AVs & Increased Accessibility

Workshop Series

May/July/September, 2019
Washington, DC

AUTO ALLIANCE
DRIVING INNOVATION

This report is a best faith effort to summarize the discussions of all attendees, which comprise of a variety of stakeholders. It is not a verbatim transcript and it does not reflect the views of the Alliance of Automobile Manufacturers or its member companies

Table of Contents

Executive Summary

The Alliance of Automobile Manufacturers organized a three-part Workshop Series, "Automated Vehicles (AVs)[1] & Increased Accessibility", to explore the accessible passenger vehicle transportation needs and potential technology solutions of people with disabilities and older adults. The Workshop Series also assessed broader impacts of assistive technologies, including the current legal and policy landscape. Outcomes of the workshop included findings and recommendations.

Findings and Recommendations

Collaboration: The pathway to future mobility continues to evolve and is dependent on future research and development. While it is being shaped, there is an opportunity to make the transportation systems of tomorrow better by increasing access to people with disabilities. To accomplish this goal, it will take collaboration among many stakeholders, including vehicle manufacturers, AV developers, wheelchair manufacturers, assistive device developers, Federal and state agencies, and most importantly, the users of these technologies.

→ **Recommendation:** There should be increased collaboration between all members of the accessible transportation ecosystem to provide transportation solutions that meet the needs of people with disabilities.

Inclusive AV Design Considerations (Table 1): The information presented and shared during Workshops 1 and 2 was used to create Table 1: *Stakeholder Attendee Input on Potential Inclusive AV Design Considerations* (Chapter 1.2). This table captures the feedback from workshop attendees regarding the proposed vehicle accessibility needs and technical considerations for each stakeholder group. In addition, analysis has been conducted to evaluate how the proposed needs are aligned with universal design goals and how technical considerations map to the system design and operation.

→ **Recommendation:** This table should serve as a starting point for a "Best Practices" document to be used by vehicle manufacturers to understand and incorporate the needs of people with disabilities and older adults in AV design. Input should also be sought from US DOT on this table.

→ **Recommendation:** Vehicle manufacturers and AV developers should seek input from people with disabilities during their design process.

→ **Recommendation:** Vehicle manufacturers and AV developers should provide training opportunities for their engineers regarding inclusive and accessible design.

[1] SAE Levels 3-5

Legal framework: As with many areas for AVs, there is not a one-stop-shop for all the laws, regulations, standards, best practices, and various guidance documents that apply to accessible AV design and operation. From a statutory perspective, certain provisions of the American with Disabilities Act (ADA) and 21st Century Video and Communications Accessibility Act (CVAA) may apply depending on the vehicle use case and ownership/operation. In 1991, the US Access Board (Board) developed standards consistent with the ADA for accessible transportation including buses, vans, rail vehicles, automated guideway systems, and trams. These standards were codified by US DOT at 49 CFR Part 27. The Board has recently issued updated standards for buses and vans, however, they have not yet been adopted as enforceable standards. In addition, the Federal Transit Administration (FTA) has published ADA guidance (FTA Circular 4710.1).

→ **Recommendation:** US DOT should work to publish guidance to help companies navigate the current legal and regulatory framework. This work could also identify areas where additional standards/guidelines would be helpful.

Wheelchair Tiedown and Occupant Restraint Systems: From a wheelchair user perspective, Wheelchair Tiedown and Occupant Restraint Systems (WTORS) should meet the following requirements: (1) provide independent use, (2) protect occupants in both low-g and high-g environments, (3) allow many combinations of vehicles and wheelchairs. Currently, there are no systems that can satisfy all three requirements. Until there is a technology solution that enables unassisted use, human attendants will be required to transport wheelchair users in order to ensure properly securement in the vehicle.

The closest docking options available today are the Universal Docking Interface Geometry (UDIG) standard, and the Q'STRAINT Quantum system, currently used in low-g applications such as buses. However, Q'STRAINT Quantum is not currently suitable for high-g. The UDIG specifications have been included in voluntary standards for some time, but requires compatible hardware in vehicles and on hardware to function. Given that standards are voluntary, no commercial products meeting UDIG requirements are available. However, the location of UDIG attachment hardware on the rear of a wheelchair prevents ground clearance problems found with other systems and would allow independent use in low and high-g conditions.

→ **Recommendation:** Additional research should be performed and serve as the basis to develop WTORS for high-g applications that can be used independently by the wheelchair user and that accommodate many types of vehicles and wheelchairs. Input should be sought from wheelchair and vehicle manufacturers.

→ **Recommendation:** With input from relevant research efforts, interested vehicle and wheelchair manufacturers should develop standards that address some of the current WTORS limitations for wheelchair users (items 1-3 above).

Wheelchair Crash Testing and Insurability: Wheelchairs are defined by the Centers for Medicare and Medicaid Services (CMS) as "durable medical equipment," which states they are meant for in-home use only. Thus, there is no insurance reimbursement for wheelchairs designed for transit and there are no requirements that wheelchairs be crash tested if the wheelchair manufacturer does not market them as such. If a wheelchair manufacturer chooses to market a crash tested chair and gain FDA approval, they must comply with RESNA WC19 / ISO 7176-19.

→ **Recommendation:** New policies or incentives should be explored regarding the insurance reimbursement for wheelchairs designed for in-vehicle use.

Payment: Payment for accessible transportation services is a central issue. Will insurance coverage be available? Will government subsidies be provided? What are the funding models for the entire broad initiative, ranging from investments in vehicles and creation of needed infrastructure, to provision of services?

→ **Recommendation:** Assess potential funding models, including the possibility of allocating federal public transit funds for accessible AV ridehailing beyond paratransit.

Other Major Findings

Transportation Accessibility Needs: The transportation accessibility needs of older adults and people with physical, sensory, and cognitive disabilities are diverse (particularly within the older adults and cognitive disability communities). However, many needs are shared by multiple disability groups so certain technology solutions may have broader benefits. Further, the technologies to address the needs of people with disabilities and older adults may benefit the general population, as evidenced by closed captioning TV and curb ramps on sidewalks. It is necessary to consider the complete trip, not just passenger interaction with a particular vehicle for one segment of the trip.

Vehicle Production Timelines: Vehicle manufacturers are market driven and have long product development cycles. Lead time is critical, especially for major changes to vehicle architecture. Typically, it takes 5 years to bring a new vehicle technology to market (2-year advance development phase plus 3-year pre-production phase). At 18 months before production, typically there is a design freeze as final testing and approvals are completed. To phase in a new technology across all platforms, it typically takes between 3 and 10 years depending upon the complexity and number of platforms.

Universal Design: Universal design is inclusive design. It is a *process* that designers and engineers may follow to ensure they are considering all aspects of user needs. Universal design is defined by eight goals[2]:

1. Body fit

[2] *Universal Design: Creating Inclusive Environments* by Steinfeld, E., & Maisel, J. Hoboken, NJ: Wiley, 2012

2. Comfort
3. Awareness
4. Understanding
5. Wellness
6. Personalization
7. Social integration
8. Cultural appropriateness

Human Machine Interface (HMI) Options: User experience R&D will be necessary to identify the HMI technology solutions that are most impactful, in particular for people with cognitive or sensory disabilities. Multi-modal interactions could be an option, potentially tailored to the individual passenger. Additional considerations include the W3 Consortium Accessibility Guidelines (WCAG) and Section 508 of the American Rehabilitation Act.

Employment: Transportation is a significant barrier to employment for people with disabilities. Accessibility to transportation would enable two million more disabled workers. The Office of Disability Employment Policy (ODEP) at the US Department of Labor (DOL) has a variety of initiatives that aim to increase the number and quality of employment opportunities for people with disabilities. In particular, ODEP and the US Department of Transportation's Accessible Transportation Technologies Research Initiative (ATTRI) recently hosted a dialogue to address how technology innovations, such as AVs, can improve mobility and employment opportunities for people with disabilities. AV stakeholder organizations can also participate in ODEP's online AV community at TransportationInnovation.IdeaScale.com.

Introduction

Automated vehicles (AVs)[3] have the potential to provide increased mobility and independence to people with disabilities and older adults. Nearly 1 in 5 people in the US have a disability (more than 57 million) and 16% of the US population is over the age of 65. According to a recent US DOT study, 25.5 million Americans age 5 and older have self-reported travel-limiting disabilities.[4] For this portion of the US population, increased access to transportation has the potential to improve quality of life by increasing independence, providing access to health care and employment opportunities.

To help advance this topic, the Alliance of Automobile Manufacturers organized a three-part Workshop Series, "AVs & Increased Accessibility," in the spring/summer/fall of 2019. The Workshop Series achieved four main objectives:

1. Establish a forum to facilitate communication among automakers, mobility service providers and user groups including older adults and people with physical, sensory and cognitive disabilities.
2. Convene relevant stakeholder groups to identify and define mobility needs, including designing accessible vehicles for the public, and identifying current gaps and associated opportunities to meet those needs.
3. Identify considerations for designing and operating a transportation solution that meets the needs of older adults and people with physical, sensory and cognitive disabilities.
4. Collect perspectives on research needs to increase AV accessibility and help realize the potential to deliver mobility solutions for older adults and people with physical, sensory and cognitive disabilities.

The first workshop focused on understanding transportation needs of people with disabilities and older adults. The second workshop explored the technology and vehicle design considerations to address these needs, and the third workshop addressed broader impacts of assistive vehicle technology solutions.

The Workshop Series was hosted by the National Academies of Sciences, Engineering, and Medicine ("National Academies") at the Keck Center. Each workshop had roughly 70 participants, including representatives from disability advocacy groups, automobile manufacturing companies, mobility companies, government agencies, the National Academies and universities. The format of each workshop included plenary presentations and a breakout session followed by breakout session report-outs and a large group dialogue.

[3] SAE Levels 3-5

[4] *Travel Patterns of American Adults with Disabilities* by Stephen Brumbaugh, US DOT, Office of the Secretary of Transportation, Bureau of Transportation Statistics, September 2018.

Chapter 1: Inclusive AV Design Considerations

This chapter summarizes the needs and technical considerations identified through the first and second workshops. Workshop 1 explored and identified AV-related needs for older adults and people with physical, cognitive, and sensory disabilities. Workshop 2 explored the concept of universal design, which suggests that technology developers should consider eight goals when developing technology: Body Fit, Comfort, Awareness, Understanding, Wellness, Social Integration, Personalization, and Cultural Awareness. Workshop 2 then had participants identify technology considerations in areas that relate to AV design and operation, including Crashworthiness, In-Vehicle HMI, Accessible Entry and Egress, Ride Service, and a catch-all Other category.

Analysis of the Workshop 1 and 2 discussions yielded 24 stakeholder needs and 76 technical considerations related to those needs. The technical considerations were grouped according to stakeholder group(s), universal design goal(s), and system design and operation category(ies). This analysis explores relationships between these aspects of technology design.

