Automated Shuttles and Buses for All Users

November 2023 | Final Report

SAFE-D
SAFETY THROUGH DISRUPTION

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16. Abstract

Numerous demonstrations and deployments of automated shuttles and buses are occurring in downtown areas, university campuses, business and medical parks, and entertainment complexes throughout the United States. This research project focused on ensuring that individuals with disabilities have equal and safe access to automated shuttles and buses to improve their mobility. The project introduced individuals with disabilities to an automated shuttle in Arlington, TX and a Smart Intersection in College Station, TX, assessing their safety perceptions and obtaining information on any safety concerns about their complete trip. The project identified enhancements in planning, vehicles, service and operations, and the street system and built environment to ensure that individuals with disabilities can safely access and use automated shuttles.

The research included interviewing individuals with disabilities before and after riding in the Arlington automated shuttles and online interviews of the Texas A&M University students using mobility devices obtaining feedback on the Smart Intersection and automated shuttles. Virtual and in-person workshops were held examining possible automated shuttle routes on the Texas A&M University–San Antonio campus and the adjacent VIDA development, and the Texas A&M University System RELLIS campus in Bryan. Guidelines for enhancing automated shuttles for individuals with mobility and visual impairments were developed.

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Abstract

Individuals using wheelchairs and those with limited or no sight face extra safety issues in the use of public transit, as well as in the use of personal vehicles, including getting to and from a bus or shuttle stop, getting on and off a vehicle, and being secure while riding in a vehicle. The pilots and demonstrations of automated shuttles and buses have included limited participation by the disabled community. This project helps address that gap by introducing individuals with disabilities to an automated shuttle in Arlington, TX and a Smart Intersection in College Station, TX, assessing their safety perceptions of riding in the shuttle, and assessing information on their complete trip. The project identified improvements in the vehicles, service operations, and the street system and built environment to ensure that individuals with disabilities have equal and safe access to automated shuttles and buses to improve their mobility.

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Introduction

Pilots, demonstrations, and deployments of automated shuttles and buses are occurring in downtown areas, university campuses, business parks, entertainment complexes, and other areas throughout the United States and other countries. This research project was undertaken to help ensure that automated shuttles and buses address the safety concerns and mobility needs of individuals with disabilities, including persons using wheelchairs and other mobility devices and those with limited or no sight. The project introduced individuals with disabilities to an automated shuttle in Arlington, TX and a Smart Intersection in College Station, TX, and assessing their safety perceptions of automated shuttles and signalized intersections and obtaining information on safety concerns with their complete trip and the built environment. The research results were used to identify enhancements in planning, vehicles, service and operations, and the street system and built environment to ensure that individuals with disabilities have equal and safe access to automated shuttles to improve their mobility.

Following this introduction, the remainder of this report is divided into four major sections. The background section highlights a few examples of incorporating the needs of individuals with disabilities via automated shuttles. The research activities and results are summarized next, including details about interviews of individuals with disabilities before and after riding in the automated shuttles in Arlington; the results of online interviews to gain feedback on automated shuttles and the Smart Intersection; and descriptions of virtual and in-person workshops focusing on possible automated shuttle services on the Texas A&M University, San Antonio (TAMU–SA) campus and the adjacent VIDA mixed-use development, and the Texas A&M University System (TAMUS) RELLIS campus in Bryan. Guidelines for enhancing automated shuttles for individuals with mobility and visual impairments based on the results of these research activities are then presented. The report concludes with a summary of the additional products. focusing on education and workforce development, technology transfer, and data developed as part of the research project. The appendices include the recruitment materials and interview scripts used with the rides in the Arlington automated shuttle and the on-line interviews on automated shuttles and the Smart Intersection.

Background

Numerous pilots, demonstrations, and deployments of automated shuttles and buses continue in metropolitan areas, smaller communities, and rural areas in the US. Similar projects are also underway in Europe and countries throughout the world. These projects have ranged from one-day showcases to multi-month or year-long demonstrations to ongoing deployment programs. Information on these activities has been summarized, presented, and documented in reports, conference proceedings, book chapters, articles, and videos.[1, 2, 3, 4, 5] In addition, research is

underway on related topics at many universities and research institutes, the Transit Cooperative Research Program, and other organizations.

Despite the growing number of projects such as those noted above, focus on the needs of individuals with disabilities has been limited in some of the pilots and demonstrations. The pilot projects conducted by the Minnesota Department of Transportation (MnDOT) and the National Parks Service (NPS) are summarized here as examples of projects that included addressing the safety and mobility needs of individuals with disabilities.

MnDOT has conducted numerous research projects and pilots focusing on automated shuttles, through the connected and automated vehicle (CAV) program, known to as the Destination CAV program. Testing an EasyMile automated shuttle under winter weather conditions at the MnROAD research facility represented an initial project. The shuttle was also operated on the Nicollet Mall in downtown Minneapolis during Super Bowl Week in January 2018. MnDOT hosted additional events to introduce the automated shuttle to diverse groups, including members of the Minnesota Chapter of the National Federation for the Blind.[3]

The Med City Mover represented the second pilot conducted by MnDOT. It included the 12-month operation of two EasyMile EZ10 vehicles in downtown Rochester, which is the home of the Mayo Clinic. The project partners included the City of Rochester, the Mayo Clinic, and Destination Medical Center. First Transit and EasyMile were the technology and transit operations partners. Vehicle and project accessibility features included wheelchair ramps and wheelchair tie-downs, signage in Braille, and the use of messages, trolly bells, and video with closed captioning to communicate with passengers with disabilities.[4]

The third pilot in 2022 and 2023 was the Bear Tracks automated shuttle in the city of White Bear Lake, a suburb to the north of the city of St. Paul. The Bear Tracks automated shuttle in White Bear Lake operated weekly from 9:30 a.m. to 1:30 p.m. on a 1.5-mile route, connecting the community YMCA, affordable housing, and a center offering day programs for adults with intellectual and developmental disabilities. In addition to MnDOT and the city of White Bear Lake, other partners were AECOM, NEWTRAX, NAVYA, and Ramsey County. The shuttles were equipped with Americans with Disabilities Act (ADA)-compliant ramps, and also used signage in Braille, messages, trolly bells, and video with closed captioning.

The fourth pilot project is goMARTI (Minnesota Autonomous Rural Transportation Initiative) which offers on-demand rides in a 17 square mile area in the Grand Rapids region. Service is provided using five May Mobility AVs, including three wheelchair-accessible vehicles. Service operates Tuesday through Friday from 2:00 p.m. to 10:00 p.m., Saturdays from 10:00 a.m. to 10:00 p.m., and Sundays from 8:00 a.m. to 2:.00 p.m. Riders can schedule trips through a smartphone app or by calling 221. Project partners include MnDOT, May Mobility, PLUM Catalyst, the city of Grand Rapids, Via, First Call211, the Blandin Foundation, the Iron Range Resources and Rehabilitation Board, Itasca County, Mobility Mania, and Visit Grand Rapids.

