journey	Mode	What are the risks if this role is not fulfilled?	Risk type	Solutions that could be implemented in the absence of a driver or onboard attendant	Feasibility rating	Challenges, assumptions and design considerations
2A	Recognising roadside passengers who want to board	Recognising someone holding their arm out. Recognising hailing cues given by a passenger with a disability (amputee, paralysed, blind) Recognising the difference between a runner out for a run vs someone running to get on the bus	Physical access	Detection	Business as usual	Before journey	Bus	May mean the passenger does not board the service they intended to, which may cause distress. This may particularly impact passengers with the following characteristics: * **Disability** - amputees, those with paralysis or vision impairments who may not be able to present the hailing cue of holding their arm out. * **Age** - young children who may not know how to hail the vehicle.	Passenger can't travel (because they can't board)	* External CCTV with AI and machine learning capabilities to recognise passengers signally for the bus to stop (doesn't exist, nor trialled) * Digital interface (i.e. smartphone apps) used to hail an approaching service using Automatic Vehicle Location (doesn't exist, nor trialled) * Vehicle programmed to stop at every bus stop regardless (exists) * Button / interface at bus stop for passenger to use to request that the vehicle stops	Yellow	* Digital interface - risk of digital exclusion * Digital interface - considerations around design of this, e.g. in what time period can you signal for the vehicle to stop (e.g. is more than 15 mins in advance allowed)?
2B	Recognising when all passengers have boarded	Recognising that the last of the passengers waiting for the service have now boarded the vehicle	Physical access	Detection	Business as usual	Passengers boarding	Bus Coach PHV	May mean passengers are stranded at the bus stop. This affects all passengers.	Passenger can't travel (because they can't board) Safety issue	* Boarding conducted in two stages, with passengers first admitted to an access controlled bus stop. The system can then check that the bus stop has emptied and thus all intended passengers have boarded	Orange	* Depends on solution - if use 'boarding in two stages' model, solution may be viable - but this requires a large change *May lose judgement of driver/ flexibility in catering for a last-minute passenger.
3	Confirming to passengers if the service or vehicle is the correct one for them to board or use	Calling out to a passenger and saying "This is the number 23 to Tin Pot Lane". Confirming to passengers that the vehicle goes to/past a certain destination. PHV confirming the name of the passenger they are due to pick up.	Providing information	Action	Business as usual	Passengers boarding	Bus Coach PHV	Passengers might not be able to find the correct service. This may particularly impact those with the following characteristics: * **Disability** - those with vision or hearing impairments, those with learning disabilities, those with anxiety, those with memory impairments. * **Age** - children / young people travelling alone. * Those who are new to the area	Passenger can't travel (because they can't board or alight)	* Help points / intercom at bus stops and on the bus (exists)	Green	* Risk of abuse to intercom at the bus stop. * Must ensure communication is fit for all passengers. Help points should feature braille for the passengers who are visually impaired and induction loops for passengers who are hard of hearing. People who are blind or who have visual impairments may currently rely on the driver calling out to them. They will need a means of locating the specific vehicle that they have hailed.

Figure 2: Screenshot of the interactive matrix

The research identified 66 roles performed by drivers or onboard attendants across buses, coaches, and private hire vehicles, that should be considered in the development of automated passenger services. The full list of roles can be found in the interactive matrix of non-driving-related roles.

The full list of roles can be found in the interactive matrix of non-driving-related roles.

The sections below provide an overview of the identified driver roles and an explanation of how they have been classified based on five key characteristics:

1. By theme
2. Detection vs action
3. All journeys vs some journeys
4. Stages of a passenger's journey
5. By mode

2.1 By theme

Beyond their primary functions, driver roles were analysed and grouped according to specific themes they addressed. These themes included 'safety', 'physical access', 'providing information', 'service quality', 'general assistance', and 'revenue protection'. The distribution of roles relating to each theme is displayed in Figure 3.

The 'safety' theme refers to maintaining the safety of passengers when engaging with the service. Roles under this theme refer to protecting the physical safety of passengers, safeguarding aspects, as well as protecting from psychological harm or harassment. Examples of roles that fall under this theme include recognising if, and preventing, the vehicle reaching capacity, and acting as a figure of authority to deter anti-social, illegal, or dangerous activities that would impact the safety of the driver or other passengers.

'Physical access' encompasses the roles that enable or facilitate all passengers to access the service and its functions. Examples of roles that fall under this theme include operating the wheelchair ramp or kneeling system and recognising that a passenger may need assistance getting into and out of the vehicle with their mobility aids, and providing that assistance.

The 'providing information' theme refer to situations where the driver provides passengers with information in order for them to be able to make informed decisions, or to enhance their journey experience. Examples of roles that fall under this theme include announcing the next stop on a bus, informing passengers about service information such as timetable, route, time to destination, and answering general inquiries.

'Service quality' consists of roles that improve the overall experience of using the service from the passengers' perspective. They are perhaps not things that are necessary, but they enhance their satisfaction levels and likelihood of using the service in the future. Examples of roles that fall under this theme include being a friendly face to passengers, listening to and actioning complaints, and responding to route or drop off preferences.

The 'general assistance' theme encompasses driver roles that are more generic and strive to make the passengers journey more pleasant. Examples of roles that fall under this theme include attending to lost property and directing passengers to areas to store luggage or bags on a bus.

'Revenue protection' refers to reducing fare evasion and ensuring everyone is travelling on the service using a valid or correctly issued ticket. Examples of roles that fall under this theme include taking fare and giving tickets and ensuring that passengers leave the vehicle at the stop they have paid to get off at.

Around half of the roles (38 out of 66) were related to 'safety' or 'physical access'.

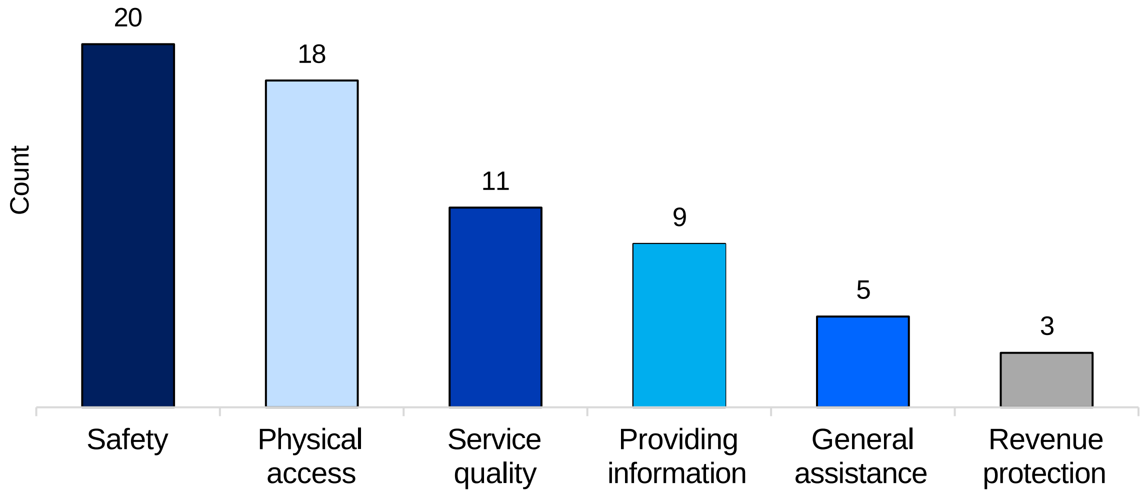

Figure 3: Distribution of driver roles according to theme

2.2 Detection vs action

Driver roles fell into two overarching categories: those centred around detection and those focused on performing an action. Detection-based roles involve identifying events and issues, while action-based roles involve responding to those identified aspects. Within these roles may be sub-categories such as informing passengers, executing tasks, or enforcing regulations. Of the 66 roles identified, the majority (41) are action-based, and the others are detection-based roles (25), as shown in Figure 4.

Examples of detection-based roles include recognising roadside passengers who want to board the vehicle and recognising medical emergencies, and examples of action-based roles include communicating the next stop to passengers and deploying the wheelchair ramp or kneeling system.

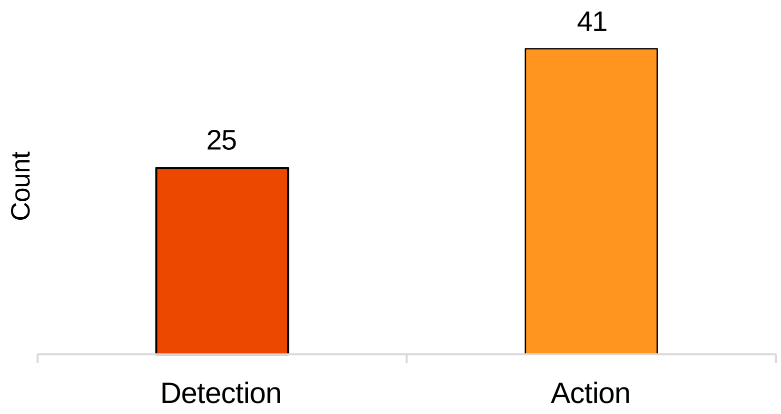

Figure 4: Distribution of driver roles according to whether they are detection-based or action-based

2.3 All journeys vs some journeys

Another dimension we used to classify driver roles was by distinguishing between roles that typically occur on all journeys and those that are activated only on some journeys. While some roles are integral to the normal function of a service, others are only invoked in response to unique situations. Of the 66 identified roles, it is a relatively balanced split as to whether they fell into the 'all journeys' category or roles that occurred on 'some journeys'. This finding is displayed in Figure 5.

Examples of roles that fall under the 'all journeys' category include taking fares and giving tickets and ensuring all passengers are stable before pulling away, while examples of roles that fall under the 'some journeys' category include communicating route changes / delays to passengers and managing the evacuation of the vehicle.

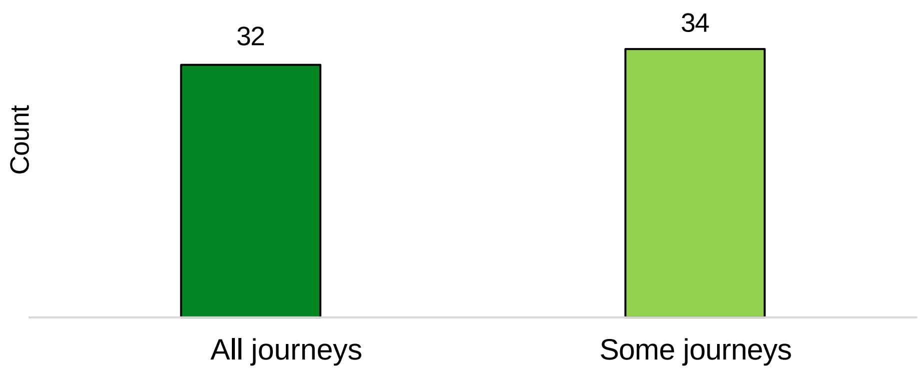

Figure 5: Distribution of roles according to whether they occur on all journeys or during some journeys

2.4 Stages of a passenger’s journey

Driver roles were also categorised based on the different stages of a passenger’s journey. These journey points include before the journey commences, when boarding or exiting the vehicle, when the vehicle is stopping, any time during the journey, or outside of the journey timeframe. Understanding roles within these journey points allowed for a more in-depth analysis of the contexts in which they occur and therefore how a potential solution may fulfil the role. As displayed in Figure 6, the majority of roles occur when passengers are boarding the vehicle, followed by at any point of the journey, during the journey, and boarding and exiting the vehicle. Other journey points included when only exiting the vehicle, when the vehicle is stopping, before the journey, and outside of the journey timeframe. Note that the number of roles does not add up to 66, as some roles occur at two stages of a passenger’s journey (both when boarding and exiting the vehicle).

An example of a driver’s role that occurs before the passenger’s journey commences is guiding a passenger to the vehicle (in the case of a PHV).

An example of a driver’s role that occurs while passengers are boarding the service is facilitating access to priority seats or wheelchair accessible spaces.

An example of a driver’s role that occurs during the passenger’s journey is responding to their route or drop off preferences.

An example of a driver’s role that occurs when the service is stopping is recognising when it is not appropriate to stop the vehicle at a certain location if the passenger is unable to disembark or continue with their journey.

An example of a driver’s role that occurs when passengers are exiting the service is helping the passenger get out of the vehicle with their crutches or mobility aids (in the case of a PHV).

An example of a driver’s role that occurs outside of a passenger’s journey time is searching round the vehicle between journeys for lost property or passengers.

An example of a driver’s role that occurs at any time is informing passengers about service information such as the timetable, route, or time to destination.

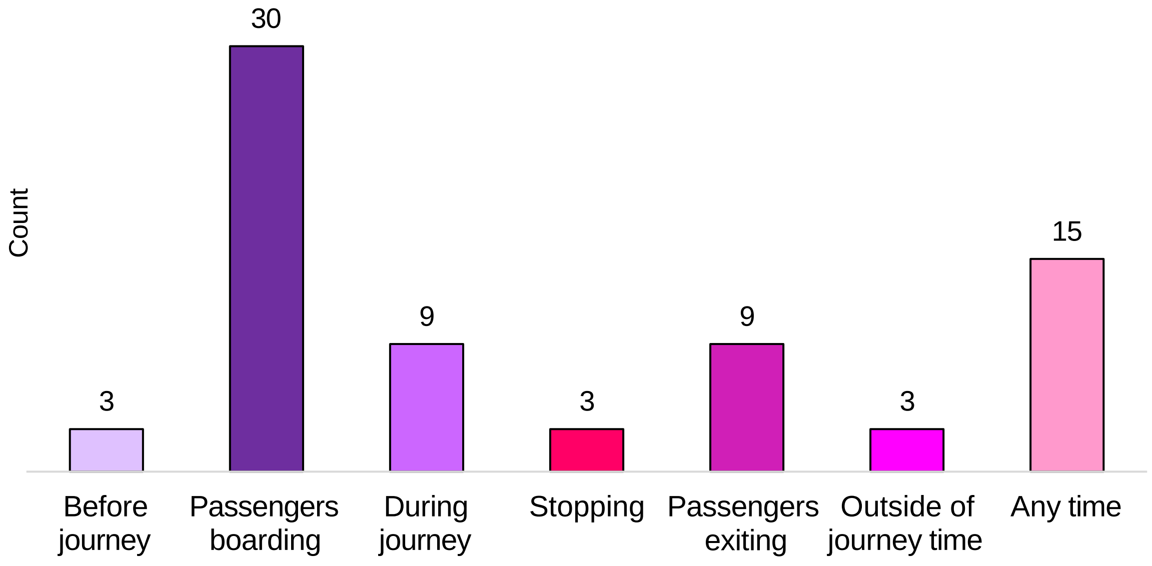

Figure 6: Split of roles according to passenger journey stage

2.5 By mode

Lastly, driver roles were further differentiated based on the specific mode and service characteristics, being in buses, coaches, or private hire vehicles. For instance, nuances in roles and associated potential solutions lie in whether the service is pre-booked or pre-paid by passengers, if routes are pre-determined and adhere to a schedule, and whether seating is reserved or operates on a first-come, first-served basis. Some roles are applicable across all modes, whereas some are only related to one or two. Roles applicable to each mode were relatively evenly distributed, with 56 roles being relevant to bus drivers, 58 roles relevant to coach drivers, and 61 roles relevant to private hire vehicle drivers, as shown in Figure 7.

Examples of roles that are specific to PHVs include ensuring passenger safety after drop-off and identifying that a passenger needs assistance locating the vehicle (and providing that assistance).

Examples of roles that are specific to coaches and PHVs include making sure the number of passengers matches the records for the journey and helping passengers load and unload belongings and storing them securely.

Examples of roles that are relevant to all buses, coaches and PHVs include recognising if the vehicle is at capacity or approaching capacity, vetting the items being brought on board by passengers, and assisting passengers with paying for the service.