1.1 Method

The input received in Workshops 1 and 2 was evaluated and compiled into a master list of Proposed Needs (Workshop 1) and Technical Considerations (Workshop 2). Based on the Workshop 1 discussions, each Proposed Need was assigned to one or more Stakeholder Group. Based on the Workshop 2 discussions, each Technical Consideration was mapped to one or more System Design and Operation category. Technical Considerations were also evaluated in accordance with the eight Universal Design Goals.

Universal design goals[5] include:

- Body Fit (human performance) – Accommodating a wide range of body sizes and abilities
- Comfort (human performance) – Keeping demands within desirable limits of body function perception
- Awareness (human performance) – Ensuring the critical information for use is easily perceived
- Understanding (human performance) – Making methods of operation and use intuitive and clear
- Wellness (health and wellness) – Contributing to health promotion, avoidance of disease and hazard
- Social Integration (social participation) – Treating all groups with dignity and respect
- Personalization (social participation) – Incorporating opportunities for choice and expression of preference

[5] *Universal Design: Creating Inclusive Environments* by Steinfeld, E., & Maisel, J. Hoboken, NJ: Wiley, 2012

- Cultural Awareness (social participation) – Respecting and reinforcing social and environmental context

System design and operations categories include:

- Crashworthiness - features within the cabin of the vehicle, including seating, geometric design, and restraints and securement
- In-Vehicle HMI - design of systems that allow the human to control, monitor and collect information about the AV and surrounding environment through audio, visual, and haptic interfaces; This includes perception internal to the vehicle, such as occupant state monitoring
- Accessible Entry and Egress - clearance and methods to enter and exit the vehicle, including method for determining and indicating when it is safe to enter and exit the vehicle
- Ride Service - provides users with a way to request and complete trips, supporting activities such as obtaining customer preferences and information, facilitating vehicle identification and entry, planning trip routing, tracking trip progress, and facilitating trip completion
- Other – catch all for other items

This report is a best faith effort to summarize the discussions of all attendees, which comprise of a variety of stakeholders. It is not a verbatim transcript and it does not reflect the views of the Alliance of Automobile Manufacturers or its member companies.

1.2 Results

This table summarizes the feedback received during Workshop 1 and 2 from the various attendees and is not intended to be prescriptive in any way. There may be technologies not listed below that would appropriately address the proposed need.

Table 1: Stakeholder Attendee Input on Potential Inclusive AV Design Considerations. A visually enhanced version of this table is available in ***Appendix A: Technical Considerations Table, Enhanced Version*** however this version may not be accessible to people with visual disabilities.

Proposed Needs Identified in Workshop 1	Technical Considerations Identified in Workshop 2	Relevant Stakeholder Groups	Relevant Universal Design Goals	Relevant System Design and Operations Considerations
Accommodate service animals	Space and floor surface (flat preferred) to accommodate a range of service animals, e.g., chihuahuas to great Danes	Cognitive, Sensory	Body Fit	Crashworthiness
	Entry / Egress for animal	Cognitive, Sensory	Body Fit	Accessible Entry and Egress
	Passenger profiles include service-animal-related needs to customize experience	Cognitive, Sensory	Personalization	Ride Service
	Allergy and contamination concerns for those with allergies or fragile breathing	Cognitive, Sensory	Wellness	Ride Service
App is easy to navigate and understand for people with sensory disabilities	Non-visual interfaces for persons with visual disabilities (e.g., audio and tactical).	Sensory	Awareness, Cultural	In-Vehicle HMI, Ride Service
	Non-audio interfaces for persons with auditory disabilities (e.g., vision and tactical).	Sensory	Awareness	In-Vehicle HMI, Ride Service
	Multi-modal interface lag time (e.g., dynamic braille) can negatively impact trip comfort and response time	Sensory	Awareness	In-Vehicle HMI, Ride Service
	Passenger profiles include disability-related HMI needs to customize experience	Sensory	Awareness, Personalization	In-Vehicle HMI, Ride Service
App is easy to navigate and understand for people with cognitive disabilities	Tunable and multi-modal interfaces can improve comprehension for persons with cognitive disabilities ranging from short term memory loss to Autism, e.g., through reduced verbosity and adjusting stimulus intensity	Cognitive, Older Adults	Awareness, Personalization, Understanding	In-Vehicle HMI, Ride Service

Proposed Needs Identified in Workshop 1	Technical Considerations Identified in Workshop 2	Relevant Stakeholder Groups	Relevant Universal Design Goals	Relevant System Design and Operations Considerations
Understand trip progress, including reminders and the possibility to communicate with remote persons	Tunable and multi-modal interfaces for persons with cognitive disabilities can reduce stress (and increase comfort) through trip progress communications	Cognitive, Older Adults	Awareness, Comfort, Personalization	In-Vehicle HMI, Ride Service
	Tunable and multi-modal interfaces for persons with sensory disabilities to receive trip progress communications	Sensory	Awareness, Comfort, Personalization	In-Vehicle HMI, Ride Service
	Line of sight issue for those in wheelchairs when seated in a vehicle which inhibits the passenger's ability to understand where they are going	Physical	Awareness, Comfort	In-Vehicle HMI, Ride Service
	Placement of screens with trip progress visible to all passengers	Older Adults, Physical	Awareness, Body Fit, Comfort	In-Vehicle HMI, Ride Service
	Tunable and multi-modal interfaces for persons to send and receive communications with rider support or caregivers	Cognitive, Older Adults	Awareness, Comfort, Personalization	In-Vehicle HMI, Ride Service
Emergency communication as needed during trip in a manner that provides sufficient passenger comfort	Consider a support solution specialist in case of vehicle-failure-related emergency, e.g., if person needs to exit vehicle.	Cognitive, Older Adults, Physical, Sensory	Awareness, Comfort, Understanding	Ride Service
	Consider a safe phrase or word, and calming music, lights, or voice for persons with cognitive disabilities	Cognitive, Older Adults	Comfort	In-Vehicle HMI, Ride Service
	Ability to detect and respond to medical emergencies, e.g., heart attack	Older Adults	Wellness	In-Vehicle HMI, Ride Service
	Inform passenger of emergency vehicles	Cognitive, Older Adults, Physical, Sensory	Awareness, Comfort	In-Vehicle HMI, Ride Service
	Public safety officials and personnel are trained for emergency situations	Cognitive, Older Adults, Physical, Sensory	Wellness	Other

Proposed Needs Identified in Workshop 1	Technical Considerations Identified in Workshop 2	Relevant Stakeholder Groups	Relevant Universal Design Goals	Relevant System Design and Operations Considerations
Controls, must be operable by persons of all ranges of motion and strength	Provide a way to open windows without physical operation	Older Adults, Physical	Body Fit, Comfort	In-Vehicle HMI
	Securement of child and child carrying devices within vehicle	Older Adults, Physical	Body Fit	Crashworthiness, Other
Controls, provide control via multiple input modes (audio, tactile)	Standardizing HMI will reduce adjustment users must make between vehicles	Cognitive, Older Adults, Physical, Sensory	Awareness, Understanding	In-Vehicle HMI, Ride Service
Help passenger connect to multimodal services (e.g., rideshare to bus to train)	Connote how to connect to next leg of trip, e.g., where are accessible doors.	Older Adults, Physical	Awareness	In-Vehicle HMI, Ride Service
	Confirm correct location.	Cognitive, Older Adults, Physical, Sensory	Awareness	In-Vehicle HMI, Ride Service
	Provide directions to access next leg of trip	Cognitive, Older Adults, Physical, Sensory	Awareness	In-Vehicle HMI, Ride Service
Help passenger identify best pathway for next destination during trip	Drop off in a location where there are accessible doors, and direct person to accessible pathway	Older Adults, Physical	Awareness, Comfort	Accessible Entry and Egress, Ride Service
Limited strength and range of motion to grab handle and open door	Automated door open & close with door control in the app remotely opening and closing the vehicle door.	Older Adults, Physical	Body Fit	Crashworthiness, In-Vehicle HMI, Ride Service
Help passenger identify correct vehicle and	Provide user with information about accessible entrances to the vehicle and boarding instructions	Cognitive, Older Adults, Physical, Sensory	Awareness	Accessible Entry and Egress, In-Vehicle HMI, Ride Service

Proposed Needs Identified in Workshop 1	Technical Considerations Identified in Workshop 2	Relevant Stakeholder Groups	Relevant Universal Design Goals	Relevant System Design and Operations Considerations
boarding location	Multi-modal queues that help persons with sensory disabilities find car, e.g., audible tones for persons with vision disabilities	Sensory	Awareness	In-Vehicle HMI, Ride Service
Indicate when it is safe to enter and exit	Provide persons with sensory disabilities with multi-modal information about potential hazards outside the vehicle, e.g., cars approaching entry / exit points	Sensory	Awareness	In-Vehicle HMI, Ride Service
	Provide persons with cognitive disabilities with information about potential hazards outside the vehicle, e.g., cars approaching entry / exit points, in a way that improves comprehension, e.g., reduced verbosity	Cognitive, Older Adults	Awareness	In-Vehicle HMI, Ride Service
	Address entry / exit queues for users with WC that have limited line of sight.	Older Adults, Physical	Awareness	Accessible Entry and Egress, In-Vehicle HMI, Ride Service
Wheelchair must be able to enter/exit vehicle	Ramp preferred over lift. For ramps, e.g., edge protection, redundancy, and slope (1" rise per 12" length, ADA regulations)	Older Adults, Physical	Body Fit	Accessible Entry and Egress
	Vehicle positioned at accessible curb area	Older Adults, Physical	Comfort	Accessible Entry and Egress, Ride Service
	Ramp deployment takes significant battery power and weight capacity	Older Adults, Physical	Body Fit	Accessible Entry and Egress
Provide guidance on how to enter and exit vehicle	Provide user with information about potential hazards outside the vehicle, e.g., cars approaching entry / exit points	Cognitive, Older Adults, Physical, Sensory	Awareness, Understanding	Accessible Entry and Egress, In-Vehicle HMI, Ride Service
	For person with sensory disability, provide multimodal information about hazards and safe exiting procedures	Sensory	Awareness, Understanding	Accessible Entry and Egress, In-Vehicle HMI, Ride Service

