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Automation in Our Parks: Automated Shuttle Pilots at Yellowstone National Park and Wright Brothers National Memorial




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13. ABSTRACT
Through its Emerging Mobility initiative, the National Park Service (NPS) implemented two electric, automated shuttle pilots at Yellowstone National Park and Wright Brothers National Memorial. “The Electric Driverless Demonstration in Yellowstone” (TEDDY) pilot operated from June to August 2021 with two Local Motors Olli shuttles operated by Beep, while the “Connected Autonomous Shuttle Supporting Innovation” (CASSI) pilot operated at Wright Brothers National Memorial from April to July 2021 with a single EasyMile EZ10 shuttle operated by Transdev. Together, the two pilots served over 13,400 riders on more than 3,300 trips. The shuttle pilots faced some operational challenges, with a significant number of disengagements and service suspensions. Survey results indicated overall satisfaction with the pilots, although most riders rode the shuttles primarily for a fun experience rather than to get to a specific destination. The NPS learned many lessons throughout the course of the two pilots, on topics such as contracting, communications, planning, visitor experience, technology, evaluation, and accessibility.

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Acronyms and Abbreviations

TERM	DEFINITION
ADA	Americans with Disabilities Act
ADS	Automated Driving System
CASSI	Connected Autonomous Shuttle Supporting Innovation
DMV	North Carolina Division of Motor Vehicles
FHWA	Federal Highway Administration
GPS	Global Positioning System
IMD	Integrated Mobility Division (part of NCDOT)
MOU	Memorandum of Understanding
MSU	Montana State University
MUTCD	Manual on Uniform Traffic Control Devices
NCDOT	North Carolina Department of Transportation
NHTSA	National Highway Traffic Safety Administration
NPS	National Park Service
OMB	Office of Management and Budget
PLTF	Public Lands Transportation Fellow
RFQ	Request for Quotation
RTK	Real-Time Kinematic
SAR	Site Assessment Report
SOW	Statement of Work
SSN	Sources Sought Notice
SVR	Site Visit Report
TEDDY	The Electric Driverless Demonstration in Yellowstone
U.S. DOI	U.S. Department of the Interior
U.S. DOT	U.S. Department of Transportation
WASO	Washington Support Office (part of NPS)

1. INTRODUCTION

In 2021, the National Park Service (NPS) launched the first-ever automated, electric shuttle pilots on any U.S. recreational public lands.[1] These demonstrations, at Yellowstone National Park and Wright Brothers National Memorial, allowed the NPS to test the suitability of automated driving systems (ADS) on public lands and in remote locations, with long-term aims of enhancing access and encouraging visitors to take green, car-free trips to these NPS units.

These pilots are part of broader NPS efforts to advance emerging mobility as a tool to realize goals related to the visitor experience, resource protection, climate change, equity, accessibility, safety, and partnerships. The NPS Emerging Mobility Working Group, an interdisciplinary group of staff and subject matter experts from across the NPS and the U.S. Department of Transportation (U.S. DOT), works to identify, research, and assess the use of emerging technologies on NPS lands.[2] The NPS is also exploring additional emerging mobility pilots at NPS locations across the country related to ride-hailing, micromobility, traveler information technologies, and electric vehicles. On November 17, 2021, the U.S. Department of the Interior (U.S. DOI) Secretary Deb Haaland and U.S. DOT Secretary Pete Buttigieg signed a memorandum of understanding (MOU) between U.S. DOT and U.S. DOI on Transportation Innovation in the National Park System at an event in Washington, D.C. The MOU strengthens the collaboration between the NPS and U.S. DOT to continue working together to proactively address these emerging transportation trends.

Over the last few years, several automated shuttle manufacturers and operators have approached the National Park Service with requests to demonstrate their technologies. The NPS is interested in better understanding how emerging automated shuttle technologies could present new mobility options for NPS visitors through technology demonstrations and evaluations. The NPS is also interested in better understanding the infrastructure required for, costs associated with, and the benefits of automated shuttle technologies for NPS use cases. Pilots are intended to demonstrate the function and capabilities of emerging technologies and how they affect factors such as safety, visitor experience, travel time, and interactions with other modes and surrounding infrastructure.

Yellowstone National Park, created as the world's first national park in 1872, represents the genesis of what would become the National Park Service and its mission to preserve unimpaired natural and cultural resources for the enjoyment, education, and inspiration of this and future generations. The NPS piloted two electric Local Motors Olli shuttles in one of the country's most cherished landscapes at Yellowstone National Park as part of the "The Electric Driverless Demonstration in Yellowstone" (TEDDY) from early June 2021 through the end of August 2021. Yellowstone National Park presented a unique, remote setting for the pilot.

The first NPS automated shuttle pilot launched at Wright Brothers National Memorial in Kill Devil Hills, North Carolina on April 20, 2021 (NPS's Transformation Tuesday, part of the annual National Park Week celebration) and ran through mid-July 2021. The NPS partnered with the North Carolina Department of Transportation (NCDOT) to deploy a third-generation electric EasyMile EZ10 shuttle—named the "Connected Autonomous Shuttle Supporting Innovation" (CASSI)—to transport visitors between the Wright Brothers Visitor Center and Wright Brothers Monument. The Wright Brothers National Memorial deployment builds on NCDOT's prior CASSI deployment at North Carolina State University.

While the two pilots took place at different NPS sites, had different vendors, used different shuttle models, and operated on different types of routes, they had similar goals. The overarching NPS goals for both pilots were to:

- Test and demonstrate the use of automated shuttle technologies for public use in novel operating

[1] For more information on low-speed automated shuttles, see the Intelligent Transportation Systems Joint Program Office (ITS JPO) report "Low-Speed Automated Shuttles: State of the Practice" available at https://rosap.ntl.bts.gov/view/dot/37060.
[2] NPS Emerging Mobility (2021). https://www.nps.gov/subjects/transportation/emerging-mobility.htm

environments, including rural/remote areas and/or recreational settings in mixed vehicle traffic movement areas, and assess how those outcomes could be applied to other Federal lands;

- Identify and overcome unforeseen regulatory, organizational, and legal barriers related to ADS and other emerging mobility technologies; and
- Enhance the visitor experience by facilitating exploration of potential new interpretive opportunities and improving mobility assistance options.

In addition to this comparative report, the NPS worked with NCDOT to co-publish a report evaluating the automated shuttle pilot at Wright Brothers National Memorial. That report, published in May 2022, is available for download at the U.S. Department of Transportation's Repository & Open Science Access Portal.[3]

[3] The publication "First in Flight, First in Automation: NCDOT and NPS Pilot an Automated Shuttle at the Wright Brothers National Memorial" is hosted on the U.S. DOT Repository & Open Science Access Portal (ROSAP): https://rosap.ntl.bts.gov/view/dot/62313.

2. YELLOWSTONE NATIONAL PARK AUTOMATED SHUTTLE PILOT

The NPS identified Yellowstone National Park as a potential location for an automated shuttle pilot in 2019, given its symbolism as the first national park, Park leadership's interest in hosting a pilot, and its variety of potential sites where a route could be established. In January 2020, the NPS issued a sources sought notice (SSN) to gather information about the state of the technology, its capabilities, and potential vendors who could provide and operate automated shuttles in a national park setting. By the time the SSN closed on February 10, 2020, the NPS had received responses from several potential vendors. The NPS moved forward with a request for quotation (RFQ) solicitation that was published on June 19, 2020 and closed on July 25, 2020.[4] As a result of the RFQ, the NPS selected Beep Inc. to operate the automated shuttle route at Yellowstone National Park and issued an award notice on Aug 31, 2020.

Following a site visit in fall 2020, Beep determined the technology to be used, and worked with NPS to approve its selection for use at Yellowstone National Park. Beep secured the subcontractors Local Motors and Robotic Research LLC to provide the technology and technical support needed to enable operations.[5] Local Motors provided two Olli 1.0 shuttles, which were equipped with an automated driving system (ADS) developed by Robotic Research LLC.[6]

In line with the SSN and RFQ documents, the NPS decided on a summer 2021 timeframe (June to August 2021) and worked with its partners to launch "The Electric Driverless Demonstration in Yellowstone" (TEDDY) at Canyon Village. A 2020 research grant from the Federal Highway Administration (FHWA) Technology and Innovation Deployment program was utilized to procure/lease and operate the automated TEDDY shuttles and to support the technical evaluations of both of the automated shuttle pilots at Yellowstone National Park and Wright Brothers National Memorial.

