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STANDARDS RESEARCH

Accessibility and Connected and Automated Vehicles: Challenges and Considerations

March 2023

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Acknowledgments

The authors would like to sincerely thank the following people and organizations for their knowledge and expertise provided during stakeholder consultations conducted as part of this study:

Eric Bloomquist, Virginia Technical Transportation Institute

Ronald Buliung, University of Toronto

Susan Clarke, Canadian Transportation Agency

The CNIB Foundation

Felice Ling, Lead UX at Motional

Jordana L. Maisel, IDEA Center, University at Buffalo

Miriam Manary, University of Michigan Transportation Research Institute

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Executive Summary

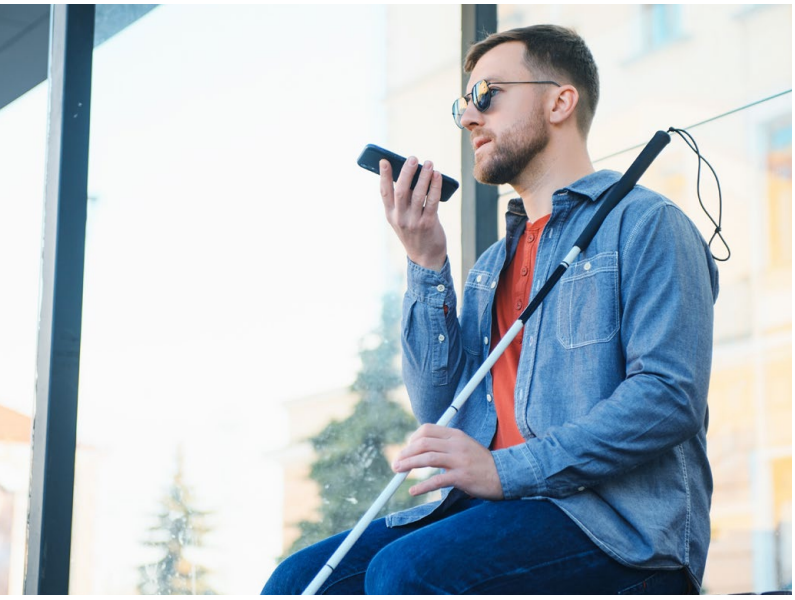
This study provides an overview of the current North American legal and technical standards landscape for accessibility that may apply to ride-sourcing services that use connected and automated vehicles (CAVs) instead of human-operated vehicles. The key difference between CAV ride-sourcing and human-operated vehicle ride-sourcing is the absence, in the former, of a human attendant who could be tasked with providing physical and/or instructional assistance to users with disabilities throughout the trip. Existing laws, regulations, and technical standards specifying accessibility for travellers with disabilities generally presume the availability of one or more human attendant(s) who will assist people as needed. The absence of this assistance for CAV ride-sourcing services poses new and added barriers and challenges for users with disabilities, some of which may be addressed with additional accessibility standards and technologies.

A high-level, preliminary assessment of gaps in standards was conducted to address accessibility for the following disability types:

- blindness;
- low vision;
- deafness / hearing impairment;
- deafblindness;
- cognitive impairment;
- upper body movement limitations;
- difficulty walking / lower body movement limitations;
- wheelchair use with ability to transfer; and
- wheelchair use without ability to transfer.

The barriers and challenges people with disabilities would be expected to face during a hypothetical CAV ride-sourcing trip were explored through consultations with stakeholders who had lived experience with disability, were experts in transportation accessibility, or both. First, the stakeholders were guided through the steps that a person without disabilities would take to complete a ride-sourcing trip. They were then asked to consider the barriers and challenges that people with disabilities might face at each step when travelling without a human attendant. If these barriers and challenges are addressed [1] [2], this would represent the approximate goal state for accessible CAV ride-sourcing services. The existing accessibility standards were compared against this goal state to provide preliminary recommendations regarding near-term opportunities for advancing accessibility standards relevant to CAV ride-sourcing services.

While it is currently infeasible to meet the needs of all people with disabilities when travelling by CAV without a human assistant, many aspects of this travel mode could be made significantly more accessible to a wider range of users with disabilities. Developing standards that support such accessibility will increase the likelihood of adoption by CAV developers and service providers, thereby helping to realize the goal of removing barriers to inclusion in society by people with disabilities.



"Widespread deployment of connected and automated vehicles (CAVs) may be a step towards meeting mobility needs, particularly those of people living with disability."

1 Introduction

More than one in five of the people in Canada aged 15 years and older has one or more disabilities, with pain-, flexibility-, and mobility-related disabilities the most common [2]. Widespread deployment of connected and automated vehicles (CAVs) may be a step towards meeting mobility needs, particularly those of people living with disability. CAV services may also appeal to people who have safety concerns with, for example, driving when it's dark or when the weather makes driving conditions unsafe. Current ride-sourcing[1] services and taxis can offer a more timely and reliable alternative to public transportation and paratransit services [3], but the automated nature of current CAV ride-sourcing services means that there may be no one available to physically assist people.

For CAVs to meet a broad range of mobility needs requires taking into account accessibility during their design and development as well as the design and development of infrastructure and supporting devices and services. Incorporating the needs of users with disabilities is a top priority among many CAV developers, ride-sourcing businesses (often referred to as "transportation network companies" or "TNCs"), and infrastructure owners/operators (IOOs), thanks to effective advocacy bolstered by industry association support [1]. In addition, advancements in assistive technologies, primarily in the form of Internet-enabled personal devices, hold great promise for extended utility, including improved safety, through wireless communications with vehicle and infrastructure devices in the vicinity. Still, acknowledgement of accessibility needs when it comes to ride-sourced CAVs is the first of many actions required to address these needs.

The key to harnessing the potential of CAV and related technologies to address mobility needs is to develop standards that promote safe implementation and support interoperability for widespread deployment.

This report presents a roadmap for standardizing CAV accessibility. It is intended to serve as an initial step in understanding the accessibility needs and requirements for CAV deployment. The study reviews national and international codes, standards, and grey literature related to accessibility and CAV technologies. It also provides guidance for advancing codes and standards for CAV accessibility aspects in North America.

2 Methods

The research team conducted a scan of technical, legal, and social/institutional grey literature that relate to the context for CAV accessibility by people with disabilities. The team compiled information on existing and emerging standards and conducted a preliminary

1 "Ride-sourcing", or "ride-hailing", refers to on-demand, commercial transportation arranged via digital applications. The technology is used for booking, paying for, and rating a ride. These services differ from taxi services, which can be street-hailed [3].

assessment of apparent gaps in standardization that included determining the expected benefits of filling these gaps.

The research team searched the content of these sources for key terms and words related to CAV and accessibility [2] and Canadian and US government websites for regulations related to accessibility. Standards development organization websites were searched using the following key terms: disabled/disability(ies), impairment/impaired, accessible/accessibility, and assistive.

Following the environmental scan and gap assessment, the research team conducted a series of interviews with stakeholders who had lived experience with disabilities and with experts in transportation accessibility. Stakeholders were recruited through the project advisory panel contacts and by outreach with relevant organizations. The stakeholders brainstormed the types of barriers and challenges people with disabilities would face when using a CAV ride-sourcing service. Their responses were used to inform the goal state for accessibility and to provide preliminary recommendations for further standards development work. Disability types were defined according to [4] and included blindness, deafness and hearing impairments, mobility and cognitive disabilities. Mobility disabilities were further categorized as upper and lower limb mobility limitations, and wheelchair users who can and cannot transfer. Cognitive disabilities included learning, developmental and other intellectual disabilities.

3 Results

3.1 Environmental Scan

This environmental scan examined three primary legislative precedents that support the rights of people with disabilities: the *Accessible Canada Act* (ACA), the *Americans with Disabilities Act* of 1990 (ADA), and the United Nations (UN) Convention on the Rights of Persons with Disabilities (CRPD). Also reviewed were the resources of several governmental departments that promote accessibility by conducting research or else financially supporting research and by providing resources and support to people with disabilities, as well as those of advocacy organizations involved in promoting transportation accessibility standards. This was followed by a preliminary gap assessment and a discussion of the benefits of standardization for advancing efforts to make CAV ride-sourcing fleets more accessible to people with disabilities.

3.1.1 Primary Legal Precedents

The following laws, regulations, and official guidance were largely written before CAV technologies were conceived, let alone deployed. Moreover, because they mainly target public transportation services and transportation services for the public, they tend to presume the availability of a human operator or attendant who can be legally obligated to provide assistance as needed. Since the most notable aspect of a CAV ride-sourcing service is the absence of a human operator/attendant, there exists a significant gap in the legal landscape of CAV accessibility.

3.1.1.1 *The Accessible Canada Act* and Related Regulations and Guidance

The *Accessible Canada Act* (ACA) was enacted on June 21, 2019 [4]. The Preamble to the law references both the pre-existing anti-discrimination law in Canada covering (among others) people with disabilities, the *Canadian Human Rights Act* [5], and the CRPD, to which Canada is a State Party (see Section 3.1.1.3 United Nations Convention on the Rights of Persons with Disabilities). The ACA also drew from Canadian provincial disability laws and regulations.

The 1985 *Canadian Human Rights Act* broadly prohibited discrimination with regard to access to goods, services, facilities, or accommodations offered to the public; to commercial premises or residential accommodations; and to employment. However, it allowed compliance exceptions if "accommodation of the needs of an individual or a class of individuals affected would impose undue hardship on the person who would have to accommodate those needs, considering health, safety and cost" [5]. The ACA effectively removes this compliance exception provision and promotes "a proactive and systemic approach for identifying, removing and preventing barriers to accessibility without delay" [4].

Predictably, given its affiliation with the CRPD, the ACA defines "disability" broadly. However, unlike the ADA and CRPD, the ACA includes temporary and episodic disabilities [4].

The goal of the ACA is to achieve a barrier-free Canada by January 1, 2040, in employment; the built environment; information and communication technologies and other types of communications; the procurement of goods, services, and facilities; the design and delivery of programs and services; transportation; and other areas as designated by regulation.

This study is concerned with ACA provisions pertaining to CAV ride-sourcing transportation services, such as those to do with the built environment, information and communications technologies, and transportation.