Proposed Needs Identified in Workshop 1	Technical Considerations Identified in Workshop 2	Relevant Stakeholder Groups	Relevant Universal Design Goals	Relevant System Design and Operations Considerations
Monitor passenger safety and health during trip	Provide a means for passengers to signal an emergency situation using multimodal input (e.g., voice, button)	Cognitive, Older Adults, Physical, Sensory	Awareness	In-Vehicle HMI, Ride Service
	Monitor passenger cognitive comfort and response, and provide communication (from vehicle) to passenger that is multimodal	Cognitive, Older Adults	Awareness, Comfort	In-Vehicle HMI, Ride Service
	Provide a means for passenger to communicate with caregiver or rider support (preferably human)	Cognitive, Older Adults, Physical, Sensory	Awareness, Understanding	In-Vehicle HMI, Ride Service
	Prepare user for potential other passengers and their service animals	Older Adults, Physical, Sensory	Comfort	In-Vehicle HMI, Ride Service
	Provide a means to get people to hospitals	Cognitive, Older Adults, Physical, Sensory	Wellness	In-Vehicle HMI, Ride Service
	Linkages to other health monitoring devices, including pacemaker, hearing aid, phones, smartwatches. Consider FDA in this discussion.	Cognitive, Older Adults, Physical, Sensory	Wellness	In-Vehicle HMI, Ride Service
	For persons with cognitive disabilities, user may consider calming effects (dim lights) and updates about detours or options to avoid loud areas, loud noises preceded by warning (e.g., construction zone), confirmation that the vehicle is on the right path, sensory stimulus can cause problems	Cognitive, Older Adults	Comfort	In-Vehicle HMI, Ride Service
No reliance on smart phone	Passenger pickup for circumstances where the person has a inaccessible phone or no phone at all, e.g., Kiosk and fixed locations	Cognitive, Older Adults, Physical, Sensory	Social	Other, Ride Service

Proposed Needs Identified in Workshop 1	Technical Considerations Identified in Workshop 2	Relevant Stakeholder Groups	Relevant Universal Design Goals	Relevant System Design and Operations Considerations
	Concierge service, such as go-go grandparent	Cognitive, Older Adults, Physical, Sensory	Awareness, Social, Understanding	Other, Ride Service
	Payment methods may be limited, consider options for unbanked (e.g., CVS offers a service)	Cognitive, Older Adults, Physical, Sensory	Social	Other, Ride Service
	Subsidized smart phones	Cognitive, Older Adults, Physical, Sensory	Social	Other, Ride Service
	Travel training can provide guidance to users	Cognitive, Older Adults, Physical, Sensory	Awareness	Other, Ride Service
Personal information must be kept secure	Don’t have to disclose service animal in cases of discrimination	Sensory	Personalization	Other, Ride Service
	Keep a passenger profile, but use preferences rather than health information, and limit access and use of data	Cognitive, Older Adults, Physical, Sensory	Personalization	Ride Service
	Limit access to personal information	Cognitive, Older Adults, Physical, Sensory	Personalization	In-Vehicle HMI, Ride Service
	Incorporate opt out feature	Cognitive, Older Adults, Physical, Sensory	Personalization	In-Vehicle HMI, Ride Service
	Consider auto-delete feature when trip ends, but do not delete from user's settings	Cognitive, Older Adults, Physical, Sensory	Personalization	In-Vehicle HMI, Ride Service

Proposed Needs Identified in Workshop 1	Technical Considerations Identified in Workshop 2	Relevant Stakeholder Groups	Relevant Universal Design Goals	Relevant System Design and Operations Considerations
Wheelchair user restraint systems should accommodate low levels of functional mobility /dexterity and provide a high level of safety	For restraints, consider "roll in" systems like Q'straint for users that may be unable to self-secure restraint	Older Adults, Physical	Body Fit	Crashworthiness
	Passengers have many different heights	Older Adults, Physical	Body Fit	Crashworthiness
	Crashworthiness standard WC19: frame is reinforced, securement brackets for tie down, handles occupant restraint forces	Older Adults, Physical	Body Fit	Crashworthiness
Seating, independence for passengers to locate seat	For users with vision disabilities, identify which seats are available	Sensory	Awareness	In-Vehicle HMI, Ride Service
Seating, independence for passenger to self-secure wheelchairs without assistance	Provide independence for the wheelchair user, i.e., not require an attendant to secure and be simple. Manual tie downs reduce independence, consider FAA airplane wheelchair securement regulation as starting point; automatic securement is ideal	Older Adults, Physical	Body Fit	Accessible Entry and Egress, Ride Service
Seating, maneuver wheelchairs into position	Make entry wide enough and height high enough (60” in at least, see latest data from University of Buffalo on wheelchair dimensions)	Older Adults, Physical	Body Fit, Comfort	Accessible Entry and Egress, Ride Service
	Clearance for wheelchair and person to fit and maneuver within vehicle, which may be a challenge for electric vehicles with batteries	Older Adults, Physical	Body Fit	Accessible Entry and Egress

Proposed Needs Identified in Workshop 1	Technical Considerations Identified in Workshop 2	Relevant Stakeholder Groups	Relevant Universal Design Goals	Relevant System Design and Operations Considerations
	ADA has standards on maneuvering, but these are likely outdated because wheelchair dimensions have increased since the ADA was published, e.g. older standards say wheelchair max dimensions are 30" by 48" length; wheelchairs are getting larger and scooters are even larger; turning radius is larger now	Older Adults, Physical	Body Fit	Accessible Entry and Egress
Seating, universality of securement mechanism for wheelchairs	Provide passenger with guidance on how to secure, e.g., identify which type of securement mechanism	Older Adults, Physical	Awareness	In-Vehicle HMI, Ride Service
	Matching of user WC type and securement type, e.g., through app preferences	Older Adults, Physical	Personalization	Ride Service
	Fit most wheelchairs, e.g., UDIG, Quantum	Older Adults, Physical	Body Fit	Crashworthiness
	Protect the occupant in both low and high g environments	Older Adults, Physical	Wellness	Crashworthiness
	Secure wheelchair and person	Older Adults, Physical	Wellness	Crashworthiness
	Provide minimal impact to the chair (e.g., increasing weight, decreasing foldability)	Older Adults, Physical	Body Fit	Crashworthiness
	Vehicle detects that securement is done correctly	Older Adults, Physical	Body Fit, Wellness	In-Vehicle HMI, Ride Service
Training for passengers and operators with disabilities	Training often done in person, but may potentially be done virtually for some aspects, e.g., websites for basic education, AbleLink, "Be my eyes"	Cognitive, Older Adults, Physical, Sensory	Awareness, Comfort, Understanding	Ride Service, Other
	Aspects of transportation systems that typically require training include payment systems, voice prompts, a-typical situations, fixed pickup locations	Cognitive, Older Adults, Physical, Sensory	Awareness, Comfort, Understanding	Ride Service, Other

Proposed Needs Identified in Workshop 1	Technical Considerations Identified in Workshop 2	Relevant Stakeholder Groups	Relevant Universal Design Goals	Relevant System Design and Operations Considerations
Vehicle does not depart until passenger is ready	Detect that the passenger is ready to move (e.g., enabled by seat belt or wheelchair securement sensor), note that more than one passenger may need to be secured, and a secured wheelchair is not the same as being prepared to depart	Cognitive, Older Adults, Physical, Sensory	Wellness	In-Vehicle HMI, Ride Service
	Provide passenger with a means of signaling he/she is ready, multimodal (e.g., voice, tactile)	Cognitive, Older Adults, Physical, Sensory	Wellness	In-Vehicle HMI, Ride Service
	Vehicle communicates to passenger before moving	Cognitive, Older Adults, Physical, Sensory	Awareness	In-Vehicle HMI

1.3 Discussion of the Results

This analysis represents the results of a high level discussion among a broad array of stakeholders. It has captured the range of potential considerations, but has not gone in-depth into identifying or prioritizing solutions.

The number of technical considerations are described by disability area below. Some of the needs and considerations were shared by multiple groups of people with disabilities and older adults. Considerations for people with physical disabilities included issues largely related to wheelchairs, entry and egress of vehicle, and interacting with machines. People with sensory disabilities benefit from considerations related to interfaces, such as multi-modal and customizable interfaces, but also included other considerations, such as accommodating service animals and handling of emergency situations. Considerations for people with cognitive disabilities focused on interfaces, including intuitive, multi-modal, and customizable interfaces, but also included considerations for issues that arise during a trip and completing the trip. Considerations for older adults largely overlap with the other groups. The following list summarizes the number of technical considerations for each stakeholder group (note that some technical considerations are shared by more than one stakeholder group):

- Physical 51

- Cognitive 38
- Older Adult 59
- Sensory 41

Technical considerations can be categorized by Universal Design goals. Awareness had the largest number of considerations, which indicates the importance of human-machine interfaces to successfully completing trips. These considerations describe types of information users may wish to exchange and ways that interfaces can help with exchanging that information, for example aspects of a trip, including hailing rides, entering and exiting the vehicle, initiating the ride, providing progress updates, dealing with issues that may arise during a trip, and connecting to the next leg of the trip. Given the function of a vehicle is to hold and transport a person, it is not surprising that Body Fit and Comfort are top goals to consider. These categories included considerations such as accommodating wheelchair entry and maneuvering, tunable and multi-modal interfaces, and addressing issues that arise during a trip. Personalization considerations related to customizable interfaces and profiles to accommodate a range of disabilities while protecting personal information. Wellness considerations related to safety, such as crashworthiness and entry / exit challenges. The following list summarizes the number of technical considerations for each Universal Design goal (note that some technical considerations are shared by more than one Universal Design group):

- Body Fit 18
- Comfort 13
- Awareness 25
- Understanding 7
- Wellness 10
- Social Integration 4
- Personalization 12
- Cultural Awareness 1

Technical considerations are described by AV design and operations categories below. Ride service had the most considerations, including many related to managing user data and preferences, which was seen as working hand-in-hand with In-Vehicle HMI to deliver and receive information from passengers. Consistent with presentations during Workshop 1, HMI is a critical area for people with disabilities. Many considerations were identified for in-vehicle HMI, including multi-modal interfaces that are sensitive to a user's disabilities. Crashworthiness considerations largely related to accommodating wheelchairs. Entry and egress considerations included issues related to clearance and access via wheelchair and providing users with guidance on safe entry and egress (e.g., situational awareness). The following list summarizes the number of technical considerations for each AV design and operations category (note that some technical considerations are shared by more than one category):

- Crashworthiness 10
- In-Vehicle HMI 42
- Accessible Entry and Egress 13

- Ride Service 55
- Other 10

1.3 Next Steps

Next steps may seek to build upon Table 1 (Stakeholder Attendee Input on Potential Inclusive AV Design Considerations) to create a “Best Practices” document that could be used by vehicle manufacturers to understand and incorporate the needs of people with disabilities and older adults in AV design.

In addition, overarching questions to consider include:

- How can the anticipated benefits associated with technical considerations be described (quantitatively, qualitatively)?
- What technical, policy, and institutional barriers and pathways influence these technical considerations?
- Where do stakeholders see opportunities to advance solutions for technical considerations?
- What level of detail about user needs is sufficient to allow an engineer to develop system requirements in priority areas?