There were no roles identified that were only specific to the roles performed by drivers or onboard attendants on buses.

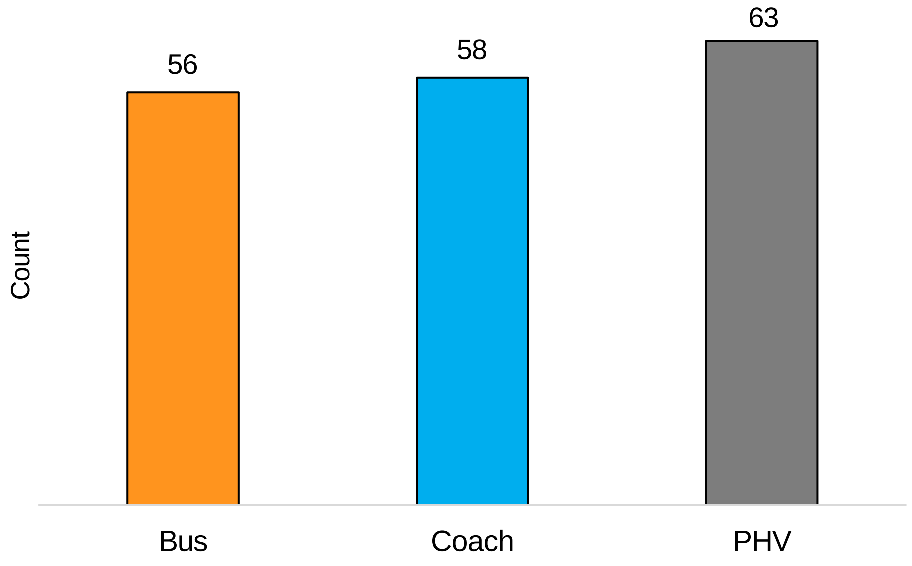

Figure 7: Split of roles applicable to mode

Summary of Section 2: An overview of identified roles

The research identified 66 driver roles. These were categorised based on the following characteristics:

- **By theme.** Most roles were classified under safety (approximately 30% of all roles) and physical access theme (just over 25% of all roles).
- **Detection-based vs action-based.** The majority of roles are action-based (approximately 60%).
- **All journeys vs some journeys.** Roles were relatively balanced between the two types.
- **Stages of a passenger's journey.** The most common time point on a passenger journey for roles to occur at was when boarding the vehicle (approximately 40%).
- **By mode.** Roles were relatively equally split between modes.

3 The extent to which roles can be fulfilled by alternative solutions

This section outlines the extent to which the team identified that the roles could be technically fulfilled by an alternative solution. This judgement was informed by stakeholder views. This section includes commentary on the proportion of roles that can and cannot be fulfilled, reflections on why this is, status of the solution (e.g. if it is already readily available and in use or not) and the consequences of these roles not being fulfilled.

3.1 Approach to technical feasibility rating

Each role was reviewed to assess whether a potential solution is, or could be, available. Each potential solution was assessed in terms of its technical feasibility. This included considering the solution readiness, i.e. whether the solution currently exists/ is in use, whether the solution exists but it hasn't been substantially trialled, or whether the solution is conceivable but doesn't currently exist.

This assessment led to a four-tier rating system, outlined in Table 1 below.

Table 1: A table outlining the four-tier system used to rate solutions

'Red'	Roles that cannot be fulfilled without a driver or onboard attendant at present (Section 3.3)
'Orange'	Roles that would be challenging to fulfil without a driver or onboard attendant (Section 3.4)
'Yellow'	Roles that could be fulfilled without a driver or onboard attendant but where there are still challenges associated with the solution (Section 3.5)
'Green'	Roles that could be fulfilled without a driver or onboard attendant with relative ease (Section 3.6)

It should be emphasised that the current assessment was carried out based on technical feasibility of the solutions. There will be other important factors to consider, including the effectiveness of the solution, the practicality and cost of implementation and acceptability of the solution by the general public. Even if a role is rated 'green' in the current assessment, this does not mean that there is a perfect solution to meet this role.

On top of this, we categorised the types of risks that may present themselves if a role is not fulfilled adequately by an alternative solution. These were grouped into the following risks, note that a role may have multiple types of risks linked to it:

- Passengers cannot travel (e.g. because they cannot board or alight).
- The experience of passengers is impacted.
- Safety issue.
- Commercial issue for operator (e.g. operator cannot collect fares).

3.2 Rating overview

Of the 66 roles identified, high-level analysis revealed that the greatest number of roles fell into the ‘green’ category (24 roles, 36%), followed by ‘yellow’ (21 roles, 32%). A smaller number of roles were rated as ‘orange’ (15 roles, 23%) and ‘red’ (6 roles, 9%). These findings are shown in Figure 8 below. The findings suggest that the majority of current driver roles can be fulfilled by alternative solutions in the case of an automated passenger service.

However, it is important to note where there are driver roles that cannot be fulfilled by alternative solutions, which we will explore in the following section.

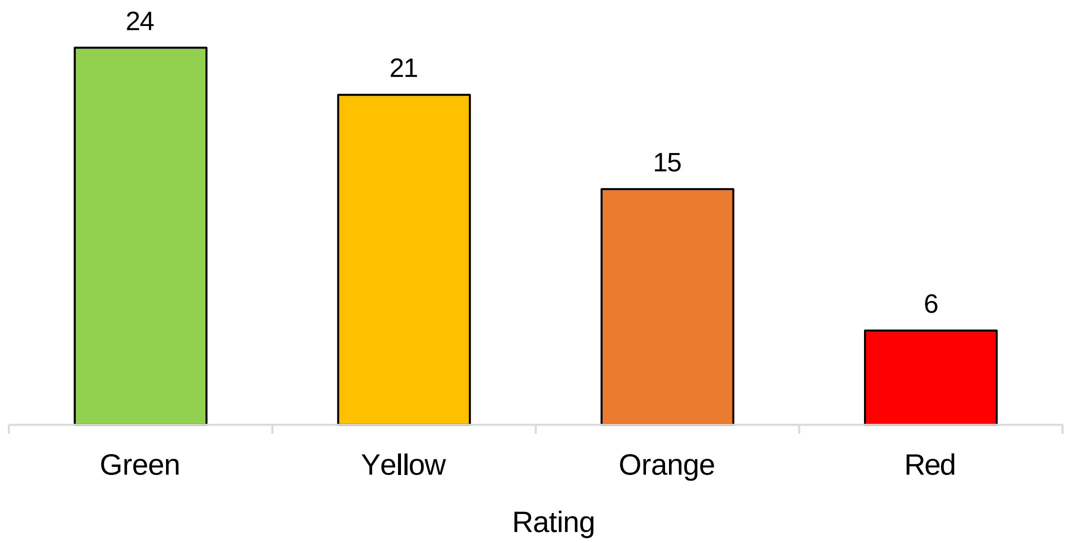

Figure 8: Distribution of role ratings across the four tiers

3.3 The roles that couldn't be fulfilled without a driver or onboard attendant ('red' roles)

Six roles (approximately 9% of all roles) have been categorised as 'red'. These are roles where potential solutions cannot fulfil the current activities of a driver or on-board attendant. A solution may arise in the future.

The roles in this category are:

- Preventing the vehicle being over-capacity e.g. stopping a passenger from boarding a coach when all the seats are occupied.
- Ensuring all passengers are stable before pulling away e.g. checking passengers are steady enough for the vehicle to pull away without anyone becoming injured.
- Ensuring that passengers leave the vehicle at the stop they have paid to get off at, and do not pay for a shorter trip than they need e.g. making sure that passengers who have paid for a trip to a certain bus stop do not remain on the bus longer than that destination.
- Recognising external or passenger issues where the vehicle needs to stop e.g. noticing an incident occurring such as a fire, a fight, a child who has been separated from their responsible adult, nausea, and other issues.
- Recognising when it is not appropriate to stop at a bus stop or location if there is a safety issue e.g. not stopping the vehicle where a fight has broken out at the drop off point or bus stop.
- Helping a passenger get into and out of the vehicle with their mobility aids e.g. taking a passenger's crutches, assisting them into their seat, and putting their crutches into the boot or back seat.

Further detail on these roles can be found in the interactive matrix of non-driving-related roles. Use the filter tool to see the roles that have been categorised as 'red' in column L, 'feasibility rating'.

3.3.1 Characteristics of 'red' roles

When looking at the characteristics of the roles in more detail, the research team identified the following, displayed in Figure 9.

- **Type:** There is an even split between whether the roles are action-based (3 roles) and detection-based (3 roles).
- **Themes:** Most of the roles fall under the 'safety' theme (4 roles), followed by 'physical access' (1 role) and 'revenue protection' (1 role).
- **Event:** There is an even split between the roles occurring on 'all journeys' (3 roles) and under 'some journeys' (3 roles).
- **Journey point:** The majority of the roles usually occur while passengers are boarding or exiting the vehicle (4 roles), followed by when the vehicle is stopping (1 role) and at any time (1 role).
- **Mode:** Most roles are relevant to buses, coaches and PHVs (5 roles), with one role being relevant to only buses and coaches.

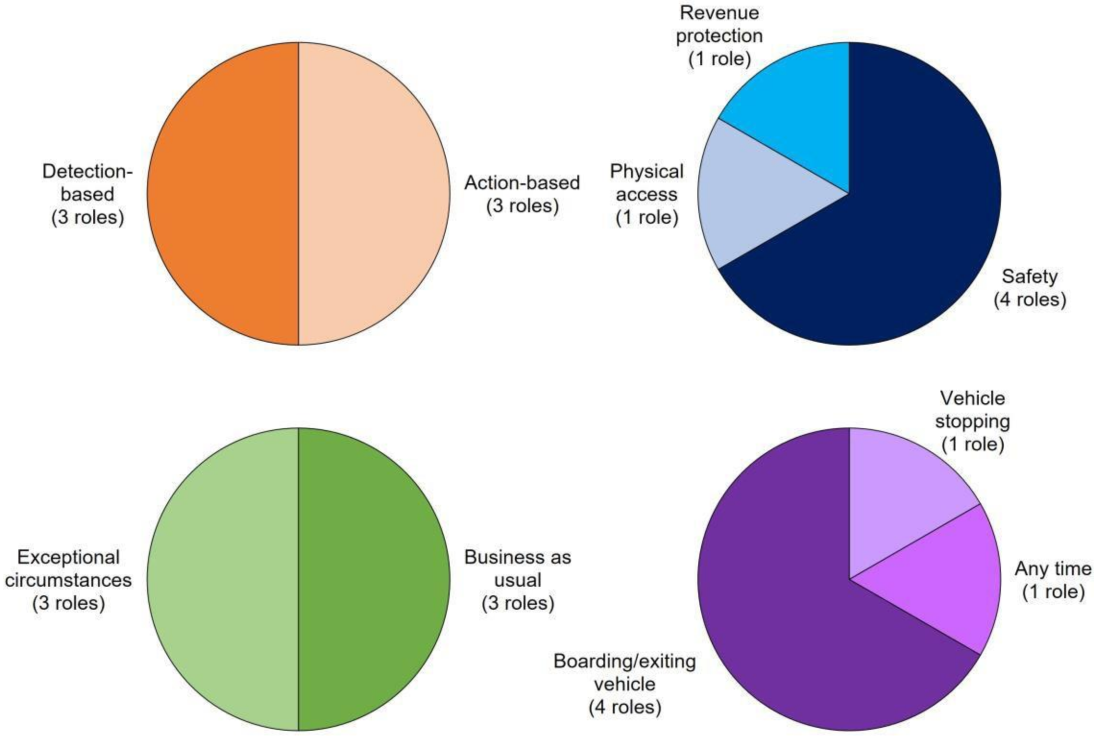

Figure 9: Summary of the characteristics of the 'red' roles

Generally, the driver roles rated 'red' tend to be the ones where the driver is making judgments about certain scenarios, physically assisting passengers, and enforcing rules. Limited solutions were identified to fulfil these types of roles although new solutions may be identified in the future.

3.3.2 Examples of 'red' roles

Some roles which fall into the 'red' category are described in more detail below. The full list of roles can be found in the interactive matrix of non-driving-related roles.

Ensuring all passengers are stable before pulling away from a stop (role 21)

Role overview: This role is applicable to buses, coaches and PHVs. It is a detection-based role, falls under the 'safety' theme, tends to happen on all journeys, and occurs when passengers are boarding.

Potential solution: A potential solution for fulfilling this role is CCTV with Artificial Intelligence (AI) capabilities to recognise passenger status and stability levels, prior to activating the moving-off phase of the service. This technology is available, as detailed in Appendix D.1.

> *"The way automated vehicles are so advanced, there is no reason why it [CCTV with AI capabilities] cannot be used on the inside of a vehicle to monitor the environment and passenger behaviours." – Accessibility organisation*

Challenges and considerations: There are challenges associated with this solution in addressing the existing driver role to the same level, or better, than a human judgment. It may be difficult for the CCTV system to define a threshold and establish whether passengers are stable or not, based on unique gaits and sturdiness levels of individuals who are older or have a health condition or disability that compromises their balance. This unreliability in the system may lead to inaccuracies in detection and could result in safety issues if the vehicle moves away before all passengers are steady. There are also performance challenges associated with CCTV systems, such as risk of vandalism and the camera being blocked.

> *"One challenge with using cameras is that people might stand in front of them and block the view – what happens then?" – Technology provider*

Why this role should be fulfilled: The risk of this role not being fulfilled adequately compromises passenger safety due to the increased risk of falls and injury. This may particularly impact passengers with mobility or balance impairments, older passengers, pregnant women, and young children. It's worth noting that this role is not currently performed on other transport modes, for example trains.

Helping a passenger get into and out of the vehicle with their mobility aids (role 8B)

Role overview: This role is applicable to buses, coaches and PHVs, and consists of the driver assisting passenger into the seat, loading their mobility aids (such as crutches) in a safe location (e.g. boot, storage area or seat next to them), assisting passenger out of the vehicle, and providing them with their mobility aids when the journey is complete. Approximately 24% of the UK population have a disability, and of this group, 47% have mobility impairments[9], highlighting the need for this role to be maintained. This is an action-based role, falls under the 'physical access' theme, occurs during some journeys occurs when passengers are boarding or exiting the vehicle.

Potential solutions: No alternative solutions were identified during this project to fulfil this role without an onboard attendant to provide assistance to passengers.

Challenges and considerations: It is important to note that not everyone wants assistance, and this should be respected by whoever is offering the support.

> *"People have good days and bad days, access needs aren't always linear, one day people might want a certain level of assistance, others they don't, and may find it annoying if they are being forced to use a system. There is a need for two-way dialogue." – Accessibility organisation*

Why this role should be fulfilled: The non-fulfilment of this role would mean passengers who have mobility impairments, are wheelchair users, are visually impaired or use any mobility aids may not be able to access the vehicle.

Figure 10: Image of a woman being assisted out of a vehicle with their crutches

Preventing the vehicle being over-capacity (role 6B)

Role overview: This role is applicable to buses, coaches and PHVs. In the case of an automated passenger service, it is therefore important for this type of access control to be maintained to protect the safety of passengers on board the vehicle. An example of this in practice is a coach driver indicating to passengers attempting to board the vehicle that it has reached capacity so they will need to wait for the next service.

Potential solution: In the case of an automated system, a potential solution could be an audio and visual announcement informing passengers that the vehicle is over capacity and *X* number of passengers need to exit the vehicle before the service resumes. An example of this is outlined in Appendix D.2. Another solution could include a system that allows passengers to report capacity of the service, to give an indication of capacity and how many seats are available. An example of this is outlined in more detail in Appendix D.3.

Challenges and risks: A challenge associated with this is that there is an argument that automated systems can easily be ignored, in comparison to the presence of a figure of authority or driver relaying the same message. The way the message is conveyed to passengers would need to be considered to ensure it is accessible to all passengers, including those who are deaf or have hearing impairments, or blind or visually impaired.