3.1.1.2 *Americans with Disabilities Act* of 1990 and Related Regulations and Guidance

The *Americans with Disabilities Act* (ADA) [6] prohibits discrimination in the provision of transportation services, including those provided by private entities. Given the newness of CAV technology, the ADA does not explicitly reference CAVs. In fact, some ADA requirements explicitly presume the presence of a human vehicle operator or attendant and require that they assist people with disabilities. Such requirements can not be met by CAV ride-sourcing services, which do not include an onboard human attendant.

The transportation-related regulations issued pursuant to the ADA are contained in the Code of Federal Regulations Title 49 "Part 37 - Transportation Services for Individuals with Disabilities (ADA)" [7] and Title 49 "Part 38 - Americans with Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles" [8]. Subpart A of Title 49 of Part 37 defines "disability" in greater detail than does the ADA by adding more types and categories. These regulations forbid discrimination in the provision of transportation services by all entities. Subpart B addresses applicability in terms of specific types of transportation services and clarifies that private entities contracted to provide public transportation services must comply with ADA regulations. Subpart D requires public entities providing non-rail-based, fixed-route, or demand-responsive transportation services to provide vehicles accessible by people with disabilities, including wheelchair users, after August 25, 1990. Subpart E specifies requirements for different types of private transportation services, the primary distinction being between those whose primary business is transporting people, such as a taxi service, and those whose primary business is not the transportation of people, such as a hotel shuttle service[2].

Code of Federal Regulations Title 49 Part 38 specifies the technical requirements for rendering vehicles accessible to people with disabilities subject to the requirements of Part 37. Most requirements specified in Part 38 pertain to fixed-route wheeled and rail-based public transit vehicles rather than to demand-responsive transportation services, which generally use smaller, non-rail-based vehicles. Subpart A allows for "departures" from specific technical requirements, provided they result in "equivalent or greater" accessibility. Such departures from technical specifications must be approved on a case-by-case basis according to procedures specified in §37.7. Subpart B specifies technical accessibility requirements for new, used, or remanufactured buses and vans (with the exception of over-the-road buses, which are covered in another subpart). Detailed requirements are specified for lifts and ramps; doors, steps, and thresholds; priority seating signs; interior circulation, handrails, and stanchions; lighting; fare boxes; public information systems; stop requests; and destination and route signs.

Multiple US federal agencies also issue official guidance, usually to aid entities in determining compliance with applicable regulations.

The US Access Board lists guidance that address accessibility standards for the built environment, including accessible routes, ramps and curb ramps, parking spaces, and passenger loading zones [9], [10]. In March 2022, the US Department of Justice issued new guidance describing ADA-prohibited website

2 Subpart C relates to Transportation Facilities, which is out of scope for this report.

accessibility barriers, for example, poor colour contrast, use of colour alone to give information, not providing captions on videos, and others [11].

The US Department of Transportation / Federal Transit Administration has issued multiple transportation-related guidance documents. These guidance documents are mostly to aid organizations in assessing their compliance with applicable ADA provisions, but they also address specific accessibility matters, such as the use of service animals and mobile devices, and special rules for paratransit service providers [12], [13], [14], [15], [16], [17]. Digital.gov provides guidance on building better digital services in government and offers links to online resources dedicated to improving Internet accessibility for all users [18].

Lastly, the Advisory Committee on Transportation Equity (ACTE) was re-established in May 2022 to "provide independent advice and recommendations to the Secretary of Transportation about comprehensive, interdisciplinary issues related to civil rights and transportation equity in the planning, design, research, policy, and advocacy contexts" [19].

3.1.1.3 United Nations Convention on the Rights of Persons with Disabilities

The CRPD [20] was adopted by the UN Assembly on December 13, 2006. The Convention's stated purpose is to "promote, protect and ensure the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities, and to promote respect for their inherent dignity." The CRPD does not define disability; it is quite broad in its applicability.

Of specific relevance to CAV ride-sourcing service providers are Articles 9 ("Accessibility") and 20 ("Personal mobility"). Article 9 specifically requires that publicly accessible transportation services and related facilities, as well as information and communications systems, which are integral features of a CAV ride-sourcing service, are made accessible [21]. Article 20 requires that ratifying countries "take effective measures to ensure personal mobility with the greatest possible independence for persons with disabilities by facilitating [their] personal mobility in the manner and at the time of their choice, and at affordable cost" [22].

The CRPD Optional Protocol [23], a side agreement to the CRPD that was adopted on December 13, 2006, and came into effect on May 3, 2008, provides a formal process for filing complaints with the Committee on the Rights of Persons with Disabilities by individuals or groups of individuals against states that have ratified this Optional Protocol and helps to adjudicate such complaints. However, Article 8 of this Optional Protocol explicitly permits states to "declare that it does not recognize the competence of the Committee" to investigate and adjudicate complaints [23]. Quite a few nation states that ratified the Optional Protocol have declined to recognize the Committee's competence to investigate and adjudicate complaints. As of December 2022, the Optional Protocol had 94 signatories and 100 ratifications [20].

Canada signed the Optional Protocol on March 30, 2007, and ratified it on March 11, 2010. Canada also opted to accept the Committee's competence to investigate and adjudicate individual complaints. The US signed the Optional Protocol on July 30, 2009, but the US opted not to accept the Committee's competence to investigate and adjudicate individual complaints; nor has it ratified the agreement.

3.1.2 Other Government Organizations Providing Resources or Support

In addition to laws, regulations, and official guidance, several governmental departments and organizations promote transportation accessibility by conducting or financially supporting necessary research and providing resources and support to people with disabilities.

3.1.2.1 Transport Canada

Transport Canada retains authority over vehicle safety, including automated driving systems (ADS) operated vehicle safety. In 2019, Transport Canada issued official guidance on safety for ADS-operated vehicles [24]. Among other topics, Safety Assessment for Automated Driving Systems in Canada addresses the "human-machine interface and accessibility of controls". Developers are directed to assess whether the vehicle is:

- "equipped with systems that allow occupants to seek assistance in the event of an emergency or when more information is needed?"

- "accessible to passengers with special needs (e.g., with mobility impairments, hearing/vision impairments, service animals, children, mobility devices)" and "what design features have been developed to meet the needs of these users?"

3.1.2.2 US Department of Transportation

The US Department of Transportation maintains a site dedicated to assisting transportation professionals and service providers with ADA compliance and accessibility information and guidance [25]. This site also provides information on program funding for transportation accessibility design and technology.

Of particular interest for CAV ride-sourcing fleets is the "Inclusive Design Reference Hub" the US Department of Transportation is in the process of setting up to "establish a library of resources for accessibility in automation, and work with outside experts to study voluntary best practices for ensuring accessibility in automated vehicles" [26]. The comment period on the proposal closed on February 19, 2021. Also of interest for CAV ride-sourcing fleets are a number of FAQs on transportation network companies and transit [27].

3.1.2.2.1 Accessible Transportation Technologies Research Initiative

The Accessible Transportation Technologies Research Initiative (ATTRI) is part of the US Department of Transportation's Intelligent Transportation Systems Joint Program Office. It has four main research tracks: "Wayfinding & Navigation"; "Pre-Trip Concierge & Virtualization"; "Safe Intersection Crossing"; and "Robotics & Automation". Figure 1 illustrates the goals of ATTRI's work in support of accessible mobility [28].

Figure 1: Example of steps in a trip using Accessible Transportation Technologies Research Initiative (ATTRI) resources. Source: Intelligent Transportation Systems Joint Program Offices [28].





"The Canadian Standards Association (CSA) has published five standards addressing accessibility issues that are relevant to CAV accessibility."

3.1.3 Non-governmental Advocacy Organizations

Numerous non-governmental organizations advocate for accessibility. These range from organizations that provide assistance and resources for people with any disability (for example, the Council of Canadians with Disabilities), to those that specialize in a specific type of disability (for example, the CNIB Foundation and the US National Federation for the Blind). The following represent some of the more notable advocacy organizations:

- Canadian Abilities Foundation (CAF) [29]
- CNIB Foundation (formerly the Canadian National Institute for the Blind) [30]
- Council of Canadians with Disabilities (CCD) [31]
- La Confédération des organismes de personnes handicapées du Québec (Confederation of Organizations of Persons with Disabilities of Quebec, or COPHAN) [32]
- National Federation for the Blind (NFB) [33]
- National Aging and Disability Transportation Center (NADTC) [34]
- USAging (formerly the National Association of Area Agencies on Aging or n4a) [35]

Some non-governmental organizations promote new standards and regulations designed to eliminate barriers to full participation in society by people with disabilities.

The following subsections list existing and emerging (i.e., "under development") standards that, based on their title and publicly available description, are relevant or potentially relevant to CAV accessibility. Due to the newness of CAV technology, and the extremely limited deployment to date, few (if any) of these standards specifically address CAVs and their unique challenges – especially the lack of a human operator/attendant. Some of the standards to do with securing wheelchairs and other mobility assistance devices assume a human assistant is available. Further analysis of the extent to which each standard addresses CAV accessibility issues, and what gaps remain, is beyond the scope of this study.

3.1.3.1 Canadian Standards Association

The Canadian Standards Association (CSA) has published five standards addressing accessibility issues that are relevant to CAV accessibility.

- CAN/CSA/ASC B651.2:22, *Accessible design for self-service interactive devices including automated banking machines* [36]
- CAN/CSA-B659-08 (R2018), *Inclusive design for an aging population* [37]
- CAN/CSA/ASC B651:23, *Accessible design for the built environment* [38]
- CAN/CSA D409-16 (R2021), *Motor vehicles for the transportation of persons with physical disabilities* [39]
- CSA Z605:16 (R2021), *Mobility aid securement and occupant restraint (MASOR) systems for motor vehicles* [40]

3.1.3.2 SAE International

SAE International (formerly known as the Society of Automotive Engineers) develops standards used for the aerospace, automotive and commercial-vehicle industries. The following, issued by the Driver Assistance Systems Steering Committee – On-Road Automated Driving Committee, are relevant to this study:

- J3171_201911, I*dentifying automated driving systems-dedicated vehicles (ADS-DVs) passenger issues for persons with disabilities* [41]
- J3261, *Resources for accommodating the needs of persons with disabilities when using ADS-DVs* (currently a "work in progress" or under development) [42]

The following, issued by the Ergonomics Steering Committee – Adaptive Devices Standards Committee, are relevant to this study:

- J2249_199901, *Wheelchair tiedown and occupant restraint systems for use in motor vehicles* [43]
- J2092_202104, *Testing of wheelchair lifts for entry to or exit from a personally licensed vehicle* [44]
- J2093_202104, *Design considerations for wheelchair lifts for entry to or exit from a personally licensed vehicle* [45]
- J1725_202112, *Structural modification for personally licensed vehicles to meet the transportation needs of persons with disabilities* [46]

3.1.3.3 International Organization for Standardization

The International Organization for Standardization (ISO) develops and publishes international standards addressing a wide range of industrial products and processes.