The partners involved in the TEDDY pilot included:

- National Park Service
  - Yellowstone National Park
  - Department of the Interior Regions 6, 7, and 8 (formerly comprising the Intermountain Region)
  - Washington Support Office (WASO)
- U.S. Department of Transportation
  - Federal Highway Administration
  - Volpe National Transportation Systems Center (technical assistance and evaluation)
- Contractors
  - Xanterra Parks and Resorts (concessionaire at Yellowstone National Park)
  - Montana State University (MSU) Public Lands Transportation Fellow (PLTF)
- Vendors
  - Beep (shuttle operator)
  - Local Motors (shuttle provider)
  - Robotic Research LLC (automated driving system developer)

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[4] More information on the RFQ is available at: https://sam.gov/opp/14491323ca854137bdf60df2360111a2/view#general.

[5] In January 2022, Local Motors went out of business. See TechCrunch "Local Motors, the startup behind the Olli autonomous shuttle, has shut down" (2022). https://techcrunch.com/2022/01/13/local-motors-the-startup-that-created-the-olli-autonomous-shuttle-has-shutdown/

[6] At the time of selection, Local Motors had an improved version of the shuttle, the Olli 2.0 available, but the two shuttles used in the pilot were Olli 1.0 shuttles.

The pilot process required extensive coordination at all stages—from pre-planning to implementation and evaluation. Leading up to the launch and throughout the pilot, an interdisciplinary team (with representatives from WASO, the Regional Office, Yellowstone National Park, the U.S. DOT Volpe Center, the PLTF, and Beep) held weekly coordination meetings. In addition, communications staff from the Region, the Park, and Beep also regularly met for coordination meetings. The U.S. DOT Volpe Center provided extensive technical assistance to the NPS at all stages of the TEDDY automated shuttle pilot, from pre-planning to pilot evaluation.[7] The PLTF monitored the pilot onsite, coordinated between NPS and Beep's ground personnel, and managed the project's visitor survey.

2.1 Pilot Overview

The TEDDY automated shuttle pilot demonstration—the first of its kind in a U.S. National Park—operated from June 9, 2021 to August 31, 2021.[8] The pilot used two automated shuttles, which traveled on two different routes (one route for the first half of the pilot and another route for the second half of the pilot) in the Canyon Village area of Yellowstone National Park. The schedule for shuttle operation included service seven days a week from 7:00 am to 9:00 pm in three, 3-hour shifts (7:00-10:00 am, 12:30-3:30 pm, and 6:00-9:00 pm) with two 2.5-hour duration breaks for recharging the batteries of the shuttles.

2.1.1 Setting

Yellowstone National Park occupies the northwest corner of Wyoming and extends into parts of Montana and Idaho. Covering nearly 3,500 square miles, Yellowstone National Park is one of the largest and most popular national parks in the United States, hosting more than four million annual visitors in recent years.[9] Yellowstone National Park has many attractions, including its wildlife (e.g., bison, grizzly bears, and wolves), hydrothermal features (e.g., geysers and hot springs), and other geological features such as mountains, valleys, waterfalls, and the Grand Canyon of the Yellowstone.

Just north of the Grand Canyon of the Yellowstone Upper and Lower Falls, at an intersection on the historic Grand Loop Road, sits Canyon Village. The general elevation in the area approaches 8,000 feet above sea level. Canyon Village has a large horseshoe-shaped parking area, surrounded by visitor service facilities including the Canyon Visitor Education Center, an adventure gear store, a general store, and the Canyon Eatery. To the southeast of the main parking area are lodging accommodations (including Moran Lodge and Washburn Lodge), while northeast of the main parking area is the Canyon Campground (with more than 270 sites for campers). Park visitors may head to Canyon Village for meals, to procure supplies, to spend the night, or to seek out the Visitor Center and/or interpretive and wayfinding information about the Grand Canyon of the Yellowstone.

2.1.2 Routes

The two NPS AV shuttle pilots took different paths to launch and service. The CASSI project was accelerated due to NCDOT's leadership to have tests completed in the State with an already-contracted vehicle. Once NCDOT selected the NPS interest for a pilot, work began on the partnership and technical details to ensure success. The NPS applied a different approach to the TEDDY project.

The NPS planned to use the SSN input to frame a contractual solicitation to oversee its own pilot at a park unit. Interest from Interior Regions 6, 7, and 8 led to regional staff outreach to several parks discussing possible deployment locations and strategies. Concurrently, the NPS WASO office applied for research funds through a new opportunity managed by FHWA's Office of Federal Lands Highway, as coordinated with Federal land partners through a newly established Federal

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[7] Volpe Center NPS Emerging Mobility (2021). https://www.volpe.dot.gov/transportation-planning/public-lands/national-park-service-emerging-mobility

[8] NPS Automated Shuttle Pilot (2021). https://www.nps.gov/yell/learn/management/automated-shuttle-pilot.htm

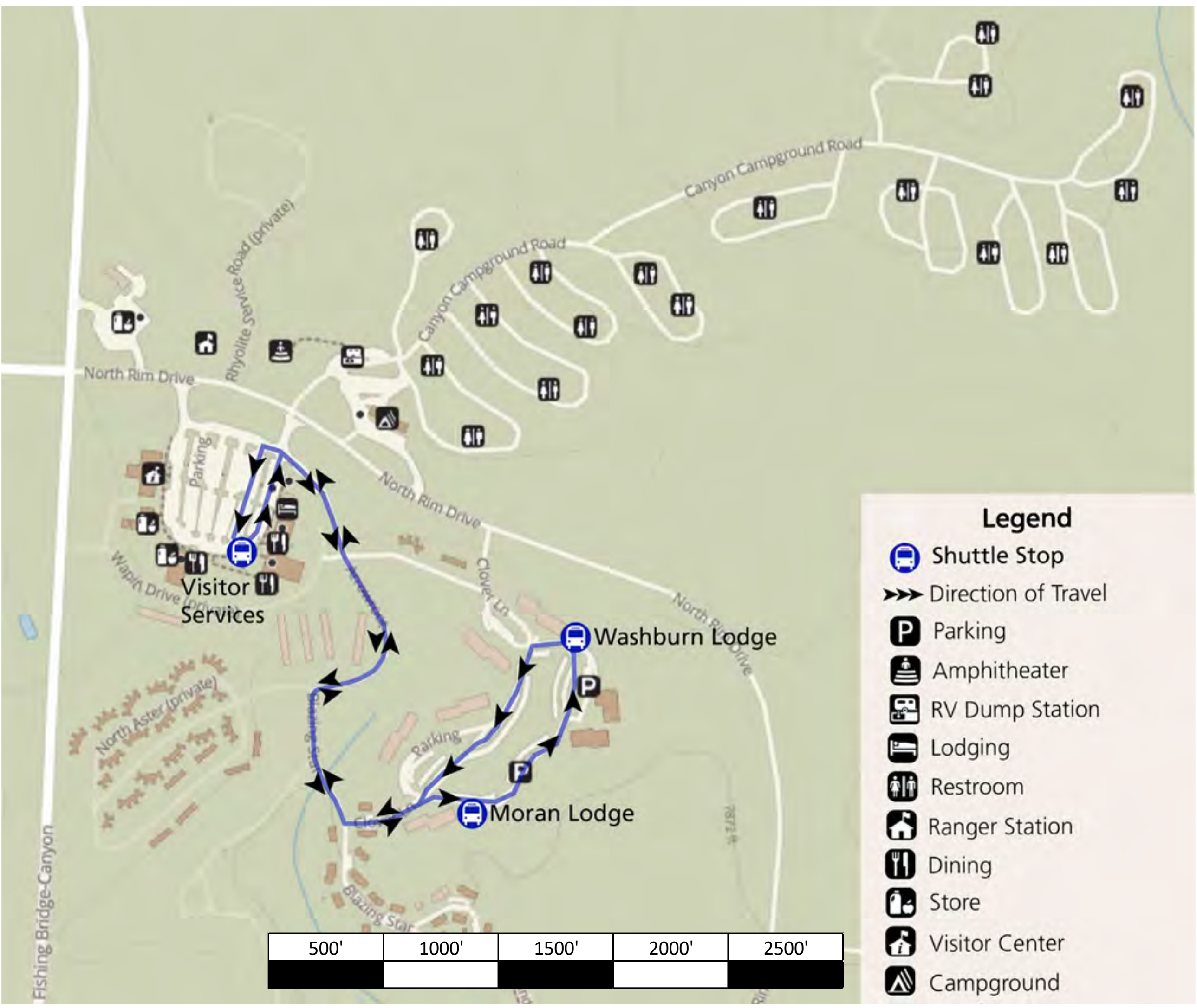
[9] Yellowstone National Park Visitation Statistics for October 2021 (2021). https://www.nps.gov/yell/learn/news/21034.htm

Lands Innovation and Research Council. The NPS successfully secured funding, and the region winnowed down the park location possibilities to Yellowstone National Park.