GoMARTI represents the first large-scale automated shuttle pilot focusing on a rural area. One of the project goals is to provide accessible mobility for residents, especially those with transportation challenges. To address this need, the project has examined getting to the shuttle (identifying optimal stop locations for ease of use and investigating app-based tools), boarding and deboarding (wheelchair accessible vehicles and assisting with securing wheelchairs), and booking a trip (call centers for phone booking, training for installing and using the app, and 24-hour local support). The project recognizes that providing accessible transportation requires different capabilities depending on individual needs. Initial project experience highlights the importance of keeping stops and access points clear of snow and ice during the winter, providing a call center for non-smartphone users, and having onboard personnel to assist with boarding, deboarding, and wheelchair securement.(6)

The National Park Service (NPS) piloted automated shuttles at the Wright Brothers National Memorial in North Carolina and Yellowstone National Park in Wyoming in the summer of 2021. The NPS has implemented innovative transit services in many parks over the past 25 years to address traffic congestion, reduce vehicle emissions, and enhance visitor experiences. The two automated shuttle pilots represent the most recent innovate transit applications. Both pilots included elements to improve the safety and positive experience of individuals with disabilities who use the shuttles. Both pilots were monitored and evaluated by the USDOT Volpe National Transportation Center.(7)

The Connected and Autonomous Shuttle Supporting Innovation (CASSI) pilot operated at the Wright Brothers National Memorial from April 20 to July 12, 2021. Two EasyMile shuttles were operated by TransDev. The pilot was a joint partnership between NPS and the North Carolina Department of Transportation. The CASSI service operated on a 1.5-mile loop around the Wright Brothers Memorial from the museum stop to the sculpture stop, with service from 10:00 a. m. to 4:30 p.m. The EasyMile EZ10 shuttle was equipped with an automated accessibility ramp, which the onboard shuttle safety officer could deploy as needed. The shuttle also had a feature which lowered the shuttle (i.e., kneeling) for easier boarding by individuals with mobility limitations.

The stop at the Memorial's sculpture did not have a minimum 3-foot-long section of curb or an elevated paved surface needed for deployment and use of the accessibility ramp. A freestanding platform and wheelchair ramp was installed at this stop to allow the use of the shuttle ramp. The platform had to be enlarged after initial testing showed that it could not accommodate the deployed ramp and provide adequate room for a wheelchair to maneuver. While a total of 191 ramp deployments were recorded, the park staff reported that they were unaware of any wheelchair users riding the shuttle. The evaluation noted that since the conducted riders' survey did not ask about wheelchair use, it was possible that the ramp was deployed to assist elderly riders and others with limited mobility.(7)

The electric driverless demonstration in Yellowstone (TEDDY) operated from June 9 to August 31, 2021. Service was provided on two routes in the Canyon Village area over the 84 days,

providing the opportunity to serve different user groups. Route 1A operated from June 9 to June 12, serving the Canyon Lodge and Cabins to Canyon Village. Route 1B provided service from the Canyon Campground to Canyon Village from July 14 to August 31, 2021. Mobility-as-a-service provider BEEP operated the service using Local Motors Olli shuttles.

A ramp was installed at the Washburn Lodge stop to improve accessibility for users. The ramp from the curb to the asphalt parking area was added, as the shuttle was not able to pull directly up to the curb and there was no curb cut. As the Olli 1.0 shuttles did not have a built-in accessibility ramp, it took approximately 7 minutes to unfold and deploy the ramp, place it at the shuttle dock, assist the wheelchair user into the vehicle, secure the wheelchair, and remove the ramp. A total of 18 passengers, out of a total of 10,057 passengers, required deployment of the ramp.

The USDOT Volpe evaluation report notes that the CASSI and TEDDY pilots helped provide a better understanding of the role current automated shuttles could play in National Parks. The report highlights elements that worked well and challenges, such as limitations with GPS and internet connectivity in Yellowstone National Park. The report notes that future pilots may focus on different use cases, technologies, and vehicle types.[7]

Research Activities and Results

This section summarizes the research undertaken as part of this project. The major activities were introducing individuals with mobility and visual impairments to the Arlington RAPID shuttles and conducting online interviews with individuals using mobility devices to gain feedback on the Smart Intersection and automated shuttles. A workshop exploring possible automated shuttle routes at the TAMUS RELLIS Campus and an online discussion of possible routes linking the TAMU-SA Campus and the adjacent VIDA development were also conducted.

Introducing Individuals with Disabilities to the Arlington RAPID Shuttle

The City of Arlington is located between Dallas and Fort Worth in North Texas. It is the 48th largest city in the US, covering 99 square miles, and has a population of approximately 396,000. The Arlington Entertainment District includes AT&T Stadium, Globe Life Field, theme parks, and other attractions. The University of Texas at Arlington (UTA) campus is close to the downtown area.

The City of Arlington has conducted three automated shuttle pilots. Using two EasyMile EZ10 automated shuttles, Milo operated on off-street trails in the Arlington Entertainment District from August 2017 to August 2018, offering rides with a trained operator onboard who could take control of the vehicle if needed. Milo served over 110 events, including 78 stadium events, 17 public demonstrations, and 13 special functions. The second pilot, conducted from October 2018 to May

2019, involved on-street operations of Drive.ai AVs operating in mixed traffic at speeds up to 35 mph in the Entertainment District. The pilot included 755 AV trips, serving 1,424 passengers.

The Arlington RAPID project was initiated in March 2021, with funding from a Federal Transit Administration Integrated Mobility Innovation grant. Partners in the project included the City of Arlington, Via, May Mobility, and UTA. The project integrated May Mobility AVs with Via's on-demand rideshare platform in the downtown area and the UTA campus.

The RAPID AV fleet included four Lexus electric SUVs and a Polaris GEM vehicle equipped with a wheelchair ramp and tie-downs. Riders could book a trip for the RAPID AVs or the standard Via vans using the Via app or the reservation telephone system. The standard Via fares ($3–$5 per person per ride or $25 for a weekly pass good for up to four rides a day) applied, with UTA students riding for free. An attendant was behind the wheel at all times and transitioned between manual and automated modes. The attendant was also able to offer assistance to passengers.