ISO has partnered with the International Electrotechnical Commission (IEC) to produce ISO/IEC Guide 71:2014, *Guide for Addressing Accessibility in Standards* [47]. This Guide:

> ... provides guidance to standards developers on addressing accessibility requirements and recommendations in standards that focus, whether directly or indirectly, on systems (i.e., products, services, and built environments) used by people. To assist standards developers to define accessibility requirements and recommendations, the Guide presents: a summary of current terminology relating to accessibility; issues to consider in support of accessibility in the standards development process; a set of accessibility goals (used to identify user accessibility needs); descriptions of (and design considerations for) human abilities and characteristics; and strategies for addressing user accessibility needs and design considerations in standards [47].

As such, this is an overarching accessibility guidance document for standards development organizations (SDOs) and their respective committees responsible for drafting standards, rather than a subject- or product-specific guidance document.

3.1.3.3.1 Ergonomics

The following standards, under development or developed by Technical Committee ISO/TC 159/SC 4 Ergonomics of Human-System Interaction, are relevant to this study:

- ISO 9241-171:2008, *Ergonomics of human-system interaction – Part 171: Guidance on software accessibility* [48] (Under development)
- ISO 9241-20:2021, *Ergonomics of human-system interaction – Part 20: An ergonomic approach to accessibility within the ISO 9241 series* [49]
- ISO 9241-971:2020, *Ergonomics of human-system interaction – Part 971: Accessibility of tactile/haptic interactive systems* [50]
- ISO 9241-920:2009, *Ergonomics of human-system interaction – Part 920: Tactile and haptic interactions* [51]
- ISO 9241-500:2018, *Ergonomics of human-system interaction – Part 500: Ergonomic principles for the design and evaluation of environments of interactive systems* [52]
- ISO 9241-210:2019, *Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems* [53]
- ISO/TS 20282-2:2013, *Usability of consumer products and products for public use – Part 2: Summative test method* [54]
- ISO/TS 21054:2020, *Ergonomics – Accessible design – Controls of consumer products* [55]

- ISO 24551:2019, *Ergonomics – Accessible design – Spoken instructions of consumer products* [56]
- ISO 24552:2020, *Ergonomics – Accessible design – Accessibility of information presented on visual displays of small consumer products* [57]

The following standard, developed by Technical Committee ISO/TC 159/SC 3 Anthropometry and Biomechanics, is relevant to this study:

- ISO 24553:2023, *Ergonomics – Accessible design – Ease of operation* [58]

The following standard, developed by Technical Committee ISO/TC 159/SC 1 General Ergonomics Principles, is relevant to this study:

- ISO 20282-1:2006, *Ease of operation of everyday products – Part 1: Design requirements for context of use and user characteristics* [59]

The following standard, which is under development by Technical Committee ISO/TC 159 Ergonomics, is relevant to this study:

- ISO/AWI TR 22411-2, *Guidance for use in the application of ISO/IEC Guide 71:2014 – Part 2: Ergonomics design considerations for accessibility* [60] (Under development)

The following standards, under development or developed by Technical Committee ISO/TC 159/SC 5, Ergonomics of the physical environment, are relevant to this study:

- ISO 24501:2010, Ergonomics – *Accessible design – Sound pressure levels of auditory signals for consumer products* [61]
- ISO 24502:2010, *Ergonomics – Accessible design – Specification of age-related luminance contrast for coloured light* [62]
- ISO 24505:2016, *Ergonomics – Accessible design – Method for creating colour combinations taking account of age-related changes in human colour vision* [63]
- ISO/DIS 24505, *Ergonomics – Accessible design – Method for creating colour combinations taking account of age-related changes in human colour vision* [64] (Under development)
- ISO/CD 24505-2, *Ergonomics – Accessible design – Method for creating colour combinations – Part 2: For people with defective colour vision and people with low vision* [65] (Under development)
- ISO 24504:2014, *Ergonomics – Accessible design – Sound pressure levels of spoken announcements for products and public address systems* [66]
- ISO 28803:2012, *Ergonomics of the physical environment – Application of International Standards to people with special requirements* [67]
- ISO 24553:2023, *Ergonomics – Accessible design – Ease of operation* [68]

3.1.3.3.2 Technical Committee 173 Assistive Products

The following standards, developed by Technical Committee ISO/TC 173/SC 2 Classification and Terminology, are relevant to this study:

- ISO 9999:2022, *Assistive products – Classification and terminology* [69]

The following standards, developed by Technical Committee ISO/TC 173 Assistive Products, are relevant to this study:

- ISO 21801-1:2020, *Cognitive accessibility – Part 1: General guidelines* [70]
- ISO 21801-2:2022, *Cognitive accessibility – Part 2: Reporting* [71]
- ISO 21802:2019, *Assistive products – Guidelines on cognitive accessibility – Daily time management* [72]

The following standards, developed by Technical Committee ISO/TC 173/SC 1 Wheelchairs, are relevant to this study:

- ISO 7176-19:2022, *Wheelchairs – Part 19: Wheelchairs for use as seats in motor vehicles* [73]
- ISO 10542-1:2012, *Technical systems and aids for disabled or handicapped persons – Wheelchair tiedown and occupant-restraint systems – Part 1: Requirements and test methods for all systems* [74]
- ISO 10542-1:2012/Amd 1:2021, T*echnical systems and aids for disabled or handicapped persons – Wheelchair tiedown and occupant-restraint systems – Part 1: Requirements and test methods for all systems – Amendment 1: Annexes K, L, M* [75]

- ISO 10542-1:2012/Cor 1:2013, *Technical systems and aids for disabled or handicapped persons – Wheelchair tiedown and occupant-restraint systems – Part 1: Requirements and test methods for all systems – Technical Corrigendum 1* [76]
- ISO 10865-1:2012, *Wheelchair containment and occupant retention systems for accessible transport vehicles designed for use by both sitting and standing passengers – Part 1: Systems for rearward-facing wheelchair-seated passengers* [77]
- ISO 10865-2:2015, *Wheelchair containment and occupant retention systems for accessible transport vehicles designed for use by both sitting and standing passengers – Part 2: Systems for forward-facing wheelchair-seated passengers* [78]
- ISO 16840-4:2009, *Wheelchair seating – Part 4: Seating systems for use in motor vehicles* [79]

The following standards, under development or developed by Technical Committee ISO/TC 173/SC 7, Assistive Products for Persons with Impaired Sensory Functions, are relevant to this study:

- ISO 17049:2013, *Accessible design – Application of braille on signage, equipment and appliances* [80]
- ISO 19027:2016, *Design principles for communication support board using pictorial symbols* [81]
- ISO 19029:2016, *Accessible design – Auditory guiding signals in public facilities* [82]
- ISO/DIS 6273, *Assistive products – Accessibility guidelines in the survey of user needs of persons with impaired sensory functions for assistive products and services* [83] (Under development)

3.1.3.3.3 ISO/IEC Joint Technical Committee 1 Information Technology

The following standard, developed by Technical Committee ISO/IEC JTC 1 Information Technology, is relevant to accessibility and CAV:

- ISO/IEC 40500:2012, *Information technology – W3C Web Content Accessibility Guidelines (WCAG) 2.0* [84]

The following standards, developed by Technical Committee ISO/IEC JTC 1/SC 35 User Interfaces, are relevant to this study:

- ISO/IEC 29138-1:2018, *Information technology – User interface accessibility – Part 1: User accessibility needs* [85]
- ISO/IEC TR 29138-2:2009, *Information technology – Accessibility considerations for people with disabilities – Part 2: Standards inventory* [86]
- ISO/IEC 29138-3:2022, *Information technology – User interface accessibility – Part 3: Requirements and recommendations on user needs mapping* [87]
- ISO/IEC 20071-5:2022, *Information technology – User interface component accessibility – Part 5: Accessible user interfaces for accessibility settings on information devices* [88]
- ISO/IEC 20071-11:2019, *Information technology – User interface component accessibility – Part 11: Guidance on text alternatives for images* [89]
- ISO/IEC TS 20071-21: 2015, *Information technology – User interface component accessibility – Part 21* [90]
- ISO/IEC 20071-23:2018, *Information technology – User interface component accessibility – Part 23: Visual presentation of audio information (including captions and subtitles)* [91]
- ISO/IEC 24786:2009, *Information technology – User interfaces – Accessible user interface for accessibility settings* [92]
- ISO/IEC 30071-1:2019, *Information technology – Development of user interface accessibility – Part 1: Code of practice for creating accessible ICT products and services* [93]
- ISO/IEC 24756:2009, *Information technology – Framework for specifying a common access profile (CAP) of needs and capabilities of users, systems, and their environments* [94]
- ISO/IEC 13066-1:2011, *Information technology – Interoperability with assistive technology (AT) – Part 1: Requirements and recommendations for interoperability* [95]
- ISO/IEC TR 13066-2:2016, *Information technology – Interoperability with assistive technology (AT) – Part 2: Windows accessibility application programming interface (API)* [96]

3.1.3.3.4 Technical Committee 204 Intelligent Transport Systems

The following standards, under development or developed by Technical Committee ISO/TC 204 Intelligent Transport Systems, are relevant to accessibility and CAV:

- ISO 13111-1:2017, *Intelligent transport systems (ITS) – The use of personal ITS station to support ITS service provision for travellers – Part 1: General information and use case definitions* [97]
- ISO/CD TR 24317, *Intelligent transport systems – Mobility integration – Mobility integration needs for vulnerable users and light modes of transport* [98] (Under development)