Once it was confirmed that Yellowstone National Park would be the location for the NPS-administered automated shuttle pilot, partners (including WASO, the Region, the Park, and the Volpe Center) worked to determine the location within the Park and conceptual service routes for the procurement process. Five locations were considered, including around the areas of Old Faithful, Norris Basin, Lake Village, Canyon Village, and Mammoth Hot Springs. Based on park staff input and evaluation of the strengths and weaknesses of each location, the Canyon Village area was selected. Prior to release of the request for quotation (RFQ) solicitation for bidding, the NPS team determined preliminary routing and service locations so that any prospective bidders could more accurately determine requirements for their responses. The RFQ issued in June 2020 included the eventual service routes to the Canyon Village lodges, campground, and visitor center area, as well as respective service requirements.

The first route (Lodge Route) operated from June 9, 2021 to July 12, 2021 (shown in Figure 1). That route provided transportation between the Canyon Village Visitor Services area and the lodge area. It was roughly 1.5 miles long and had three stops (Visitor Services, Moran Lodge, and Washburn Lodge).

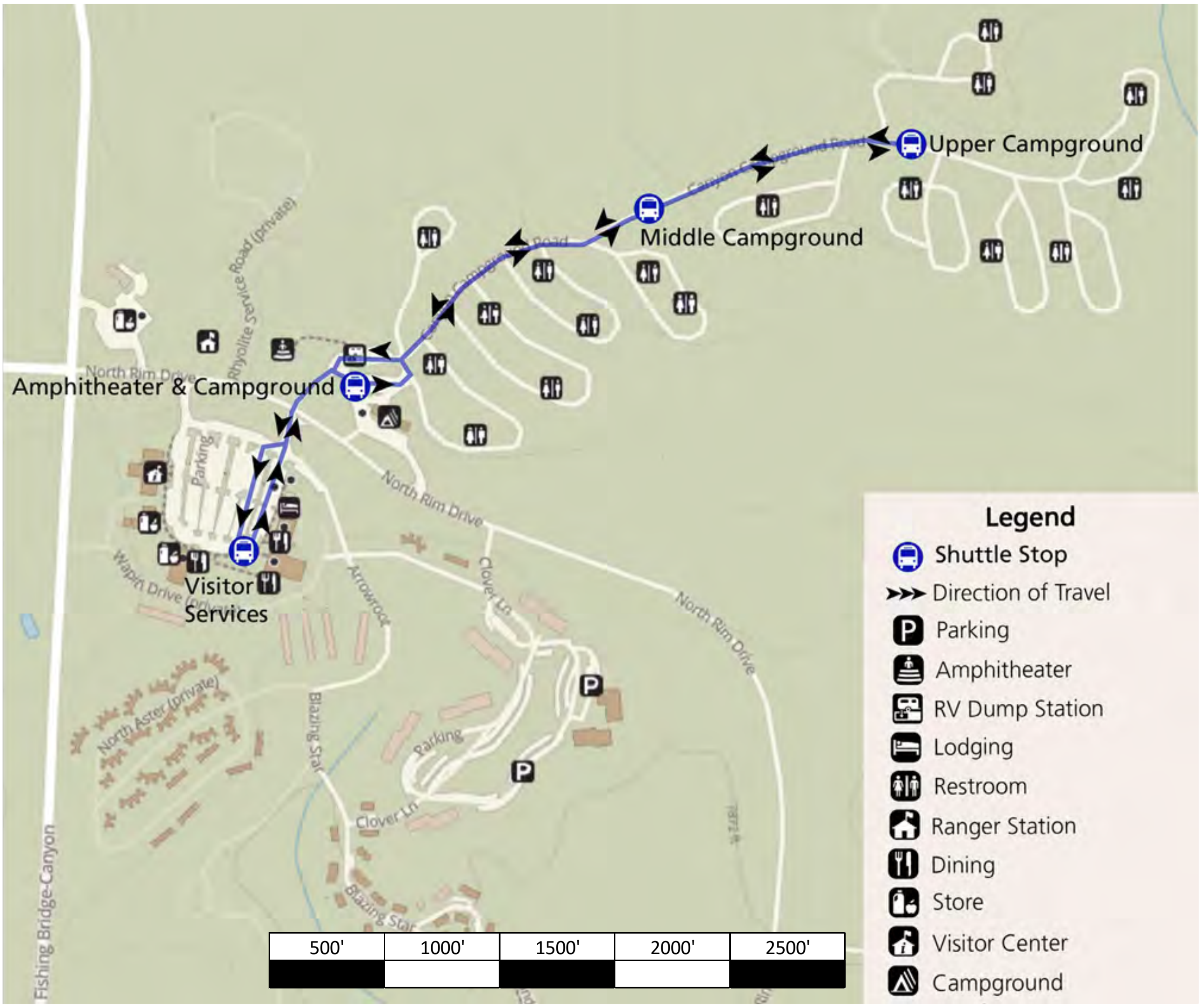
Figure 1: Map of First Automated Shuttle Route (Lodge Route)



Source: NPS and U.S. DOT Volpe Center

After a brief changeover period on July 13, 2021, the second route (Campground Route) operated from July 14, 2021 to August 31, 2021 (shown in Figure 2). That route provided transportation between the main parking area and the campground. It was roughly 1.6 miles long and had four stops (Visitor Services, Amphitheater & Campground, Middle Campground, and Upper Campground).

Figure 2: Map of Second Automated Shuttle Route (Campground Route)



Source: NPS and U.S. DOT Volpe Center

While the two routes provided service to different parts of the Canyon Village area, both shared a portion of the route in the horseshoe-shaped parking area and shared the same "Visitor Services" stop. Figure 3 shows the automated shuttles at the Visitor Services stop.

Figure 3: Automated Shuttles at the Visitor Services Stop

Source: NPS and U.S. DOT Volpe Center

2.1.3 Vehicle Specifications

The TEDDY shuttles were Local Motors Olli 1.0 shuttles (see Figure 4 for the exterior of the shuttles and Figure 5 for the interior of the shuttles).[10] The Local Motor Olli shuttle has four wheels and is approximately 12.9 feet long, 6.7 feet high, and 8.2 feet wide.[11] When empty, it weighs just under 4,000 lbs. The shuttles were each equipped with various sensors (e.g., lidar, radar, and camera units) and an ADS capable of operating at SAE automation level 4,[12] indicating that the

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[10] Since the completion of the pilot, Local Motors has ceased operations and no longer maintains a website with information on the Local Motors Olli shuttle. For more information on the Local Motors Olli shuttle and its specifications, see: TechCrunch "IBM's Watson makes a move into self-driving cars with Olli, a minibus from Local Motors" (2016). https://techcrunch.com/2016/06/16/ibms-watson-makes-a-move-into-self-driving-cars-with-olli-a-minibus-from-local-motors/, and for more information on the Olli 2.0 shuttle (a similar shuttle with some improvements over the Olli 1.0), see: TechCrunch "Meet Olli 2.0, a 3D-printed autonomous shuttle" (2019). https://techcrunch.com/2019/08/31/come-along-take-a-ride/.