In cooperation with the City of Arlington, May Mobility, Via, and UTA, this research project introduced individuals with mobility and visual impairments to the RAPID AVs. Researchers worked with staff from the City of Arlington, Via, North Central Texas Council of Governments, organizations supporting blind and individuals with disabilities with mobility impairments, and other groups to recruit participants. A copy of the flyer used in the recruitment process is provided in Appendix A.

Even with extensive outreach, it was difficult to attract participants for the research project. There were no requests for use of the Polaris GEM vehicle by individuals using wheelchairs, and traveling to the location of the interviews and rides may have been a problem for some individuals. Further, no reimbursement was provided for participating in this phase of the project. The following five individuals participated in the interviews and rides:

- Younger male using a wheelchair with a companion
- Middle age blind female with a guide dog
- Middle-aged color-blind male
- Older female using a walker with a companion
- Older male using a walker

May Mobility provided the use of their offices as the meeting place for the interviews and provided the rides in the AVs. The guide for the sessions, including the interview questions, is provided in Appendix B.

Each session began with an introduction covering the purpose of the project, a review of the activities, and an explanation of the consent form. Individuals were asked if they had ridden in a self-driving vehicle and if so, to describe their experience. The participants then took a ride in the

vehicle on a pre-determined route around the downtown area and the UTA campus. The individual using a wheelchair rode in the GEM vehicle and the other participants rode in the Lexus SUVs.

The May Mobility staff explained that the vehicle would operate in both manual and automated modes. All the participants, except the color-blind male, needed some type of assistance from the May Mobility staff to enter and exit the vehicle. As illustrated in Figure 1, staff deployed the wheelchair ramp on the GEM vehicle and assisted in pushing the wheelchair up the ramp and securing it inside the vehicle. They provided similar assistance after the ride when the individual disembarked from the vehicle. Assistance was provided to the blind individual and her guide dog to enter and exit the vehicle. The guide dog sat in the back seat with the individual and was able to enter and exit without any problem. Figure 2 highlights the blind participant and guide dog after the ride.

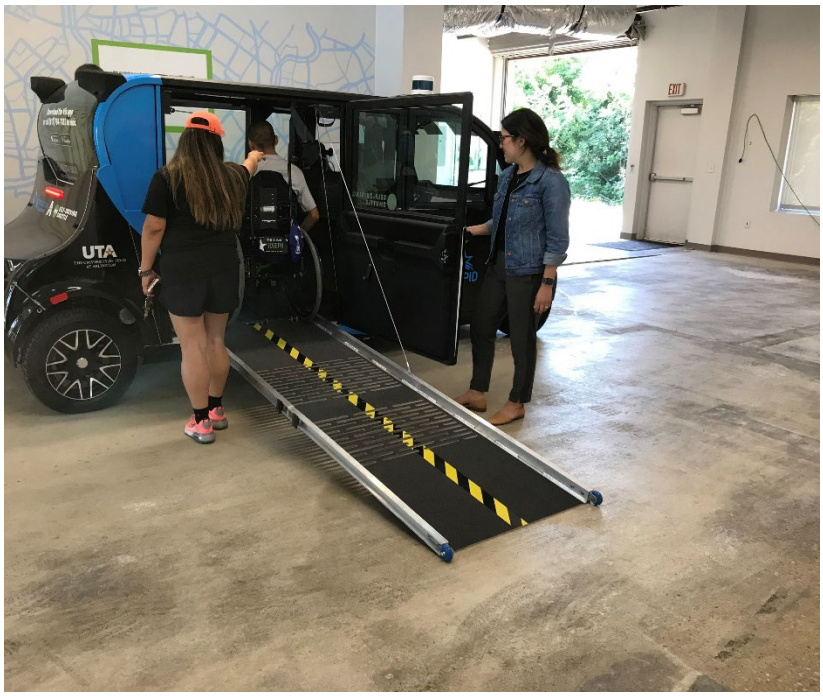

Figure 1. Providing assistance for wheelchair boarding.
Photo Used with Permission.

Figure 2. Blind participant with guide dog.
Photo Used with Permission.

Interviews were conducted with participants after the rides, with questions focusing on their reactions to the experience. Participants were also asked to describe their general travel experiences, their complete trips, and elements of the built environment that may hinder their mobility. The major points and common themes from the interviews are summarized below.

Reactions to Shuttle Ride

- It was the first time riding in an AV for all of the participants, and all expressed positive reactions to riding in the RAPID shuttles. The participants noted that they felt comfortable and safe during the trip. Some noted that they could tell when the automated mode started, while others indicated that they could not tell the difference between the automated and manual modes. Participants indicated the vehicle slowed when it should at corners, stop lights, and when pedestrians were nearby.
- The individual using a wheelchair noted that the process of entering and exiting the vehicle via the ramp went smoothly, although assistance was needed to get up and down the ramp. The individual reported that securement of the wheelchair inside the vehicle was also good.
- All of the participants noted that having an assistant on the vehicle was important. The blind individual said that she felt safe in the vehicle but that having the safety operator was important. She stressed the need to provide information in a variety of methods, including non-visual, for blind individuals. She also stressed the importance of verifying the pick-up and drop-off locations for blind individuals. She did express some concerns about sharing

rides with other unknown passengers and reinforced the importance of an onboard attendant in these situations. She also suggested providing training for blind individuals and their guide dogs to ensure both are comfortable with using the automated shuttles.

- All of the participants reported that they would use automated shuttles on a regular basis if they were available. Participants suggested that automated shuttles could help people maintain self-sufficient lifestyles regardless of age or disability.
- The participants asked questions about the operation of the automated shuttles, including those related to how quickly the safety operator could take control if needed. Some participants noted the difference in the Lexus and GEM vehicles, and the perception that the GEM shuttle was not the same quality as the Lexus vehicle. It was suggested that similar quality vehicles be used for all types of riders.

Comments on General Travel and the Built Environment

- Sidewalks in good condition, the presence of curb cuts and ramps, adequate handicap parking spaces, and the location of accessible building entrances were all noted by participants as important features for their complete trips. These elements are key to being able to get to and from shuttle stops or pick-up/drop-off points. It was apparent that individuals using wheelchairs, walkers, and other mobility devices have different limitations and needs. All groups should be considered in designing sidewalks and roadways. Providing updates on sidewalk and roadway repairs and the resultant temporary changes was identified as being important. The blind individual suggested that the use of guide dogs should be considered when making improvements to sidewalks, crosswalks, and building entrances. She also stressed the need for non-visual methods to communicate information on drop-off/pick-up locations, trip times, and the status of vehicles. Providing similar pick-up and drop-off areas for all types of services was also suggested as being beneficial to users.
- All participants expressed concern over the speed of traffic in their neighborhoods and areas they visit. Participants stressed the need to slow vehicles down, enforce traffic laws, and take other actions to ensure the safety of pedestrians, bicyclists, and individuals with disabilities. Some participants suggested reducing speed limits to 30 mph around the UTA campus and other areas. Finally, participants emphasized the need for safe stopping locations for transit buses, shuttles, and vans.