3.1.3.4 International Telecommunications Institute / Telecommunication Standardization Sector

The International Telecommunications Institute (ITU) is a UN agency that facilitates international connectivity in communications networks. Through its Telecommunication Standardization Sector, ITU develops recommendations for telecommunications standards that may be adopted in UN regulations. The following ITU standards are relevant to this study:

- ITU-T Y.4211 (12/2020), *Accessibility requirements for smart public transport services* [99]
- ITU-T Y.4204 (02/2019), *Accessibility requirements for the Internet of things applications and services* [100]

3.1.3.5 European Telecommunications Standards Institute

The European Telecommunications Standards Institute (ETSI) develops standards related to information and communications technology across all industries. ETSI standards are frequently specified in European regulations. The following are relevant to this study:

- EN 301 549 V3.2.1 (2021-03), *Accessibility requirements for ICT products and services* [101]
- ETSI EG 203 350 V1.1.1 (2016-11), *Human Factors (HF); Guidelines for the design of mobile ICT devices and their related applications for people with cognitive disabilities* [102]
- ETSI EG 202 848 V1.1.1 (2011-02), *Human Factors; Inclusive eServices for all: Optimizing the accessibility and the use of upcoming user-interaction technologies* [103]
- ETSI EG 202 116 V1.2.2 (2009-03), *Human Factors (HF); Guidelines for ICT products and services; "Design for All"* [104]

3.1.3.6 British Standards Institute

The British Standards Institute develops standards addressing a wide range of industrial products and processes. The following are relevant to this study:

- BS EN 17161:2019, *Design for All. Accessibility following a Design for All approach in products, goods and services. Extending the range of users* [105]
- BS EN 301549:2021, *Accessibility requirements for ICT products and services* [106]
- BS 8878:2010, *Web accessibility. Code of Practice* [107]
- BS 8603:2020, *Wheelchair transport passport schemes. Code of practice* [108]
- BS EN 17478:2021, *Transport services. Customer communications for passenger transport services. A Universal Design approach* [109]
- BS EN 16334-1:2014+A1:2022, *Railway applications. Passenger Alarm System. System requirements for mainline rail* [110]

3.1.3.7 Institute of Transportation Engineers

The Institute of Transportation Engineers (ITE) develops standards aimed at improving mobility and safety for transportation system users globally. The following are relevant to this study:

- Special Report: Accessible Public Rights-of-Way – Planning and Designing for Alterations [111]
- Transportation Planning Handbook, 4th Edition [112]

3.1.3.8 American Association of State Highway and Transportation Officials

In the US, the American Association of State Highway and Transportation Officials (AASHTO) has historically played a large role in harmonizing road infrastructure standards across the 50 states, including at the local level. The following guidebook is relevant to this study:

- AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities, 2nd Edition [113]

3.1.3.9 World Wide Web Consortium

The World Wide Web Consortium (W3C) is an international standards development organization specifically addressing web use. The following developed standards, guidelines, or works in progress are relevant to this study:

- Web content accessibility guidelines (WCAG) 2.0[3] [114]
- Web content accessibility guidelines (WCAG) 2.1[4] [115]
- Web content accessibility guidelines (WCAG) 2.2[5] [116] (Under development – Last updated January 25, 2023)
- W3C accessibility guidelines (WCAG) 3.0 [117] (Under development – Last draft December 07, 2021)
- Authoring tool accessibility guidelines (ATAG) 2.0 [118]
- User agent accessibility guidelines (UAAG) 2.0 [119]
- Accessible rich Internet applications (WAI-ARIA) 1.1 [120]
- Accessibility conformance testing (ACT) rules Format 1.0 [121]
- Requirements for WAI-Adapt specification [122] (Under development – Last draft June 09, 2022)
- WAI-Adapt: Symbols module [123] (Under development – Last draft January 05, 2023)
- Natural language interface accessibility user requirements [124] (Under development – Last draft September 03, 2022)
- RTC accessibility user requirements [125]
- Mobile accessibility: How WCAG 2.0 and other W3C/WAI guidelines apply to mobile [126]
- Understanding SC 1.3: Adaptable [127]
- Understanding SC 1.4: Distinguishable [128]
- Understanding SC 2.2: Enough time [129]
- Understanding SC 2.4: Navigable [130]
- Understanding SC 3.1: Readable [131]
- Understanding SC 3.2: Predictable [132]
- Understanding SC 3.3: Input assistance [133]
- Making content usable for people with cognitive and learning disabilities [134]

3.1.3.10 Rehabilitation Engineering and Assistive Technology Society of North America

The Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) is a professional organization that provides a range of products and services addressing the technological needs of people with disabilities, including assistive technology standards. The following are relevant to this study:

- ANSI/RESNA CA-1:2018, *American National Standard for Cognitive Accessibility - Volume 1: Universal Criteria for Reporting the Cognitive Accessibility of Products and Technologies* [135]
- ANSI/RESNA WC-4:2017, *American National Standard for Wheelchairs Volume 4: Wheelchairs and Transportation* [136]

3.1.3.11 CNIB Foundation

The CNIB Foundation published Clear Print Accessibility Guidelines [137] in 2018 that specify best practices for making printed materials more readable for people with low visual acuity. CNIB provides recommendations on contrast, type colour, point size, leading (i.e., line spacing), font family and size, font heaviness, letter spacing, margins and columns, paper finish, and clean design and simplicity.

3.2 Preliminary Gap Assessment

The research team employed a matrix approach to conduct a high-level, preliminary standardization gap assessment. This approach aligns complete user trip needs with disability types [4] as listed in Table 1. This alignment defines the scope of the potential accessibility standards space. Note, however, that this gap analysis is preliminary, as it is not based on a detailed reading of each standard to determine specific applicability to CAVs and adequacy with respect to the indicated need. In addition, the standards identified for this study were written for and about conventional vehicles operated by humans, rather than ADS-dedicated CAVs without a human operator or attendant who could assist a ride-sourcing user with one or more disabilities. As such, they may have limited or no applicability for CAVs operated in ride-sourcing fleets.

3 WCAG 2.0 is approved as ISO standard ISO/IEC 40500:2012 [84].
4 WCAG 2.1 extends the requirements of WCAG 2.0. Both standards exist and are meant to provide alternate means of conformance.
5 WCAG 2.2 extends the requirements of WCAG 2.1. Both standards exist and are meant to provide alternate means of conformance.

Many of the standards listed in section 3.1 support or facilitate accessibility standards development, rather than specifying ways to address accessibility by people with specific disabilities (e.g., standards that establish relevant terms and definitions, or that specify software interoperability). Such supporting standards are not included in the gap assessment.

Table 1 shows the number of standards (published or in progress) applicable to the indicated disability type/need combination. Table 2 shows the standards that apply to each of the categories in Table 1.

3.3 Stakeholder Consultations

This study's research team also collected feedback from multiple stakeholders with lived experience with disability and expertise in transportation accessibility. The feedback provided by these stakeholders, reinforced by information from the series of workshops conducted by the Alliance of Automobile Manufacturers in 2019 [1], provides an overview of the goal state for accessibility. This also supports the assessment of unaddressed gaps.

Prior to the consultations, stakeholders were sent an email explaining the purpose of the study (to identify standardization needs in support of CAV accessibility); how the consultations would be conducted (virtually, via web conference); how long the consultation was expected to last (30 minutes); and whether they or the organization they represent preferred to remain anonymous or be acknowledged when the study is published. During the consultations, stakeholders were asked to review (in order) the steps that a person without disabilities would take to use a CAV-ride-sourcing service, once they arrive at the expected pick-up area, and to identify anticipated barriers or challenges that people with disabilities might face in attempting to complete each step. The following steps in using a CAV-ride-sourcing service were identified:

Locate the marked CAV at curbside.

1. Validate the correct CAV (e.g., enter code to access vehicle) and authenticate.
2. Enter and get seated in the vehicle.
3. Fasten seatbelt.
4. Use an accessible device to summon and communicate with a remote human assistant in the event of an emergency.
5. Maintain situational awareness at drop-off location in order to find/verify destination.
6. Unfasten seatbelt and exit the vehicle.

Responses are grouped according to the types of disabilities listed in Table 1 and Table 2, namely, low vision; blindness; deafness / hearing impairment; cognitive impairment; upper body movement limitations; difficulty walking / lower body movement limitations; wheelchair use with the ability to transfer; and wheelchair use without the ability to transfer.[6]

It should be noted that, although feedback was requested on anticipated barriers and challenges to completing each CAV trip step, many stakeholders also suggested potential solutions for overcoming such barriers and challenges; these are also included in the tables of responses.

6 The disability type "deafblindness" was omitted because accommodating the complete needs of deafblind users travelling via CAV ride-sourcing service without a human attendant is infeasible at this time. Currently, the only means of communicating the range of complex information required for safety and security while a person is traveling alone in a CAV is through a voice or visual display. A person who is unable to see or hear will therefore require a human attendant who is able to see and/or hear safety and security instructions and provide assistance when required. Similarly, as "cognitive impairment" can be a result of developmental conditions (such as Down Syndrome or autism spectrum disorder), aging-related diseases (such as Alzheimer disease and other types of dementia), and injury-related conditions (such as traumatic brain injury and chronic traumatic encephalopathy), it is currently technically infeasible to accommodate all the needs of people who have more than mild cognitive impairment when they are travelling via CAV ride-sourcing service without a human attendant.

3.3.1 Barriers, Challenges, and Potential Issues

Table 1: Number of Standards that Address CAV Trip Step Needs by Type of Disability

Disability	Trip Step								
	Trip Planning	Pick-up Location	Find ADS-DV	Authenticate	Ingress	In-vehicle Interactions	Drop-off Location	Egress	Find Destination
Low Vision	28	3	0	28	0	2	3	0	0
Blindness	2	1	0	2	0	2	1	0	0
Deafness / Hearing Impairment	23	0	0	23	0	1	0	0	0
Deafblindness	2	0	0	2	0	2	0	0	0
Cognitive Impairment	12	12	0	12	0	12	12	0	0
Upper Body Mobility Limitation	2	0	0	2	0	2	0	0	0
Lower Body Mobility Limitation	0	5	0	1	5	0	5	5	0
Wheelchair Use With Transfer Ability	0	5	0	0	5	0	5	5	0
Wheelchair Use Without Transfer Ability	0	5	0	0	19	0	5	19	0

Abbreviations: **ADS-DV** = automated driving systems – dedicated vehicles; **CAV** = connected and automated vehicles.