[11] University of South Florida Center for Urban Transportation Research (2018). "Campus Automated Shuttle Service Deployment Initiative" https://www.cutr.usf.edu/usfcampusshuttle/

[12] For more information on levels of automation, see SAE J3016 "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles" available at: https://www.sae.org/standards/content/j3016_202104/

vehicle's ADS was "fully responsible for driving tasks within limited service areas."[13] For safety purposes, and as required by the National Highway Traffic Safety Administration (NHTSA), trained operators were always on board while the shuttle was operating, and they could switch the shuttle to "manual mode" and take over when necessary. The shuttle was programmed to stop at all crosswalks and stop signs, and to proceed only once it was safe to do so. While the shuttles were able to proceed through intersections in automated mode, they often needed manual prompting from operators, typically when other traffic was present at an intersection.

The maximum seated capacity of the Local Motors shuttle was eight passengers plus the operator, who stood while operating the vehicle. While the Local Motors Olli shuttle has a nominal maximum speed of up to 25 mph, actual operating speeds are typically much slower (for operating speed estimates in the TEDDY pilot, see the discussion in the Pilot Evaluation section).[14] The TEDDY service did not operate at reduced passenger capacity due to COVID-19 safety precautions.[15] Passengers were, however, required to wear masks while onboard.

Figure 4: Exterior of Local Motors Olli 1.0 Shuttle

Source: U.S. DOT Volpe Center

[13] NHTSA Automated Vehicles for Safety. https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety
[14] TechCrunch "Meet Olli 2.0, a 3D-printed autonomous shuttle" (2019). https://techcrunch.com/2019/08/31/come-along-take-a-ride/
[15] NPS issued a memo in late May 2021, which lifted the capacity limitations for NPS transit. Because the TEDDY pilot did not commence until June 2021, its shuttles were not subject to passenger capacity limitations associated with COVID-19. The shuttle for the CASSI pilot, which started in April 2021, was subject to passenger capacity limitations associated with COVID-19.

Figure 5: Interior of Local Motors Olli 1.0 Shuttle

Source: U.S. DOT Volpe Center

The Local Motors Olli 1.0 shuttles did not have built-in accessibility ramps. Beep procured a portable folding accessibility ramp that the operator could deploy when necessary.[16] When deployed, the ramp would be placed at the door of the vehicle so that wheelchair users or other riders who could not step up into the vehicle could board and alight (Figure 6 shows the process of unfolding and placing the ramp at the entrance of a shuttle). During a site visit, the research team observed that it took approximately two minutes for two staff to set up the ramp, and a total estimated time of five to seven minutes for staff to set up the ramp, secure a wheelchair, and remove the ramp. Staff also reported that they would kneel the vehicle (i.e., lower the suspension of the vehicle to decrease the height of the vehicle floor) if they observed a passenger with mobility difficulties.

[16] The RFQ specified that the vehicle needed to comply with ADA, which requires ramps to be a minimum of 30 inches wide. The ramp that Beep procured was only 29 inches wide, so it did not meet ADA requirements.

Figure 6: Deployment of Automated Shuttle Accessibility Ramp

Source: U.S. DOT Volpe Center

2.2 SITE MODIFICATIONS

Project partners had to make many site modifications in order to enable operation of the shuttle on the two routes. For instance, NPS staff and Xanterra had to add or change some directional and safety signage to accommodate the shuttle route. During the course of the pilot, the NPS and Xanterra relocated a dumpster that was causing the shuttles' ADS systems to brake as the shuttles passed, performed pothole maintenance, and added gravel at a point where the shuttle had to drive partly on the shoulder of the road to execute a turn (Figure 7).[17] Other changes included adding shuttle stop signage (temporary "sandwich boards" with information on the route and service), installing traffic stop signs along both routes, providing storage and charging setups for the shuttles, adding equipment to help the shuttle more accurately determine its location, and installing an accessibility ramp at one shuttle stop.[18]

[17] Note that, during the site visit, research staff noted that running the shuttle repeatedly in the exact same route led to some rutting and roadway damage (spalling) at the edge of the roadway.

[18] The infrastructure modifications (i.e., installation of the ramp and signage) were included in the contract with Beep, but ultimately, the NPS and Xanterra made these changes to enable the operation of the shuttle.

Figure 7: Road Damage Resulting from a Repeated Shuttle Turn

Source: PLTF

2.2.1 Shuttle Stop Signage

NPS designed sandwich board signs, and Beep placed them at shuttle stops to indicate where shuttle stops were located. Signs included information on operating days and times, stops being served, a map of the route, and other details related to riding the shuttle (Figure 8). The sandwich board signs also contained a QR code that directed users to a website with more information on TEDDY. Some potentially-useful information was not included on the shuttle stop signs, since it was not identified until after the signs had been printed. For instance, the signs did not indicate that masks were required to ride, specify that the shuttles were free to use, or provide information on the frequency of service.

NPS expected Beep to offer up designs for the shuttle stops, including features like seating. When Beep did not address that issue, NPS staff worked with Xanterra (the concessions operator in the Canyon Village) to design and implement enhancements to the stops. The benches placed at each stop were designed and created for a different project at Yellowstone National Park, and five of them were temporarily repurposed for the shuttle pilot. NPS staff planned where to put the benches in coordination with Xanterra. Two benches went to Canyon Village and stayed there for the duration of the pilot. Initially one bench was positioned at the Moran Lodge stop and two benches went to Washburn Lodge stop. When the time came to switch routes, the three benches at the Moran and Washburn Lodges were moved by NPS staff to the Campground Route before service recommenced.

Figure 8: Sandwich Board Signs for the First Route (left) and Second Route (right)

Source: U.S. DOT Volpe Center

In addition to the sandwich board signs, NPS and Xanterra added seven additional stop signs to the two routes in order to reduce speeds of other vehicles and help increase safety at intersections. They added four stop signs along the Lodge Route and three stop signs along the Campground Route. In addition, for one of the intersections on the Campground Route, they added a sign that read "Prepare To Stop-Shuttle Ahead" near the route, given that a shuttle stop was located near an intersection at the bottom of a hill, and the approach to the intersection had somewhat limited visibility (Figure 9).

Figure 9: "Prepare To Stop Shuttle Ahead" Sandwich Board Sign on Second Route

Source: U.S. DOT Volpe Center

2.2.2 Storage and Charging

NPS staff provided access to an existing garage at the park to ensure that the shuttle could be safely stored (Figure 10). Beep charged the shuttles in the garage overnight, and the operators used it during the day as a break room. In the morning, operators manually drove shuttles from the storage garage to the service route; at the end of the day, operators manually directed shuttles from the service route back to the storage garage. The storage garage was located approximately 0.8 miles from the shuttle route.

In addition to the charging capabilities at the storage garage, additional charging capability was added in the main Canyon Village horseshoe-shaped parking area, which allowed for midday charging during breaks in service (Figure 11). Charging in the main parking area was neither in the original plans for the pilot nor in the contract that was signed by NPS and the vendor—the vendor response to the RFQ indicated that the shuttles could operate using only charging infrastructure available at the storage site. NPS staff noted that the flexibility on the part of NPS to support charging in the parking area enabled the pilot to be successful and reduced the amount of time that would have been required to bring the shuttle back to the storage garage.

The parking area charging site also allowed the shuttles to remain in a publicly-visible location where visitors could see them, ask questions, and engage with operators or park staff.[19] The NPS blocked off five parking spaces to provide the two shuttles with space to park and connect to the charging infrastructure.

[19] In most cases, the shuttles were not typically attended during midday charging, so engagement during charging was fairly minimal.

Figure 10: Interior of the Storage Garage with and without an Automated Shuttle

Source: U.S. DOT Volpe Center

Figure 11: Charging Equipment at the Storage Garage (left) and at the Main Horseshoe-Shaped Parking Area (right)

Source: U.S. DOT Volpe Center

2.2.3 Localization

ADS-equipped vehicles can use sensors in conjunction with detailed maps to help the systems understand where the vehicle is along its route. This process is called localization. The use of satellite-based positioning, such as the Global Positioning System (GPS), is another source of information that an ADS can use for localization. In order to improve the accuracy of GPS information and assist with localization, Beep and Robotic Research LLC worked to install a GPS-based, real-time kinematic (RTK) base station in the Canyon Village area (Figure 12). The RTK base station assisted with the localization of the automated shuttles by providing an additional distance measurement to augment the positioning information that the GPS system on the shuttle was receiving directly from GPS satellites. With that additional information, the shuttle had a more accurate position reading, allowing it to precisely maintain its pre-mapped route.[20]

[20] A GPS receiver determines its location by using radio signals to measure its distance from multiple satellites with known locations in a process called trilateralization. An RTK base station improves the accuracy of the process by adding an additional known

Figure 12: RTK Base Station in the Canyon Village Area

Source: U.S. DOT Volpe Center

2.2.4 Accessibility Ramp

In order to make the Washburn Lodge stop in the first route more accessible, NPS worked with Xanterra to install a ramp from the curb down to the asphalt of the parking area (see Figure 13). The installation of this ramp allowed for a safe accessible path for riders to get to the shuttle. It removed one parking spot, but it was deemed necessary since the curb geometry prevented the shuttle from pulling directly up to the curb at that stop location and there was no nearby curb cut at the stop.