Why this role should be fulfilled: The risk of this role not being fulfilled means that the service may become very over-crowded, impacting on both passenger safety and comfort, as passengers become crushed, there is an invasion of personal space, and a higher risk of pickpocketing. This may particularly impact passengers who are neurodiverse or have anxiety, pregnant women, small children, and women who are at risk of unwanted sexual contact. It's worth noting that this role is not currently performed on other transport modes, for example trains, implying that this risk is sometimes mitigated by the presence of the train driver or conductor as a position of authority. It will be up to the individual to judge if there is sufficient space to board.

The full list of roles can be found in the interactive matrix of non-driving-related roles.

Summary of Section 3.3: The roles that couldn't be fulfilled without a driver or onboard attendant (red roles)

Six roles have been identified as 'red' (approximately 6% of all roles).

These tend to be roles where:

- Drivers are making judgments about certain scenarios, physically assisting passengers, or enforcing rules.
- There are no alternative solutions to fulfil the role to the extent to which a driver or onboard attendant currently performs them.

Most of the roles fell under the safety theme, which means that the associated risk of not fulfilling these roles is high - as non-fulfilment of the roles may result in passenger injury in the most extreme cases. Many of the roles are also categorised as all journeys, which implies that they would occur frequently when operating the service.

Other risks associated with non-fulfilment of these roles are that people may not be able to travel as they cannot board or alight the vehicle.

3.4 The roles that would be challenging to fulfil without a driver or onboard attendant (‘orange’ roles)

15 roles (23% of all roles) have been categorised as ‘orange’. These are roles where there are some potential solutions to fulfil the role of a driver or on-board attendant but hold various feasibility challenges.

Some examples of roles which fall under this category are:

- Recognising and addressing medical emergencies e.g. noticing a passenger having a seizure and calling the emergency services.
- Admitting or refusing passenger entry based on items being brought on or their behaviour e.g. refusing entry of passengers who are displaying signs of drunkenness and aggression or are attempting to bring unsuitable items on board.
- Helping passengers load and unload belongings and storing them securely e.g. opening the boot or hold area of the vehicle and helping them store the luggage.
- Ensuring wheelchairs are secured properly before pulling away e.g. using the tethers or restraints provided to secure the wheelchair and confirming to the passenger that this has been done.
- Acting as a friendly face e.g. smiling and greeting passengers as they enter the vehicle.
- Managing the evacuation of the vehicle e.g. communicating to passengers what to do in the event of a fire.

The full list of roles can be found in the interactive matrix of non-driving-related roles. Use the filter tool to see the roles that have been categorised as ‘orange’ in column L, ‘feasibility rating’.

3.4.1 Characteristics of ‘orange’ roles

The characteristics of the ‘orange’ roles are outlined below and displayed in Figure 11.

- **Type:** There is a relatively even split between action-based and detection-based roles (9 v 6).
- **Themes:** The majority of roles fall under the ‘physical access’ (6 roles) and ‘safety’ themes (6 roles), with the others being ‘service quality (2 roles) and ‘general assistance’ (1 role).
- **Event:** Eight of the roles tend to occur under ‘some journeys’, while five are roles which usually occur as ‘all journeys’.
- **Journey point:** Most of the roles tend to occur when passengers are boarding or exiting the vehicle (9 roles), followed by at any time of the journey (5 roles), and when the vehicle is stopping (1 role).
- **Mode:** The majority of the roles are relevant to all buses, coaches and PHVs (14 roles), with one role being relevant to only coaches and PHVs.

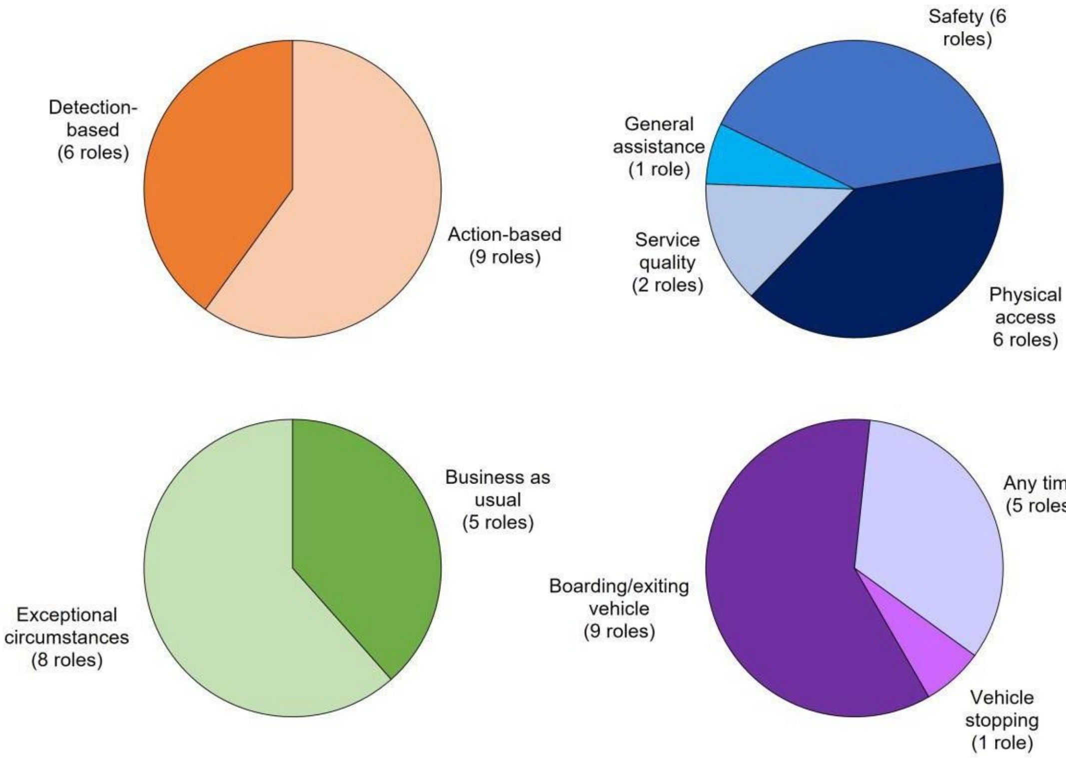

Figure 11: Summary of the characteristics of the 'orange' roles

The 'orange' roles are not deemed as 'red' as there are some appropriate solutions but there are also important considerations when thinking about how potential solutions perform the roles to the same extent, or better than drivers currently perform them.

Some of the roles related to detection are in the 'orange' category because there are significant technical challenges associated with alternative solution's ability to recognise certain objects or characteristics presented by passengers. Examples of 'orange' roles include vetting items being brought on by passengers, and recognising medical emergencies, when it is not appropriate to stop at a certain location, if priority seats or wheelchair accessible spaces are occupied, and when all passengers have boarded the vehicle.

Other roles related to action are in the 'orange' category as there are difficulties around alternative solutions making appropriate judgment-based decisions, physically assisting passengers, and enforcing service rules. Some examples of 'orange' roles include admitting or refusing entry based on the carriage of items or passenger behaviour, addressing medical emergencies, negotiating or waiving a fare, helping passengers load belongings, ensuring wheelchairs are secured and acting as a friendly face.

3.4.2 Examples of 'orange' roles

Some roles which fall into the 'orange' category are described in more detail below. The full list of roles can be found in the interactive matrix of non-driving-related roles.

Recognising medical emergencies (role 31A)

Role overview: This role is applicable to buses, coaches and PHVs. Medical emergencies can range from incidents such as passengers experiencing seizures, falls, allergic reactions, strokes, choking, fainting, and more. It is currently within the capacity of the driver to be able to interpret the severity of a medical scenario to be able to make an appropriate judgment on how to address it. This role is detection-based, falls under the 'safety' theme, occurs on some journeys, and can occur at any point of the journey.

Potential solution: CCTV with AI capabilities could be used to determine medical emergencies through machine learning and person detection and take appropriate action such as stopping the vehicle and calling the emergency services. This technology is in development and is outlined in more detail in Appendix D.1.

Challenges and considerations: There are challenges associated with the performance of the AI technology to correctly detect a more covert medical emergency and take action in a timely manner. This may also raise privacy concerns.

Why this role should be fulfilled: The risks of this role not being fulfilled are that passengers may not receive the medical attention they require, leading to injury, and the emergency services may not be notified in a timely manner, or wrongly notified in the event of a false-positive. This may be particularly impactful for passengers who are disabled, passengers who are more susceptible to experiencing medical emergencies such as older people, pregnant women, and young children.

Admitting or refusing entry onto the service based on items being brought on and/or passenger behaviour (roles 13A and 13B)

Role overview: These roles are applicable to buses, coaches and PHVs. These roles are the subsequent enforcement after a driver or onboard attendant detects that a passenger is attempting to bring on a banned item or is behaving in such a way that is deemed dangerous. Banned items include things such as weapons, e-scooters, inappropriately sized luggage. Passenger behaviours that would allow the driver to refuse entry onto the service include aggressive or abusive behaviour and drunkenness. These roles are action-based, falls under the 'safety' theme, occurs on all journeys, and occurs when passengers are boarding the vehicle.

Potential solution: With regards to detecting and allowing certain items onboard, a potential solution is passengers using an ID card to be scanned to allow entry of specific items, e.g. assistance dogs, onto the service. This would mean that service animals are not challenged. Examples of this solution were not identified during our search. Another potential solution to identifying certain objectives include CCTV with AI capabilities (see Appendix D.1), particularly the object detection element of the technology.

In terms of detecting and refusing entry based on passenger behaviour, CCTV with AI capabilities could also be used, particularly using the person detection element of the technology. This allows the camera to pick up specific activities, such as aggressive body language/behaviour, by evaluating the passengers body and facial movements. The vehicle could be programmed to not open its doors if banned items or dangerous passenger behaviour has been detected.

Challenges and considerations: A challenge associated with enforcement in the absence of a driver or onboard attendant is that passengers may find it easy to simply ignore automated messaging or a system explaining the reason that they are not allowed to use the service. A further layer is then the ability of an automated system to resolve conflict. Another challenge associated with rightfully refusing entry onto a service is that it is firstly difficult to establish passenger characteristics, as some features such as imbalanced gait and slurred speech could be interpreted as intoxication, when the passenger may have a disability. The use of technology to detect objects or behaviour may also raise privacy concerns.

Why this role should be fulfilled: The risk of this role not being fulfilled is that the passenger, who was allowed entrance onto the vehicle, may pose a risk or danger to the other passengers on the service. The risk associated with incorrect vetting of items or judgment of passenger characteristics could cause service delays, frustration, discrimination, or embarrassment.

Figure 12: Image of a CCTV system with AI capabilities

Helping passengers load and unload belongings and storing them securely (role 10)

Role overview: This role is applicable to coaches and PHVs. This role is classified as action-based, falls under the 'general assistance' theme, occurs on some journeys and occurs when passengers are boarding and exiting the vehicle.

Potential solution: A potential solution to fulfil this role is a humanoid robot which could assist with the lifting and storage of luggage. This technology is under development – one example is outlined in more detail in Appendix D.5.

Challenges and considerations: There are various feasibility challenges associated with this such as the maximum carry load and the ability to perform the required activity. Another consideration is the risk of the technology being abused, vandalised or stolen.

Why this role should be fulfilled: The risk of this role not being fulfilled is that passengers may not be able to take some items of luggage on the service, and thus not be able to board. This may particularly impact passengers who are disabled, are older, or are pregnant.

Ensuring wheelchairs are secured properly before pulling away (role 20)

Role overview: This role is applicable to buses, coaches and PHVs. It is classified as action-based, falls under the theme of 'physical access', occurs on some journeys and occurs when passengers are boarding.

Potential solution: A potential solution to fulfil this role are automated wheelchair tiedown and occupant restraint systems. Options include a 4-point strap tiedown system paired with a seatbelt, a docking station paired with a seatbelt, rear-facing stations, and a docking station paired with automatic seatbelt. In terms of an assessment based on independent use, crashworthiness level, and wheelchair/vehicle compatibility, the docking station paired with automatic seatbelt is the most feasible for an automated passenger service. This technology is in the initial stages of development, as outlined in Appendix D.6.

Challenges and considerations: Our research implies that this is a challenging role to replicate in an automated passenger service without human intervention and confirmation. Furthermore, the element of providing accessible confirmation that the wheelchair has been secured appropriate holds its difficulties.

> *"I think there is a regulation that drivers need to confirm that a wheelchair user is positioned safely. This needs to be replicated in automated services somehow." – Government body*

Why this role should be fulfilled: The risk of this role not being performed immediately neglects the needs of wheelchair users, as it risks the wheelchair being loose, meaning it can potentially cause harm and injuries to the passenger and others, as well as causing significant distress and causing a loss of confidence to use an automated passenger service in the future.

The full list of roles can be found in the interactive matrix of non-driving-related roles.

Summary of Section 3.4: The roles that would be challenging to fulfil without a driver or onboard attendant ('orange' roles)

Fifteen roles have been identified as 'orange' (approximately 23% of all roles).

These tend to be the roles where:

- Similarly to the roles rated as red, the driver recognises certain objects or characteristics presented by passengers, makes appropriate judgment-based decisions, physically assists passengers, or enforces service rules.
- There are some appropriate solutions linked to addressing them, but there are significant challenges associated with how well these solutions perform the roles. This is the key distinguishing factor between 'orange' and red-rated roles.

Most of the roles fell under the safety or physical access theme. Non-fulfilment of the roles may result in passengers not being able to travel at all or result in passenger injury in extreme cases.

3.5 The roles that could be fulfilled without a driver or onboard attendant but require more work ('yellow' roles)

Twenty-one roles (32% of all roles) have been categorised as 'yellow'. These are roles where potential solutions to fulfil the role without a driver / on-board attendant exist, but where there are still some challenges associated with the potential solutions.

Some examples of roles which fall under this category are:

- Recognising roadside passengers who want to board e.g. noticing someone holding their arm out on the side of the road by a bus stop.
- Communicating the reasons for refusing entry onto the service e.g. explaining why they are being refused entry, such as potential danger to other passengers.
- Recognising when service rules and regulations are not being adhered to e.g. noticing passengers who do not have their seatbelts on.
- Acting as a visual figure of authority to deter anti-social, illegal or dangerous behaviour e.g. deterring anti-social behaviour or illegal activities such as substance abuse.
- Listening to customer service complaints and feedback e.g. listening to a passenger explaining their dissatisfaction with the service.
- Recognising the need to operate the wheelchair ramp / kneeling system / features to assist access onto the vehicle e.g. noticing a passenger who is in a wheelchair waiting at the bus stop.
- Recognising when a route change / delay / drop off change is going to occur e.g. recognising the conditions ahead that will delay the vehicle such as roadworks or a protect.

Directing passengers to the correct onward direction when exiting the vehicle e.g. informing passengers of the correct onward direction to their desired destination, such as saying "up there and to your left after the traffic lights".

The full list of roles can be found in the interactive matrix of non-driving-related roles. Use the filter tool to see the roles that have been categorised as 'yellow' in column L, 'feasibility rating'.

3.5.1 Characteristics of 'yellow' roles

Characteristics of 'yellow' roles are outlined below and displayed in Figure 13.

- **Type**: There is an even split between whether the roles are detection based (10 roles) or action based (11 roles)
- **Themes**: Most of the roles fell under the 'physical access' theme (7 roles). Many fell under 'safety' (5 roles) and 'service quality' (4 roles). The rest were split across 'providing information (3 roles), 'revenue protection' (1 roles) and 'general assistance' (1 role).
- **Event**: More of the roles would be carried out on some journeys (12 roles) compared to all journeys (9 roles).