Table 2: Preliminary Gap Assessment with Standards Listed

Needs	Trip Planning	Pick-up Location	Find ADS-DV	Authenticate	Ingress	In-vehicle Interactions	Drop-off Location	Egress	Find Destination
Disabilities									
Low Vision	CAN/CSA/ASC B651.2-22 [36] SAE J3171_201911 [41] ISO 9241-171:2008 [48] ISO 9241-500:2018 [52] ISO 9241-210:2019 [53] ISO/TS 21054:2020 [55] ISO 24552:2020 [57] ISO 20282-1:2006 [59] ISO 24502:2010 [62] ISO 24505:2016 [63] ISO/DIS 24505 [64] ISO/CD 24505-2 [65] ISO/DIS 6273 [83] ISO/IEC 40500:2012 [84] ISO/IEC 29138-3:2022 [85] ISO/IEC 30071-1:2019 [93] ETSI EG 202 848 V1.1.1 (2011-02) [103] ETSI EG 202 116 V1.2.2 (2009-03) [104] BS EN 17161:2019 [105] W3C/WCAG 2.0 [114] W3C/WCAG 2.1 [115] W3C/WCAG 2.2 [116] W3C/WCAG 3.0 [117] W3C/UAAG 2.0 [118] W3C/ACT [121] W3C/natural language [124] W3C/RTC [125] CNIB Clear Print Accessibility Guidelines [137]	ISO 9241-500:2018 [52] ISO 24551:2019 [56] ISO 28803:2012 [67]	—	CAN/CSA/ASC B651.2-22 [36] SAE J3171_201911 [41] ISO 9241-171:2008 [48] ISO 9241-500:2018 [52] ISO 9241-210:2019 [53] ISO/TS 21054:2020 [55] ISO 24552:2020 [57] ISO 20282-1:2006 [59] ISO 24502:2010 [62] ISO 24505:2016 [63] ISO/DIS 24505 [64] ISO/CD 24505-2 [65] ISO/DIS 6273 [83] ISO/IEC 40500:2012 [84] ISO/IEC 29138-3:2022 [85] ISO/IEC 30071-1:2019 [93] ETSI EG 202 848 V1.1.1 (2011-02) [103] ETSI EG 202 116 V1.2.2 (2009-03) [104] BS EN 17161:2019 [105] W3C/WCAG 2.0 [114] W3C/WCAG 2.1 [115] W3C/WCAG 2.2 [116] W3C/WCAG 3.0 [117] W3C/UAAG 2.0 [118] W3C/ACT [121] W3C/natural language [124] W3C/RTC [125] CNIB Clear Print Accessibility Guidelines [137]	—	ISO/TS 21054:2020 [55] ISO 24551:2019 [56]	ISO 9241-500:2018 [52] ISO 24551:2019 [56] ISO 28803:2012 [67]	—	—
Blindness	ISO 17049:2013 [80] ISO/IEC 20071-11:2019 [89]	ISO 28803:2012 [67]	—	ISO 17049:2013 [80] ISO/IEC 20071-11:2019 [89]	—	ISO/TS 21054:2021 [55] ISO 24551:2019 [56]	ISO 28803:2012 [67]	—	—

Needs	Trip Planning	Pick-up Location	Find ADS-DV	Authenticate	Ingress	In-vehicle Interactions	Drop-off Location	Egress	Find Destination
Disabilities									
Deafness / Hearing Impairment	CAN/CSA/ASC B651.2-22 [36] ISO 9241-171:2008 [48] ISO 9241-971:2020 [50] ISO 9241-920:2009 [51] ISO 20282-1:2006 [59] ISO 24501:2010 [61] ISO 24504:2014 [66] ISO 19029:2016 [82] ISO/IEC 40500:2012 [84] EN 301 549 V3.2.1 (2021-03) [101] ETSI EG 202 848 V1.1.1 (2011-02) [103] ETSI EG 202 116 V1.2.2 (2009-03) [104] BS EN 17161:2019 [105] BS EN 301549:2021 [106] BS 8878:2010 [107] W3C/WCAG 2.0 [114] W3C/WCAG 2.1 [115] W3C/WCAG 2.2 [116] W3C/WCAG 3.0 [117] W3C/UAAG 2.0 [118] W3C/ACT [121] W3C/natural language [124] W3C/RTC [125]	–	–	CAN/CSA/ASC B651.2-22 [36] ISO 9241-171:2008 [48] ISO 9241-971:2020 [50] ISO 9241-920:2009 [51] ISO 20282-1:2006 [59] ISO 24501:2010 [61] ISO 24504:2014 [66] ISO 19029:2016 [82] ISO/IEC 40500:2012 [84] EN 301 549 V3.2.1 (2021-03) [101] ETSI EG 202 848 V1.1.1 (2011-02) [103] ETSI EG 202 116 V1.2.2 (2009-03) [104] BS EN 17161:2019 [105] BS EN 301549:2021 [106] BS 8878:2010 [107] W3C/WCAG 2.0 [114] W3C/WCAG 2.1 [115] W3C/WCAG 2.2 [116] W3C/WCAG 3.0 [117] W3C/UAAG 2.0 [118] W3C/ACT [121] W3C/natural language [124] W3C/RTC [125]	–	ISO/TS 21054:2021 [55]	–	–	–
Deafblindness	ISO 9241-971:2020 [50] ISO 9241-920:2009 [51]	–	–	ISO 9241-971:2020 [50] ISO 9241-920:2009 [51]	–	ISO 9241-971:2020 [50] ISO 9241-920:2009 [51]	–	–	–
Cognitive Impairment	ISO 20282-1:2006 [59] ISO 21801-1:2020 [70] ISO/DIS 21801-2:2022 [71] ISO 21802:2019 [72] ISO 19027:2016 [81] ETSI EG 203 350 V1.1.1 (2016-11) [102] W3C/WCAG 2.0 [114] W3C/WCAG 2.1 [115] W3C/WCAG 2.2 [116] W3C/WCAG 3.0 [117] W3C/UAAG 2.0 [118] ANSI/RESNA CA-1:2018 [135]	ISO 20282-1:2006 [59] ISO 21801-1:2020 [70] ISO/DIS 21801-2:2022 [71] ISO 21802:2019 [72] ISO 19027:2016 [81] ETSI EG 203 350 V1.1.1 (2016-11) [102] W3C/WCAG 2.0 [114] W3C/WCAG 2.1 [115] W3C/WCAG 2.2 [116] W3C/WCAG 3.0 [117] W3C/UAAG 2.0 [118] ANSI/RESNA CA-1:2018 [135]	–	ISO 20282-1:2006 [59] ISO 21801-1:2020 [70] ISO/DIS 21801-2:2022 [71] ISO 21802:2019 [72] ISO 19027:2016 [81] ETSI EG 203 350 V1.1.1 (2016-11) [102] W3C/WCAG 2.0 [114] W3C/WCAG 2.1 [115] W3C/WCAG 2.2 [116] W3C/WCAG 3.0 [117] W3C/UAAG 2.0 [118] ANSI/RESNA CA-1:2018 [135]	–	ISO 20282-1:2006 [59] ISO 21801-1:2020 [70] ISO/DIS 21801-2:2022 [71] ISO 21802:2019 [72] ISO 19027:2016 [81] ETSI EG 203 350 V1.1.1 (2016-11) [102] W3C/WCAG 2.0 [114] W3C/WCAG 2.1 [115] W3C/WCAG 2.2 [116] W3C/WCAG 3.0 [117] W3C/UAAG 2.0 [118] ANSI/RESNA CA-1:2018 [135]	–	–

Needs	Trip Planning	Pick-up Location	Find ADS-DV	Authenticate	Ingress	In-vehicle Interactions	Drop-off Location	Egress	Find Destination
Disabilities									
Upper Body Mobility Limitation	ISO/TS 20282-2:2013 [54] ISO 24553:2023 [68]	–	–	"ISO/TS 20282-2:2013 [54] ISO 24553:2023 [68]"	–	ISO/TS 20282-2:2013 [54] ISO 24553:2023 [68]	–	–	–
Lower Body Mobility Limitation	–	CAN/CSA/ASC B651.2-22 [36] ISO 28803:2012 [67] ITE Accessible Public Rights-of-Way [111] ITE Transportation Planning Handbook [112] AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities [113]	–	ISO 24553:2023 [68]	CAN/CSA/ASC B651.2-22 [36] ISO 28803:2012 [67] ITE Accessible Public Rights-of-Way [111] ITE Transportation Planning Handbook [112] AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities [113]	–	CAN/CSA/ASC B651.2-22 [36] ISO 28803:2012 [67] ITE Accessible Public Rights-of-Way [111] ITE Transportation Planning Handbook [112] AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities [113]	CAN/CSA/ASC B651.2-22 [36] ISO 28803:2012 [67] ITE Accessible Public Rights-of-Way [111] ITE Transportation Planning Handbook [112] AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities [113]	–
Wheelchair Use With Transfer Ability	–	CAN/CSA/ASC B651.2-22 [36] ISO 28803:2012 [67] ITE Accessible Public Rights-of-Way [111] ITE Transportation Planning Handbook [112] AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities [113]	–	–	CAN/CSA/ASC B651.2-22 [36] CAN/CSA D409-16 (R2021) [39] ISO 28803:2012 [67] ITE Accessible Public Rights-of-Way [111] ITE Transportation Planning Handbook [112] AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities [113]	–	CAN/CSA/ASC B651.2-22 [36] ISO 28803:2012 [67] ITE Accessible Public Rights-of-Way [111] ITE Transportation Planning Handbook [112] AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities [113]	CAN/CSA/ASC B651.2-22 [36] CAN/CSA D409-16 (R2021) [39] ISO 28803:2012 [67] ITE Accessible Public Rights-of-Way [111] ITE Transportation Planning Handbook [112] AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities [113]	–
Wheelchair Use Without Transfer Ability	–	CAN/CSA/ASC B651.2-22 [36] ISO 28803:2012 [67] ITE Accessible Public Rights-of-Way [111] ITE Transportation Planning Handbook [112] AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities [113]	–	–	CAN/CSA/ASC B651.2-22 [36] CAN/CSA D409-16 (R2021) [39] CSA Z605:16 (R2021) [40] SAE J2249_199901 [43] SAE J2092_202104 [44] SAE J2093_202104 [45] SAE J1725_202112 [46] ISO 28803:2012 [67] ISO 7176-19:2022 [73] ISO 10542-1:2012 [74] ISO 10542-1:2012/AMD 1:2021 [75] ISO 10542-1:2012/COR 1:2013 [76] ISO 10865-1:2012 [77] ISO 10865-2:2015 [78] ISO 16840-4:2009 [79] ITE Accessible Public Rights-of-Way [111] ITE Transportation Planning Handbook [112] AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities [113] ANSI/RESNA WC-4:2017 [136]	–	CAN/CSA/ASC B651.2-22 [36] ISO 28803:2012 [67] ITE Accessible Public Rights-of-Way [111] ITE Transportation Planning Handbook [112] AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities [113]	CAN/CSA/ASC B651.2-22 [36] CAN/CSA D409-16 (R2021) [39] CSA Z605:16 (R2021) [40] SAE J2249_199901 [43] SAE J2092_202104 [44] SAE J2093_202104 [45] SAE J1725_202112 [46] ISO 28803:2012 [67] ISO 7176-19:2022 [73] ISO 10542-1:2012 [74] ISO 10542-1:2012/AMD 1:2021 [75] ISO 10542-1:2012/COR 1:2013 [76] ISO 10865-1:2012 [77] ISO 10865-2:2015 [78] ISO 16840-4:2009 [79] ITE Accessible Public Rights-of-Way [111] ITE Transportation Planning Handbook [112] AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities [113] ANSI/RESNA WC-4:2017 [136]	–