Figure 13: Ramp Installation at the Washburn Stop

Source: U.S. DOT Volpe Center

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location. RTK can provide accuracy within a few centimeters, whereas standalone GPS without RTK typically provides accuracy within a few meters. For more information on how GPS works, see the educational resources section of the official U.S. government GPS website: U.S. Space Force. https://www.gps.gov/students/

2.3 PILOT EVALUATION

2.3.1 Data Collection and Methodology

This evaluation used a mixed-methods approach, relying on statistics, survey data, and qualitative interviews with relevant stakeholders. There were two main sources of data available at varying levels of granularity and frequency—metrics directly collected by the vendor and survey input provided by visitors.

Vendor-Provided Data: The first source of data was operational and ridership data provided to the evaluation team. This data was delivered in spreadsheet form and contained a number of variables related to the operation of the vehicles. This data includes ridership numbers, trip counts, weather data, battery charging information, service availability, manual disengagements, passengers with visible disabilities (or those declaring a disability),[21] service suspensions, and ADS disengagements. The disengagement data is only available from July 2021 through the end of the pilot, as a system error resulted in no available data for June 2021. The data also suffered from challenges related to getting accurate positioning information (i.e., some coordinate data that was collected was quite far from the shuttle route), resulting in some difficulties in getting accurate estimates related to speed and distance. For more precise details on the data provided, please refer to Appendix B: Data Tables.

Survey Responses: The second data source was a visitor survey. The survey was approved through the United States Office of Management and Budget (OMB) (OMB control number 1090-0011). As passengers departed the shuttle, the shuttle operators encouraged those riders to take the survey. The survey asked respondents about topics such as how safe they felt on the vehicle, whether the shuttle took them to their destination in a reasonable amount of time, why they rode the shuttle, and whether they would ride again. Several questions were multiple choice, while others solicited open-ended responses. The survey received 222 responses where the respondent answered at least one survey question. The full survey questionnaire is provided in Appendix A: Survey Questionnaire.

Site Visits: Members of the evaluation team visited the site twice: first on June 8–10, 2021, and again on August 23–25, 2021. The team conducted informal interviews about the pilot with staff from the operator, park, and concessionaire. The team also rode on the shuttle and observed its operations. This anecdotal evidence, as well as that collected by the PLTF throughout the deployment, is also used to inform the findings of this report.

2.3.1.1 Limitations

There are several limitations to the available data. A significant limitation is the survey response rate—with 222 responses and 10,057 total passengers, the survey response rate was only 2 percent.[22] A survey response rate of at least 50 percent would have been ideal, while a response rate of at least 20 percent would have instilled greater confidence in the survey findings. The responses that were received are invaluable to this evaluation; however, the low response rate could mean that responses are not reflective of the entire population of riders.[23] An additional survey limitation is the lack of demographic data, which would have been helpful in understanding the characteristics of those who rode the shuttle. The survey collected general age data, but no other ridership demographics. The survey was also subject to

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[21] These passengers were referred to as "Americans with Disabilities Act (ADA) passengers" in the date reporting.

[22] The estimate of 10,057 passengers does not represent unique passengers, as many people may have ridden the shuttle in both directions and accordingly were double counted. Under that construct, using half the total estimate (5,029) would increase the response rate from 2 percent to 4 percent, which is still considered a low response rate.

[23] This could be due to non-response bias, which occurs in surveys when those who respond are different in some fundamental way from those that do not respond. Often, those that respond to a survey have extreme opinions (either positive or negative) while individuals with more neutral opinions do not respond. Because the survey was opt-in; that is, self-selection for survey participation is a decision made by each shuttle rider, it is likely that the pool of individuals who did respond to the survey does not represent the entire population of riders.

Federal regulations regarding government-run surveys, and the project team limited the survey to 10 or fewer questions to streamline the review and approval process.

Another limitation is that data was not available on a per-stop level. When evaluating a transit service, the data ideally should exist on a per-stop level—with the simplicity of the route in this pilot, this would mean having data on the number of passengers on every trip taken by the shuttle from one stop to the other. Having passenger data available per-stop offers much more detail on the use of the shuttle over the course of the day. Such data is not available for the evaluation, however.

There are other types of data that would also have been beneficial to have on a per-ride level, such as the time of arrival and departure, average speeds, and dwell times at each stop (dwell times were not available at all in the data). These additional types of data would have allowed for more robust analyses related to vehicle performance, on-time performance, usage, and more. As previously noted, some of the data is flawed due to the positioning information challenges present in the pilot.

Beyond the quality and detail of the data itself limited internet connectivity in Yellowstone National Park meant that the vendor was unable to transfer data directly from the park. As a result, the vendor had to ship physical hard drives back to its office in order to download data for analysis. While this solution allowed the data to be transmitted and later shared with other partners, it required more time and effort than would have been necessary for a pilot that occurred in a less remote setting.

2.3.2 Data Analysis

The shuttles were originally scheduled to run every day from May 24, 2021 through August 31, 2021, for a total of 100 days of operation. Due to delays from snow and a water main break that closed portions of the route, the start date was pushed back until June 9, 2021, reducing the total planned days of operation to 84. However, due to multiple service suspensions caused by shuttle battery issues, weather conditions, and shuttle incidents, there were only 38 days over the 100 planned days of the pilot operation where both shuttles ran in full service for the entire day. In total, the two shuttles ran for a combined 2,544 trips and carried 10,057 passengers.

Table 1: Overview of TEDDY Operation

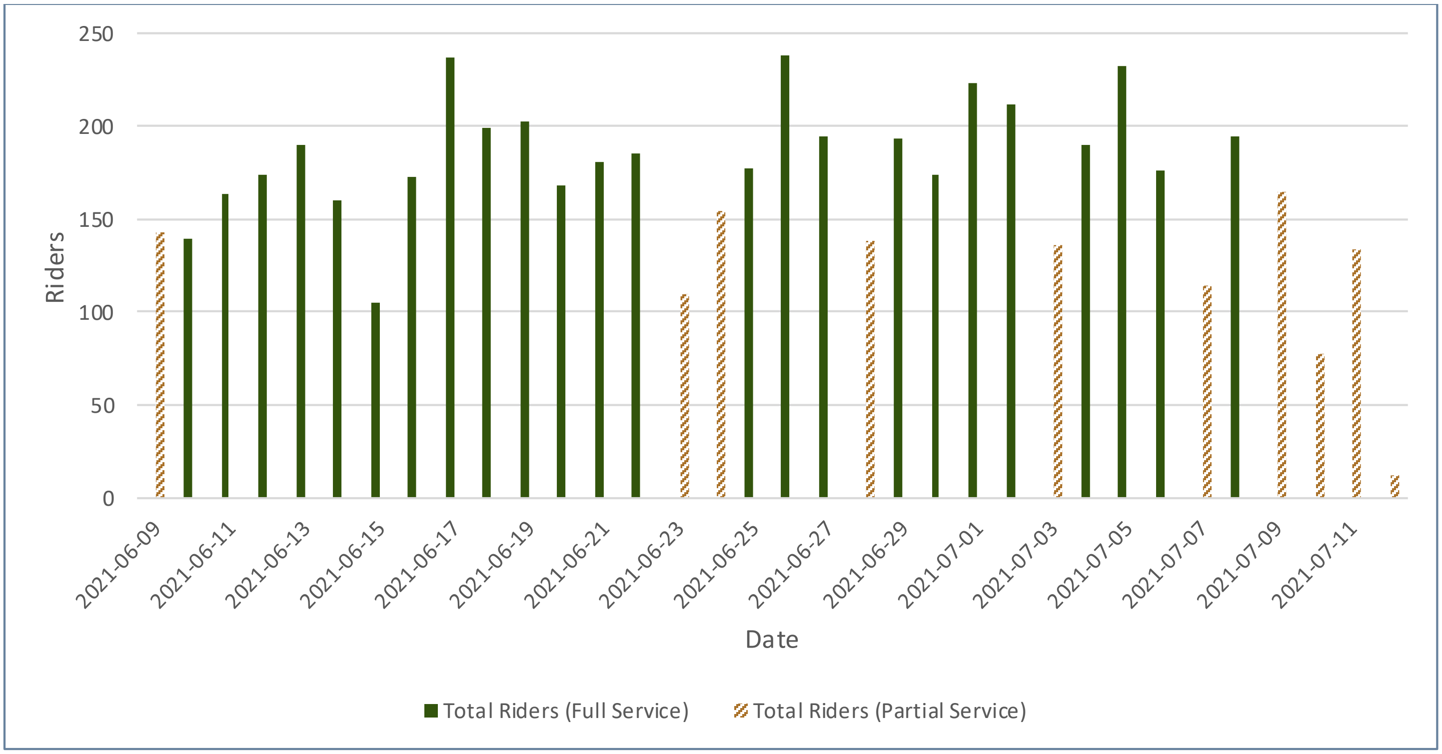
Category	Scheduled	Actual
Number of Days with at least one Shuttle in Partial Operation	84	74
Hours of Operation*	1,512	1,084
Number of Trips	N/A	2,544
Number of Passengers	N/A	10,057