- **Journey point:** The majority of roles usually occur while passengers are boarding or exiting the vehicle (10 roles), followed by during journey (5 roles), at any time (3 roles), before the journey (1 role) and stopping (1 role).
- **Mode:** The majority of roles are related to buses, coaches and PHVs (18 roles), with some being relevant to only PHVs (2 roles), and only buses and coaches (1 role).

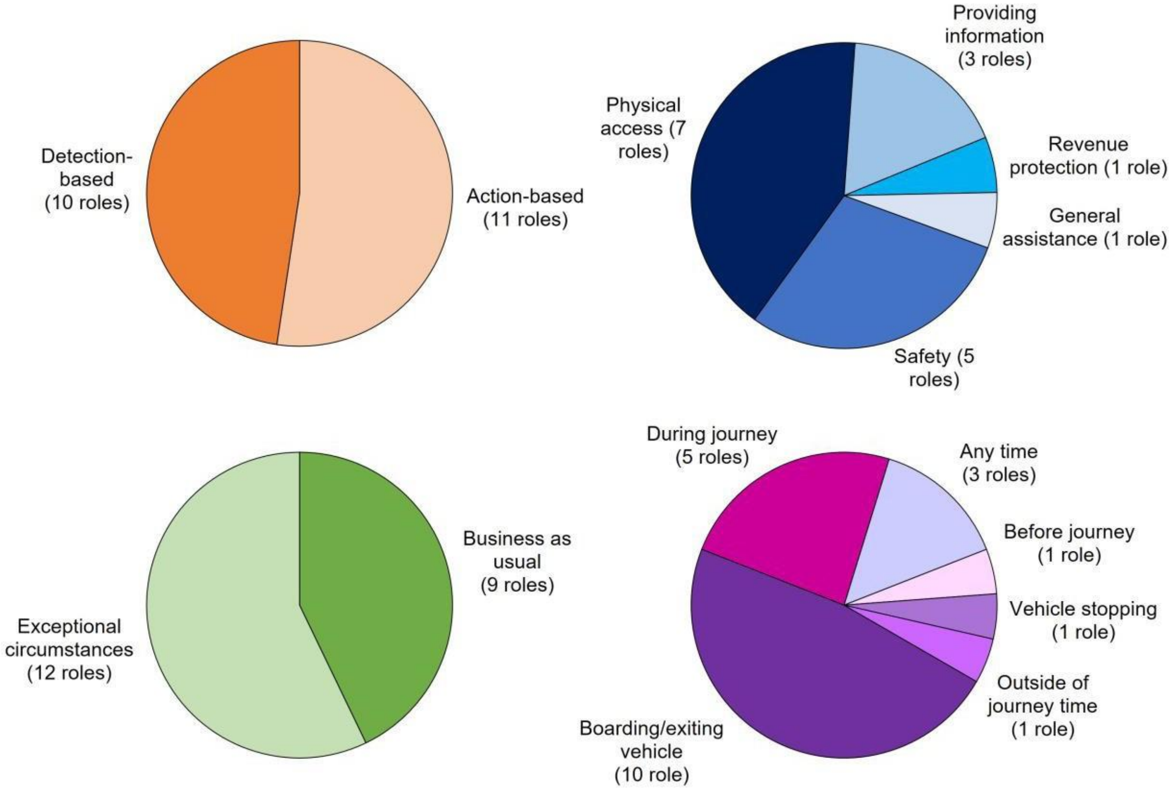

Figure 13: Summary of characteristics of the 'yellow' roles

Some of the roles related to detection are in the 'yellow' category because:

- There are existing technology/systems which can fulfil the detection requirement (for example, detecting if seatbelts are being worn).
- There is an assumption that passengers could communicate something to the vehicle themselves (for example, alerting the vehicle in advance that they will need additional time to find a seat before it moves away).
- The vehicle system could *always* provide something, so detection is not necessary to begin with (for example, the vehicle always 'kneels' or provides a ramp to aid boarding).

Other roles related to action are in the 'yellow' category because the action is possible (once the need for it has been detected) if the vehicle can be pre-programmed on what to do in various scenarios. For example, if it has been detected that there is a blockage at a bus stop, the vehicle could be programmed to either stop further along the bus stop or skip the bus stop and continue to the next one.

3.5.2 Examples of 'yellow' roles

Some roles which fall into the 'yellow' category are described in more detail below. The full list of roles can be found in the interactive matrix of non-driving-related roles.

Recognising roadside passengers who want to board (role 2A)

Role overview: This role is applicable to buses and coaches. This would cover recognising someone holding their arm out, recognising cues given by someone who cannot hold their arm out but indicates in another way (e.g. standing close to the kerb), and recognising the difference between a runner out for a jog and someone running to get on the vehicle. This role is applicable to buses. It is a detection-based role, falls under the 'physical access' theme, tends to happen on all journeys, and occurs before the journey. An additional layer of this role is the ability of the driver in understanding the difference between someone who wants to board the service, versus someone who doesn't, who may be stood near the vicinity of other passengers waiting to board. Reading and interpreting the body language cues of individuals is a challenging role to perform even by humans.

Potential solutions: There are various potential solutions to this role. One solution may be that each stop has a button / interface to use to request a vehicle to stop. Another solution could be for the vehicle to be programmed to stop at every bus stop regardless. These are solutions which exist already and could viably be implemented. Alternatively, if a service uses an Automatic Vehicle Location system (see Appendix D.7), passengers could see the approaching service through a smartphone app and indicate if they wish to board the service. Finally, a system could be implemented which employs CCTV and AI capabilities to recognise passengers signalling for the vehicle to stop. This technology exists and is outlined in more detail in Appendix D.1.

> *"Need to consider how an automated service will interact with people waiting to use the bus by putting their arm or cane out to stop the bus." – Accessibility organisation*

> *"Some shuttles stop at every stop currently – in the future there will likely be more recognition – obstacle detection to recognise when people want to get on/off. You could teach the system to recognise certain visual cues (i.e. a cane or guide dog)." – Transport operator*

Challenges and considerations: One challenge with these solutions relates to digital exclusion; digital interfaces and apps may not be suitable for all. There may be a challenge with passenger acceptance of new ways of flagging down a vehicle.

> *"The thing to recognise is that smartphone ownership among disabled people is generally low, particularly amongst those with learning disabilities, so there is a need [to ensure] that we are not creating a digital divide." – Government body*

We also note that there is a level of interpretation and flexibility that human drivers/on-board attendants currently use to fulfil this role. This includes detecting if someone would like to board but is unable to indicate to that effect (for example if they cannot hold their arm out or cannot see the vehicle). This also includes flexibility in waiting for passengers who may be rushing to board the vehicle, which may be particularly valuable in rural areas where services may not be frequent.

We also note that passengers may want extra reassurance that the vehicle is going to stop to allow them to board.

> *"It would be good if vehicles could communicate externally to passengers. People may be anxious waiting for buses. Has it seen me or not? If you put your hand out, we could use our external displays to acknowledge that it's seen you and it's stopping" – Technology provider*

Why this role should be fulfilled: If this role is not fulfilled, passengers may not be able to board the service, preventing them from making their journey. The non-fulfilment of this role may particularly impact children, passengers who are disabled, and those who are travelling in more rural areas. Serving these passengers is a legal requirement.

Figure 14: Image of a passenger in a wheelchair waiting at a bus stop

Communicating the reasons for refusing entry onto the service (role 13C)

Role overview: This role is applicable to buses, coaches and PHVs. This would cover the driver or on-board attendant telling a passenger why certain devices or items are not permitted on the service (e.g. illegal substances, certain classes of mobility scooters) or why the passenger cannot board due to their behaviour (e.g. intoxicated, aggressive behaviour). It is an action-based role, falls under the 'providing information' theme, tends to happen on some journeys, and occurs when passengers are boarding.

Potential solutions: One potential solution is for the service to use an audio announcement or text on a screen to communicate a pre-determined response with the passenger. This solution is already in use and is outlined in more detail in Appendix D.2. Alternatively, there could be an interface linking the passenger to a human in a remote monitoring centre, who could then communicate this information. This technology exists and could viably be implemented.

Challenges and considerations: This solution would rely on the effective detection of scenarios where there is a reason for entry to be refused (see roles 13A and 13B). The technology to communicate information exists, but the information would need to be personalised to the situation. Consideration is needed around the protocol for a scenario where there are follow-up questions from the passenger or where any conflict arises from the interaction and how that is then mitigated. Consideration is also needed around enforcement of decisions. Additionally, the way a message is conveyed to passengers needs to be accessible for all.

Why this role should be fulfilled: If this role is not fulfilled, passengers may not understand the reason for being refused entry and may feel discriminated against. The non-fulfilment of this role would impact all passengers but may particularly impact passengers who carry items/ accessibility devices which are not commonplace or may require some explanation.

Recognising when service rules and regulations are not being adhered to (role 26A)

Role overview: This role is applicable to buses, coaches and PHVs. This covers the driver or on-board attendant detecting safety-related scenarios such as passengers not wearing seatbelts, bags left unattended or items being in the way of fire exits or stairs. It is a detection-based role, falls under the 'safety' theme, tends to happen on all journeys, and occurs during the journey.

Potential solutions: Solutions would depend on the specific scenario that needs to be detected.

One potential solution is the use of specific technology to detect these scenarios. For example, to detect if seatbelts are being worn, a sensor system similar to the technology used in cars could be used. Scenarios related to unattended bags and items in prohibited areas could be identified through object detection technology – cameras with advanced analytical functions, which could detect object location, size and presence in zones of interest. This solution has been trialled at Schiphol Airport in Amsterdam and is outlined in more detail in Appendix D.1.

> *"Potentially there could be facial recognition to note who is doing it and sending a text to people's phones if they are putting bags in the way." – Transport operator*

Another option would be for a human in a remote monitoring centre to monitor key areas of the vehicle, although this may be resource intensive.

Challenges and considerations: The functionality of object detection technology can depend on environmental conditions such as fog, low lights and glare. There may also be challenges around cameras being blocked and some concerns around privacy.

Consideration will also need to be given to what the vehicle does when these rules are not adhered to – for example the vehicle could remain stationary until the rule is no longer broken. If this is the case, there is a risk of passengers abusing the system, for example by deliberately not wearing seatbelts to purposefully delay the journey. An alternative option would be for a human in a remote monitoring centre to make a decision about the appropriate course of action. Enforcement of rules will also need to be considered.

Why this role should be fulfilled: The role could relate to various scenarios (seatbelts, left luggage, whatever the specific rules of the particular service are). Depending on the specific scenario, passenger safety or experience may be compromised.

Acting as a visual figure of authority to deter anti-social, illegal or dangerous behaviour (role 37)

Role overview: This role is applicable to buses, coaches and PHVs. This covers the driver / on-board attendant being present as a deterrent for anti-social or illegal behaviour such as smoking, harassment or substance abuse. It is an action-based role, falls under the 'safety' theme, tends to happen on all journeys, and occurs at any time.

> *"Drivers are a massive deterrent compared to where there is no one in situ. It's clear that no one is driving DLR, but safety operatives patrol them who act as a deterrent." – Transport operator*

Potential solutions: Psychological deterrents could be implemented. Examples of this include: the placement of overt CCTV; the use of life-size pictures of attendants; or robots or electronic systems which give the sense that the vehicle is being monitored. These solutions are frequently employed.

Announcements which highlight the course of action if passengers spot anti-social or illegal behaviour (similar to the 'see it, say it, sorted' message on London Underground services operated by Transport for London[10]) may also give the impression that anti-social or illegal behaviour is not tolerated, and therefore act as a deterrent. This solution is outlined in more detail in Appendix D.9. An alternative solution could be ensuring that the vehicle is being remotely monitored, with this also being communicated to passengers.

> *"There needs to be a way to disincentivise anti-social and selfish behaviour." – Accessibility organisation*

Challenges and considerations: Over time, passengers may become desensitised to features which aim to act as psychological deterrents. This may happen if no repercussions are experienced when undesirable behaviour occurs, as passengers may not believe that the systems are effective.

Why this role should be fulfilled: Passengers may not feel safe or comfortable. They might be at greater risk of attack or anti-social behaviour. This could potentially prevent them from making journeys on that service at particular times or at all. The non-fulfilment of this role would impact all passengers but may particularly impact groups at greater risk of discrimination or hate crimes, such as women, and those which fall in other protected characteristic categories including disability, race, religion, gender reassignment or sexual orientation.

Figure 15: Image of a CCTV camera

The full list of roles can be found in the interactive matrix of non-driving-related roles.

Summary of Section 3.5: The roles that could be fulfilled without a driver or onboard attendant but require more work ('yellow' roles)

21 roles (approximately 30% of all roles) have been categorised as 'yellow'.

These tend to be roles where:

- Detection of something is possible due to a) existing technology b) an assumption that passengers can communicate something themselves or c) the system will always provide something so detection isn't necessary.
- The action is possible (once successfully detected) because the vehicle can be programmed on what to do in various scenarios.
- Potential solutions exist, even if they may not be the most effective or as good as a driver / on-board attendant.

About half of the roles in this category fell under the safety or physical access theme. Non-fulfilment of the roles may result in passengers not being able to travel at all or result in passenger injury in extreme cases.

3.6 The roles that could be fulfilled without a driver or onboard attendant with relative ease (‘green’ roles)

24 roles (36% of all roles) have been categorised as ‘green’. These are roles where there are potential solutions to fulfil the role without a driver / on-board attendant, and these solutions are fairly advanced and reliable.

Some examples of roles which fall under this category are:

- Answering passengers' general questions, not related to the service e.g. responding to a passenger asking how to open the windows of the vehicle.
- Recognising that a passenger might need help to get into and out of the vehicle with their mobility aids e.g. noticing a passenger has crutches before entering the vehicle.
- Taking fares and giving tickets e.g. taking payment and handing tickets to passengers.
- Deploying wheelchair ramps / kneeling system / features to assist access.
- Maintaining a clean interior e.g. wiping down mud at the entrance point of the vehicle.
- Informing passengers of service rules and regulations e.g. informing passengers that they are not allowed to smoke or vape on board the vehicle.
- Attending to lost property e.g. helping a passenger look for their passport.
- Conversing with a passenger using their preferred communication method e.g. writing down the next stop and handing it to the passenger.

The full list of roles can be found in the interactive matrix of non-driving-related roles. Use the filter tool to see the roles that have been categorised as ‘green’ in column L, ‘feasibility rating’.

3.6.1 Characteristics of ‘green’ roles

Characteristics of ‘green’ roles are outlined below and shown in Figure 16.

- **Type**: More of the roles are action based (18 roles) compared to detection based (6).
- **Themes**: Roles were split across the themes of ‘providing information’ (6 roles), ‘physical access’ (5 roles), ‘service quality’ (5 roles), ‘general assistance’ (3 roles), ‘safety’ (4 roles) and ‘revenue protection’ (1 role).
- **Event**: There is a fairly even split between whether roles would be carried out on all journeys (13 roles) compared to some journeys (11 roles).
- **Journey point:** The majority of roles usually occur while passengers are boarding or exiting the vehicle (9 roles), followed by at any time (6 roles), during journey (5 roles), before the journey (2 roles) and outside of journey time (2 roles).
- **Mode:** Most roles are relevant to buses, coaches and PHVs (16 roles), while less are relevant to only PHVs (6 roles), only buses and coaches (1 roles), and only coaches and PHVs (1 role).