Chapter 2: Workshop 1

Workshop Series: AVs & Increased Accessibility

Assessing the Passenger Vehicle Transportation Needs of People with Disabilities and Older Adults

Alliance of Automobile Manufacturers

May 3, 2019

Keck Center

National Academies of Sciences, Engineering and Medicine

Washington, DC

2.1 Introduction

The first workshop was held on May 3, 2019, at the National Academies' Keck Center in Washington, DC. There were roughly 70 participants, including representatives from disability advocacy groups, automobile manufacturing companies, mobility companies, government agencies, the National Academies and universities.

The plenary session featured speakers that could represent the needs of those with physical, sensory, and cognitive disabilities, as well as older adults. These speakers helped frame the needs of people with disabilities in the context of transportation, and presented examples of relevant technologies and programs. There was also a session on the processes whereby vehicles are designed, manufactured and brought to market. The emphasis was on where and how new vehicle technologies can be incorporated in the vehicle production process.

The afternoon was devoted to five breakout groups organized by type of disability or older adult with 10-12 people per group. Participants selected the breakout group in which they wished to participate. There were two groups on physical disabilities, and one each on sensory disabilities, cognitive disabilities and older adults. Breakout groups were asked to propose needs whose satisfaction would enable access to AVs by these populations. When possible, breakout group participants identified common needs shared by more than one population. The breakout groups' findings are presented in the Inclusive AV Design Considerations section of this report

2.2 Agenda

	Agenda Item	Speaker(s)
8:00AM	Continental Breakfast	
8:30AM	Welcome	Dr. Al Romig, NAE Executive Officer
8:40AM	Antitrust Reminder	Dr. Anne Marie Lewis, Senior Director of Technology and Innovation Policy, Auto Alliance
8:45AM	Opening Remarks	Dave Schwietert, Interim President and CEO, Auto Alliance
9:00AM	US DOT Remarks	Derek Kan, Under Secretary of Transportation for Policy, US DOT
9:15AM	Keynote - Call to Action	Anna Landre, Student at Georgetown University
9:30AM	The Opportunity – A perspective from the US Department of Labor	Lindsey Teel, Policy Advisor, US DOL Office of Disability Employment Policy (ODEP)
9:50AM	Populations • Physical disabilities • Sensory disabilities	Kent Keyser, Public Policy Fellow, United Spinal Association; Sam Drzymala[6], We Will Ride Coalition John Paré, Executive Director for Advocacy and Policy, National Federation of the Blind (NFB)
10:30AM	Break	
10:50AM	Populations – Continued • Cognitive disabilities • Older adults	Dr. Scott Robertson, Policy Advisor, US DOL Office of Disability Employment Policy (ODEP) & Co-founder of the Autistic Self-Advocacy Network (ASAN) James L. Martin, Founder/Chairman, 60 Plus Association
11:30AM	Auto Design	Scott Schmidt, Senior Director of Safety and Regulatory Affairs, Auto Alliance

[6] Filling in for Henry Claypool, Technology Policy Consultant, AAPD

12:00PM	Breakout Groups (includes working lunch) • Needs of people with cognitive disabilities **ROOM# Keck 105** • Needs of people with physical disabilities (GROUP 1) **ROOM# Keck 101** • Needs of people with physical disabilities (GROUP 2) **ROOM# Keck 201** • Needs of people with sensory disabilities **ROOM# Keck 106** • Needs of older adults **ROOM# Keck 103**	
2:00PM	Break	
2:30PM	Breakout Group Reports & Discussion	Volunteers from each breakout group
4:00PM	Plenary Discussion of Findings & Next Steps	Dr. Anne Marie Lewis, Senior Director of Technology and Innovation Policy, Auto Alliance
4:30PM	Adjourn	

2.3 Plenary Presentations

Dr. Al Romig, Executive Officer at the National Academy of Engineering (NAE), welcomed workshop participants to the Keck Center and provided a brief perspective of the Academy's efforts in complex public-private systems such as the Workshop Series is addressing.

Dave Schwietert, Interim President and CEO of the Auto Alliance, then provided a welcome from the Alliance, outlining the potential individual and societal benefits of AVs and increased mobility. He encouraged workshop participants to exchange ideas freely throughout the Workshop Series and noted the importance of collaboration.

Derek Kan, Under Secretary of Transportation for Policy, US Department of Transportation, provided opening remarks and discussed the goal of universal accessibility in the context of addressing the needs of the entire society. He stressed the importance of integrating accessibility into the overall transportation system, noting that, "If one part of the trip isn't accessible, the trip isn't accessible." He emphasized the need for universal design and inclusion.

Anna Landre, a sophomore at Georgetown University who uses a wheelchair gave a highly motivational keynote. Anna was the valedictorian of her high school and is achieving high marks at Georgetown while living with spinal muscular atrophy. When her health insurance provider said they would stop providing the same level of assistance if she accepted a $14/hour internship, she fought back and has since become an impactful advocate in the community. Regarding access to transportation, Anna's experiences currently involve long wait times. She emphasized that accessible transportation is critical to achieving independence and gave a call to action for the transportation leaders in the room to work together to make this a reality.

Lindsey Teel, Policy Advisor at the Office of Disability Employment Policy (ODEP), US Department of Labor (DOL), emphasized the need for government to partner with industry, advocacy, and the research community to achieve an accessible transportation future. Speaking from the perspective of someone who is visually impaired, she highlighted the opportunity of AVs to give people who are blind or visually impaired the freedom and independence that they hope for. From the DOL perspective, she noted that transportation is a significant barrier to employment. She cited the 2017 study by Securing America's Future Energy (SAFE) and the Ruderman Family Foundation that predicted that two million people with disabilities in the United States could pursue job opportunities with an accessible deployment of AVs. She argued for vehicles to be accessible right off the assembly line, not through retrofit.

Kent Keyser and **Sam Drzymala** delivered the presentation by Henry Claypool, a technology policy consultant to the American Association of People with Disabilities (AAPD). The presentation focused on wheelchairs and wheelchair accessible vehicles (WAVs) and advocated for a sufficient supply of WAVs with service times comparable to other vehicle services. Kent elaborated on these point from a personal perspective as a

wheelchair user. Their presentation also explained that it is often difficult to convert electric vehicles to be wheelchair accessible because the floor cannot safety be lowered due to battery placement. Kent and Sam emphasized that device securement and occupant restraint need to be assured and that that OEMs and government should play a role to meet these needs.

John Paré, Executive Director for Advocacy and Policy at the National Federation of the Blind noted that AVs have the opportunity to provide independence for people who are blind or visually impaired. Transportation is one of the biggest barriers for this community so autonomous vehicles are needed as soon as possible. He stated that the World Health Organization reports 36 million blind people and 217 people million with impaired vision, so the need is immense. John suggested that there are four parts of a trip that should be considered: 1) locating the vehicle to begin the trip, 2) starting the trip, 3) during the trip and 4) the end of the trip. Solutions are needed for calling vehicles (likely via app), navigating to destinations and adjusting air, radio, windows, as well as understanding emerging situations.

Dr. Scott Robertson, a Policy Advisor at the Office of Disability Employment Policy (ODEP) at the US Department of Labor and co-founder of the Autistic Self-Advocacy Network, provided an overview of ODEP's initiatives to increase employment of people with disabilities. Speaking as someone who is autistic, he emphasized cognitive accessibility in terms of improving access for atypical thinking, learning, information processing, and cognitive sensing. Cognitive access features include prompts, multi-sensory access, wording in plain English, and apps that interface to accessible and assistive technology. He provided examples of autism and cognitive access. He advocated travel training for those with disabilities. He also advocated including people with disabilities on design teams.

James L. Martin, founder and Chairman of the 60 Plus Association, stressed the importance of AVs for greater independence and safety. He noted that mobility fosters independence and enhances self-image, which greatly benefits health. He argued that independence is the great equalizer. He advocated that Congress should urgently address this need.

Scott Schmidt, Senior Director of Safety and Regulatory Affairs at the Auto Alliance, provided an overview of how auto makers address vehicle design and development. He began by indicating technology, regulatory, social, and economic barriers to progress, as well as coordination and management of such obstacles. He clarified distinctions between vehicle models and platforms and provided insight into vehicle development cycle timelines. Scott explained that it typically takes 5-7 years to bring a new vehicle technology to market and that major vehicle design decisions need to be made early in the process. At 18 months before production, typically there is a design freeze where final testing and approvals are completed. To phase in a new technology across all platforms, it typically takes between 3 and 10 years depending upon the complexity and number of platforms.

These plenary presentations provided insights and motivations for the subsequent breakout groups to synthesize transportation needs of people with physical, sensory, and cognitive disabilities, as well as older adults.

2.4 Breakout Session Results

These are included in the Inclusive AV Design Considerations section.

2.5 Themes and Takeaways

- Transportation is central to the mobility of people with disabilities and older adults; mobility enables employment, access to services and, for older adults, aging in place.
- Accessibility of transportation requires that a wide variety of needs be met; these needs relate to design of vehicles, operation of vehicles, and passengers' interactions with the vehicle and ride services.
- Recommendations for automated vehicles and ride services include the ability to request vehicle services, locate and access vehicles, monitor trip progress, address issues that arise during a trip, enable a complete trip, and provide disability-specific training.
- Addressing these user needs may have implications on many aspects of technology and vehicle design, including interior design, vehicle body design, human-machine interface, AV software, perception, and ride services.
- These needs and the means to address them cut across disabilities and age – many needs are shared by multiple disability groups, and design enhancements to address these needs may benefit the general population.

Chapter 3: Workshop 2

Workshop Series: AVs & Increased Accessibility

Technologies for Providing Increased Vehicle Accessibility to People with Disabilities and Older Adults

Alliance of Automobile Manufacturers

July 19, 2019

Keck Center

National Academies of Sciences, Engineering and Medicine

Washington, DC

3.1 Introduction

The second of the three-part Workshop Series, "AVs & Increased Accessibility," was held on July 19, 2019, at the National Academies' Keck Center in Washington, DC. There were roughly 70 participants, including representatives from disability advocacy groups, automobile manufacturing companies, mobility companies, government agencies, the National Academies and universities.

The morning was devoted to presentations on technologies and approaches to meet the passenger vehicle mobility needs of older adults and people with physical, sensory, and cognitive disabilities, as identified in the first workshop. These presentations are summarized in the Plenary Presentations section of this report.

The afternoon featured a breakout group session – 4 groups with 15-20 people per group. Participants selected the breakout group in which they wished to participate. Two groups focused on hardware technologies and the other two groups discussed software technologies. Each group was asked to propose technologies and approaches to meet the mobility needs of older adults and people with physical, sensory, and cognitive disabilities. The breakout groups' findings are presented in the Inclusive AV Design Considerations section of this report.