*Per shuttle, scheduled hours of operation were 756. One shuttle (named "Olli 19") ran for approximately 535.5 hours and the other shuttle (named "Olli 20") ran for approximately 548 hours.
Source: Beep and U.S. DOT Volpe Center

2.3.2.1 Ridership

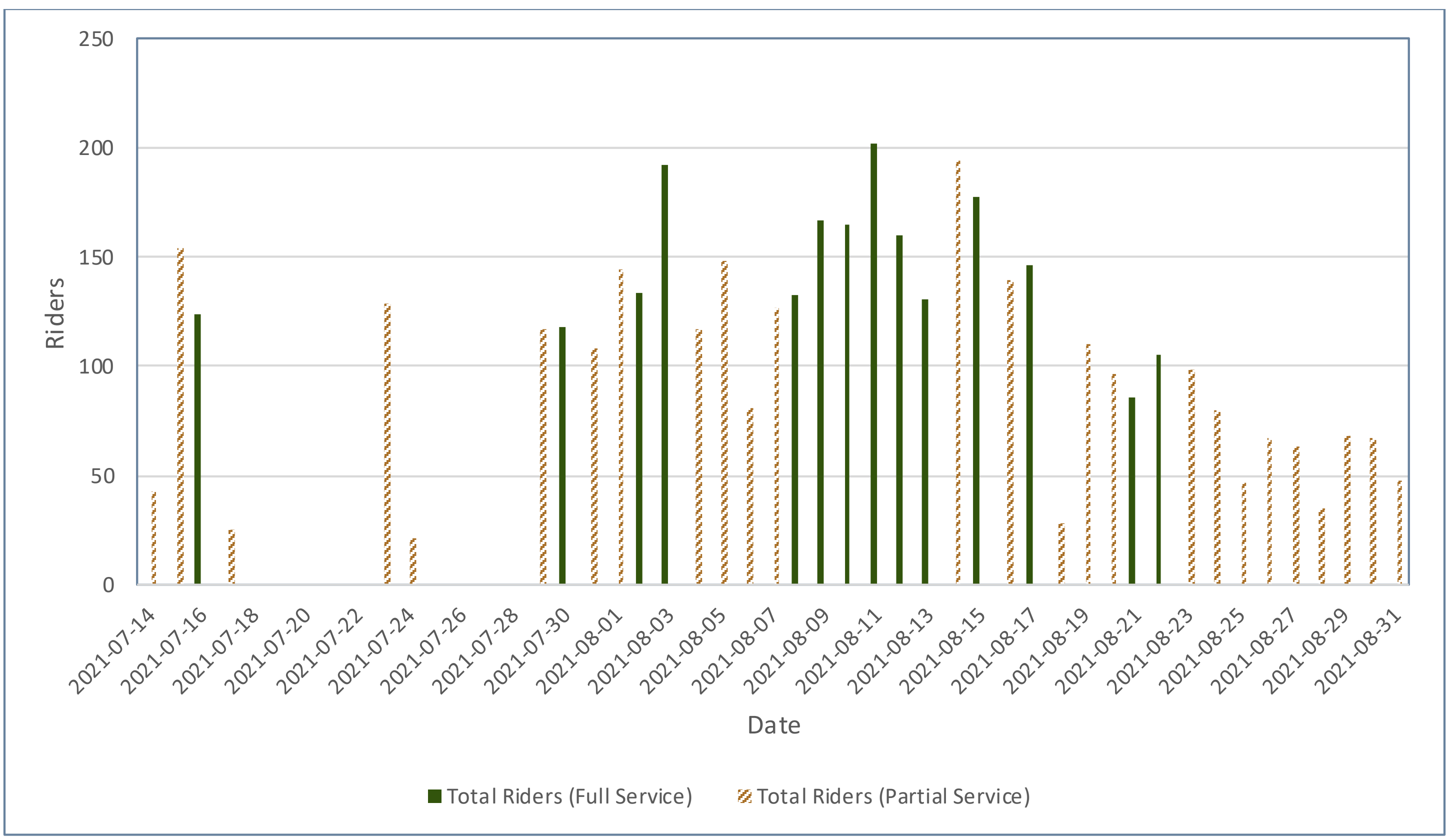
The number of riders varied considerably over the course of the pilot, even when accounting for service suspensions. As Figure 14 shows, the number of riders per day ranged from fewer than 90 to more than 230 on days with full, two-shuttle service. The average number of riders per day, for days in which both shuttles were fully operational all day, was 171.6. That puts the average number of riders per day per shuttle at 85.8. The riders per day can be seen for the Lodge and Campground Routes in Figure 14 and Figure 15, respectively.

Figure 14: TEDDY Shuttles Riders per Day: Lodge Route, June–July 2021



Source: Beep and U.S. DOT Volpe Center

Figure 15: TEDDY Shuttles Riders per Day: Campground Route, July–August 2021

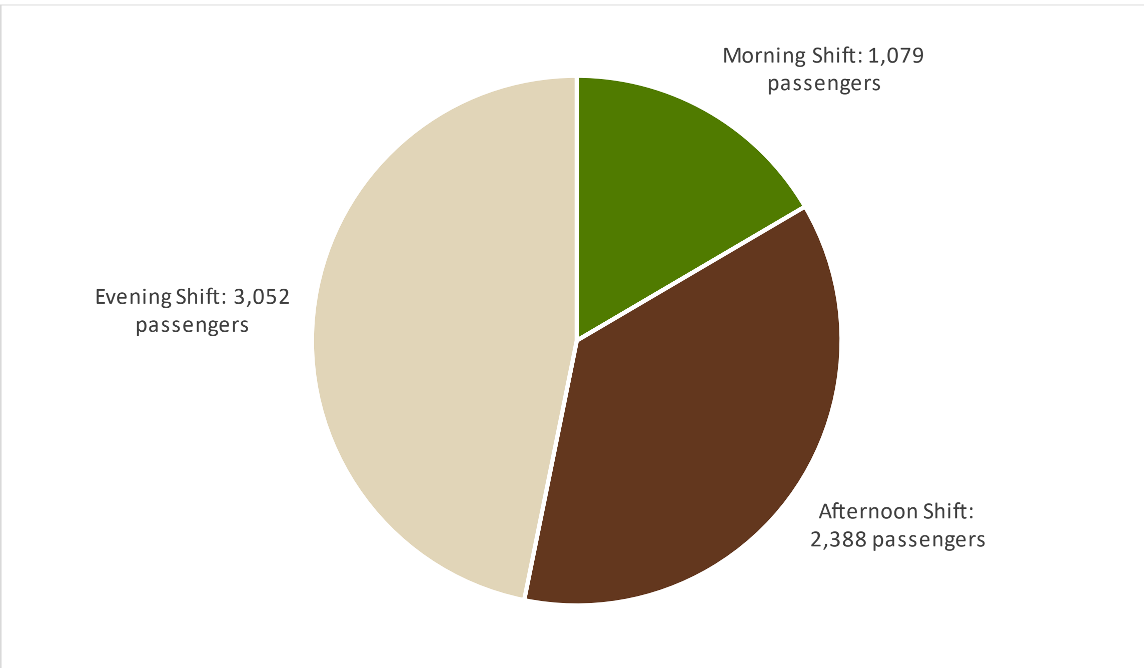


Source: Beep and U.S. DOT Volpe Center

With 2,544 trips and 10,057 passengers throughout the pilot, a single shuttle carried approximately 3.9 passengers per trip (the shuttles have a maximum capacity of 8 passengers). If there were no passengers waiting to board at the first shuttle stop, operators sometimes chose to delay departure until passengers arrived, which decreased the total number of trips and raised the passenger/trip ratio.