3.3.2 Considerations Applicable to People With Disabilities

During the consultations, stakeholders pointed out barriers, challenges, and potential issues for CAV ride-sourcing services to consider when addressing the needs of individuals with disabilities. Some of the most frequent issues encountered across user groups are in this section.

3.3.2.1 CAV Service Termination

People with disabilities may require more time to complete tasks necessary for car travel, so it is important that the CAV and/or CAV service is able to accommodate their temporal needs and does not "time out" automatically.

3.3.2.2 Availability of Remote Human Assistance

Several stakeholders recommended that there be a means of summoning remote human assistance at the CAV provider's fleet operations centre, preferably augmented by camera and/or sensing technology, to provide the remote assistant with situational awareness of the CAV, its users and its surroundings. Such assistance would not only help to address error recovery when required, but also help with trust concerns that people may have when using an unattended vehicle, whether travelling alone or in the company of strangers. Such a feature could be beneficial for many users, regardless of ability or disability type.

3.3.2.3 Remote Human Assistants Trained in Effective Remote Communications With People With Disabilities

The existing standards for one-to-one communications in, for example, the public transportation sector, generally presume in-person voice communications, rather than remote, technology-mediated communications. Augmented standards in this regard are required and would benefit all users regardless of ability.

Table 3: Standards Gaps for Accessible CAVs: Blindness and Low Vision

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability	
		Blindness	Low Vision
Locate the marked CAV at curbside	Audible signal in addition to visible signage	S	S
	Audible signals need to be heard over ambient noise	S	S
	There are devices that use auditory tones to assist in locating items in space for people who are blind or have low vision	NA	NA
	User may require more time to locate CAV	G	G
	Enable remote assistance by CAV service provider and/or care-giver (error recovery)	G	G
	Provide correct, clear and precise information on CAV pick-up location in advance	G	G
Locate the marked CAV at curbside	Path to CAV needs to be unobstructed	(S)	(S)
	CAV needs to have environmental / situational awareness; extra sensors in the vehicle and possibly also in the environment	G	G
	Ensure that the particular vehicle stands out as that person's CAV, e.g., wireless code to a hand-held device	NA	(S)

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability	
		Blindness	Low Vision
Validate the correct CAV (e.g., enter code to access vehicle) and authenticate	Provide advance information/instruction	G	G
	Auditory interface raises potential privacy/security concerns if displays personal identifiable information (PII)	G	G
	Need for high-contrast visual displays (white text on black background)	NA	S
	Smartphone/device interface are OK, but not all users will own one or have one with them	NA	NA
	Human-to-human option as a back-up and/or for error recovery	G	G
	Possible use for biometrics (fingerprint, facial recognition, retinal scan – although retinal scans don't work on all blind people)	(S)	(S)
	Provide braille keypad	NA	NA
	Standardized interface and location	(S)	(S)
	Allow user to customize interface (e.g., customizable sound or cue word)	G	G
Enter and get seated in the vehicle	Need for precise location technology to position person and vehicle for optimal ingress/egress	(S)	(S)
	Provide advance information on type of vehicle and orientation at pick-up location	NA	G
	Provide seat map in advance, assistance in orienting to seat location	G	G
	In a shared CAV, inform the user which seats they have been allocated or are available before they enter the vehicle	G	G
	Need for visible/audible cue that car has unlocked for ingress	(S)	(S)
	Knowing step-in height and head clearance in advance	G	G
	Need accessible stowage space for white canes, service animals, packages/luggage	NA	NA
Fasten your seatbelt	Need restraints for service animals	G	G
	If restraints are automated, provide advance information to users	NA	NA
	Buckles and interfaces that are easier to use are needed	G	G
	Provide remote assistance as needed	G	G
	If seatbelt is damaged or unavailable, need a way to recover	NA	NA

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability	
		Blindness	Low Vision
Use an accessible device to summon and communicate with a remote human assistant in the event of an emergency	Provide instruction in advance plus audible instruction upon entry	G	G
	Guidelines for remote assistants on how to interact with CAV users who are blind or have low vision	S	S
	Guidelines for stop/flee responses that are safe for all road users	G	G
	Back-up power so feature is available even after a crash	(S)	(S)
	Standardized, universal design of accessible device in standard location	(S)	(S)
	Redundant means of access (hardware and software), including via personal device	(S)	(S)
	Customizable interface needed for accessible device	(S)	(S)
	In shared vehicles, need to be mindful of privacy implications with audible interfaces	G	G
	Allow summoning assistance through connected personal assistive device	G	G
Maintain situational awareness at drop-off location in order to find/verify destination	CAV should prevent exit while in motion and provide indication when it's safe to exit	(S)	(S)
	Vehicle needs to clarify when approaching destination when a stop is interim vs. terminal	G	G
	Announcement of arrival (progressive: approaching, arrival, safe to exit)	(S)	(S)
	CAV should provide audible/visible qualitative description of external environment at drop-off location and instruction for when and where to exit	G	G
	Technology to enable safe egress (e.g., not in path of vehicle or bike lane)	G	G
	Make sure CAV users are not exiting on unlevel ground or in obstructed areas such as snowbanks	NA	NA
	Video-audio connection to a human assistant, as needed	G	G
	Vehicle should inform the CAV user which side/door to use for egress	G	G
	CAV should provide orientation information on user destination (e.g., "It's the building across the street on your left"), including through which door to enter	G	G
	Vehicle should not leave until released by the CAV user	G	G

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability	
		Blindness	Low Vision
Unfasten seatbelt and exit the vehicle	Means for error recovery if person leaves something behind and needs to re-enter or otherwise access the vehicle	NA	NA
	Allow more time for people with disabilities to exit	G	G
	Releasing the seatbelt should not release the vehicle	G	G
	Consider issues with unloading purchases, equipment, or service animal	G	G
	Auditory instructions for exiting (e.g., step down, including information on distance down)	G	G
	Vehicle should not leave until released by the user	G	G

Abbreviations: CAV = connected and automated vehicle; **G** = gap (no standards identified that address issue); **NA** = "not applicable" (not suitable for technical standardization); **S** = standard(s) available that address issue; **(S)** = standard(s) available that may address or partially address issue.

Table 4: Standards Gaps for Accessible CAVs: Deafness and Hearing Impairment

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Locate the marked CAV at curbside	Visible, accessible displays	S
	Consistency in signage/cues	(S)
	Clear visual cues, e.g., high-intensity strobes	(S)
	If designated area, should be clearly marked with accessible, multimodal signage	(S)
Validate that it is the correct CAV (e.g., enter code to access vehicle) and authenticate	Allow user to customize options (could be customizable sound or cue word)	G
Enter and get seated in the vehicle	None	NA
Fasten seatbelt	If seatbelt is damaged or unavailable, need a way to recover	NA
Use an accessible device to summon and communicate with a remote human assistant in the event of an emergency	Guidelines for stop/flee responses that are safe for all road users	G
	Guidelines for remote assistants on how to interact with deaf or hearing impaired CAV users	S
	Provide instructions on CAV location and how to use in advance	G
	Fully accessible (reach, usability, etc.)	(S)
	Allow summoning assistance through connected personal assistive device	G
Maintain situational awareness at drop-off location in order to find/verify destination	None	NA
Unfasten seatbelt and exit the vehicle	None	NA

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Table 5: Standards Gaps for Accessible CAVs: Cognitive Disabilities

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Locate the marked CAV at curbside	Enable remote monitoring by a caregiver	G
	For cognitive impairment, the less stimulus the better; simple displays	S
	Need an intuitive interface; entering a code is not intuitive	(S)
	Allow user options (could be customizable sound or cue word)	G
	Ensure that the particular vehicle stands out as that person's CAV, e.g., wireless code to a hand-held device	(S)
	For cognitive disability, may require training/assistance	(S)
	Biometrics: fingerprint/facial recognition (app based)	(S)
	Consider personalization: analogue of always requisitioning the same driver	G
Validate the correct CAV (e.g., enter code to access vehicle) and authenticate	None	NA
Enter and get seated in the vehicle	None	NA
Fasten seatbelt	Could have trouble with being restrained	NA
	CAV should also accommodate caregivers, service animals, friends, family members in attendance as well as packages/luggage	NA
	Should have a remote assistant available to help	G
	Potential for some people to unfasten seatbelts en route and possibly open doors	NA
	If seatbelt is damaged or unavailable, need a way to recover	NA
Use an accessible device to summon and communicate with a remote human assistant in the event of an emergency	Guidelines for stop/flee responses that are safe for all road users	G
	Guidelines for remote assistants for interacting with passengers who have mild cognitive impairment	S
	Audible instruction or guidance on location and use of the feature; what to expect	G
	Simple design, no menus	(S)
	Allow summoning assistance through connected personal assistive device	(S)
	Easy to manipulate and use, but not so easy that it is inadvertently activated	(S)
	Allow non-emergency interactions with human assistants	NA