Introducing Individuals Using Mobility Devices to the Smart Intersection and Automated Shuttles

Online interviews were conducted with students from Texas A&M University (TAMU) and Blinn College who used mobility devices to obtain their reactions to a smart intersection that alerts pedestrians to buses making left-hand turns and to automated shuttles. Established in 1876, TAMU

is in College Station, TX. With current enrollment at approximately 74,000 students, the campus covers 5,200 acres. TAMU is one of only 24 higher education institutions to hold triple designations as a land-grant, sea-grant, and space-grant university. The Blinn College-Bryan campus has approximately 6,000 students offering 2-year degrees. Blinn has buildings in two locations in Bryan, TX, including new facilities on the TAMUS RELLIS Campus.

Researchers worked with the TAMU Transportation Services and Disability Services, Blinn College Disability Services, and the Brazos Valley Council of Government Aging and Disability Resource Center to recruit participants. The recruitment flyer is presented in Appendix C. A $40.00 payment was provided to individuals to encourage participation.

A PowerPoint presentation was developed for use with the interviews. The PowerPoint followed the interview script, which is provided in Appendix D. The interview began with a review of the consent information and the process for payment for participating. After a review of the research objective, participants were asked questions about their typical travel, the built environment, and other features that may restrict their mobility. A video was shown on the operation of the smart intersection and participants were asked about their reaction to the system. Pictures of the Arlington RAPID vehicles were presented, and participants were asked to describe their reaction to potentially using automated shuttles. Each interview took approximately 30 minutes.

Five individuals (3 male and 2 female) participated in the interviews. All five had some type of mobility disability, with four participants using wheelchairs. The major points made by the participants are summarized in the following section.

Comments on Travel and the Built Environment

- Participants voiced concerns about the poor condition of sidewalks, as well as the lack of sidewalks, in their neighborhoods and on the routes they travel. One participant described problems with narrow sidewalks that slope sideways, including some with broken and uneven pavement. Participants noted that these conditions are very difficult to navigate in a wheelchair. Other participants reported similar concerns, with some noting the absence of curb cuts at intersections and potholes in crosswalks. Concerns were voiced over the potential of getting a wheel stuck and being hit by a car. Participants also noted that bicycles, e-scooters, golf carts, construction equipment, and other items are sometimes parked on sidewalks, requiring them to maneuver around the objects or use a different route.
- Participants described problems with the accessibility of some buildings on campus. One building was noted as having a ramp only on the back side, requiring wheelchair users to go all the way around the back to enter. Participants noted that bicycles are sometimes chained to the ramps at the building entrances, blocking wheelchairs from entering.

- Participants described safety concerns crossing at signalized and unsignalized intersections. One participant noted they do not travel off-campus much for fear of being hit crossing a street. They described this situation as very stressful. Participants noted they try to travel with other people who are standing. The use of flags on a wheelchair was also noted as an approach to improve safety.
- Participants noted the lack of curb cuts on all four corners of some intersections on campus and in neighborhoods. These issues cause problems not only for individuals in wheelchairs, but also for people with baby strollers and people using crutches and walkers.
- One participant said that having more automatic doors on building entrances and internal rooms would be beneficial. It was suggested that there is a need to focus on accessibility beyond just meeting the bare minimum required by law.
- Some participants noted that they use the bus and paratransit services in College Station and other communities. One participant noted that electric wheelchairs can sometimes be difficult to maneuver and secure on buses. A few participants described experiences with mechanical problems with the ramps on buses and vans.
- One participant with vision problems voiced concerns about the lack of adequate lighting in many locations, including intersections, sidewalks, and building entrances. They reported using a flashlight on some trips to be sure they could see.
- Participants voiced concerns about navigating intersections with vehicles not yielding to pedestrians and bicyclists in the crosswalks. They noted that when the walk signal comes on, the light also turns green, and vehicles start turning.
- One participant noted that maneuvering a wheelchair on trains, at stations, and at airports can be challenging. Other travelers do not always look down to see a wheelchair and may inadvertently block access.
- One participant described the difficulty of loading a wheelchair into a car when they are a passenger. They noted the need for assistance in getting their wheelchair in and out of a vehicle and the need for assistance to get themselves out as well.
- One participant reported difficulty using the pedestrian tunnel under the railroad track by the Memorial Student Center and Kyle Field, explaining that it is hard to make it up the incline, even using an electric wheelchair.

Comments on the Smart Intersection

- All participants provided positive feedback on the smart intersection. Participants noted that they would feel safer and more comfortable crossing the street at this type of intersection. They noted that because wheelchairs are lower to the ground than pedestrians and bicyclists, they can be harder for bus drivers and motorists to see. The smart

intersection would help in alerting individuals with disabilities, including those using wheelchairs, that a bus is turning.

- Some participants suggested it would also be beneficial to alert the bus operator and drivers that pedestrians and bicyclists are crossing the street. One participant suggested having a second message indicating when it was safe to walk, which would be especially beneficial for blind individuals. Another participant asked about having all intersections equipped with this technology and the potential to build additional redundancies into the system.

Comments on Automated Shuttles

- Four participants reported that they had not ridden in an automated shuttle, while one reported riding in the TAMU's automated shuttle demonstration. Some participants were knowledgeable about AVs, while others reported lower levels of background knowledge.
- All of the participants reported that they would feel safe riding in automated shuttles. One individual questioned the technology used with the vehicle and one reported that it might take time to get used to not having an operator driving the vehicle.
- Participants indicated that they would use automated shuttles on a regular basis if they were available and met their travel needs. Some participants noted that this type of service would greatly improve their mobility and could be a great benefit. One participant indicated that he would still use his own van for most trips.
- Participants had several questions about using automated shuttles and AVs. These questions focused on the accessibility of all vehicles or only some shuttles, the type of ramps, the availability of assistance boarding and deboarding, if needed, and the wheelchair securement technology on the vehicle.

Workshops on Automated Shuttles

The research team conducted an online meeting and an in-person workshop to gain additional insights into planning and operating automated shuttles to safely enhance the mobility of individuals with disabilities. The online meeting focused on the TAMU-SA campus and the adjacent VIDA residential development. The workshop focused on the TAMUS RELLIS Campus in Bryan. The 580-acre TAMU-SA campus is located 12 miles south of downtown San Antonio off of I-410. The RELLIS Campus in Bryan, TX is located on a former World War II Air Base. The 2,000-acre campus includes research and testing facilities, education buildings, and workforce development centers.