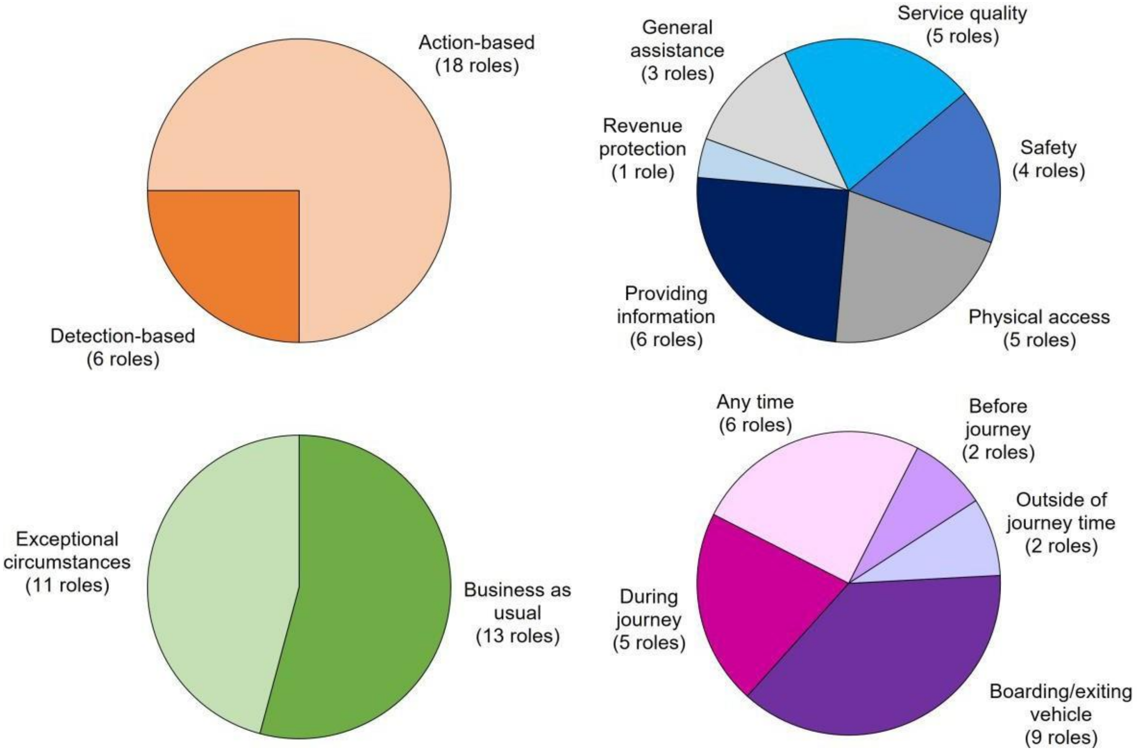

Figure 16: Summary of the characteristics of the 'green' roles

These roles are 'green' because they tend to be roles:

- Which involve providing information, which is often achieved without a driver / on-board attendant currently (for example, timetable information).
- Where detection of something is possible due to an assumption that passengers can communicate something themselves (for example, that they need a car seat for a child).
- Where the action is possible because the technology is already available (for example, systems to regulate the heating, lighting, and ventilation systems).

3.6.2 Examples of 'green' roles

Some roles which fall into the 'green' category are described in more detail below. The full list of roles can be found in the interactive matrix of non-driving-related roles.

Answering passengers' general questions, not related to the service (role 40)

Role overview: This covers the driver / on-board attendant responding to general queries, such as how to make an onward journey, whether there's a pharmacy nearby, or which cafe is the best one in the area. This role is applicable to buses, coaches and PHVs. It is an action-based role, falls under the 'providing information' theme, tends to happen on all journeys, and occurs at any time.

"Information while inside the vehicle, how do I open the window? How do I change the heating? If you aren't sure, you would usually ask the driver. Simple things like how do I charge my phone? It's the softer stuff, where it gets woolly." – Accessibility organisation

Potential solutions: One potential solution is an interface for passengers to use to ask questions, which could either be linked to a computer / search engine / AI functionality or linked to a human in a remote monitoring centre if needed. This type of solution exists already, through search engines on people's devices, ChatGPT and digital totems for wayfinding. This solution is outlined in more detail in Appendix D.10.

Figure 17: An image of a woman using an interactive screen

Challenges and considerations: One challenge here relates to lack of skills or confidence with digital interfaces. Any interfaces would also need to be made accessible for passengers with different accessibility needs. Additionally, a digital interface may not have the same level of local knowledge as a driver or onboard attendant who knows the area well, to be able to answer a passenger's question such as "what is the best shop for XYZ?".

"The knowledge of the driver is one of the most important roles that needs to be fulfilled and performed. It takes up to four years for drivers to memorise thousands of routes which gives them unrivalled levels of knowledge." (This is related to PHV drivers) – Automotive manufacturer

Why this role should be fulfilled: If this role wasn't fulfilled, passenger experience of the journey would be negatively impacted. This may particularly impact groups at greater risk of digital exclusion, for example older passengers or those with disabilities.

Recognising that a passenger might need help to get into and out of the vehicle with their mobility aids (role 8A)

Role overview: This role covers detecting when a passenger may need additional assistance when boarding or alighting the vehicle, for example requiring assistance lowering themselves into a seat or loading crutches into the boot of a PHV. This role is applicable to PHVs and coaches. It is a detection-based role, falls under the 'physical access' theme, tends to happen on some journeys, and occurs when boarding and exiting.

Potential solutions: One solution would be an app / interface to enable passengers to log their needs before the journey commences or when they arrive at the vehicle. This solution exists, for example when booking a train, outlined in more detail in Appendix D.11.

> *"If the person is carrying a phone, they could log into an app. People could put their needs into it. That app could say to the vehicle: 'this is Mr X who has the following needs'" – Technology provider*

Challenges and considerations: There may be a challenge around digital exclusion (if passengers don't own a device on which to book), and lack of skills or confidence with digital interfaces. Any interfaces would need to be made accessible for passengers with different accessibility needs.

Another challenge relates to ability of the system to *respond* to passengers' needs immediately (see role 8B). Ideally passengers would not have to log their requirements far in advance. This links to the discussion around the desire for 'turn up and go' services.

Why this role should be fulfilled: Passengers may not be able to access the vehicle. Passengers could be left stranded. The non-fulfilment of this role may particularly impact passengers with disabilities, including those who are mobility impaired, wheelchair users, those who use mobility aids, and those with vision impairments.

Taking fares and giving tickets (role 16)

Role overview: This role covers taking payments from passengers and issuing tickets. This role is applicable to buses, coaches and PHVs. It is an action-based role, falls under the 'revenue protection' theme, tends to happen on all journeys, and occurs when boarding or exiting.

Potential solutions: One potential solution is a greater roll-out of 'tap in' systems, which are widely used, whereby passengers touch their payment card or device to a reader to make payment. Other potential solutions which are also widely used include ticket machines at vehicle stops, or ticket machines on the vehicle itself. It's possible that passengers could also be automatically registered and charged when they board the vehicle (using geofencing attached to a payment method). These payment-based solutions are outlined in more detail in Appendix D.12.

> *"Perhaps there could be sensors that recognise you when you board and get off – so that there's no need to tap in or out" – Technology provider*

> *"There could be a touchscreen or voice control to talk to a vehicle about things; this would be handy for people with visual impairments. There could also be a button connecting to someone monitoring a vehicle to allow for some sort of human interaction." – Transport operator*

Challenges and considerations: Any interfaces would need to be made accessible for passengers with different accessibility needs. There may be a consideration around those who do not have bank accounts or digital ways of paying.

Why this role should be fulfilled: If this role is not fulfilled passengers may be unable to purchase a travel ticket. This could impact operators as they may face a drop in revenue, possibly leading to services becoming unsustainable and being terminated.

Deploying wheelchair ramps, kneeling systems or other features to assist access (role 7B)

Role overview: This role covers the deployments of features to assist physical access, including wheelchair ramps and kneeling systems. This role is applicable to buses, coaches and PHVs. It is an action-based role, falls under the 'physical access' theme, tends to happen on some journeys, and occurs when boarding and exiting.

Potential solutions: Automatic ramps and kneeling systems are already used on some vehicles. This technology could be refined and rolled out to additional vehicles. Another potential longer-term solution would be to develop vehicles and road infrastructure (i.e. pavements) to allow for level-access boarding – to reduce the need for kneeling and ramps altogether.

Figure 18: An image of an access ramp on a bus

Challenges and considerations: There have been challenges with automatic ramps breaking or not deploying correctly. This would have to be addressed before full reliance on these systems.

> *"Automation of boarding devices is possible, but doing it in a way which is robust, reliable and can be used consistently every time is challenging." – Government body*

Automatic ramps and kneeling systems are currently less feasible on PHVs – vehicle designs would have to be adjusted to allow for this technology.

Automatic wheelchair ramps would need to be aligned appropriately with the pavement, out of the way of street furniture or other potential obstacles such as wheelie bins, or at a location that is not on a dropped kerb. See role 42D. There is also a risk of any buttons to start ramp deployment being abused.

> *"A lot in theory can be automated with sensors being used to retract the ramp if it hits an obstacle, however in practice they are prone to failure." – Government body*

Why this role should be fulfilled: Passengers may be unable to board the vehicle. This may particularly impact those who are mobility impaired or would struggle to lift/ manoeuvre items (e.g. wheelchair users, pregnant women, passengers with pushchairs or luggage).

The full list of roles can be found in the interactive matrix of non-driving-related roles.

Summary of Section 3.6: The roles that could be fulfilled without a driver or onboard attendant with ease ('green' roles)

24 roles (approximately 35% of all roles) have been categorised as 'green'.

These tend to be roles:

- Which involve providing information, which is often achieved without a driver / on-board attendant currently.
- Where detection of something is possible due to an assumption that passengers can communicate something themselves (for example, that they need a car seat for a child).
- Where the action is possible because the technology is already available (for example, systems to regulate the heating, lighting, and ventilation systems).

4 Discussion

This project has examined the non-driving-related roles that drivers and onboard attendants currently carry out with a view to ensuring that future journeys using automated transport modes are inclusive for passengers.

During this research, gaps and risk areas were identified such as roles which would be hard to fulfil with technology alone. We also extrapolated areas for further consideration and future research. This is outlined in the subsequent sections.

4.1 Gaps and associated risks

Sixty-six roles were identified altogether. Twenty-one of these roles were rated ‘red’ or ‘orange’ on technical feasibility. These are roles which would be harder to fulfil without a driver or onboard attendant.

From analysis of the roles and potential solutions, there were some recurring themes around the roles that may be harder to fulfil without a driver or onboard attendant (the ‘red’ and ‘orange’ roles). We first examine roles related to detection before discussing those related to action.

4.1.1 Detection roles which would be hard to fulfil

Nine of the 21 ‘red’ and ‘orange’ roles related to detection. This includes roles such as recognising medical emergencies and ensuring all passengers are stable before pulling *away*. Detection roles can be harder to fulfil when they rely on a level of judgement or interpretation. In some cases, it may not be obvious if a scenario is occurring. Currently the driver may use their judgement to assess the situation. Whilst it’s possible to programme various scenarios into the vehicle system, these are unlikely to be exhaustive, and so there will naturally be times when the vehicle will rely on human intervention to interpret the situation.

There will also be a risk of false positives, when something is assessed as being against the service rules or being a medical emergency when in reality it is not. These misinterpretations may erode the experience of and trust in automated passenger services. It should however be noted that even with a driver involved, there are still instances of misinterpretation – the driver is also not the perfect solution.

In seven of these nine detection roles, the non-fulfilment of the role will present a safety risk. For example, the inability to detect medical emergencies appropriately or detect when it is not appropriate to stop at a certain location could lead to passenger injury. Potential solutions to these roles need to be carefully considered.

In three of these nine detection roles, the non-fulfilment of the role may mean that people cannot board or alight. For example, the inability to recognise if priority seats or wheelchair spaces are being taken by other passengers (who do not need it) may mean that passengers do not know if they are able to board the service in the first place.

4.1.2 *Action roles which would be hard to fulfil*

There were several types of action roles that were assessed as challenging to fulfil.

Six of the 'red' and 'orange' roles related to physical intervention, for example placing a passengers' luggage in the storage area of the vehicle or addressing medical emergencies. We did not identify many solutions that could feasibly fulfil these roles. It may be possible to design solutions to these scenarios, but they are likely to be complex in nature or require the vehicle or service model to be redesigned.

The non-fulfilment of these roles could lead to safety issues or the inability to board/alight.

Other roles require a level of interpretation about a suitable course of action, for example what type of emergency response is necessary. As discussed above, the system could be pre-programmed with scenarios, but there are likely to be edge cases that have not been accounted for.

More widely, there is a question around what may happen in scenarios in which drivers currently use their discretion in making a decision between conflicting priorities. For example, a driver may currently allow a passenger to board for their own safety, even if they cannot pay the fare and appear to be intoxicated. Or a driver may stop in a place that they are not supposed to because the correct bus stop is blocked. These scenarios may be more challenging for an automated service to address.

Four of the 'red' and 'orange' roles related to enforcement of rules. Whilst there are psychological mechanisms that can be put in place, these are unlikely to be as effective in practice, as notices and announcements may be easier to ignore than a human presence. The non-fulfilment of these roles could lead to safety issues (e.g. if banned items are brought onboard, if the vehicle becomes over capacity) and commercial issues for the operator (e.g. if passengers cannot be removed from the vehicle if they haven't paid the correct fare).

Summary of Section 4.1: Gaps and associated risks

21 out of the 66 roles were assessed as being hard to fulfil without a driver or onboard attendant (six roles were assessed as red, 15 assessed as 'orange'). For many of these roles, there are safety risks if the role is not fulfilled. In other cases, passengers may not be able to board/alight the services successfully. Potential solutions for these roles should be explored as a priority.

Certain roles currently mandated by law for buses, coaches, and PHVs have been identified in this study as lacking clear solutions in an automated context. This situation requires us to prioritise developing solutions for these roles.

4.2 Considerations moving forward

4.2.1 Limitations of potential solutions

Even where there are potential solutions to fulfil roles, some assumptions or limitations were noted. These are outlined below.

- Many solutions have a digital component. This has implications for those who are digitally excluded. Most notably, disabled people are more likely to be digitally excluded or have lower digital skills than other groups[11]. Linked to this group are older people, however it must be noted that the number of older adults who own a smartphone has risen dramatically from 18% in 2013 to 83% (age 50-64) and 61% (age 65+) in 2021[12]. Any digital interfaces also need to be designed in a way that is accessible, including visual, auditory and possibly haptic features.

  "Digital exclusion is a big issue here, both in terms of those who cannot afford or cannot use the technology, apps or interfaces, as well as rural areas where signal is non-existent." – Accessibility organisation

- There is an assumption that mechanical or technological solutions always work correctly and consistently. However, this is unlikely to be the case (for reasons such as failing technology or vandalism) and so consideration needs to be given to situations where functionality is reduced. What happens when things go wrong?
- Linked to the above points, the cybersecurity of systems is going to be crucial. There are risks related to data privacy and functionality of systems, for example, a risk of hacking.
- Some solutions rely on passengers doing more themselves, for example downloading an app or registering that they may need specific types of support – either in advance or when they come into contact with the vehicle. Whilst this is already the case in some transport services today, there is a question over whether it is always acceptable to place this burden on the passenger, as it may require greater effort on their part.
- Communicating to passengers and providing information was assessed as being relatively easy for an automated system to do, as much of this is not carried out by human drivers currently. However, consideration should be given around the tone of the communication – this may not be so easily replicated and could lead to poor experience on the service.

  "There are accessibility considerations around the language, tone, simplicity, visual and auditory cues. There might need to be a way passengers can anonymously interact with a help point, if they do not want to speak out loud." – Accessibility organisation

- Some solutions assumed that there may be changes in the wider environment or infrastructure – for example a greater consistency in pavement height. There is a question over whether these wider changes are feasible.

4.2.2 Further assessment of solutions

This research has assessed potential solutions in terms of technical feasibility.

Public acceptability will be a large part of the success or failure of these solutions. For example, an intercom to a person in a remote monitoring centre could be provided – but this may not fulfil the desire for connection or reassurance that some passengers have. Services could require passengers to make requests in advance, but this may not be feasible or desirable for them.