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Maintain situational awareness at drop-off location in order to find/ verify destination	CAV should indicate when it's safe to exit	G
	CAV should prevent premature exit (e.g., when vehicle is still in motion)	G
	CAV needs to have greater environment or situational awareness; extra sensors in the vehicle and possibly also in the environment	G
	Provide map-based, audible updates during ride	G
	At drop-off, multimodal confirmation of arrival and location confirmation	G
	Radio frequency identification (RFID) tags may be used to verify arrival at destination	(S)
	Provide designated drop-off zones	S
	Provide information on location (e.g., "it's the red building on your left") and which door to enter	G
	Video-audio connection to a human assistant, as needed	G
Unfasten seatbelt and exit the vehicle	Audible/visible instruction for when and where to exit	G
	If multiple options for exiting, specify safest exit door	G
	Vehicle should not leave until released	G

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Table 6: Standards Gaps for Accessible CAVs: Upper Body Movement Limitations

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Locate the marked CAV at curbside	None	NA
Validate the correct CAV (e.g., enter code to access vehicle) and authenticate	None	NA
Enter and get seated in the vehicle	Handlebars/grab handles	(S)
	Automatically closing doors (especially for door closing)	(S)
	Automatic door only on command (to avoid rushing people)	(S)
	Knowing vehicle type, dimensions, step-in height in advance	G
	Vehicle height may challenge people with mobility limitations	(S)
	Upper body mobility limitations may affect getting into the vehicle and getting seated	G
	Height adjustable for children and tall adults	(S)
	Users may need assistance with ingress and package/luggage storage and securement	G

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Fasten seatbelt	Reachability	S
	May not have strength or dexterity to manually fasten seatbelts	G
	Simpler, easier to use interfaces for people with dexterity issues	G
	CAV should take into account limited range of motion, strength, or dexterity	G
	Auto-donning system needed: belt buckled already, drapes across user (similar to automatic seatbelts from 1980s)	(S)
	If seatbelt is damaged or unavailable, need a way to recover	NA
Use an accessible device to summon and communicate with a remote human assistant in the event of an emergency	Fully accessible (reach, usability, etc.)	(S)
	Needs to be easy to manipulate and use, but not so easy that it is activated inadvertently	G
	If user falls, how will they recover?	G
Maintain situational awareness at drop-off location in order to find/ verify destination	None	NA
Unfasten seatbelt and exit the vehicle	Simpler, easier to use interfaces (for people with dexterity issues)	(S)
	CAV should take into account limited range of motion, strength, or dexterity	(S)
	CAV should be fully accessible (reach, usability, etc.)	(S)
	CAV should facilitate this process (auto-unlocking restraints, doors, etc.)	(S)
	Users may need assistance with egress and package/luggage removal	G
	Make sure CAV users are not exiting on unlevel ground or in obstructed areas such as snowbanks	(S)

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Table 7: Standards Gaps for Accessible CAVs: Difficulty Walking / Lower Body Movement Limitations

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Locate the marked CAV at curbside	Tripping hazards: path to CAV needs to be clear and unobstructed	(S)
	Consider difficulty of parking lot pick-up points (vs. curbside)	G
Validate the correct CAV (e.g., enter code to access vehicle) and authenticate	None	NA
Enter and get seated in the vehicle	Lowered ingress threshold and/or automated steps	(S)
	Handlebars/grab handles	(S)
	Automatically closing doors (especially for door closing)	(S)
	Automatic door only on command (to avoid rushing people)	(S)
	Knowing vehicle type, dimensions, step-in height in advance	G
	Vehicle height may challenge people with mobility limitations	G
	Upper body movement limitations may affect ability to get into the vehicle and get seated	(S)
	Users may need assistance with ingress and package/luggage storage and securement	G
Fasten seatbelt	If seatbelt is damaged or unavailable, need a way to recover	NA
Use an accessible device to summon and communicate with a remote human assistant in the event of an emergency	Fully accessible (reach, usability, etc.)	(S)
Maintain situational awareness at drop-off location in order to find/verify destination	None	NA

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Unfasten seatbelt and exit the vehicle	Handlebars/grab handles	(S)
	Make sure CAV users are not exiting on unlevel ground or in obstructed areas such as snowbanks (this is especially important for people who use wheelchairs or mobility scooters)	(S)
	CAV should facilitate unfastening the seatbelt and exiting the vehicle with, e.g., auto-unlocking restraints and doors, etc.	(S)
	Automated ramps	(S)
	Releasing the seatbelt should not release the vehicle	G
	Auditory instruction – e.g., step down to exit (including information on distance down)	G
	Automatic opening/closing doors may help (smart doors that do not close on occupants)	(S)
	If user falls, how will they recover?	G
	Users may need assistance with egress and package/ luggage removal	G
	CAV needs to ensure that person has fully exited	G
	Make sure CAV users are not exiting on unlevel ground or in obstructed areas such as snowbanks	(S)

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Table 8: Standards Gaps for Accessible CAVs: Wheelchair Users Who Can Transfer

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Locate the marked CAV at curbside	Street parking: a person in a wheelchair is lower than cars, which may occlude their view of the CAV at the curbside. Need for higher visual signage, audible signalling	G
	Curb cut needed at pick-up points for wheelchair/mobility scooter users; pick-up/drop-off points should not be at intersections. Slip-resistant surfaces at drop-off (with textured surface; shorelining)	(S)
	Pick-up point (including waiting area) should avoid rights-of-way (RoW) for other travellers (cars, pedestrians, bike lanes) to mitigate crash risk	(S)
	Should be dedicated pick-up location – not shared with other delivery vehicles	(S)
	Designated pick-up points needed to allow both parking and physical accessibility for wheelchair/mobility scooter users	(S)
	If designated area, should be clearly marked with accessible, multimodal signage	(S)
	Consider difficulty of parking lot pick-up points (vs. curbside)	G

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Validate the correct CAV (e.g., enter code to access vehicle) and authenticate	None	NA
Enter and get seated in the vehicle	Lowered ingress threshold and/or automated steps	(S)
	Handlebars/grab handles	(S)
	Automatically opening and closing doors (especially for door closing)	(S)
	Automatic door only on command (to avoid rushing people)	(S)
	Need for precise location technology to position the CAV user and the vehicle for optimal ingress/egress	G
	Users need to know in advance how to enter and use ramps, lifts, and restraints	G
	Users should know where to position themselves in relation to expected entrance	G
	Users should know vehicle type, dimensions, step-in height in advance	G
	Users may need assistance with ingress and package/luggage storage and securement	G
	Need to standardize minimum clearances	(S)
	Need a way to stow wheelchair/mobility scooter, if the CAV user transfers	G
	Physical design should allow for zero-step entry	
Fasten seatbelt	Height adjustable for children and tall adults	S
	Reachability	S
	CAV should also accommodate caregivers, service animals, friends, family members in attendance as well as packages/luggage	NA
	If seatbelt is damaged or unavailable, need a way to recover	NA
	Auto-donning system needed: belt buckled already, drapes across user (similar to automatic seatbelts from 1980s)	(S)
	Should have a remote assistant available to help	G
Use an accessible device to summon and communicate with a remote human assistant in the event of an emergency	Fully accessible (reach, usability, etc.)	(S)
	Needs to be easy to manipulate and use, but not so easy that it is activated inadvertently	G
Maintain situational awareness at drop-off location in order to find/verify destination	Technology to enable safe egress (e.g., not in path of bike lane)	(S)
	Means to set safe drop-off point	G
	Back-up location if initial location is blocked	G

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Unfasten seatbelt and exit the vehicle	Releasing the seatbelt should not release the vehicle	NA
	Consider issues with unloading purchases including large, bulky items	G
	Need to provide specific information about drop-off point (e.g., presence of bike lane)	G
	When dealing with street-side congestion, the CAV user may be dropped off on the wrong side of the street	NA
	Automatic opening/closing doors may help (smart doors that do not close on occupants)	(S)
	If the CAV user falls, how will they recover?	G
	CAV needs to ensure that the person has fully exited (with packages, etc.)	G
	Ensure that CAV parks where it is safe to exit (adequate clearance, out of right-of-way)	(S)
	Ensure CAV stops close to destination and that this destination is accessible (slip-resistant curb cuts; not blocked; not in the right-of-way of vehicles and bicycles)	(S)
	Users may need assistance with egress and package/luggage removal	G
	Make sure CAV users are not exiting on ground that is not level or in obstructed areas (especially important for wheelchair/mobility scooter users)	(S)

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Table 9: Standards Gaps for Accessible CAVs: Wheelchair Users Who Cannot Transfer

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Locate the marked CAV at curbside	A person using a wheelchair/mobility scooter may not be able to see over street-parked vehicles to where their CAV has stopped for pick-up. Need for higher visual signage or audible signalling	G
	Curb cut needed at pick-up points for wheelchair/mobility scooters users; pick-up/drop-off points should not be at intersection. Slip-resistant surfaces are needed at drop-off (with textured surface and shorelining)	(S)
	Pick-up points (including waiting areas) should avoid rights-of-way (RoW) for other travellers (cars, pedestrians, bike lanes) to mitigate crash risk	(S)
	Pick-up points should be dedicated pick-up location that is not shared with other delivery vehicles	(S)
	Designated pick-up points needed to allow both parking and physical accessibility for wheelchair/mobility scooter users	(S)
	If designated area, should be clearly marked with accessible, multimodal signage	(S)
	Consider difficulty of parking lot pick-up points (vs. curbside)	G
	Angle of ramp navigable by the user is shallow; only one end of the ramp is controlled by the vehicle. Curb cut-out could make ramp steeper. Need to locate suitable pick-up locations that don't increase ramp incline. Approximately 28 cm (11 in) of vertical offset is appropriate (higher incline can be unstable for the wheelchair user)	G
	Designated loading zones with adequate space	(S)
	Subset of CAVs need to be specially equipped to meet the needs of users with special mobility needs	G