The online meeting was held on June 9, 2022, with representatives from Southstar Communities, the developer of VIDA. The meeting expanded on discussions over the past few years on the potential of an automated shuttle serving the new development and the TAMU-SA campus. VIDA is a mixed-use planned community located directly north of the TAMU-SA campus.

When fully built out, VIDA will include single-family homes, apartments, townhomes, shops, and restaurants. It will also include a university health hospital and wellness campus.

Topics discussed during the meeting included the timing of the different phases of the VIDA development, the schedule for the hospital and wellness center, and planned additions to the TAMU-SA campus. The existing bus service provided by VIA was reviewed and possible routes for automated shuttles were identified. Possible routes linking the town center, the amenity center, and the apartment and townhome areas, the hospital, and the TAMU-SA campus were discussed. Different ways to serve the single-family neighborhoods were also considered. Possible points for linking the automated shuttle routes and VIA service were identified, along with potential transit hubs. The sidewalk intersections, access points, and other features needed to ensure the safe use by individuals with disabilities were discussed.

The workshop on the potential of a RELLIS automated shuttle was held on January 20, 2023. Participants included representatives from TAMU Transportation Services, the Bryan-College Station Metropolitan Planning Organization, the Brazos County Regional Mobility Authority and the RELLIS campus administration. Topics covered in the meeting included the existing TAMU bus routes and potential automated shuttle routes, vehicle charging and storage needs, and possible funding sources for vehicle procurement and ongoing operations. Considerations related to vehicle designs, posted speed limits, service operations, sidewalks, building access, and communications to ensure the safe use by individuals with disabilities were identified and discussed.

Participants noted that the new buildings on campus all have good accessibility for individuals with mobility and sight limitations, but that the legacy buildings from the World War II air base days may have limitations. Participants suggested that the lack of sidewalks linking the different area of the campus poses a safety concern for all groups, including persons with disabilities. Possible routes serving the different areas of the RELLIS Campus were discussed, as was using automated shuttles for demand-responsive passenger and food delivery service at the campus.

Guidelines for Enhancing Automated Shuttles for Individuals with Mobility and Visual Impairments

The results of the activities conducted in the research project were used to develop guidelines for enhancing the use of automated shuttles by individuals with mobility and visual impairments. The guidelines focus on the six general categories of (1) overarching approach (2) planning, (3) the built environment and the complete trip, (4) automated shuttle vehicles, (5) service and operations, and (6) ongoing monitoring and evaluation. Table 1 highlights the key elements in these six areas and, following the table, more information is provided on each topic within this section. The guidelines should be of use to transit agencies, local communities, metropolitan planning

organizations, state departments of transportation, community organizations, universities, vehicle manufacturers, and other groups.

Table 1. Categories and Key Elements of Guidelines for Enhancing Automated Shuttles for Individuals with Mobility and Visual Impairments

Category	Key Elements
Overarching Approach	• Focus on the needs of all user groups, with extra emphasis on the needs of individuals with disabilities. • Be inclusive of all individuals. • Exceed the requirements of federal, state and local accessibility laws and regulations. • Utilize universal mobility principles, user-centered design approaches, and other related guides.
Planning	• Actively engage individuals with disabilities and organizations in identifying and addressing their needs and safety concerns throughout the planning process. • Focus on the mobility issues, needs, and problems to be solved by automated shuttles. • Develop community-driven approaches. • Avoid technology searching for a problem. • Focus on the origins and destinations of interest and use by individuals with disabilities. Consider the other guidelines in the planning process, especially the built environment and complete trip needs.
Built Environment and Complete Trip	• Consider the needs of individuals with disabilities in the entire travel chain and their complete trip. • Elements to consider include the status and conditions of sidewalks, curb cuts, intersections, transit stops and stations, building access, and other facilities. Lighting, roadway speeds, and driveway access points should also be considered.

Category	Key Elements
Automated Shuttle Vehicles	• Ensure that comparable vehicles are deployed for all user groups. • Meet ADA and other federal, state, and local vehicle requirements. These requirements focus on boarding, securement, and deboarding. Requirements related to providing information external and internal to a vehicle should also be considered. • Consider and address the needs of individuals with disabilities for assistance in boarding/deboarding, securing wheelchairs, and during the trip. The need for onboard personnel to provide assistance should be considered. • Use onboard cameras, voice-activated assistance, and other approaches if an attendant is not on board an automated shuttle. • Address the needs of blind individuals with guide dogs in the design and operation of automated shuttles.
Service and Operations	• Consider the needs of individuals with disabilities in service planning and operations, including route and schedule planning, the location of stops, operating hours, and service frequency. • Conduct special outreach activities to introduce individuals with disabilities to automated shuttle services, including blind individuals with guide dogs. Partner with agencies and organizations focusing on individuals with disabilities to conduct these activities.
Monitoring and Evaluation	• Develop and conduct ongoing monitoring and evaluation programs for automated shuttle services with specific measures related to use by individuals with disabilities. • Use interviews, surveys, and other approaches to gain feedback from disabled riders, including information on any safety concerns. • Review the results of evaluations with the individuals with disabilities and arrange and make changes as needed to address any issues identified during the ongoing evaluations.

Overarching Approach

The overarching approach focuses on addressing the needs of all user groups, with an extra emphasis on the needs and safety of individuals with disabilities, including those using mobility devices and those with limited or no sight. The following elements highlight this overarching approach.

- Be inclusive of all individuals. Meet the needs of all user groups, including individuals with disabilities.
- Exceed the requirements of federal, state, and local accessibility laws and regulations. Examples of these laws include the Architectural Barriers Act of 1968, Section 504 of the

Rehabilitation Act of 1973, the Fair Housing Amendments Act of 1988, and the ADA of 1990. While these acts set the minimum requirements, opportunities to do more to meet the needs of individuals with disabilities should be considered and pursued.

- Utilize universal mobility principles, user-centered design approaches, and other related approaches in all phases of planning, designing, operating, and monitoring automated shuttles.
- Consider the safety of individuals with disabilities in all elements of automated shuttles and the complete trip.

Planning

While the traditional transit and transportation planning processes include considering the needs of individuals with disabilities and other diverse groups, ensuring extensive engagement and participation is especially important to ensure their safety and mobility with automated shuttles.