3.2 Agenda

	Agenda Item	Speaker(s
8:00AM	Continental Breakfast	
8:30AM	Welcome	Dr. Guru Madhavan, Director of Programs, National Academy of Engineering
8:40AM	Antitrust Reminder	Anne Marie Lewis, PhD Senior Director Technology & Innovation Policy, Auto Alliance
8:45AM	Opening Remarks	Dave Schwietert, Interim President and CEO, Auto Alliance
8:55AM	US DOT Remarks	Finch Fulton, Deputy Assistant Secretary for Transportation Policy, US DOT
9:05AM	Call to Action	Carol Tyson, Government Affairs Liaison, Disability Rights Education and Defense Fund (DREDF)
9:15AM	Technologies and Tools to Support Vehicle Access for People with Cognitive Disabilities: Design Considerations	Dr. Scott Robertson, Policy Advisor, US DOL Office of Disability Employment Policy (ODEP) & Co-founder of the Autistic Self-Advocacy Network (ASAN)
9:35AM	Wheelchair Accessibility Technologies and Current Overview of Related Standards	Nichole Orton, Biosciences Research Specialist, UMTRI Don Clayback, Executive Director, NCART
10:10AM	Break	
10:20AM	Considerations for Designing Accessible Low Speed Vehicles	David Woessner, Executive Vice President Corporate Development and Regulatory Affairs, LM Industries
10:40AM	US DOT Research Initiatives	Murat Omay, Senior Transportation Program Analyst, ATTRI, US DOT
11:00AM	SAE J3171: Identifying Automated Driving Systems - Dedicated Vehicles (ADS-DV) Passenger Issues for Persons with disabilities	Rebecca Grier, Human Factors Engineer, Ford
11:20AM	Perspectives from Rideshare Provider	Malcom Glenn, Head of Global Policy, Accessibility and Underserved Communities, Uber

11:40AM	Panel Presentation: Universal Design – What does it mean?	Dr. Jordana Maisel, Director of Research Activities, Center for Inclusive Design and Environmental Access (IDeA), University at Buffalo Henry Claypool, Technology Policy Consultant, American Association of People with Disabilities (AAPD)
12:30PM	Breakout Groups (includes working lunch) • Hardware-Based Assistive Vehicle Technologies • Software-Based Assistive Vehicle Technologies	
2:00PM	Break	
2:30PM	Breakout Group Reports & Discussion	Volunteers from each breakout group
4:00PM	Plenary Discussion of Findings & Next Steps	Angel Preston, Director of Safety, Auto Alliance Anne Marie Lewis, PhD, Senior Director Technology & Innovation Policy, Auto Alliance
4:30PM	Adjourn	

3.3 Plenary Presentations

Dr. Guru Madhavan, Director of Programs at the National Academy of Engineering (NAE), welcomed workshop participants to the Keck Center and provided a brief overview of the Academy's work, noting their particular interest in the topics discussed during the Workshop Series. **Dave Schwietert**, Interim President and CEO of the Auto Alliance, then provided a welcome from the Alliance and framed the day's discussion with a focus on potential technologies that could be used to increase AV accessibility.

Finch Fulton, Deputy Assistant Secretary for Transportation Policy at US DOT provided opening remarks, expressing strong DOT support for the workshop series and the objectives being pursued. On the 50th Anniversary of the moon landing, he suggested that full mobility and access for all is akin to a transportation "moon shot" that DOT would like to help make happen.

Carol Tyson, Government Affairs Liaison, Disability Rights Education and Defense Fund (DREDF), provided a call to action. Carol suggested "Reimagining Mobility" as an overarching theme and argued that access to transportation is a civil right. Carol noted the "Curb Cut Effect," whereby everybody benefits from an intervention motivated by the needs of one subpopulation.

Carol noted that AVs have the potential to dramatically improve both mobility and roadway safety for people with disabilities, but access and equity needs must be taken into account. Carol proposed the following universal design and full accessibility policies:

- Anti-discriminatory licensing and insurance
- Accessible AV crashworthiness & occupant safety standards
- Safety for all pedestrians: wheelchair users, bicyclists, people of color
- Funding for travel training

Carol elaborated equity policies:

- Transit, city & state access to data for mobility and congestion planning
- Access for low income and underserved communities
- Title VI of the Civil Rights Act and ADA compliance
- Workforce transition plans

Carol stated that OEMs and AV operators have opportunities to improve vehicle accessibility by listening to and meeting with disability and underserved communities, prioritizing and committing to access and equity, and developing best practice standards (working with and learning from the US Access Board, SAE and US DOJ).

Dr. Scott Robertson, Policy Advisor, US DOL Office of Disability Employment Policy (ODEP) and Co-Founder of Autistic Self-Advocacy Network (ASAN), focused on technologies and tools to support vehicle access for people with cognitive disabilities, with particular emphasis on autism. He stated that ODEP's mission is to increase the number and quality of employment opportunities for people with disabilities. He reported that

transportation to work is a central challenge, and that people with disabilities have a low percentage of drivers' licenses.

Dr. Robertson advocated the importance of paying careful attention to the users' experiences (UX) of people with disabilities and suggested that UX can be explored using a method called Contextual Inquiry. He projected that virtual intelligent agents would play increasingly important roles in supporting people with cognitive disabilities. Their success will depend in understanding cognitive affordances and usability, likely enabled, in part, by cognitive accessibility profiles.

Don Clayback, Executive Director, National Coalition for Assistive and Rehab Technology (NCART), addressed current wheelchair standards and gave an overview of wheelchair transportation issues. Current wheelchair standards are primarily focused on mobility - not transportation - and include performance and durability standards. Don pointed out that while not all wheelchairs are crash tested or compatible with transit options, transportation is only one consideration for wheelchair users when purchasing a wheelchair. Funding is also a key consideration as many insurance plans do not cover crashworthy wheelchairs. Don emphasized that securing third-party funding to cover occupant transit systems must be pursued.

Don also stated that standardization of a docking interface is critical for adoption. Wheelchair manufacturers must be included in discussions around docking design and wheelchair/vehicle integration, particularly as wheelchair design modifications require significant lead time and added cost is a significant constraint (third party funding for wheelchairs is fixed).

Nichole Orton, of the University of Michigan Transportation Research Institute (UMTRI), discussed wheelchair securement systems and occupant protection issues for wheelchair seated passengers. She provided an overview of the current Wheelchair Transportation Safety (WTS) RESNA and ISO standards that have been developed, including Wheelchair Tiedown and Occupant Restraint Systems (WTORS) and the only wheelchair crash test standards, RESNA WC19 / ISO 7176-19. She discussed how different vehicle environments will have different wheelchair safety solutions. Namely, if a vehicle is a low-g environment (e.g. bus), the type of occupant restraint will look different than for a high-g environment (e.g. passenger vehicle).

Nichole stated that for AVs, WTORS will need to satisfy the following requirements: (1) provide independent use, (2) protect occupants in both low-g and high-g environments, (3) allow many combinations of vehicles and wheelchairs. Currently, there are no docking systems that can satisfy all three requirements. Regarding occupant restraints, there are three types of crashworthy seat belts: (1) lap and shoulder belt that only anchor to vehicle, (2) lap and shoulder belt with ends of lap belt anchored to the wheelchair, and (3) a crashworthy 5-point system that anchors to the wheelchair. Wheelchair-anchored belts typically offer a better fit to the rider and are easier to use.

Lastly, Nichole summarized WTS challenges for AVs as follows:

- Ramp angles
- Door openings
- Heavier and larger wheelchairs
- Interior space and room for turns
- Changing distribution of crash directions
- Independent securement of wheelchairs
- Independent donning of seat belts
- Headroom
- Wheelchairs often place occupants higher and more upright than conventional seating, so occupant protection systems need to accommodate this difference in position

David Woessner, EVP for Corporate Development and Regulatory Affairs at LM Industries, discussed their AV, known as "Olli". Olli is an (80% 3D printed) automated transit van that is already deployed on college campuses for fixed routes. The vehicle was designed to provide accessibility solutions for older adults and people with physical, cognitive and sensory disabilities. As such, the vehicle is designed with unique HMI features including audio welcomes passengers by name. David noted that due to privacy concerns, the user is required to "opt in" for the vehicle to have access to any personal information.

Murat Omay, a Senior Analyst at the US DOT Accessible Transportation Technology Research Initiative (ATTRI), focused on ATTRI's funded projects and technology solutions to provide people with disabilities "The Complete Trip." For example, Pathways Solutions is a wayfinding tool designed for wheelchair users and people with visual impairment. Murat noted that the employment rate of people with disabilities (currently half the rate of the overall population) could be significantly increased if transportation options improve. Overall, the ATTRI investment portfolio includes four classes of technologies, all with an emphasis on universal design:

- Smart Wayfinding & Navigation
- Pre-Trip Concierge & Virtualization
- Robotics & Automation
- Safe Intersection Crossing

Dr. Rebecca Grier, a Human Factors Engineer at Ford, presented the work of the SAE Task Force of which she is Chair, *Identifying Automated Driving Systems - Dedicated Vehicles (ADS-DV) Passenger Issues for Persons with Disabilities (SAE J3171)*. This Task Force is developing an Issue Document that provides an assessment of the potential issues to be addressed for providing access to ADS-DVs for people with disabilities. Their findings are informed by interviews with stakeholders, published literature on universal design principles/goals, and accessible HMI standards. Some of the main findings include that on and off-boarding are key issues for people with visual impairments and people using wheeled mobility devices (WMDs). Additionally, the technology solutions will likely differ for people who can transfer themselves to a vehicle seat and those who remain in a WMD.

Rebecca presented universal design principles (see Table 2), reported by in a 1997 report supported by the National Institute for Disability & Rehabilitation research under the U.S. Department of Education.

Principle	Implications
Equitable use	Great user experience/safety for everyone
Flexibility in use	Tasks can be performed by those with differing abilities
Simple & intuitive use	Don't make me think; KISS
Perceptible information	Multimodal; Considers impact of environment (sun, noise)
Tolerance for error	Prevents mistakes; Makes error recovery easy
Low physical effort	Operable without contortion or exertion; by either hand
Size & shape for approach & use	Usable by different body shapes, sizes, & productivity tools

Table 2. Universal Design Principles

Malcolm Glenn, Head of Global Policy, Accessibility, and Underserved Communities at Uber provided an overview of Uber's work to provide access for people with disabilities. He noted that the barriers to AV adoption are regulatory (need a clear pathway for AV testing), psychological (need to educate the public) and technical (need to get the technology right). Over the last year, Uber has begun working with MV Transportation to obtain wheelchair accessible vehicles. They are currently deploying these vehicles in 8 cities. However, there is still a need to lower wait times and obtain more wheelchair accessible vehicles in their fleet.