The number of trips and passengers varied by both day and shift, and the shift variation had a clear overall pattern. The morning shift had the fewest number of total trips and passengers and had the lowest passenger/trip ratio. On days for which both shuttles were in service for the entire day, the morning shift (7:00–10:00 am) averaged 2.7 passengers per trip, the afternoon shift (12:30–3:30 pm) averaged 4.5 passengers per trip, and the evening shift (6:00–9:00 pm) averaged 5.2 passengers per trip. The breakdown of total passengers between shifts can be seen in Figure 16.

Figure 16: TEDDY Shuttles Riders by Shift for Days of Full Service

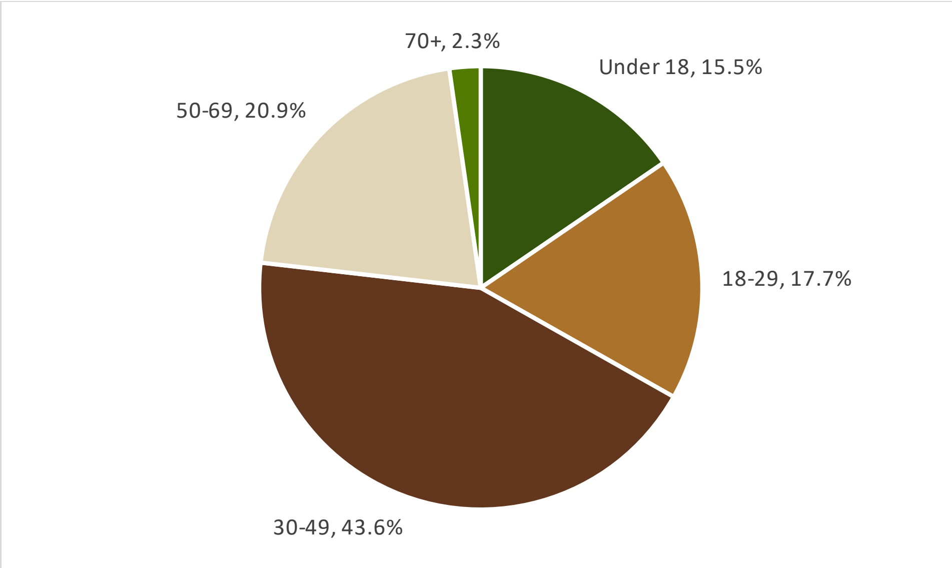


Source: Beep and U.S. DOT Volpe Center

The data also indicated that there were 18 total passengers that required deployment of the ramp during the pilot. Unfortunately, the survey data does not directly ask passengers if they needed mobility assistance or required ramp deployment, and there is no indication in the operator-provided data whether these passengers found the shuttle to be easily accessible or whether the ramp deployment functioned as intended. There is also no way to know whether or not there were additional passengers with mobility-impairments who chose not to ride the shuttle out of concerns related to their mobility.

The survey responses do provide some insight into the age of riders. Figure 17 shows the survey respondents by age. It is possible there is bias in the survey results, in that some age groups may have been more likely to respond to the survey than others, but the survey results showed that the plurality of riders who took the survey were between 30 and 49 years old (43.6 percent), with the next largest group being riders between 50 and 69 years old (20.9 percent).

Figure 17: TEDDY Survey Respondents Age



Source: Montana State University (MSU) and U.S. DOT Volpe Center

2.3.2.2 Vehicle Performance

This section describes vehicle performance as it relates to incidents, speed, battery usage, impacts of weather, and disengagements.

Incidents

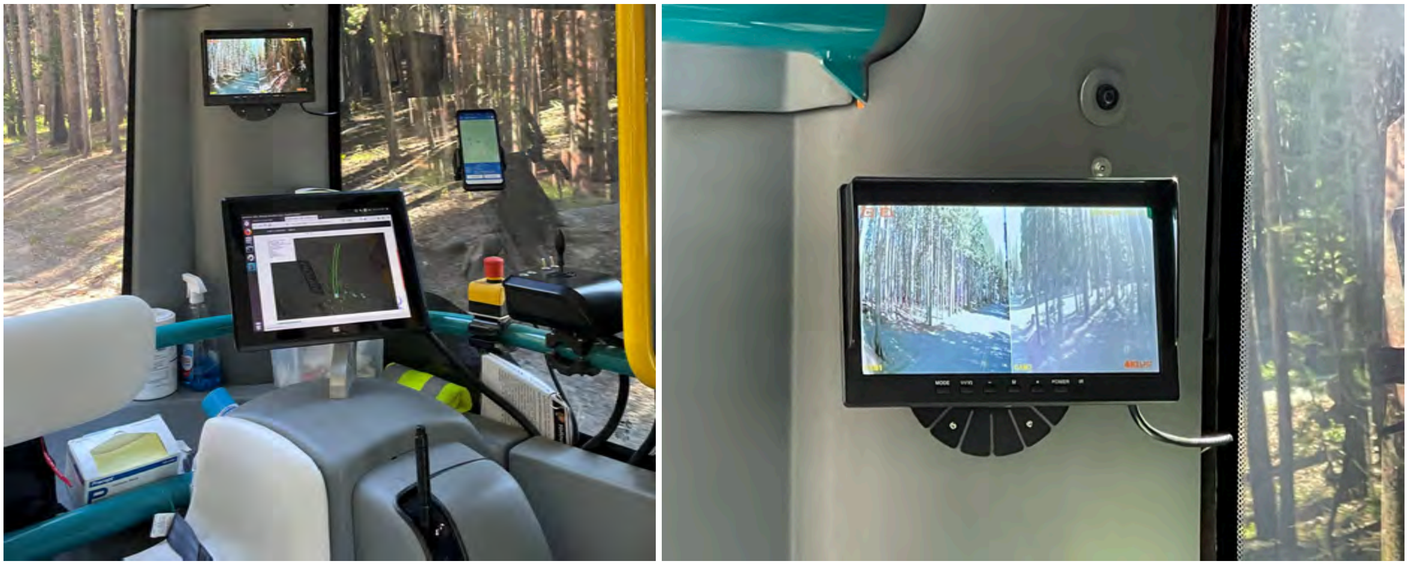
The shuttles were involved in two incidents, one on June 24, 2021 and the other on August 23, 2021. On June 24, 2021, another road user backed into one of the shuttles. There were eight passengers onboard at the time, and there were no injuries reported. The incident on August 23, 2021 was very similar, when another road user backed into one of the shuttles in the parking area.

For both incidents, the investigations showed that the shuttle and the shuttle operator were not at fault. The incidents both resulted from another vehicle backing out of a parking space, where the driver could not fully see the shuttle or assumed that the shuttle would stop more quickly than it did. The incident on August 23, 2021, while minor, did damage the shuttle enough for it to be taken out of service for the remainder of the pilot.

In addition to the two incidents in Yellowstone National Park, in June 2021, a Local Motors Olli shuttle operated by Beep struck a pedestrian in Dunedin, Florida. [24] The operator of the shuttle was manually operating the vehicle at the time. Following an investigation into the incident, additional cameras were installed on the TEDDY shuttles to help reduce the size of blind spots and improve safety of the shuttles (Figure 18).