> *"One of the main things for individuals with protected characteristics is reassurance, especially for the older and partially sighted people who like to sit close to the driver to communicate." – Technology provider*

> *"People value the human element a lot, especially those with a disability or people who live alone – having a person to put you at ease." – Automotive manufacturer*

Effectiveness of the solutions will also be important. While something may be possible, it may not be as efficient or effective as a human alternative. Alternatively, it may more effective, for example, if a chatbot with AI-generated responses could converse with passengers in their preferred language or communication method, which is a solution that performs the role, in most cases, better than a driver might be able to.

In discussions with stakeholders, one wider theme emerged regarding the standard of automated passenger services. Questions were raised around whether automated passenger services should aim to maintain the current level of support provided by drivers or onboard attendants, or whether systems should strive to surpass existing standards by delivering more accessible and inclusive services. Additionally, it is important to consider the role of drivers of other modes of transport, such as trains and tubes, to understand which roles are seen to be necessary.

Finally, while some solutions may be effective and acceptable to passengers, it is important to assess the other barriers to implementation. These might include logistical challenges, regulatory hurdles, or financial constraints that could impede the implementation of the proposed solutions.

Summary of Section 4.2: Considerations moving forward

This section highlighted that even where there are potential solutions to fulfil roles, there are some assumptions or limitations which should be considered. These include aspects such as digital exclusion, reliability of mechanical or technical solutions, cybersecurity risks, relying on passengers taking on more responsibilities, communication methods, and the role of the wider environment.

5 Conclusion

The Centre for Connected and Autonomous Vehicles serves as a central hub for collaboration and innovation to enhance UK capabilities in automated vehicle technology and acceptance. As technologies and systems advance, it is crucial to ensure that this development considers the needs of all passengers, including those with protected characteristics such as disabilities, age, and gender identity.

This research has gathered valuable insights into the complex landscape of automated passenger services, by providing an overview of identified non-driving-related driver roles and potential alternative solutions to fulfilling these roles on automated passenger services. It aimed to outline the types of roles that may or may not be easily fulfilled without a driver or onboard attendant present, offering descriptions of their characteristics and associated risks, along with considerations for future developments.

Through bespoke research methodology, our findings imply that it is evident that while most roles can potentially be fulfilled without a driver, there are a notable portion that present significant challenges. Specifically, 21 out of the 66 identified roles were assessed as difficult to fulfil without a driver or onboard attendant present. Among these, roles essential for safety and passenger accessibility emerged as particularly problematic areas requiring further attention.

While the focus of this research has primarily been on the technical feasibility of alternative solutions, any potential future research should investigate public acceptability, effectiveness of solutions, or other practical barriers to implementation.

In conclusion, this work represents a significant step towards understanding the complexities of realising safe and inclusive automated passenger services and sheds light on both promising opportunities and significant challenges. By increasing understanding, the report contributes towards the national agenda of working towards future transport systems that are accessible for all.

Appendix A Detailed research method

A.1 Evidence review

An evidence review was conducted to identify the literature around driver roles and duties in ensuring services are inclusive for all, and information about alternative solutions in the absence of a driver in an autonomous passenger service.

The review was conducted in December 2023 and January 2024 and consisted of two strands. The first strand was a review of the articles provided by CCAV, or that we had retrieved for a similar project. The second strand was a new literature review where we reviewed both peer-reviewed articles and grey literature.

A.1.1 Review of known papers

The project first began by assessing the papers that CCAV were aware of and had sent to us, and the papers from a similar automated vehicle project. We assessed the abstract of each of the 32 studies on accessibility, inclusivity and safety from CCAV, and the 20 papers from our similar project to assess if these papers were relevant to the present project. We also searched to see if the word "driver" appeared in these articles, to confirm whether the article noted current driver duties. We included eight of the papers from CCAV and 20 of the papers from our similar project here. The list of known papers can be found in Appendix B.1 and Appendix B.2.

A.1.2 Review of peer-reviewed articles

In collaboration with CCAV, we created search terms under search term themes that would answer each research question (below)

- **RQ1:** What are the current roles and duties of drivers?
- **RQ2:** What are the potential implications if these support mechanisms are not provided?
- **RQ3:** What alternative solutions could be implemented in the absence of a human driver to ensure the continued inclusivity of automated passenger services?

For example, for research question 1, we created lists of search terms for the following search term themes, which would help us identify papers answering this research question. Boolean operators were used to combine these search term themes to ensure the review was precise and displayed relevant results. This mean that papers would need to combine at least one word from each search term theme to be included.

Search terms were developed under themes to answer specific research questions, as follows:

- **Driver** (used for RQ1 and 2), e.g. "driver", "operator", "taxi driver", "bus driver", "onboard attendant".
- **Passenger support** (used for all RQs), e.g. "roles", "duties", "responsibilities", "assist*", "tasks".

- **Type of transport** (used for all RQs), e.g. “public transport”, “bus”, “coach”, “private hire vehicle”.
- **Accessibility** (used for all RQs), e.g. “access*”, “inclusive*”, “protected characteristics”, “disabled*”.
- **Automation** (used for RQ2 and 3), e.g. “driverless”, “automat*”, “self-driving”.
- **Implications** (used for RQ2), e.g. “implications”, “risks”, “challenges”, “consequences”.
- **Solutions** (used for RQ3), e.g. “alternative”, “solution”, “technology”, “digital”.

The search terms were applied to a number of search engines including Google Scholar, TRID and Science Direct. The search results were imported into a spreadsheet and duplicates were removed. The abstracts of the papers were reviewed then scored based on a set of inclusion criteria of relevance, quality, and timeliness, as outlined in Table 2.

Table 2: Scoring matrix

	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
Quality	Non-scientific article (e.g. online source, newspaper, or magazine article)	Evidence review / case study investigation	Randomised controlled trial / before-after comparison of real-world data
Timeliness	Published over 10 years ago	Published between 5-10 years ago	Published within the past 5 years

Of the 64 sourced articles, 17 were excluded, and 47 were reviewed in full. These 47 papers were selected for review based on receiving the highest scored on the inclusion criteria and having been deemed of relevance to answering the research questions. Each of the included papers were presented in a row in Microsoft Excel, with summaries of information related to each specific research questions in subsequent columns.

The list of peer-reviewed articles can be found in Appendix B.3.

A.1.3 Review of grey literature

Following the review of peer-reviewed articles, we conducted a review of grey literature to ensure we covered off more informal driver duties and how these could be conducted. To do this we used a selection of search terms from within our search term themes (i.e. one search string was “Bus Driver duties disabled people”). These strings were entered into Google. As part of this process, we came across some job adverts for bus drivers, which noted specific driver duties. We used these roles as an initial basis for the driver duties. This search identified 9 additional sources of information. The list of grey literature can be found in Appendix B.4.

A.2 Stakeholder research

Virtual roundtables and interviews were conducted to fill in the gaps identified in the evidence review and collect additional driver roles and potential alternative solutions.

A.2.1 Roundtables

Roundtables were categorised into two groups to enhance productivity and tailor the priority of topics to align with the expertise of stakeholders (transport operators and accessibility and safety organisations).

Stakeholders were recruited via email outreach conducted by CCAV. Existing relationships were leveraged to compile an initial contact list, and online searchers were utilised with relevant key words to identify individuals or teams pertinent to the topic.

An initial email was dispatched to stakeholders to gauge their interest in participating in a roundtable. If stakeholders felt like they could not contribute significant or could not attend the session, they were encouraged to forward the email to an appropriate colleague or team. Following confirmation of interest, stakeholders were sent the Teams invitation for the virtual event. A total of 33 stakeholders from 24 organisations were contacted to participate in a roundtable discussion.

Stakeholders were sent an information sheet and pre-read material including the summary of the evidence review findings in advance of the session. Stakeholders were asked to review the material and come to the roundtable prepared to discuss.

A topic guide (see Appendix C) was used to structure the sessions. Two online roundtables took place in February 2024 and lasted approximately 60-minutes each. One researcher from TRL facilitated the conversations while another took notes. Representatives from CCAV attended in an observational capacity. The roundtables were recorded and transcribed to ensure all insight was collected. In total, 14 stakeholders from 11 organisations took part in the roundtables.

Notes were taken during the sessions and stakeholder insights were captured directly into a spreadsheet that has fed into the final reporting of the roles and duties of a driver and potential alternative solutions for future automated passenger services.

A.2.2 Interviews

Ten online interviews were conducted to engage with stakeholders who expressed a preference to be consulted in a more private, confidential setting, to follow-up with stakeholders who could not attend the roundtable session, or to gather insight from stakeholders from organisations who do not directly fit in the above-mentioned roundtable groups.

The same recruitment tactic was employed for contacting new stakeholders about the interviews. CCAV contacted stakeholders via email to gauge their interest in participating in an interview. Following confirmation of interest, stakeholders were sent the Teams invitation for the interview. A total of 18 stakeholders from 16 organisations were contacted to participate in an interview.

A topic guide (see Appendix C) was used to structure the sessions. The interviews took place across February and March 2024 and lasted between 30 and 45-minutes each. A researcher from TRL facilitated each interview and took notes. The interviews were recorded and transcribed to ensure all insights were collected. In total, 13 stakeholders from 9 organisations took part in the interviews.

Notes were taken during the interviews and stakeholder insights were captured directly into a spreadsheet that has fed into the final reporting of the roles and duties of a driver and potential alternative solutions for future automated passenger services.

Appendix B List of reviewed papers

B.1 Existing papers: received from CCAV

Bęczkowska, S. A., & Zysk, Z. (2021). Safety of people with special needs in public transport. Sustainability (Switzerland), 13(19). https://doi.org/10.3390/su131910733

Kim, S., Chang, J., Park., H., Song, S., cha, C., Kim, J. & Kang, N. (2019). Autonomous taxi service design and user experience. International journal of human-computer interaction. 429-448

Law Commission, Scottish Law Commission. Automated Vehicles: Consultation Paper 2 on Passenger Services and Public Transport: A joint Consultation Paper. (2019). https://cloud-platform-e218f50a4812967ba1215eaecede923f.s3.amazonaws.com/uploads/sites/30/2019/10/Automated-Vehicles-Consultation-Paper-final.pdf

Law Commission, Scottish Law Commission. Automated Vehicles: Analysis of Responses to Consultation Paper 2. (2020). https://cloud-platform-e218f50a4812967ba1215eaecede923f.s3.amazonaws.com/uploads/sites/30/2020/06/AV-Analysis-of-consultation-responses-2020.pdf

Miller, K., Chng, S., & Cheah, L. (2022). Understanding acceptance of shared autonomous vehicles among people with different mobility and communication needs. Travel Behaviour and Society, 29, 200–210. https://doi.org/10.1016/j.tbs.2022.06.007

Schuß, M., Manger, C., Löcken, A., & Riener, A. (2022). You'll Never Ride Alone: Insights into Women's Security Needs in Shared Automated Vehicles. Main Proceedings - 14th International ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications, AutomotiveUI 2022, 13–23. https://doi.org/10.1145/3543174.3546848

Chowdhury, S., & van Wee, B. (2020). Examining women's perception of safety during waiting times at public transport terminals. Transport Policy, 94, 102–108. https://doi.org/10.1016/j.tranpol.2020.05.009

Schräder, T., Graubohm, R., Salem, N. F., & Maurer, M. (2022). Designing an Automated Vehicle: Strategies for Handling Tasks of a Previously Required Accompanying Person. ArXiv Preprint ArXiv:2209.11083. http://arxiv.org/abs/2209.11083

B.2 Existing papers: crossover with parallel project

Bayless, S. H., & Davidson, S. (2019). Driverless cars and accessibility: Designing the future of transportation for people with disabilities.

Boadi-Kusi, S. B., Amoako-Sakyi, R. O., Abraham, C. H., Addo, N. A., Aboagye-McCarthy, A., & Gyan, B. O. (2023). Access to public transport to persons with visual disability: A scoping review. British Journal of Visual Impairment, 02646196231167072.

Dicianno, B. E., Sivakanthan, S., Sundaram, S. A., Satpute, S., Kulich, H., Powers, E., ... & Cooper, R. A. (2021). Systematic review: Automated vehicles and services for people with disabilities. Neuroscience Letters, 761, 136103.

Emory, K., Douma, F. & Cao, J. (2022). Autonomous vehicle policies with equity implications: Patterns and gaps. Transp Res Interdiscip Perspect. 13, 100521. doi:10.1016/j.trip.2021.100521

Epting, S. (2021). Ethical requirements for transport systems with automated buses. Technology in Society, 64, 101506.

Etminani-Ghasrodashti, R., Patel, R. K., Kermanshachi, S., Rosenberger, J. M., Weinreich, D., & Foss, A. (2021). Integration of shared autonomous vehicles (SAVs) into existing transportation services: A focus group study. Transportation Research Interdisciplinary Perspectives, 12, 100481.

Hwang, J., Li, W., Stough, L., Lee, C., & Turnbull, K. (2020). A focus group study on the potential of autonomous vehicles as a viable transportation option: Perspectives from people with disabilities and public transit agencies. Transportation research part F: traffic psychology and behaviour, 70, 260-274.

Kassens-Noor, E., Kotval-Karamchandani, Z., & Cai, M. (2020). Willingness to ride and perceptions of autonomous public transit. Transportation Research Part A: Policy and Practice, 138, 92-104.

Kett, M., Cole, E., & Turner, J. (2020). Disability, mobility and transport in low-and middle-income countries: a thematic review. Sustainability, 12(2), 589.

Klinich, K. D., Manary, M. A., Orton, N. R., Boyle, K. J., & Hu, J. (2022). A literature review of wheelchair transportation safety relevant to automated vehicles. International journal of environmental research and public health, 19(3), 1633.

Law Commission, Scottish Law Commission. Automated Vehicles: Joint Report.; 2022. https://cloud-platform-e218f50a4812967ba1215eaecede923f.s3.amazonaws.com/uploads/sites/30/2022/01/Automated-vehicles-joint-report-cvr-03-02-22.pdf

Marson, J., Dickinson, J., & Ferris, K. (2021). Regulating Connected and Autonomous Vehicles Through a Lens of Inclusivity. Hong Kong LJ, 51, 983.

Neven, A., & Ectors, W. (2023). “I am dependent on others to get there”: Mobility barriers and solutions for societal participation by persons with disabilities. Travel behaviour and society, 30, 302-311.

Park, J., & Chowdhury, S. (2022). Towards an enabled journey: barriers encountered by public transport riders with disabilities for the whole journey chain. Transport Reviews, 42(2), 181-203.

Riggs, W., & Pande, A. (2022). On-demand microtransit and paratransit service using autonomous vehicles: Gaps and opportunities in accessibility policy. Transport Policy, 127, 171-178.

Strickfaden, M., & Langdon, P. M. (2018). Improving design understanding of inclusivity in autonomous vehicles: A driver and passenger taskscape approach. In Breaking down barriers: Usability, accessibility and inclusive design (pp. 181-193). Springer International Publishing.

Tabattanon, K., Sandhu, N., & D’Souza, C. (2019, November). Accessible design of low-speed automated shuttles: A brief review of lessons learned from public transit. In

Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 63, No. 1, pp. 526-530). Sage CA: Los Angeles, CA: SAGE Publications.

Unsworth, C., So, M. H., Chua, J., Gudimetla, P., & Naweed, A. (2021). A systematic review of public transport accessibility for people using mobility devices. Disability and rehabilitation, 43(16), 2253-2267.

Wu, X., Cao, J., & Douma, F. (2021). The impacts of vehicle automation on transport-disadvantaged people. Transportation research interdisciplinary perspectives, 11, 100447.

Yousfi, E., & Métayer, N. Improving Mobility for People Living with a Disability: Automated Vehicles' Opportunities and Future Challenges. Available at SSRN 4250791.