Dr. Jordana Maisel, Director of Research Activities at the Center for Inclusive Design and Environmental Access (IDEA) at the University of Buffalo focused on the concept of universal design in general and as it relates to AVs. She emphasized that universal design is a *process* and outlined 8 universal goals that the IDEA research center has developed:[7]

1. Body fit
2. Comfort
3. Awareness
4. Understanding
5. Wellness
6. Personalization
7. Social integration

[7] *Universal Design: Creating Inclusive Environments* by Steinfeld, E., & Maisel, J. Hoboken, NJ: Wiley, 2012

8. Cultural appropriateness

Jordana emphasized that accessibility is not equivalent to universal design. For instance, if a wheelchair lift is installed in a particularly quiet part of a museum it may increase accessibility but not satisfy social integration goals due to the noise associated with its use. She emphasized that universal design for AVs should include not just vehicle design, but fleet design, street infrastructure and connectivity of users.

Henry Claypool, Technology Policy Consultant for the American Association of People with Disabilities (AAPD), advocated that technology trends present an opportunity to rethink vehicles. He pointed out that hybrids or fully electric vehicles may store the battery in the floor of the vehicle. This presents an issue for decreasing vehicle height to provide access for people in wheelchairs. He noted that the wheelchair population doubled between year 2010 and 2014. Healthcare appointments are a major driver of mobility needs, with an additional challenge being that institutional care (e.g., hospitals) is transitioning to community care (e.g., clinics). Henry noted that Transportation Network Companies (TNCs) are increasing demand from wheelchair users and that state/local regulators are taking action to require TNCs to provide WAV service or find another way to ensure that mobility demands are met.

3.4. Breakout Session Results

These are included in the Inclusive AV Design Considerations section.

3.5 Themes and Takeaways

- To fulfill advanced mobility goals, it is necessary to consider of the complete trip, not just passenger interaction with a particular vehicle for one segment of the trip.
- Universal design is a *process* defined by eight design goals. These universal design goals should be considered when designing accessible AVs.
- An important passenger objective is employment and career pathways. Mobility is a means to this end.
- Wheelchair transit safety standards for Wheelchair Tiedown and Occupant Restraint Systems (WTORS) have previously focused on low-g environments, e.g. public transit. Additional research may be necessary to develop WTORS for high-g applications and that can be used independently by the wheelchair user. In addition, entry and egress from the vehicle must be considered.
- User experience R&D will be necessary to identify the HMI technology solutions that are most impactful, in particular for people with cognitive or sensory disabilities. Multi-modal interactions could be an option, potentially tailored to the individual passenger. Additional considerations include the WCAG and Section 508 of the American Rehabilitation Act.

- There are current deployments of low speed autonomous shuttles on fixed routes, e.g., on college campuses and tourist destinations. Broader deployment must address a variety of regulatory, psychological, and technical barriers.

Chapter 4: Workshop 3

Workshop Series: AVs & Increased Accessibility

Broader Impacts of Assistive Transportation Technologies

Alliance of Automobile Manufacturers

September 10, 2019

Keck Center

National Academies of Sciences, Engineering and Medicine

Washington, DC

4.1 Introduction

The third of the three-part Workshop Series, "AVs & Increased Accessibility," was held on September 10, 2019, at the National Academies' Keck Center in Washington, DC. There were roughly 70 participants, including representatives from disability advocacy groups, automobile manufacturing companies, mobility companies, government agencies, the National Academies and universities.

The morning was devoted to presentations on broader issues associated with meeting the mobility needs of people with physical, sensory, and cognitive disabilities, as well as older adults that were identified in the first two workshops. The broader issues included legal issues, payment issues, and adoption issues. These presentations are summarized in the Plenary Presentations section of this report.

The afternoon was devoted to four breakout groups with 10-15 people per group. Participants were assigned to breakout groups. The breakout groups addressed legal issues, payment issues, and adoption issues. Breakout groups were asked to suggest how issues should be addressed – regulations, standards development, legislative action, collaboration opportunities or other. The breakout groups' findings are presented in the Section 3.4 of this Chapter.

4.2 Agenda

	Agenda Item	Speaker(s)
8:00AM	Continental Breakfast	
8:30AM	Welcome	Dr. Guru Madhavan, Director of Programs, National Academy of Engineering
8:40AM	Opening Remarks	Dave Schwietert, Interim President and CEO, Auto Alliance
8:50AM	Call to Action	Finch Fulton, Deputy Assistant Secretary for Transportation Policy, US DOT
9:00AM	Antitrust Reminder	Dr. Anne Marie Lewis, Senior Director of Technology and Innovation Policy, Auto Alliance
9:10AM	Keynote	US Representative Cathy McMorris Rodgers (WA-05)
9:20AM	ADA and Transportation Accessibility	David Knight, Trial Attorney, US DOJ
9:40AM	US Access Board's Role in Advancing Accessible Transportation	Scott Windley, Accessibility Specialist, US Access Board Randall Duchesneau III, Accessibility Specialist, US Access Board
10:00AM	Break	
10:10AM	21st Century Video and Communications Accessibility Act (CVAA)	Will Schell, Disability Advisory Committee Designated Federal Officer, Disability Rights Office, FCC
10:30AM	VW Inclusive Mobility Initiative	Shani Jayant, Volkswagen Group of America Principal UX Designer, Inclusive Mobility
10:50AM	Via's Accessibility Initiatives	Andrei Greenawalt, Head of Public Policy, Via
11:10AM	Travel Patterns of American Adults with Disabilities	Stephen Brumbaugh, Economist, Office of the General Counsel, US DOT
11:30AM	Health Care Transformation, Independent Living and the Importance of Accessible Transportation	Kelly Cronin, Deputy Administrator, Innovation and Partnership, HHS Administration for Community Living
11:50AM	AARP's Public Policies on Autonomous Vehicles	Susanna Montezemolo, Policy Development and Integration Director, Consumer & Livable Communities Issues, AARP

12:10PM	The Promise and Challenge of Accessible Autonomous Vehicles: An Automotive Mobility Industry Perspective	Amy Schoppman, Director of Government Relations, NMEDA Kevin Frayne, Director of Advanced Mobility Solutions, BraunAbility Ovidius Turcanu, R&D Manager, Q'STRAINT
12:30PM	Breakout Groups (includes working lunch)	
2:30PM	Break	
3:00PM	Breakout Group Reports & Discussion	Volunteers from each breakout group
4:00PM	Plenary Discussion of Findings & Next Steps	Dr. Anne Marie Lewis, Senior Director of Technology and Innovation Policy, Auto Alliance
4:30PM	Adjourn	

4.3 Plenary Presentations

Dr. Guru Madhavan, Director of Programs at the National Academy of Engineering (NAE), welcomed workshop participants to the Keck Center and provided a brief perspective of the Academy's initiatives, noting that they are interested in advancing the topic of AVs and increased accessibility beyond the Workshop Series. **Dave Schwietert**, Interim President and CEO of the Auto Alliance, then provided a welcome from the Alliance and an overview of what we have learned to date from the Workshop Series.

Finch Fulton, US Department of Transportation, Deputy Assistant Secretary for Transportation Policy, provided opening remarks, expressing strong US DOT support for the workshop series and the objectives being pursued. He noted that on October 29th US DOT will be hosting an event, the *Access and Mobility for All Summit*, that will build upon the momentum of the Alliance Workshop Series. He indicated that this year's version of the US DOT's Federal Strategy for Automated Vehicles will soon be released. Formulation of this strategy has involved more than 30 Federal Departments, Agencies, and EOP Offices.

US Representative Cathy McMorris Rodgers (WA-05) reported on relevant Congressional priorities including the recent voluntarily commitment announcement from automakers to add rear seat reminders in new vehicles as a child safety measure. Rep. Rogers envisions that AVs will increase the efficiency of our current transportation networks by optimizing routing and reducing congestion. However, she cautioned to not forget those who live in rural areas. Rep. Rogers would like to see the US lead the world in realizing the benefits of AVs. For this reason, she is committed to working on federal AV legislation.

David Knight, a Trial Attorney with the US Department of Justice, Civil Rights Division, Disability Rights Section, provided an overview of key terms and types of transportation under the Americans with Disabilities Act (ADA). The ADA was signed in 1990. DOT regulations were issued in 1991. Modifications were issued in 2015. The regulations differentiate "fixed route" vehicles (e.g., city bus) from "demand responsive" vehicles (e.g., taxi). They also differentiate public from private providers.

All providers must not discriminate. According to the ADA, taxis are not required to purchase or lease accessible "automobiles", but vehicles other than "automobiles" must be accessible or have equivalent service available. Shuttle companies operated as "demand responsive" must comply with a different set of rules: purchase or lease of a new vehicle over 8 passengers must be accessible or provide equivalent service. Equivalence is assessed in terms of schedule/response time, fares, area of service, hours and days of service, availability of information, reservation capabilities, capacity, and restrictions. To date, vehicle accessibility standards for public transit have been addressed by the US Access Board and the FTA.

Scott Windley and **Randall Duchesneau III**, Accessibility Specialists with the US Access Board, an independent Federal agency, provided an overview of the US Access Board

("Board"). The laws concerning the Board are the Architectural Barriers Act (1968), Americans with Disabilities Act (1990), Telecommunications Act (1996), Rehabilitation Act Amendments (1998), and the Patient Protection and Affordable Care Act (2010). The areas addressed by the Board include buildings and facilities, recreation facilities, outdoor areas, IT and communications, medical diagnostic equipment, passenger vessels, public rights of way, and transit systems.

Scott and Randall reviewed accessibility guidelines for transportation vehicles in terms of walking surfaces; handrails, stanchions, and handholds; and operable parts. For instance, door opening widths and heights must provide at least 56 inches in height and 32 inches in width. They also reviewed requirements for ramps, lifts, wheelchair spaces, and securement systems.

Will Schell, of the Disability Advisory Committee is a Designated Federal Officer in the Disability Rights Office of the Federal Communications Commission (FCC). He summarized requirements for advanced communications services, which includes internet-based communications like SMS, email, and instant messaging, as well as devices for communication between people such as computers, tablets, phones, etc.

Under the 21st Century Video and Communications Accessibility Act (CVAA), these services must be accessible, compatible and usable, unless "not achievable." These factors should be considered early in the design stage with user input. Designers may build in access or use third party solutions, e.g. apps.

In general, video devices of all sizes must provide captioning, video description, and emergency access, if achievable. Easy access to closed captioning and video description must be provided, perhaps through a button, key or icon. User interfaces must be accessible, if achievable, for people who are blind or visually impaired, including access to on-screen text menus and programming guides. Compliance may be through software, a peripheral device, or other solutions and must be provided free to the requester within a reasonable time.