- Actively engaging individuals with disabilities and organizations to identify and address their needs early, often, and throughout the planning process. Groups and organizations representing individuals with disabilities are typically involved in the state, metropolitan planning organization, and local planning processes. These existing contacts provide a starting point for automated shuttle services planning. Expanding these contacts may be needed to ensure that all groups are represented, and that all voices are heard during the planning process.
- Ensure that the planning process focuses on mobility, needs, problems, and safety concerns of individuals with disabilities. The approach should focus on solving real problems rather than on technology in search of a problem. Develop a community-driven approach through listening sessions, meetings, focus groups, brainstorming sessions, and other mechanisms to gain input.
- The other guidelines, especially the built environment and complete trip elements, should be considered in the planning process. For example, identifying issues with the built environment early in the planning process can help in developing approaches to meet the needs and potential safety concerns of individuals with disabilities. Online maps and photographs, reports and records, and onsite visits can all be used to identify safety issues and problem areas.

Built Environment and Complete Trip

The results of the interviews conducted with the rides in the RAPID automated shuttles and the online discussions highlighted numerous concerns with safety and the built environment. The participants noted that impediments in the built environment limited their mobility and increased safety concerns. The following guidelines can assist in identifying and addressing these issues.

- Consider the needs and safety concerns of individuals with disabilities in their entire travel chain and their complete trip. The links in the travel chain include planning the trip, traveling to the stop or pick-up point, navigating the stop, boarding the vehicle,

riding in the vehicle, exiting the vehicle, and traveling to their destination. A trip might also involve a transfer to another vehicle at a stop or station.

- Specific elements to consider include the status and condition of sidewalks, curb cuts, intersections, transit stops and stations, building access, and other built environment features. Other elements to consider are lighting, roadway traffic speeds, and driveway access points. Onsite visits tracing the travel routes of individuals with disabilities can be conducted to identify potential safety issues. Addressing any identified issues should be part of a project to ensure that individuals with disabilities are able to access automated shuttles.

Automated Shuttle Vehicles

One of the challenges with many of the automated shuttle pilots conducted to date has been the limited availability of AVs in general, especially those with features addressing the needs of individuals with disabilities and that meet ADA requirements. These limitations may be reduced as new AV types become available. The design of automated shuttles should incorporate the safety and mobility needs of individuals with disabilities.

The guidelines presented here focus on not just meeting the federal, state, and local regulations, but also going beyond the requirements to address the needs of individuals with disabilities who may require additional features or measures. The ADA guidelines address various features, including walking surfaces, vehicle ramps, bridge plates and lifts, level boarding, steps, doorways, securement, and illumination. Meeting these guidelines is required for all public transit services, including automated shuttles. The following guidelines provide additional focus for ensuring the safety of individuals with disabilities using automated shuttles.

- Ensure that comparable vehicles are deployed for all user groups. Some pilots have used different types of vehicles for transporting individuals using wheelchairs, giving the impression that the service quality may be lower.
- Consider and address the needs of individuals with disabilities, for assistance in boarding/deboarding, securing a wheelchair, and during the trip.
- Use onboard cameras, voice-activated assistance, and other approaches if an onboard assistant is not present on an automated shuttle.
- Address the needs of blind individuals with guide dogs in the design and operation of automated shuttles. Provide focused outreach and training with use of the automated shuttle features to disabled groups, including blind individuals with guide dogs.

Service and Operations

The needs of individuals with disabilities should be considered in automated shuttle services and operations. The following guidelines can help ensure the service addresses the needs of individuals with disabilities.

- Consider the needs of individuals with disabilities in service planning and operations, including route and schedule planning, operating hours, and service frequency.
- Target services to origins and destinations frequented by individuals with disabilities and focus on their identified needs.
- Conduct special outreach activities to introduce individuals with disabilities to the automated shuttle service. These activities could include group and individual sessions highlighting all aspects of using the system. Establishing partnerships with agencies and organizations focusing on individuals with disabilities represents a good approach for conducting these outreach activities.

Monitoring and Evaluation

It is important to monitor and evaluate automated shuttle services on an ongoing basis to ensure the intended goals are being met. As outlined in the guidelines, these efforts should include specific measures related to use by individuals with disabilities.

- Develop and conduct an ongoing monitoring and evaluation program for automated shuttle services. Develop specific performance measures focusing on the use by individuals with disabilities.
- As part of the evaluation program, use interviews, surveys, focus groups, and other approaches to gain feedback and input from individuals with disabilities. Summarize the results and provide information to appropriate user groups and individuals. Make changes to address any issues identified during the ongoing evaluations.

Additional Products

The additional products developed as part of this project are summarized in this section.

Education and Workforce Development Products

A course lecture on the topics covered in this research project was developed and is available for use by others. The lecture covers the ADA, automated shuttles, and the activities conducted as part of this research project. The lecture includes a small group exercise. A reading list supporting the lecture is also provided.

Technology Transfer Products

Technology Transfer (T2) was an important part of this project. Presentations on the projects were given at the following conferences, symposiums, and webinars:

1. Roundtable Forum, Texas Department of Transportation Research Project, Automated and Connected Vehicle Test Bed to Improve Transit, Bicycle, and Pedestrian Safety, June 22, 2021, College Station, TX

2. 2021 Transportation Research Board (TRB) Automated Road Transport Symposium, July 12-15, 2021, Virtual.
3. TRB Conference on Advancing Transportation Equity, September 10, 2021, Virtual (Recorded Presentation).
4. Online meeting with representatives from the Texas Department of Transportation, the Ohio Department of Transportation, the Florida Department of Transportation, the University of Florida, and Ohio State University, September 15, 2021.
5. Texas Institute of Transportation Engineering (TexITE) Spring Conference, May 5, 2022, Corpus Christi, TX.
6. 2022 TRB Automated Road Transport Symposium, July 20, 2022, Garden Grove, CA.
7. Safe-D Webinar, March 28, 2023, Virtual.
8. American Society of Civil Engineers (ASCE) Transportation and Development Conference, June 16, 2023, Austin, TX.
9. 2023 TRB Automated Road Transport Symposium, July 12, 2023, San Francisco, CA.

Data Products

In addition to the class lecture, the PowerPoint used in the Safe-D webinar is available for viewing and use. They are linked on the project website : https://safed.vtti.vt.edu/projects/4075-2/

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2. Federal Transit Administration. Strategic Transit Automation Research Plan. U.S. Department of Transportation, 2018.

3. Turnbull, K., Jones, C., Elefteriadou, L., Catching up with Low-Speed Autonomous Shuttles. In: Meyer, Ge., Beiker, S., (eds) Road Vehicle Automation 7, AVS 2019, Lecture Notes in Mobility. Springer, Cham. 2020.

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7. Cregger, J., Mahavier, K., Holub A., Machek, E., Crayton, T., Patel, R., Suder, S. Automation in Our Parks: Automated Shuttle Pilots at Yellowstone National Park and Wright Brothers National Memorial. DOT-VNTSC-NPS-22-03. National Park Service, 2022.