B.3 New papers: evidence review

Bhalearo, A., Birari, S., Kale, S., Narrra, S. A., Pravin Shelar, P., Zhang, C., Jia, B., & Bao, S. (2022). Autonomous Transit Service Design for Riders with Vision Impairment. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 66(1), 1299–1303. https://doi.org/10.1177/1071181322661462

Gluck, A., Boateng, K., Huff, E. W., & Brinkley, J. (2020). Putting Older Adults in the Driver Seat: Using User Enactment to Explore the Design of a Shared Autonomous Vehicle. Proceedings - 12th International ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications, AutomotiveUI 2020, 291–300. https://doi.org/10.1145/3409120.3410645

Kwakye, K., Dadzie, E., Seong, Y., & Yi, S. (2022). Social Responsibility Considerations for Autonomous Vehicles Implementation: Design and Legislature for Equity towards Vulnerable Groups. SSRN. https://ssrn.com/abstract=4175764

Pakusch, C., Bossauer, P., & Stevens, G. (2020). The Unintended Social Consequences of Driverless Mobility Services: How Will Taxi Drivers and their Customers Be Affected? ACM International Conference Proceeding Series, 98–106. https://doi.org/10.1145/3401335.3401346

Mirnig, A., Gartner, M., Fussl, E., Ausserer, K., Meschtscherjakov, A., Wallner, V., Kubesch, M. & Tscheligi, M. (2020). Suppose your bus broke down and nobody came. A study on incident management in an automated shuttle bus. Personal and Ubiquitous Computing, 24, 797-812. https://doi.org/10.1007/s00779-020-01454-8

Transport Focus (2023). Your Bus Journey: Interim Report. https://d3cez36w5wymxj.cloudfront.net/wp-content/uploads/2023/09/27092232/EMBARGOED-YOUR-BUS-JOURNEY-INTERIM-REPORT-SEPT-2023-FINAL.pdf

Broome, B., Worrall, L. E., Fleming, J. M., & Boldy, D. P. (2011). Identifying age- friendly behaviours for bus driver age-awareness training. Canadian Journal of Occupational Therapy, 78, 118-126. doi: 10.2182/cjot.2011.78.2.7

Meng, L. (2023). Journey Towards Independence: Exploring the potential of autonomous buses in supporting independence of children with mild cognitive impairments. Thesis from UMEA University. https://www.diva-portal.org/smash/get/diva2:1777480/FULLTEXT01.pdf

Salonen, A. & Haavisto, N. (2019). Towards Autonomous Transportation. Passengers' Experiences, Perceptions and Feelings in a Driverless Shuttle Bus in Finland. Sustainability, 11 (3), 588. https://doi.org/10.3390/su11030588

Lopez-Lambas, M. & Alonso, A. (2019). The Driverless Bus: An Analysis of Public Perceptions and Acceptability, Sustainability, 11 (18), 4986. https://doi.org/10.3390/su11184986

Rohani, M., Wijeyesekera, D. & Karim, A. (2013). Bus Operation, Quality Service and The Role of Bus Provider and Driver. Procedia Engineering, 53, 167-178. https://doi.org/10.1016/j.proeng.2013.02.022.

B.4 New papers: grey literature

Fast, D. (2018). Transportation Accessibility: Exploring the Input of Individuals Who are Blind to Create an In-Service Training for Bus Drivers. Journal of Blindness Innovation and Research.

Scope: Transport for Disabled People (2024). [online]. [Accessed April 2024]. Available from World Wide Web: https://www.scope.org.uk/advice-and-support/finding- accessible-transport#Buses-and-coaches-click

Wilson, K. (2022). Will 'Autonomous' Buses Force Drivers Out of a Job — Or Make Them More Important Than Ever?'. [online]. [Accessed April 2024]. Available from World Wide Web: https://usa.streetsblog.org/2022/05/31/will-autonomous-buses-force-drivers-out-of-a-job-or-make-them-more-important-than-ever

Linderman, T. (2018). Human bus drivers will always be better than robot but drivers. [online]. [Accessed April 2024]. Available from World Wide Web: https://www.vice.com/en/article/43bkx3/bus-driver-automation

Replaced by Robot. Will "bus driver" be replaced by robots? [online]. [Accessed April 2024]. Available from World Wide Web: https://www.replacedbyrobot.info/69117/bus- driver

Leigh, E. (2019). Will making the bus driver redundant save public transport? [online]. [Accessed April 2024]. Available from World Wide Web: https://www.smartertransport.uk/will-making-the-bus-driver-redundant-save-public-transport/

Lutin, J. (2018). Not if, but when: autonomous driving and the future of transit. Journal of Public Transportation, 21 (1), 92-103. https://doi.org/10.5038/2375-0901.21.1.10

London Assembly (2005). The driver on the bus… The Transport Committee's review of bus driving standards. Available from: https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/archives/assembly-reports-transport-busdrivers.pdf

Netherlands Institute for Human Rights (2017). Accessibility on the bus? Study report on the accessibility of public bus transport for wheelchair users in the Netherlands.

Appendix C Stakeholder research topic guide

Section 1: Introduction and welcome

Points covered:

- Introduction to the project (background and aims)
- Introduction to TRL and CCAV
- Purpose of the engagement
- Housekeeping (duration, breaks, recording)

Section 2: Identifying driver roles and duties

Researcher to share screen of evidence review findings, focusing on a theme at a time

1. Are there any driver roles missing from our list?
2. Are there any roles you'd like to elaborate on or give context to?
    a. Prompt: for example … *researcher identifies one role*
3. Do you have any ideas on what alternative solutions could be implemented in the case of an autonomous service?
4. Are you aware of any current research/ development that has been done in this area, or anything in the pipeline?
5. What would be the impact or risk if this role wasn't fulfilled by an alternative solution?

Section 3: Exploring potential alternative solutions in the absence of a driver

1. What solutions have been trialled or implemented to fill some of the driver roles, to ensure the service is inclusive?
2. Are there any potential solutions that we haven't got on our list and haven't been trialled or implemented before that may help fill a role of a driver to ensure the service is inclusive?
3. What are the challenges associated with implementing these solutions, if any?
4. Are you aware of any current research/ development that has been done in this area, or anything in the pipeline?

Section 4: Close and debrief

1. Does anyone have any final thoughts before we close the session?

Points covered:

- Reminder to send further reflections following the session.
- Thank stakeholders for attending

Appendix D Case studies of solutions

D.1 CCTV with Artificial Intelligence capabilities

Artificial intelligence (AI) technologies use computer science and data to enable problem solving in machines. AI CCTV[13] can be used for the following functions:

- **Face recognition** – faces can be matched accurately with automatic AI recognition software. The technology collects facial data of a person to identify and authenticate them. This could be used for access control (matching a passenger with an identity to allow access into the vehicle in the case of a PHV or matching with a coach ticket).
- **Person detection** – specifically for suspicious and criminal activities. With AI deep learning, body and facial movements can be learned, tracked and analysed. The 'normal and typical' behaviour of a person is learned and defined by AI technology, giving a better outcome to identify a suspicious individual. E.g. systems such as Smart Camera[14] can detect suspicious behaviour, deter and respond (through a 24/7 monitoring system with a speaker and microphone to challenge individuals, a pre-recorded audio message, or a siren).
  This technology was trialled on the London Underground between 2022 and 2023[15] [16]. In a test at one station, Transport for London used a computer vision system to try and detect crime and weapons, people falling on the tracks, and fare dodgers. The system used AI surveillance software to detect particular movement, behaviour and body language.
- **Object detection** – using rule-based intelligence, AI and video analysis tools enable security teams to detect potential criminal and suspicious activity in advance and more proactively, pre-empting possible events before they occur. Object detection includes capture, analysis and metadata extraction of an object's properties. These can include object type (i.e. human, laptop, bicycle, cat, dog, bird), location and size, colour, persistence, motion tracking, presence and absence in zones of interest, and counting. This technology is being trialled in Schiphol Airport in Amsterdam, which is using algorithms developed by security companies, powered by computing services, AI, machine learning and computer vision. It's claimed that it cannot only detect prohibited items but also use the data-mining capability of AI to identify anomalies and unusual patterns that would suggest a coordinated attempt to breach security.

D.2 Audio announcements

Onboard audio announcements[17] can be used to streamline operations and to provide passengers with consistent service information. Integrated voice systems complement the driver display units and integrated driver fare consoles. Voice announcements enable passengers to identify the next stops without having to read the display. Systems can be pre-programmed to announce passengers of upcoming road diversions or simply to provide cheerful greetings.

To support this solution to ensure it is inclusive, onboard passenger information[18], using LED displays, can be used to display critical route and destination information, public safety measures and other announcements.

D.3 Service capacity reporter

Capacity reporting could be used to allow prospective passengers to be aware of the capacity of the service they are wishing to use. An example of this in practice is Transport for Wales's Capacity Checker, which provides passengers with an indication of the services which are often full and the ones with plenty of seats available[19]. Another example of this system is Trainline's Crowd Alerts[20], which works when passengers indicate whether they are able to abide to social distancing (during the COVID-19 pandemic in 2020) by clicking a 'thumbs up' or 'thumbs down' button and reporting whether they are at the front, middle or back of the train.

D.4 Remote monitoring systems

In-vehicle monitoring includes a manned surveillance system whereby a human in a control centre has access to real-time footage of the interior and exterior of a service. It can be used to enhance passenger safety and security, for example through person detection (seat occupancy, seat belt detection, people counting), child detection (abandoned child, child seat), behaviour detection (smoke detection, violent or anti-social behaviour), and pet, object and event detection (pet detection, fire detection, abandoned backpacks or other suspicious objects, threat detection).

D.5 Humanoid robots

A robot could be used to assist passengers with loading luggage and other items into the boot of PHVs and storage areas of buses and coaches. Chinese manufacturers SUPCON has announced the integration of AI technology into its humanoid robot, Navigator α[21]. Navigator α is a humanoid robot standing at a height of 1.5 meters and weighing 50 kilograms. It features hardware components such as a planetary reducer, lightweight humanoid mechanical arms, and a hand with 15 finger joints and six active degrees of freedom. The hand itself has a weight of 600 grams and its fingertips can exert a force of 10N. The robot's joint speed reaches up to 150 degrees per second.

D.6 Automated wheelchair tiedown and occupant restraint systems

There has been research[22] into using automated wheelchair tiedowns and occupant restraint systems in the US. These particular systems use computational modelling to optimise placement of the wheelchair station to be able to locate the wheelchair anchorages, optimise belt anchor locations and determine airbag characteristics in the event of impacts.

D.7 Automatic Vehicle Location systems

An Automatic Vehicle Location (AVL) system[23] consists of two parts, an on-board GPS system that tracks the vehicle's real-time location, and a software programme displaying that particular vehicle's location on a map. AVL systems can report vehicle information such as location, speed, and stops, to allow for fleet managers and passengers to monitor service routes and for deploying on-board voice announcements.

D.8 Psychological deterrents

Psychological deterrents such as life-sized cut outs of police officers or figures of authority could be used to deter anti-social behaviour. An example of this in practice is a life-sized cutout of a police officer outside of a shop in the UK[24], with an objective to reduce shoplifting and other crimes in the local area. This saw the number of thefts decreased 5% from 1,340 to 1,273 in five months following implementation – see Appendix D.8.

It is suggested that these cardboard cut outs have recently helped cut out lawlessness around shops, minimise criminality at sports events and slow high-speed drivers at accident hotspots.

D.9 Solutions similar to ‘see it, say it, sorted’

‘Help’ buttons can be used in PHVs in the event of an accident or emergency. Driverless taxis operated by Cruise have a ‘HELP’ button on the ceiling of their vehicles for passengers to be able to connect with Cruise Support.

Help points[25] can provide a direct line of communication to operational staff and emergency services, ensuring rapid response in case of accidents, medical emergencies or security concerns. Passengers can also use help points to seek information about schedules/timetables, ticketing, route changes or general enquiries. Help points can be equipped with accessibility features such as tactile instructions, visual indicator lamps and induction loops, making them user-friendly for individuals with disabilities. Lastly, help points can contribute to automated passenger service security by serving as a deterrent to anti-social behaviour and vandalism.

D.10 Wayfinding methods

Interactive totems could be used by passengers to ask real-time wayfinding questions.

Trueform’s Smart City Digital Totems[26], currently in place in the UK, can be used to guide passengers through digital wayfinding.

ChatGPT[27] can be used to assist passengers in their journeys.

D.11 Travel assistance applications

Passenger Assistance[28] is a travel app for disabled people that simplifies the process of booking assisted travel. It allows passengers to input their accessibility requirements and receive travel information. This app is currently being used on all trains in the UK.

D.12 Alternative payment methods

Freestanding Roadside Ticket Machines[29] are used to reduce boarding time at busy bus stops. These machines also allow Transport for London to operate their fleet of bendy buses without having conductors.

Central London's 'Pay Before You Board' zone are currently being used at 300 bus stops, all of which are fitted with kerbside ticket machines[30].

Tap on / off or tap in / out systems consist of passengers touching contactless cards or smartphone pay on a card reader at the start of the journey and at the end of the journey.

Amazon's 'Just Walk Out' technology implemented in Amazon Fresh shops allows shoppers to pay for their shopping by scanning a QR code[31]

D.13 Additional potential solutions

Below is a list of additional potential solutions that were not covered in the main body of this report but provides insight into the other options that could address various other driver roles.

D.13.1 Assistance applications

D.13.1.1 Applications

Access Now is a community-driven app that pinpoints accessible locations on an interactive map. Users can look up places like restaurants, museums and attractions and view accessibility ratings.

NotNav[32] is an orientation aid for the blind and visually impaired people. NotNav continuously announces users' compass heading, the nearest street address, any nearby cross streets and any nearby user defined waypoints.

Be My Eyes is a mobile app which connects blind and low-vision individuals with sighted volunteers and AI systems to assist and navigate them in real-time.

D.13.1.2 AI powered tools

AI Cam is a wearable device that can create and send audio messages to blind people. Individuals can wear the device to be given information about their surroundings in real time. AI Cam can read text, recognise faces, identify products, detect money, barcodes and colour. AI Cam is attached to the eyeglass frame and can provide feedback to the user.

Be My AI[33] is a collaboration between Be My Eyes and Open AI and is currently being tested. It will give users a detailed description of an image, and users can chat and ask further questions through the app.

D.13.1.3 Wearable devices

Travel aids[34] – Environmental information beacons locate a point in space using active or passive radio-frequency identification (RFID) tags or infrared transmitters. They may have additional functions, such as providing information about located facilities or requesting that vehicle doors are opened. Bluetooth low-energy (BLE) beacons have been used in navigation systems, particularly for large complex indoor environments. BLE systems generally involve apps on smartphones, with many apps providing specific contextual information that is relevant to both blind and partially sighted people e.g., find my bus and find my bus stop.

D.13.2 Potential solutions related to service quality

Temperature sensors[35], similar to thermostats in homes, can be used to assess the temperature in different areas of the vehicle, establishing automated monitoring and notification linked to each temperature record with real-time positioning information for accurate decision making.

Cleaning robots, such as Navia Robotics[36], can be used to elevate passenger satisfaction through providing a clean, safe and efficient transport solution. Confirmation that cleaning has taken place (such as at Heathrow Airport[37]) on the vehicle may also be of benefit to passengers.

Case study – Heathrow robot cleaners[38] (UVD Robots, supplied by Nesa Robotics). These were installed shortly after international travel bans were lifted following the COVID-19 pandemic.

Humanoid robots could be used to act as a ‘friendly face’. Robots are being trialled in various airports across the world, greeting passengers and escorting them to their gates and restaurants. They can also inform passengers about flights and passenger convenience services. Case studies include ‘Josie Pepper’ at Munich Airport[39], and Temi robot assistance at Coimbatore International Airport[40].

D.13.3 Potential solutions related to providing physical access

SmartRider[41] is an advanced smart levelling system, providing unmatched accessibility for all passengers using intelligent kneeling with variable height capability. It uses intelligent technology to kneel and adjust to environmental surroundings and offers optimised boarding from the curb to the aisle.