Shani Jayant, a Principal UX Designer at the Volkswagen Group of America, described Volkswagen's Inclusive Mobility Initiative. The goal of the Initiative is to design vehicles and services that improve transportation and the quality of life for people with disabilities. VW has been working with a range of advocacy groups and has led two government roundtables over the past year.

A major focus of the Initiative is currently wheelchair self-securement. To address this need, VW hopes to find interest among other OEMs and wheelchair manufacturers to work collaboratively to shape cross-industry standards. Looking ahead, VW is also exploring what other interfaces to assistive devices or tech ecosystems may benefit from standardization. Shani noted that they are not looking to standardize the end user interfaces, which provide opportunities for innovation and differentiation among automotive OEMs.

Andrei Greenawalt, is the Head of Public Policy at Via Transportation, Inc., an American Transportation Network Company (TNC) and real-time ridesharing company headquartered in New York City. He addressed the company's commitment to convenient, affordable, sustainable, and accessible shared mobility. Via's on-demand public transit service will incorporate AVs once available. Andrei provided brief overviews of their ongoing service offerings in the US, Europe, and Australia.

Stephen Brumbaugh, an Economist in the Office of the General Counsel at the US Department of Transportation discussed travel patterns of American adults with disabilities. He reported the following conclusions based on the 2017 National Household Travel Survey:

- People with disabilities make fewer trips and travel by personal vehicle less often than people without disabilities.
- People with disabilities who live in rural areas have additional differences in travel behavior.
- Technology may help people with disability-related transportation issues, but people with disabilities use related technologies less often.

His current research addresses the difficulties people have getting the transportation they need, trips that people do not take, circumstances that would lead people to give up driving, and vehicles modified with adaptive devices or equipment.

Kelly Cronin, Deputy Administrator, Innovation and Partnership, Department of Health and Human Services (HHS), Administration for Community Living, discussed the Social Determinants of Health and the importance of accessible transportation in this framework. She noted that transportation is central to independent living. However, 48% of older adults are "mobility impaired." Lack of transportation is the leading cause of no shows for medical appointments. Many of these issues will be addressed in HHS' new initiative, the Assistive Technology Leadership Expert Panel.

Susanna Montezemolo is the Policy Development and Integration Director for Consumer & Livable Communities Issues at AARP. She is focused on enhanced mobility for people of all ages and ability levels. The AARP Autonomous Vehicle Policy includes considerations of universal design, equity in AV service, cost, impact on public transit and other forms of transportation, and underserved populations. AARP also advocates for advancing safety, consumer education, consumer protections, and integration with the built environment. She suggested that workshop participants read AARP's Public Policy Book, Chapter 9: Livable Communities.

The last plenary presentation was by **Amy Schoppman**, Director of Government Relations at the National Mobility Equipment Dealers Association (NMEDA), **Kevin Frayne**, Director of Advanced Mobility Solutions at BraunAbility, and **Ovidius Turcanu**, R&D Manager at Q'STRAINT. NMEDA is the trade association for the automotive mobility industry of which BraunAbility and Q'STRAINT are members. BraunAbility performs van conversions to enable access by people with disabilities and Q'STRAINT provides securement technologies. Their collective focus is on independence/quality of life,

employment opportunities, increased transportation options, and improved transportation experiences.

After providing an overview of the offerings of BraunAbility and Q'STRAINT, the three speakers summarized the challenges they are mutually addressing. There are thousands of different mobility device designs, including wheelchairs and scooters. Existing mobility device design standards are insufficient. Safety testing standards for AVs are currently undefined. The structural base/floor strength of AV must be considered in order to achieve wheelchair/mobility device securement, load distribution. They raised two questions:

- Will the market support a fully independent wheelchair/mobility device securement system?
- When will fully independent wheelchair/mobility device securement systems be necessary?

Answering these questions requires understanding the interactions of standards, legislation, and markets/payments.

4.4 Breakout Session Results

Four concurrent breakout sessions with 15-20 people per group were conducted to explore the broader impacts that AVs and increased accessibility have on current legal and policy frameworks. The sessions were organized by impact areas grouped into three broad categories: legal, payment, and adoption. Two of the breakout sessions looked at payment issues. For each issue, the group discussed potential policy options, including regulations, standards, legislation, and collaboration among stakeholders.

Participants discussed concepts introduced by speakers from the morning sessions, which included a variety of agency jurisdictions and policies. These speakers helped frame the needs of people with disabilities in the context of relevant regulations, standards, insurance, subsidies and consumer adoption issues. Findings from the breakout sessions detail diverse and collective insight of roughly 70 stakeholders, who represented perspectives of those with physical, sensory, and cognitive disabilities, as well as older adults, in addition to the presentations from the expert speakers. Many of the impacts cut across stakeholder groups, i.e., addressing a single payment issue has the potential to benefit multiple groups of people with disabilities and older adults.

The breakout groups discussed the following topics:

- Legal: ADA compliance, CVAA compliance, and safety regulations, covering a range jurisdictions and programs at DOJ, FCC, DOT/NHTSA, and the Access Board.
- Payment: Personally paid services (e.g., programs to reduce personal cost), insurance (e.g., coverage for ADS), and subsidies (e.g., discounted fares and offsets from revenue from increased employment).

- Adoption: Consumer acceptance and trust, exceptions to regulations (e.g., FMVSS), and paradigm shits (e.g., travel behavior)

The breakout discussions yielded several observations:

- Legal: Accessibility compliance for AVs may result in broader adoption, but the boundaries of jurisdictions governing accessibility compliance are not well understood, and developing effective policy depends on a better understanding of gaps and opportunities.

- Payment: Regulatory and policy reform could make assistive transportation technology more affordable. Ensuring that funding is appropriated towards intended programs can be a challenge.

- Adoption: In order for people with disabilities to benefit from AV technologies, the considerable challenge of consumer trust must be overcome.

One primary outcome from these breakout sessions was to identify implications for future work. Breakout group participants suggested the following opportunities to advance accessibility for AVs through policy:

- Legal:
    - Research is needed to understand the complex ecosystem of legal jurisdictions, including DOJ, FCC, DOT, and the Access Board, and where there are overlaps or gaps that future standards, regulations, and other policy instruments could address. This should consider authorities related to ADA, CVAA, Web Content Accessibility Guidelines (WCAG) and crashworthiness compliance. This research will benefit from collaboration among many public and private stakeholders.

- Payment:
    - Standards may provide clarity and ease reimbursement. For example, standards for wheelchair interface/docking could reduce costs for equipment manufacturers, while increased availability will increase competition and potentially reduce costs. Standards could harmonize AV accessibility design such that more vehicles work for more wheelchair users, thereby improving the level of service and experience for users.
    - Policy reform for tax incentives, such as clarifying coverage under Medicare and subsidies, could reduce out of pocket costs. For example, the cost of certain users may be subsidized across a large user base.
    - Research and collaboration is needed to better understand relevant funding allocations by jurisdiction, and what may be used towards AV accessible technologies.
    - Cities, states, and federal governments receive quantifiable economic benefits from increased employment of people with disabilities and can use

subsidies or other funding programs to maximize economic upside for each entity.

- Adoption:
  - Collaboration, including AV demonstrations and education that expose the public to the technology, can reduce risks, and help consumers understand implementation challenges. Education should consider the unique understanding of AVs within various demographics.
  - Clear definitions and responsibility for liability, including through regulation, legislation, and standards is needed.
  - Accessibility of transportation likely requires that a wide variety of needs be met. These needs may relate to regulations that govern design of vehicles, operation of vehicles, and passengers' interactions with the vehicle and ride services. More research is needed to quantify costs and benefits of assistive transportation technologies, and objective analysis is needed to support regulatory decision making.
  - Technologies may benefit from regulatory exemptions and updates, e.g., FMVSS exemptions allowing a limited deployment of AVs without driver controls. People with disabilities may be willing to accept higher risk to gain mobility benefits associated with these regulatory exemptions. Research is needed to better understand and quantify benefits of regulatory changes that improve accessibility of users with physical, sensory, and cognitive disabilities, as well as older adults.
  - Changing driver behavior, e.g., from a single occupant to multiple occupant rides, may benefit from targeted campaigns that recognize varied concerns within different demographics.

4.5 Themes and Takeaways

- Transportation is an influential Social Determinant of Health. Currently, the lack of transportation is the leading cause of no-shows for medical appointments.

- As with many areas for AVs, there is not a one-stop-shop for all the laws, regulations, standards, best practices, etc. that apply to accessible AV design and operation. From a statutory perspective, certain provisions of the ADA and 21st Century Video and Communications Accessibility Act (CVAA) may apply depending on the vehicle use case and ownership/operation. The US Access Board has developed standards for accessible vehicles used in surface transportation.

- Volkswagen's Inclusive Mobility Initiative is focused on helping design accessible transportation solutions for people with disabilities; in particular, wheelchair and occupant securement solutions.

- Via, a Transportation Network Company (TNC), has a software app platform that can provide increased access for older adults and people with disabilities.

- Mobility equipment providers are facing new challenges due to the increasing number of mobility device designs (including wheelchairs and scooters) and the lack of standards that address this issue and meet the needs of mobility equipment users.

- Payment for accessible transportation services is a central issue. Will insurance coverage be available? Will government subsidies be provided? What are the funding models for the entire broad initiative, ranging from investments in vehicles and creation of needed infrastructure, to provision of services?

This report is a best faith effort to summarize the discussions of all attendees, which comprise of a variety of stakeholders. It is not a verbatim transcript and it does not reflect the views of the Alliance of Automobile Manufacturers or its member companies.

Appendix A: Technical Considerations Table, Enhanced Version with Visual Effects

This table summarizes the feedback received during Workshop 1 and 2 from the various attendees and is not intended to be prescriptive in any way. There may be technologies not listed below that would appropriately address the proposed need.

Please note that an accessible version of this table is provided in Chapter 1.