Appendix/Appendices

Appendix A

Interested in Riding in a RAPID Self-Driving Vehicle?
Looking for Riders for Research Study
June 16, 17, and 18, 2021

The Texas A&M Transportation Institute (TTI) is working with the City of Arlington, May Mobility, Via Rideshare, and the University of Texas at Arlington on a research study gathering information on the use of self-driving vehicles by individuals with mobility or visual impairments, who are interested in taking a short ride in the Arlington RAPID Shuttle on June 16, 17, or 18 and answering a few questions on the experience.

All study participants must be at least 18 years of age and meet at least one the following criteria:

- Use some type of mobility device (wheelchair, walker, or other mobility device)
- Have a visual impairment

Here is how the study will work.

1. You will schedule a ride with a TTI researcher (Brittney Gick, b-gick@tti.tamu.edu or (817) 462-0513) for **Wednesday, June 16 and Thursday, June 17 between 9:00 am and 6:00 pm, or Friday, June 18 from 9:00 am to Noon.**
2. The trip will depart from the May Mobility Offices, 500 East Front Street (see map on the next page). Please arrive 10 minutes before your scheduled departure time.
3. Before your trip begins, a TTI researcher will explain the study and will ask you a few questions about any previous experience riding in a self-driving vehicle.
4. A May Mobility attendant will be in the vehicle during the trip and can take control of the vehicle if needed. A TTI researcher will accompany you to collect your feedback during the trip. You have the option of having a companion or helper ride with you. Your ride will consist of a 5-10 minute trip through the service area.
5. After the trip we will ask you a few questions about your experience riding in the RAPID vehicle, your general trip making behavior and possible improvements to sidewalks and streets that would improve your mobility.
6. After you have answered these final questions, your participation in the study is over. The entire experience will last approximately thirty minutes.

To schedule a ride in the RAPID shuttle, please contact Brittney Gick at TTI
b-gick@tti.tamu.edu or (817) 462-0513

Texas A&M Transportation Institute

Frequently Asked Questions

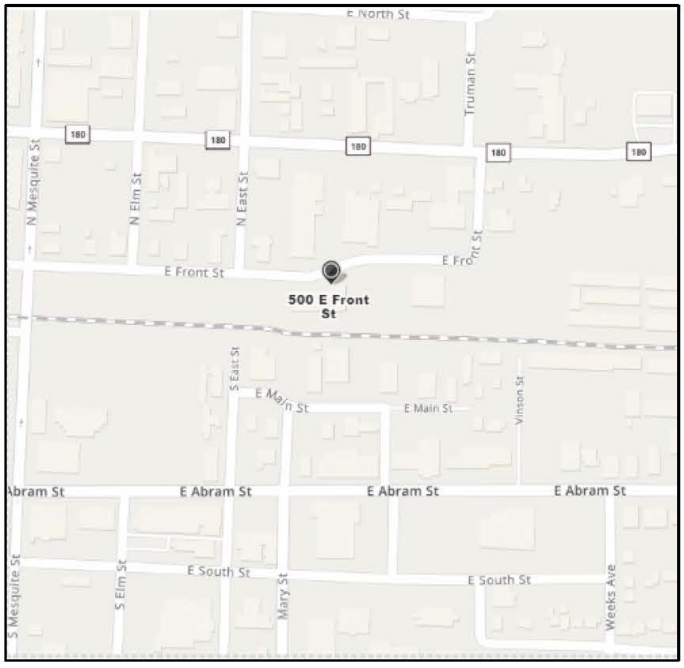
What is the Arlington RAPID Shuttle? The Arlington RAPID Shuttle is a self-driving shuttle sponsored by the City of Arlington, with funding from the Federal Transit Administration (FTA) of the U.S. Department of Transportation. Project partners include Via Rideshare, May Mobility, and the University of Texas, Arlington. More information can be found at the project website: https://www.arlingtontx.gov/city_hall/departments/office_of_strategic_initiatives/rapid.

What kind of vehicle will I ride in? The RAPID fleet includes four hybrid-electric vehicles, and one fully electric vehicle that is equipped to carry a wheelchair. All RAPID vehicles are capable of sensing the environment and operating without human involvement. These vehicles are monitored by on-board Fleet Attendants at all times to ensure a safe and enjoyable experience for passengers. May Mobility owns and operates the fleet of autonomous vehicles.

Is the vehicle safe? Yes. A trained Fleet Attendant will always be on board. The vehicles' self-driving technology comes with collision avoidance systems that detect other vehicles, cyclists, pedestrians, and obstacles. It is also equipped with multiple safety features. The RAPID vehicles can travel up to approximately 25 miles per hour and will always comply with posted speed limits.

Will I have to pay to participate? No. Participation, including the trip, is free.

What are the possible benefits of this study? The results of the study will be used to help ensure that the design and operation of self-driving shuttles meet the needs of individuals with mobility or visual impairments. Possible improvements to sidewalks and roads to improve mobility will also be identified.



Who will know about my participation in this study? Your name will be kept private. Only first names will be used during the interview. Your comments will be recorded to help with the summary. The recording will be erased after the researchers summarize the information from the interviews.

Appendix B

Interview Guide – Introducing the Arlington RAPID Shuttle to Individuals Using Wheelchairs, Walkers, or other Mobility Devices and Individuals with Limited or No Sight

Topic	Question
Introduction (5 minutes)	Thank you for participating in this study which is introducing individuals with mobility or visual impairments to riding in a driverless shuttle, known as the Arlington RAPID Shuttle. We would like to hear about your experience riding in the RAPID Shuttle. We would also like to learn more about how you typically travel around Arlington and any changes in streets, sidewalks, intersections, curbs, and other built environment elements that would improve your safety and mobility. Explain and have them sign Consent Form.
Introduction to RAPID Shuttle (5 minutes)	The Arlington RAPID Shuttle is a self-driving shuttle sponsored by the City of Arlington, with funding from the Federal Transit Administration (FTA) of the U.S. Department of Transportation. Project partners include Via Rideshare, May Mobility, and the University of Texas, Arlington. Taking a ride in the self-driving shuttle is voluntary. There will be a safety attendant in the RAPID vehicle at all times, but you may stop at any point if you feel uncomfortable. 1) Have you ridden in a self-driving vehicle before? If yes, what was your experience?
Ride in RAPID Shuttle (25 minutes)	Ride in Shuttle. Answer any questions they may have, and also take notes of any comments made during the ride.
Reaction to Shuttle Ride (15 minutes)	Please tell me your reaction to riding in the Shuttle. 1) What is your overall reaction to riding in the Shuttle? 2) How comfortable were you? 3) How safe did you feel? 4) How secure did you feel in comparison to riding in a shuttle or vehicle with a driver? 5) Are there any design or operating features that would make you feel more comfortable, safe, or secure? 6) How likely is it that you would use this type of service if it were currently available for you to use? 7) If likely: What are the reasons you would use it? 8) If not likely: What are the reasons you would not use it? 9) What types of questions do you have about how to use this type of service in the future?