Automatic bus kneeling systems[42] could be used to provide physical access to passengers. Systems are based on measured distances between the bus stair and the curb or ground. This increases the efficiency of the conventional bus kneeling system during boarding and exiting.

Accessible bus stops design guidance[43] including locations, waiting areas, bus stop areas, bus stop layouts, bus boarders, bus bays, kerb profiles and heights, and bus stop improvements.

Cruise have revealed its Wheelchair Accessible Vehicle[44] which includes a pre-production vehicle being able to lower itself to the kerb, deploying a ramp for wheelchair users to go up, before different securement options (docking and straps) are used to keep the wheelchair in place while moving off. There are also features that allow users to make journeys as comfortable as possible, such as allowing passengers to unlock the wheelchair, call remote assistance or start and stop the ride. It is also possible to operate the doors and ramp from passengers' smartphones. The WAV has not yet got regulatory approval in the USA.

D.13.4 Potential solutions related to providing information to passengers

Chatbots with AI-generated responses, located at interchanges, bus stops or in-vehicle, can be used to answer passenger questions about their route.

Wearable travel aids or devices[45] for blind and partially sighted passengers can be used to inform them (by buzzing) when they are close to their chosen stop. The wearable would be linked up with their ticket.

Vehicle-to-everything (V2X) technology[46] allows interactions between vehicles and virtually everything in their surrounding ecosystem. By using V2X, vehicle systems can detect their location with regards to other things on the route ahead. This information could be displayed like a map to passengers on advanced displays. However, for this technology to work, the other things need to be V2X enabled too.

D.13.5 Potential solutions related to controlling access into the vehicle

AI CCTV can be used for people counting and heat maps – demographic breakdowns, such as gender and age, can be captured, as well as people's expressions, moods and attitudes, which is captured through AI facial recognition.

Turnstiles on a bus or coach (such as TiSO in Ukraine[47]) can be used to control passenger access onto vehicles.

Automatic passenger counting systems[48] can be carried out through various technologies, outlined below:

- Automatic passenger counting systems (such as Transign in the US[49]) uses business analytic reporting functions to enable an accurate measurement of ridership levels while in service.
- Monitoring of single passengers, usually by technologies on-board the vehicle such as sensors. This can be expensive due to the need for development appropriate counting stations, e.g. for a 12m, 3-door bus, 6 sensors and 2 dedicated stations may be required.
- Monitoring of the overall load on the vehicle, with technologies applied to the suspensions/air springs on the ground.
- Counting related to the ticket, sometimes also recognised as Electronic Registering Fareboxes solutions.

- Treadle mat sensors, placed on the steps of a bus, register passengers as they step on the mat. The metal structure can be covered by a layer of rubber and attached to the steps by means of purposely allocated attachment structures, or simply glued by means of high seal adhesives; the latter solution is less frequently applied because it may deteriorate rather quickly.

Automated Passenger Services: Researching Driver Roles and Passenger Inclusivity

Abstract

The global market for connected and autonomous vehicles is projected to reach £650 billion by 2035, with the UK expected to capture £41.7 billion. Recognising the potential of autonomous transport, the UK government established the Centre for Connected and Autonomous Vehicles (CCAV). This report investigates the role of automated passenger services in meeting the needs of all passengers, especially in the absence of a driver or onboard attendant. The study aims to contribute towards research around ensuring an inclusive and safe transport network by considering the unique challenges faced by individuals with disabilities and other protected characteristics.

Objectives included identifying non-driving-related roles currently performed by drivers, assessing the implications of these roles not being fulfilled, and exploring alternative solutions. A comprehensive review of literature and stakeholder engagement identified 66 non-driving-related roles classified based on theme, detection vs. action, all journeys vs. some journeys, stage of the passenger journey, and mode of transport. Most roles were related to passenger safety and physical access, with most occurring during boarding.

The feasibility of alternative solutions was evaluated, revealing that while many roles can be addressed with relative ease (36% rated as 'green'), a notable portion presents challenges (23% 'orange' and 9% 'red' roles). Roles deemed challenging often involve judgement, physical intervention, or enforcement.

The research gathered valuable insights into the complex landscape of automated passenger services and concludes that further work is needed to develop solutions for some important driver roles, prioritising safety and accessibility. Future research should also consider public acceptability and barriers to implementation of potential solutions.

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Endnotes

[1] Connected Places Catapult: Market Summary for Connected and Autonomous Vehicles. Available here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/919260/connected-places-catapult-market-forecast-for-connected-and-autonomous-vehicles.pdf

[2] Department for Transport (2019). Future of Mobility: Urban Strategy. Available here: https://assets.publishing.service.gov.uk/media/5dcd8417ed915d071ca239e9/future-of-mobility-strategy.pdf

[3] House of Commons Library (2023). UK Disability Statistics: Prevalence and Life Experiences. Available here: https://researchbriefings.files.parliament.uk/documents/CBP-9602/CBP-9602.pdf

[4] Department for Transport (2023). Disability, accessibility and blue badge statistics, England, 2022 to 2023. [online]. [Accessed April 2024]. Available from World Wide Web: https://www.gov.uk/government/statistics/disability-accessibility-and-blue-badge-statistics-2022-to-2023/disability-accessibility-and-blue-badge-statistics-england-2022-to-2023#:~:text=In%202022%3A,the%20over%2060s%20(35%25)

[5] Luiu, C. & Tight, M. (2021). Travel difficulties and barriers during later life: Evidence from the National Travel Survey in England. *Journey of Transport Geography.* https://doi.org/10.1016/j.jtrangeo.2021.102973

[6] Mencap: How common is learning disability? [online]. [Accessed April 2024]. Available from World Wide Web: https://www.mencap.org.uk/learning-disability-explained/research-and-statistics/how-common-learning-disability

[7] Anxiety Statistics UK (2023). [online]. [Accessed April 2024]. Available from World Wide Web: https://championhealth.co.uk/insights/anxiety-statistics/

[8] Automated Vehicles Bill: Explanatory Notes (2023). [online]. [Accessed April 2024]. Available from World Wide Web: https://bills.parliament.uk/publications/52900/documents/3973

[9] House of Commons Library (2023). UK Disability Statistics: Prevalence and Life Experiences. Available here: https://researchbriefings.files.parliament.uk/documents/CBP-9602/CBP-9602.pdf

[10] See it. Say it. Sorted. (2024). [online]. [Accessed April 2024]. Available from the World Wide Web: https://www.btp.police.uk/police-forces/british-transport-police/areas/campaigns/see-it-say-it-sorted/

[11] Lloyds Bank. (2021). Essential Digital Skills Report 2021. Third Edition – Benchmarking the Essential Digital Skills of the UK. Available here: https://www.lloydsbank.com/assets/media/pdfs/banking_with_us/whats-happening/210923-lb-essential-digital-skills-2021-report.pdf

[12] Faverio, M. (2022). Share of those 65 and older who are tech users has grown in the past decade. *Pew Research Center, 13*(7).

[13] AI CCTV – Artificial Intelligence Surveillance. [online]. [Accessed April 2024]. Available from World Wide Web: https://www.techcube.co.uk/blog/ai-cctv-artificial-intelligence-surveillance/#:~:text=What%20is%20AI%20CCTV%3F,Number%20Plate%20Recognition%20(ANPR)

[14] Smart Camera: Anti-social behaviour detection. [online]. [Accessed April 2024]. Available from World Wide Web: https://www.smartcamera.services/antisocial-behaviour

[15] London Underground is testing real-time AI surveillance tools to spot crime (2024). [online]. [Accessed May 2024]. Available from World Wide Web: https://www.wired.com/story/london-underground-ai-surveillance-documents/

[16] FOI request detail: AI Detection. (2024). [online]. [Accessed May 2024]. Available from World Wide Web: https://tfl.gov.uk/corporate/transparency/freedom-of-information/foi-request-detail?referenceId=FOI-3155-2324

[17] Voice announcement system: Improving intelligibility of transit industry (2021). [online]. [Accessed April 2024]. Available from World Wide Web: https://transignllc.com/voice-announcement-system-improving-intelligibility-of-transit-industry/

[18] Passenger information systems. [online]. [Accessed April 2024]. Available from World Wide Web: https://transignllc.com/products/passenger-information-systems/

[19] Service Status Capacity Checker (2024). [online]. [Accessed April 2024]. Available from World Wide Web: https://tfw.wales/service-status/capacity-checker

[20] Trainline launches crowdsourcing app feature, Crowd Alerts, to help customers flag busy trains to each other (2020). [online]. [Accessed April 2024]. Available from World Wide Web: https://www.trainlinegroup.com/media/en/press-releases/trainline-launches-crowdsourced-app-feature-crowd-alerts-help-customers-flag-busy-trains-each-other/#:~:text=Crowd%20Alerts%20works%20when%20customers,or%20'thumbs%20down'%20button.

[21] SUPCON integrates AI in Navigator a Humanoid Robot (2024). [online]. [Accessed April 2024]. Available from World Wide Web: https://www.rockingrobots.com/supcon-integrates-ai-in-navigator-%ce%b1-humanoid-robot/

[22] Klinich, K., Manary, M., Orton, N., Boyle, K., Hu, J. (2022). A Literature Review of Wheelchair Transportation Safety Relevant to Automated Vehicles. *International Journal of Environmental Research and Public Health*, 31;19(3):1633. doi: 10.3390/ijerph19031633. PMID: 35162657; PMCID: PMC8835052.

[23] Automatic bus location announcement system – what you need to know (2019). [online]. [Accessed April 2024]. Available from World Wide Web: https://transignllc.com/automatic-bus-location-announcement-system-what-you-need-to-know/#:~:text=Voice%20announcements%20enable%20commuters%20to,simply%20to%20provide%20cheerful%20greetings.

[24] 'Cardboard cops' in Hull help cut shoplifting (2010). [online]. [Accessed April 2024]. Available from World Wide Web: https://www.bbc.co.uk/news/uk-england-humber-11405491#:~:text=In%20March%2C%20life%2Dsize%20cut,the%20same%20period%20in%202009.

[25] Help points, keeping railway stations safe. [online]. [Accessed April 2024]. Available from World Wide Web: https://trans-data.com/help-points/#:~:text=What%20Are%20Help%20Points%3F,notably%20in%20UK%20railway%20stations.

[26] Smart City Digital Totems. [online]. [Accessed April 2024]. Available from World Wide Web: https://trueform.com/products/smart-city-digital-totems/#2

[27] ChatGPT 3.5. [online]. [Accessed April 2024]. Available from World Wide Web: https://chat.openai.com/

[28] App Store Preview: Passenger Assistance. [online]. [Accessed April 2024]. Available from World Wide Web: https://apps.apple.com/gb/app/passenger-assistance/id1542190496

[29] RTM ticket machine cloak. [online]. [Accessed April 2024]. Available from World Wide Web: https://trueform.com/products/rtm-ticket-machine-cloak/

[30] On-street coin-operated bus ticket machines (2011). [online]. [Accessed April 2024]. Available from World Wide Web: https://www.london.gov.uk/who-we-are/what-london-assembly-does/questions-mayor/find-an-answer/street-coin-operated-bus-ticket-machines-2

[31] An update on Amazon's plans for Just Walk Out and checkout-free technology [online]. [Accessed May 2024]. Available from World Wide Web: https://www.aboutamazon.com/news/retail/amazon-just-walk-out-dash-cart-grocery-shopping-checkout-stores

[32] NotNav GPS Accessibility 3.9.2. [online]. [Accessed April 2024]. Available from World Wide Web: https://notnav-gps-accessibility.soft112.com/#google_vignette

[33] Introducing: Be My AI. [online]. [Accessed April 2024]. Available from World Wide Web: https://www.bemyeyes.com/blog/introducing-be-my-ai

[34] Hersh, M. (2022). Wearable Travel Aids for Blind and Partially Sighted People: A Review with a Focus on Design Issues. *Sensors,* 22 (14). https://doi.org/10.3390/s22145454

[35] Bus temperature monitoring and control through telematics to ensure the passengers comfort in your fleet. [online]. [Accessed April 2024]. Available from World Wide Web: https://en.didcom.com.mx/blog/bus-temperature-monitoring-and-control-through-telematics-to-ensure-the-passengers-comfort-in-your-fleet/

[36] Solutions for airports, train stations and public transport facilities. [online]. [Accessed April 2024]. Available from World Wide Web: https://www.naviarobotics.com/transportation.php#First%20Name

[37] Ultraviolet cleaning robots at Heathrow to encourage passengers to return to air travel (2020). [online]. [Accessed April 2024]. Available from World Wide Web: https://www.itv.com/news/london/2020-07-15/ultraviolet-cleaning-robots-at-heathrow-to-encourage-passengers-to-return-to-air-travel

[38] Van Der Hoeven, M. (2021). *Heathrow reopens Terminal 3, robots cleans premises* [online]. [Accessed April 2024]. Available from World Wide Web: https://www.rockingrobots.com/heathrow-reopens-terminal-3-robot-cleans-premises/

[39] AI-equipped robot 'Josie Pepper' to greet passengers at Munich Airport (2018). [online]. [Accessed April 2024]. Available from World Wide Web: https://www.internationalairportreview.com/news/67023/ai-equipped-robot-josie-pepper-greet-passengers-munich-airport/

[40] AI-powered robots to welcome, assist passengers at Coimbatore Airport (2022). [online]. [Accessed April 2024]. Available from World Wide Web: https://timesofindia.indiatimes.com/city/coimbatore/ai-powered-robots-to-welcome-assist-passengers-at-airport/articleshow/92091958.cms

[41] SmartRider. [online]. [Accessed April 2024]. Available from World Wide Web: https://www.newflyer.com/tools-tech/smartrider/#:~:text=SmartRider%E2%84%A2%20is%20an%20advanced,the%20curb%20to%20the%20aisle

[42] An automatic bus kneeling system. [online]. [Accessed April 2024]. Available from World Wide Web: https://mytechmart.mosti.gov.my/ms/node/16890

[43] Transport for London (2006). *Accessible bus stop design guidance*. [online]. [Accessed April 2024]. Available from World Wide Web: https://nacto.org/wp-content/uploads/2016/02/TfL-accessibile-bus-stop-design-guidance.pdf

[44] General Motors' Cruise unveils wheelchair-accessible robotaxi (2023). [online]. [Accessed April 2024]. Available from World Wide Web: https://www.reuters.com/business/autos-transportation/general-motors-cruise-unveils-wheelchair-accessible-robotaxi-2023-09-14/#:~:text=N)%20%2C%20opens%20new%20tab%20robotaxi,deploy%20vehicles%20without%20human%20controls.

[45] Wearable technology buzzes for bus stops (2015). [online]. [Accessed April 2024]. Available from World Wide Web: https://www.electronicsweekly.com/blogs/gadget-master/consumer-electronics/wearable-technology-buzzes-bus-stops-2015-04/

[46] V2X technology: Revolutionising safe and efficient transportation. [online]. [Accessed April 2024]. Available from World Wide Web: https://www.nearbycomputing.com/v2x-technology/#:~:text=R%20Traffic%20efficiency%3A%20V2X%20technology,congestion%2C%20and%20improve%20traffic%20flow.

[47] Turnstiles for bus. [online]. [Accessed April 2024]. Available from World Wide Web: https://tiso-turnstiles.com/news/364-turnstile-for-bus

[48] Automatic passenger counting systems for public transport (2010). [online]. [Accessed April 2024]. Available from World Wide Web: https://www.intelligenttransport.com/transport-articles/3116/automatic-passenger-counting-systems-for-public-transport/

[49] Automatic passenger counting (APC) – how it works (2019). [online]. [Accessed April 2024]. Available from World Wide Web: https://transignllc.com/automatic-passenger-counting-apc-how-it-works/