Proposed Needs Identified in Workshop 1	Technical Considerations Identified in Workshop 2	Stakeholder Group				Universal Design Goal								System Design and Operation				
		Physical	Cognitive	Older Adults	Sensory	Body Fit	Comfort	Awareness	Understanding	Wellness	Social Integration	Personalization	Cultural Awareness	Crashworthiness	In-Vehicle HMI	Accessible Entry	Ride Service	Other
Accommodate service animals	Space and floor surface (flat preferred) to accommodate a range of service animals, e.g., chihuahuas to great Danes		X		X	X								X				
	Entry / Egress for animal		X		X	X										X		
	Passenger profiles include service-animal-related needs to customize experience		X		X							X					X	
	Allergy and contamination concerns for those with allergies or fragile breathing		X		X					X							X	
App is easy to navigate and understand for people with sensory disabilities	Non-visual interfaces for persons with visual disabilities (e.g., audio and tactile).				X			X					X		X		X	
	Non-audio interfaces for persons with auditory disabilities (e.g., vision and tactile).				X			X							X		X	
	Multi-modal interface lag time (e.g., dynamic braille) can negatively impact trip comfort and response time				X			X							X		X	
	Passenger profiles include disability-related HMI needs to customize experience				X			X				X			X		X	
App is easy to navigate and understand for people with cognitive disabilities	Tunable and multi-modal interfaces can improve comprehension for persons with cognitive disabilities ranging from short term memory loss to Autism, e.g., through reduced verbosity and adjusting stimulus intensity		X	X				X	X			X			X		X	
Understand trip progress, including reminders and the possibility to communicate with remote persons	Tunable and multi-modal interfaces for persons with cognitive disabilities can reduce stress (and increase comfort) through trip progress communications		X	X			X	X				X			X		X	
	Tunable and multi-modal interfaces for persons with sensory disabilities to receive trip progress communications				X		X	X				X			X		X	
	Line of sight issue for those in wheelchairs when seated in a vehicle which inhibits the passenger's ability to understand where they are going	X					X	X							X		X	
	Placement of screens with trip progress visible to all passengers	X		X		X	X	X							X		X	
	Tunable and multi-modal interfaces for persons to send and receive communications with rider support or caregivers		X	X			X	X				X			X		X	

This report is a best faith effort to summarize the discussions of all attendees, which comprise of a variety of stakeholders. It is not a verbatim transcript and it does not reflect the views of the Alliance of Automobile Manufacturers or its member companies.

Proposed Needs Identified in Workshop 1	Technical Considerations Identified in Workshop 2	Stakeholder Group				Universal Design Goal								System Design and Operation				
		Physical	Cognitive	Older Adults	Sensory	Body Fit	Comfort	Awareness	Understanding	Wellness	Social Integration	Personalization	Cultural Awareness	Crashworthiness	In-Vehicle HMI	Accessible Entry and	Ride Service	Other
Emergency communication as needed during trip in a manner that provides sufficient passenger comfort	Consider a support solution specialist in case of vehicle-failure-related emergency, e.g., if person needs to exit vehicle	X	X	X	X		X	X	X								X	
	Consider a safe phrase or word, and calming music, lights, or voice for persons with cognitive disabilities		X	X			X								X		X	
	Ability to detect and respond to medical emergencies, e.g., heart attack			X						X					X		X	
	Inform passenger of emergency vehicles	X	X	X	X		X	X							X		X	
	Public safety officials and personnel are trained for emergency situations	X	X	X	X					X								X
Controls, must be operable by persons of all ranges of motion and strength	Provide a way to open windows without physical operation	X		X		X	X								X			
	Securement of child and child carrying devices within vehicle	X		X		X								X				X
Controls, provide control via multiple input modes (audio, tactile)	Standardizing HMI will reduce adjustment users must make between vehicles	X	X	X	X			X	X						X		X	
Help passenger connect to multimodal services (e.g., rideshare to bus to train)	Connote how to connect to next leg of trip, e.g., where are accessible doors	X		X				X							X		X	
	Confirm correct location	X	X	X	X			X							X		X	
	Provide directions to access next leg of trip	X	X	X	X			X							X		X	
Help passenger identify best pathway for next destination during trip	Drop off in a location where there are accessible doors, and direct person to accessible pathway	X		X			X	X								X	X	
Limited strength and range of motion to grab handle and open door	Automated door open & close with door control in the app remotely opening and closing the vehicle door.	X		X		X								X	X		X	
Help passenger identify correct vehicle and boarding location	Provide user with information about accessible entrances to the vehicle and boarding instructions	X	X	X	X			X							X	X	X	
	Multi-modal queues that help persons with sensory disabilities find car, e.g., audible tones for persons with vision disabilities				X			X							X		X	
Indicate when it is safe to enter and exit	Provide persons with sensory disabilities with multi-modal information about potential hazards outside the vehicle, e.g., cars approaching entry / exit points				X			X							X		X	
	Provide persons with cognitive disabilities with information about potential hazards outside the vehicle, e.g., cars approaching entry / exit points, in a way that improves comprehension, e.g., reduced verbosity		X	X				X							X		X	
	Address entry / exit queues for users with WC that have limited line of sight	X		X				X							X	X	X	
Wheelchair must be able to enter/exit vehicle	Ramp preferred over lift. For ramps, e.g., edge protection, redundancy, and slope (1" rise per 12" length, ADA regulations)	X		X		X										X		
	Vehicle positioned at accessible curb area	X		X			X									X	X	
	Ramp deployment takes significant battery power and weight capacity	X		X		X										X		
Provide guidance on how to enter and exit vehicle	Provide user with information about potential hazards outside the vehicle, e.g., cars approaching entry / exit points	X	X	X	X			X	X						X	X	X	
	For person with sensory disability, provide multimodal information about hazards and safe exiting procedures				X			X	X						X	X	X	

This report is a best faith effort to summarize the discussions of all attendees, which comprise of a variety of stakeholders. It is not a verbatim transcript and it does not reflect the views of the Alliance of Automobile Manufacturers or its member companies.

Proposed Needs Identified in Workshop 1	Technical Considerations Identified in Workshop 2	Stakeholder Group				Universal Design Goal								System Design and Operation				
		Physical	Cognitive	Older Adults	Sensory	Body Fit	Comfort	Awareness	Understanding	Wellness	Social Integration	Personalization	Cultural Awareness	Crashworthiness	In-Vehicle HMI	Accessible Entry and	Ride Service	Other
Provide guidance on how to enter and exit vehicle	Provide user with information about potential hazards outside the vehicle, e.g., cars approaching entry / exit points	X	X	X	X			X	X						X	X	X	
	For person with sensory disability, provide multimodal information about hazards and safe exiting procedures				X			X	X						X	X	X	
Monitor passenger safety and health during trip	Provide a means for passengers to signal an emergency situation using multimodal input (e.g., voice, button)	X	X	X	X			X							X		X	
	Monitor passenger cognitive comfort and response, and provide communication (from vehicle) to passenger that is multimodal		X	X			X	X							X		X	
	Provide a means for passenger to communicate with caregiver or rider support (preferably human)	X	X	X	X			X	X						X		X	
	Prepare user for potential other passengers and their service animals		X	X	X		X								X		X	
	Provide a means to get people to hospitals	X	X	X	X					X					X		X	
	Linkages to other health monitoring devices, including pacemaker, hearing aid, phones, smartwatches. Consider FDA in this discussion.	X	X	X	X					X					X		X	
	For persons with cognitive disabilities, user may consider calming effects (dim lights) and updates about detours or options to avoid loud areas, loud noises preceded by warning (e.g., construction zone), confirmation that the vehicle is on the right path, sensory stimulus can cause problems		X	X			X								X		X	
No reliance on smart phone	Passenger pickup for circumstances where the person has a inaccessible phone or no phone at all, e.g., Kiosk and fixed locations	X	X	X	X						X						X	X
	Conceirge service, such as go-go grandparent	X	X	X	X			X	X		X						X	X
	Payment methods may be limited, consider options for unbanked (e.g., CVS offers a service)	X	X	X	X						X						X	X
	Subsidized smart phones	X	X	X	X						X						X	X
	Travel training can provide guidance to users	X	X	X	X			X									X	X
Personal information must be kept secure	Don't have to disclose service animal in cases of discrimination				X							X					X	X
	Keep a passenger profile, but use preferences rather than health information, and limit access and use of data	X	X	X	X							X					X	
	Limit access to personal information	X	X	X	X							X			X		X	
	Incorporate opt out feature	X	X	X	X							X			X		X	
	Consider auto-delete feature when trip ends, but do not delete from user's settings	X	X	X	X							X			X		X	
Wheelchair user restraint systems should accommodate low levels of functional mobility /dexterity and provide a high level of safety	For restraints, consider "roll in" systems like Q'straint for users that may be unable to self secure restraint	X		X		X								X				
	Passengers have many different heights	X		X		X								X				
	Crashworthiness standard WC19: frame is reinforced, securement brackets for tie down, handles occupant restraint forces	X		X		X								X				

Proposed Needs Identified in Workshop 1	Technical Considerations Identified in Workshop 2	Stakeholder Group				Universal Design Goal								System Design and Operation				
		Physical	Cognitive	Older Adults	Sensory	Body Fit	Comfort	Awareness	Understanding	Wellness	Social Integration	Personalization	Cultural Awareness	Crashworthiness	In-Vehicle HMI	Accessible Entry and	Ride Service	Other
Seating, independence for passengers to locate seat	For users with vision disabilities, identify which seats are available				X			X							X		X	
Seating, independence for passenger to self-secure wheelchairs without assistance	Provide independence for the wheelchair user, i.e., not require an attendant to secure and be simple. Manual tie downs reduce independence, consider FAA airplane wheelchair securement regulation as starting point; automatic securement is ideal	X		X		X										X	X	
Seating, maneuver wheelchairs into position	Make entry wide enough and height high enough (60" in at least, see latest data from University of Buffalo on wheelchair dimensions)	X		X		X	X									X	X	
	Clearance for wheelchair and person to fit and maneuver within vehicle, which may be a challenge for electric vehicles with batteries	X		X		X										X		
	ADA has standards on maneuvering, but these are likely outdated because wheelchair dimensions have increased since the ADA was published, e.g. older standards say wheelchair max dimensions are 30" by 48" length; wheelchairs are getting larger and scooters are even larger; turning radius is larger now	X		X		X										X		
Seating, universality of securement mechanism for wheelchairs	Provide passenger with guidance on how to secure, e.g., identify which type of securement mechanism	X		X				X							X		X	
	Matching of user WC type and securement type, e.g., through app preferences	X		X								X					X	
	Fit most wheelchairs, e.g., UDIG, Quantum	X		X		X								X				
	Protect the occupant in both low and high g environments	X		X						X				X				
	Secure wheelchair and person	X		X						X				X				
	Provide minimal impact to the chair (e.g., increasing weight, decreasing foldability)	X		X		X								X				
	Vehicle detects that securement is done correctly	X		X		X				X					X		X	
Training for passengers and operators with disabilities	Training often done in person, but may potentially be done virtually for some aspects, e.g., websites for basic education, AbleLink, "Be my eyes"	X	X	X	X		X	X	X								X	X
	Aspects of transportation systems that typically require training include payment systems, voice prompts, a-typical situations, fixed pickup locations	X	X	X	X		X	X	X								X	X
Vehicle does not depart until passenger is ready	Detect that the passenger is ready to move (e.g., enabled by seat belt or wheelchair securement sensor), note that more than one passenger may need to be secured, and a secured wheelchair is not the same as being prepared to depart	X	X	X	X					X					X		X	
	Provide passenger with a means of signaling he/she is ready, multimodal (e.g., voice, tactile)	X	X	X	X					X					X		X	
	Vehicle communicates to passenger before moving	X	X	X	X			X							X			