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Validate the correct CAV (e.g., enter code to access vehicle) and authenticate	None	NA
Enter and get seated in the vehicle	Automatically opening and closing doors (especially for door closing)	(S)
	Automatic door only on command (to avoid rushing people)	(S)
Enter and get seated in the vehicle	Automated driving vehicle-equivalent solution for wheelchair/mobility scooter accessibility: back opens and person in a wheelchair/mobility scooter drives it into the vehicle and self-docks the device (automated docking solution)	(S)
	Need for precise location technology to position the CAV user and the vehicle for optimal ingress/egress	G
	Wheelchair/mobility scooter user needs to know in advance how to enter and use ramps, lifts, and restraints	G
	Wheelchair/mobility scooter users should know where to position themselves in relation to expected entrance	G
	Knowing vehicle type, dimensions, step-in height in advance	G
	Users may need assistance with ingress and package/luggage storage and securement	G
	Wheelchair/mobility scooter users need to be able to deploy the ramp	(S)
	Need additional vertical space in the CAV to accommodate wheelchairs/mobility scooters	(S)
	Need to standardize minimum clearances	(S)
	Floor surface needs to be smooth and unobstructed – nothing over 0.6 cm (¼ in)	(S)
	Space specified by the US Americans with Disabilities Act (ADA) is quite small; more space is better	NA
	Entering from the side of the vehicle (vs. rear) means that there must be room for the CAV user to turn to be forward-facing (for safety) after entering the vehicle	(S)
	Tiedown solution needs to accommodate a wide range of wheelchairs/mobility scooters; current solutions require human assistance	(S)
	Automatic docking solutions are generally customized (vehicle and wheelchair/mobility scooter) and therefore not suitable for ride-share vehicles	G
	Universal docking interface (UDIG) requires standards for both wheelchair/mobility scooter and vehicle-based docking hardware (similar to trailer hitch standardization for long-haul trucks: more flexibly standardized solution)	S

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Enter and get seated in the vehicle	Guidelines for aligning wheelchairs/mobility scooter with universal docking interface (UDIG)	G
	Adequate head clearance is required to accommodate CAV users and their wheelchair/mobility scooters or other devices	(S)
Fasten seatbelt	Need for purpose-built vehicles for automated wheelchair/mobility scooter tiedowns	(S)
	Reachability	S
	Ensure safe positioning of restraints (e.g., doesn't choke or bind)	G
	CAV should also accommodate caregivers, service animals, friends, family members in attendance as well as packages/luggage	NA
	Automated restraints should be explained in advance	(S)
	Auto-donning system needed: belt buckled already, drapes across user (similar to automatic seatbelts from 1980s)	(S)
	If seatbelt is damaged or unavailable, need a way to recover	NA
	Some users expect belt to provide postural stability during the trip (i.e., prefer locking seatbelts) – possibly make user-selectable	(S)
	Should have a remote assistant available to help	G
Use an accessible device to summon and communicate with a remote human assistant in the event of an emergency	Fully accessible (reach, usability, etc.)	(S)
	Needs to be easy to manipulate and use, but not so easy that it is activated inadvertently	G
Maintain situational awareness at drop-off location in order to find/ verify destination	Means to set safe drop-off point	G
	Back-up location if initial location is blocked	G
	Ensure vehicle stops at a location close to destination that is accessible (curb cuts; not blocked, not in the right-of-way of vehicles, bicycles)	G

Trip Steps	Barriers/Challenges/Potential Solutions	Standard Availability
Unfasten seatbelt and exit the vehicle	CAV should facilitate the process of auto-unlocking restraints, doors, etc.	(S)
	Automated ramps	(S)
	Special parking spots/spaces for rear vs. side-loading vehicles	(S)
	Releasing the seatbelt should not release the vehicle	NA
	Consider issues with unloading purchases including large, bulky items	G
	Need to provide specific information about drop-off point (e.g., presence of bike lane)	G
	When dealing with street-side congestion, the CAV user may be dropped off on the wrong side of the street	NA
	In an emergency, what if there is a malfunction and CAV users are unable to unlatch or undock?	G
	Automatic opening/closing doors may help (smart doors that do not close on occupants)	(S)
	If CAV user falls, how will they recover?	G
	CAV needs to ensure when person has fully exited (with packages, etc.)	G
	Wheelchair/mobility scooter users can face forward while exiting	G
	Require effective guard rails to prevent people falling off the ramps	(S)
	The end of the ramp should flare out so that entry and exit can be at an angle	(S)
	Ensure that the CAV parks where it can be safely exited (adequate c learance, out of right-of-way)	(S)
	Make sure CAV users are not exiting on unlevel ground or in obstructed areas (especially important for wheelchair/mobility scooter users)	(S)

3.3.2.4 User Profiles

Enabling CAV users to set up a user profile in advance would help to ensure the CAV service provider takes into account their needs and sends the appropriate type of vehicle and equipment (e.g., a passenger car rather than a utility vehicle or van, or a wheelchair-accessible vehicle, or one that includes restraints for service animals). This is similar to current practice for paratransit providers; users may request a particular driver who knows their needs in advance and is known to be willing and able to accommodate them.

3.3.2.5 CAV Ride-sourcing Services Should Not Require Users to Have or Use a Hand-held Device

Multiple stakeholders recommended against solutions that require a user to travel with a smartphone or other assistive device for reasons of cost or inability to use such devices without assistance. While it may be necessary to use a telephone, smartphone or computer to initially requisition a CAV ride-sourcing service, the rest of the trip should not require that the CAV user continue to use such devices to complete a trip. It should be noted, however, that multiple stakeholders



"As a matter of safety and security, the vehicle should remain with the CAV user until purposely released by them, so that CAV users are not inadvertently stranded at an unsafe location."

also requested that CAV ride-sourcing services accommodate the use of smartphones and other assistive devices owned or used by people with disabilities if that facilitates their access to everyday functions, including travelling.

3.3.2.6 CAV Should Not Leave a User at Their Destination Until Purposely Dismissed

As a matter of safety and security, the vehicle should remain with the CAV user until purposely released by them, so that CAV users are not inadvertently stranded at an unsafe location. A stakeholder recounted an incident in Canada when a user of a human-operated ride-sourcing service was dropped off in extremely cold weather at a remote location that turned out to be closed. They were unable to summon help and succumbed to hypothermia.

3.3.3 Standardization Opportunities by Disability Type

Stakeholders identified the following standardization opportunities relevant to specific disability types.

3.3.3.1 Blindness

- Consider standardizing the location, interface accessibility, and saliency of CAV devices for authenticating the CAV and for communicating with a remote human assistant. If an audible interface is used, care should be taken to protect the user's personal identifiable information (PII) from other people who may be within hearing range. Standardizing the location and interface accessibility of these CAV aspects also benefits other users.
- Consider establishing guidelines for the provision of advanced information to the user regarding the vehicle type and relevant dimensions (step-in height, head clearance, etc.); seating locations (and which seats are available, if shared with other users); the pick-up location; how to locate the correct CAV; how to locate and use the in-vehicle interface for summoning remote assistance; when and where to exit at destination; and orientation information about the final destination relative to the drop-off location.

3.3.3.2 Low Vision

- In addition to the standardization opportunities identified for CAV users who are blind, those with low vision would benefit from standardization of the visibility aspects of the CAV and its pick-up locations, markings, signage, and displays. This entails enlarging visuals and making them high contrast (e.g., white lettering on black background) to facilitate visibility in a broad range of ambient lighting conditions, which could benefit many sighted users.

3.3.3.3 Deafness / Hearing Impairment

- Consider standardizing saliency parameters for visual cues/signage on CAVs. For example, locating a CAV in a crowded environment can be difficult even for users who are not deaf or hearing impaired. Providing important visual cues and signage could potentially benefit many sighted users, and especially those with mild cognitive impairment.

3.3.3.4 Upper Body Movement Limitations

- Consider standardizing automated (or semi-automated) seatbelts/restraint systems for CAV users with upper body movement limitations that make the manipulation of conventional seatbelts and restraint systems difficult or impossible without human assistance. These solutions would benefit many users, especially those with a limited range of motion or issues with dexterity, as well as people with mild cognitive impairment.
- Consider standardizing accessibility aspects of automated doors (opening and closing). Automated opening and closing doors of the sliding type are common on vans and minivans, but not on wing-type doors where potential interference with vehicles/bicycles/pedestrians travelling in an adjacent right-of-way presents a safety risk. Wing-type doors may also present a challenge for anyone who struggles to move out of the way to accommodate door motion. Automated doors would benefit many users, but especially those with limited mobility, ranges of motion, and dexterity, those who use wheelchairs or mobility scooters, and those with mild cognitive impairment.

3.3.3.5 Wheelchair and Mobility Scooters Use Without the Ability to Transfer

- CAVs for users of wheelchairs and mobility scooters must be purpose-built to accommodate these devices. Such vehicles must be larger and provide necessary clearances for ingress, egress, and (in some cases) manoeuvring within the vehicle. They also need to provide automated (or semi-automated) lockdowns/restraints for both the wheelchair/mobility scooter and for the user to protect them in the event of a crash. The technology for designing and building such vehicles exists, along with numerous standards (both existing and emerging). However, gaps remain in terms of interoperability (i.e., between different wheelchair/mobility scooter designs and automated lockdown mechanisms) and usability/acceptance. As such, additional standards development work would be beneficial.

4 Conclusions

As automated driving technology advances toward driverless capability, some ride-sourcing services will switch from using human-operated vehicles to CAVs. In the absence of a human attendant who is obligated to provide users with disabilities the assistance they require to use a ride-sourcing service, other means of facilitating safe travel need to be provided. By exploring the current legal and technical standards landscape through an environmental scan and positing an approximate goal state for accessibility, this study identifies near-term opportunities to develop standards to enhance the accessibility of CAVs and CAV ride-sourcing services. Developing such standards will help increase the likelihood of adoption by CAV developers and ride-sourcing service providers and help to achieve the goal of removing barriers to inclusion.

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