Topic	Question
General Travel and Built Environment (10 minutes)	Now I would like to ask you about your typical travel and the built environment. • What types of trips do you make on a regular basis and what transportation services do you use? We are interested in local travel, not long-distance travel. • Thinking about the area you live – are there built environment elements that restrict your ability to reach public transit or other services you use on a regular basis? Examples might be lack of sidewalks, lack of curb cuts, and lack of signals at intersection. • Thinking about the destinations you frequent on a regular basis – are there built environment elements at those destinations that restrict your mobility? Examples might be lack of sidewalks, lack of curb cuts, and lack of signals at intersection. • Are there any other elements that would make travel in your neighborhood or destinations easier, more convenient, and safer for you?
Closing (5 minutes)	Thank you very much for your time today. Do you have any questions or final comments as we conclude the session?

Background Information

To be completed by the facilitator.

Sex: Male _____ Female _____

Approximate Age

20 – 34 years of age _____

35 – 49 years of age _____

50 – 65 years of age _____

Disability/Assistance Device

Wheelchair _____

Walker _____

Other Device _____

Limited Sight _____

No Sight _____

Long White Cane

Service dog

Appendix C

Interested in Providing Input on Smart Intersections and Self-Driving Shuttles?

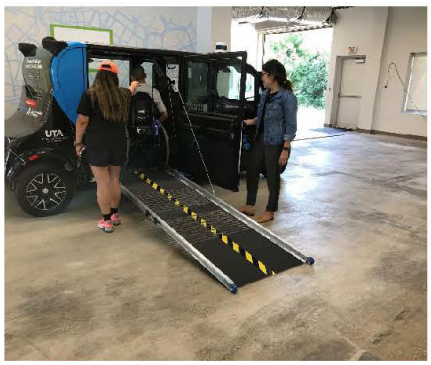
Participate in a Virtual Interview
As part of a Research Project Conducted by the
Texas A&M Transportation Institute

The Texas A&M Transportation Institute (TTI) is conducting a research study gathering information on the potential use of smart intersections and self-driving shuttles by individuals with mobility impairments. All study participants must be at least 18 years of age and use some type of mobility device (wheelchair, walker, or other mobility device).

Participants will be interviewed by a TTI researcher via a Teams or WebEx meeting. The interviews will include viewing videos and photographs of the operation of the smart intersection demonstration at Penberthy Boulevard and George Bush Drive and self-driving shuttles in Arlington, Texas. Participants will be asked questions about their perceptions on using smart intersections and self-driving shuttles, as well as improvements in sidewalks, streets, and other built environment elements.

The interviews will take approximately 30 minutes and will be scheduled between 9:00 am and 6 pm on April 11-15. Participants will be paid $40 for completing the interview through their choice of Venmo, PayPal, or an Amazon e-gift card.

Please contact TTI researcher Brittney Gick, b-gick@tti.tamu.edu or (817) 462-0513 to schedule an interview.



Texas A&M Transportation Institute

Appendix D

Interview Script – Introducing the Smart Intersection and Self-Driving Shuttles to Individuals Using Wheelchairs, Walkers, or other Mobility Devices

Topic	Question
Introduction	Thank you for participating in this interview introducing individuals with mobility impairments to a Smart Intersection on the Texas A&M Campus and self-driving shuttles. The Smart Intersection provides visual and audio alerts to pedestrians and bicyclists when a bus is turning left at the intersection. Self-driving shuttles have been demonstrated on campus and in other areas in Texas and the U.S. We will be using video clips and slides to highlight the operation of the Smart Intersection and self-driving vehicles. In addition to your reactions to the Smart Intersection and self-driving shuttles, we would like to learn about your regular travel experiences and any changes in intersections, streets, sidewalks, and other built environment elements that would improve your safety and mobility. Review Study Information Sheet.
General Travel and Built Environment	I would like to begin by discussing your typical travel and any issues or challenges with travel that are caused by the built environment – for instance sidewalks or curbs. • What types of trips do you make on a regular basis and what modes or services do you use? • Thinking about the area you live – are there elements that restrict your mobility and ability to reach public transit or other services you use on a regular basis? Examples might be lack of sidewalks, lack of curb cuts, and lack of signals at intersection. • Do you have any specific concerns crossing signalized intersections? • Thinking about the destinations you frequent on a regular basis – are there built environment elements at those destinations that restrict your mobility and ability to reach public transit or other services you use on a regular basis? Examples might be lack of sidewalks, lack of curb cuts, and lack of signals at intersections. • Do you have any specific concerns crossing signalized intersections? Are there any other elements that would make travel in your neighborhood or destinations easier, more convenient, and safer for you?
Introduction to the Smart Intersection	Show video on the operation of the Smart Intersection at George Bush Drive and Penberthy and explain the operation of the intersection.

Reaction to the Smart Intersection	10) Do you think you would feel more comfortable crossing at this type of intersection than a regular intersection? a. Why or why not? 11) Do you think you would feel more safe crossing at this type of intersection? a. Why or why not? 12) Are there any design or operating features at this intersection that would make your feel more comfortable, safe, or secure? 13) Are there any changes in the Smart Intersection technology or operation that you would recommend? 14) What types of questions would you have about the use of this type of intersection?
Introduction to Self-Driving Shuttles	Show slides of the Arlington and other self-driving Shuttles.
Reaction to Self-Driving Shuttles	Please tell me your reaction to self-driving shuttles. 1) Have you ridden in a self-driving shuttle? a. If yes, what was your experience? b. Are there any design or operating features that would make you feel more comfortable, safe, or secure? 2) Do you think you would feel safe riding in this type of vehicle? 3) How likely is it that you would use this type of service if it was available for you to use? a. If likely, what are the reasons you would use it? b. If not likely, what are the reasons you would not use it? 4) What questions do you have about how to use this type of service in the future?
Closing	Thank you very much for your time today. Do you have any questions or final comments as we conclude the session?

Background Information

To be completed by the interviewer.

Sex: Male _____ Female _____

Approximate Age

20 – 34years of age _____

33– 49 years of age _____

50 – 65 years of age _____

Disability/Assistance Device:

Wheelchair _____

Walker _____

Other Device _____