[24] Cohen, M. (2021). "79-year-old woman hit by an autonomous vehicle in Dunedin." Tampa Bay Times. June 25, 2021. Retrieved form: https://www.tampabay.com/news/breaking-news/2021/06/25/79-year-old-woman-hit-by-an-autonomous-vehicle-in-dunedin/.

Figure 18: Additional Monitor Added to Address Blind Spots



Source: PLTF

Speed

Although the shuttles are capable of a maximum speed of 25 mph, in practice, operating top speeds for automated shuttles are significantly slower, both in the NPS pilots as well as other automated shuttle pilots.[25] There were challenges related to gathering the speed data, due to issues related to collecting accurate positioning information that was required to estimate speeds along the route, as well as difficulties in removing dwell times (when the shuttles are stopped) from the average speed estimates. The average speeds attained by the two shuttles along both routes were around 3 to 4 mph, and the maximum speeds typically ranged between 10 and 11 mph. Those low speeds were expected, as the automated technology is still under development and low speeds are safer at this time. In a long-term deployment, however, it may not be feasible for the automated shuttles to move significantly slower than other vehicular traffic, as they could negatively impact traffic flow, visitor experience, or cause other issues.

Battery Usage

On average, each shuttle used around 40 percent of its battery's charge per shift, with an hourly battery usage rate of 13 percent, but this rate was highly variable across shifts. Some shifts would use as little as 9 percent of the battery's charge (3 percent per hour), while other shifts could use as much as 73 percent of the battery's charge (24 percent per hour). This is likely due to each shift having a different number of trips and operation of the air conditioning system at different levels.

The operators and park staff had to change the planned charging schedule to allow for additional charging during the day. Originally, the schedule would have included a single break for midday charging (two service shifts), but it had to be revised to include two breaks for charging (three service shifts). During each break, the shuttles charges for more than two hours. The substantial amount of time needed to recharge the shuttles during the middle of the day was identified as a technology limitation that would need to be addressed before the shuttle would be ready for broader use to provide regular service.

The additional midday charging time was required as the shuttle batteries were depleted faster than anticipated, an issue that was exacerbated as temperatures began to increase, requiring more frequent use of air-conditioning on the

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[25] For example, in recent automated shuttle pilots in Utah, top speeds were typically around 10 to 11 mph. For more detail on those pilots, see https://transportationtechnology.utah.gov/download/automated-shuttle-pilot-project-final-report/.

shuttles. Prior to the launch of the shuttle, Park staff added an additional charging station in the parking area to allow for charging during the day. Before the addition of the additional charging station, staff had considered mitigating battery drain by limiting use of the air-conditioning system, which would have negatively affected conditions for both drivers and visitors on the shuttle. The electrical chargers were able to connect to existing electrical infrastructure, and while charging, the two shuttles used five parking spots in the Canyon Village lot.

Weather Impacts

The shuttles operated primarily in clear weather conditions, with most days having little-to-no rain recorded and average wind speeds of 5 mph or less. The temperature was more varied, with a low of 29 °F and a high of 85 °F, and an average temperature around 56 °F. Humidity was also high, averaging around 50 percent. The shuttles did need to frequently run the air conditioning to remain comfortable for passengers, but otherwise the weather did not greatly impact the service for most days.

There were a few days where service had to be temporarily suspended due to the weather conditions. The days where weather is specifically noted as causing a service suspension include June 23–24, July 3, July 31, August 5–6, and August 19. For all of these days, the weather condition causing the service suspension was rain of varying levels of intensity, with the exception of June 23, when service was suspended due to concerns of heavy wind and hail. The ADS installed in the shuttles used for TEDDY pilot struggled to run in inclement weather conditions—this is acceptable for a pilot test, but any long-term deployment would need a shuttle that can run in a wider range of weather conditions.

Disengagements

Both TEDDY shuttles experienced numerous disengagements throughout the pilot, with a total of 257 disengagements recorded on the Lodge Route and 221 disengagements recorded on the Campground Route.[26] The disengagements can be seen plotted on the two routes in Figure 19. Some of the disengagements are notably not mapped onto either of the two routes, which is assumed to be due to issues in accurately recording the location of the disengagement.

Figure 19: Maps of TEDDY Shuttle Disengagements for the Lodge Route (left) and Campground Route (right)

[26] A disengagement refers to a shift in vehicle control from automated driving to manual driving—essentially, the automated technology has "disengaged" and the human operator must take over. This can either be triggered either by the system itself or manually be the operator. As previously noted, all disengagement data from June 2021 was lost, which would result in fewer reported disengagements for the Lodge Route than the actual total value.

Source: Beep and U.S. DOT Volpe Center

The disengagement data included information on the initiation of the disengagement (operator or ADS) and a description of the cause. Almost all disengagements were due to obstacle detection (90.0 percent), but there were also several disengagements due to a weak signal (9.0 percent),[27] as well as a few due to operator error (0.4 percent) and deviations from the path (0.6 percent).

Weak Signal

As previously noted, several of the disengagements were due to a "weak signal error" (43 total disengagements, 9.0 percent of all disengagements). In those cases, a weak cellular signal from the RTK base station could cause the shuttle's ADS to have difficulty with localization, causing it to disengage, and requiring the operator to take over manually until the signal strengthened. Communications in a remote, mountainous location like Yellowstone National Park are a known challenge, and challenges related to the communications were apparent throughout the pilot. To deploy automated shuttles as a longer-term service option, the automated driving system being used would need to be able to function in these types of environments where communications have historically been challenging.

Disengagement Location

An analysis was done on the location of the disengagements. The location data for some of the disengagements maps them to places that are neither on the route or even on a road. Of the total 478 recorded disengagements, 54 of them (11 percent) are not mapped onto the route. The Campground Route experienced a slightly higher percent of mapping problems with the disengagements than the Lodge Route, but both routes had challenges.

Of the correctly mapped 233 disengagements for the Lodge Route, most of the disengagements occurred near the lodges (144 disengagements, 62 percent). The remaining disengagements occurred either in the parking area (63 disengagements, 27 percent) or on the route between the lodges and the parking area (26 disengagements, 11 percent).

Of the correctly mapped 191 disengagements for the Campground Route, most of the disengagements occurred in the parking area (107 disengagements, 56 percent). The area near Camp Services had the second most disengagements (43 disengagements, 23 percent). The remaining disengagements occurred either on the route between the parking area and Camp Services (17 disengagements, 9 percent) or at the campgrounds (24 disengagements, 13 percent).

The location of the disengagements would tend to suggest that the automated technology performed the best on roadways, and that it struggled more in parking areas. Parking area environments are more likely to have unpredictable vehicle and pedestrian movements, whereas a roadway may be a straighter drive with fewer obstacles.

Disengagements by Route

As previously noted, all disengagements from June 2021 were lost, making it challenging to compare the performance of the vehicle as it relates to disengagements between the two routes, as less than two weeks of data are available for the first route (Lodge Route). However, the data does still show some interesting changes. Overall, there are more recorded disengagements for the Lodge Route than the Campground Route (257 disengagements from July 3–12 compared with 221 disengagements from July 14–August 31), which is surprising given that many more days of data are available for the Campground Route. This suggests that the Lodge Route had a much higher rate of disengagements per day.

To further test this, days of full service were examined to develop an estimate of disengagements per day. Given the limited nature of the disengagement data for the Lodge Route, there are only four days of disengagement data available

[27] RTK solutions often rely on cellular connectivity to provide signal corrections to the vehicle's GPS receiver. In the absence of reasonable cellular coverage, the vehicle may experience a loss in GPS precision, which can lead to a disengagement.

in which both shuttles were fully in service all-day (July 4–6, and July 8). Accordingly, to create an accurate comparison, four days of full service data were selected from the Campground Route—these days are specifically the last four days of full service on the route (August 15, 17, 21, and 22) to ensure that both routes are being compared toward the end of their deployment. This analysis shows that the Lodge Route experienced 42.5 disengagements/day (21.3 per shuttle) on average and that the Campground Route experienced 6.8 disengagement/day (3.4 per shuttle) on average.

It is unclear exactly why the Lodge Route experienced a higher rate of disengagements, although it may be due—at least in part—to characteristics mentioned in the findings of the previous subsection. The Campground Route had more of its journey on roadways and spent less time in the parking area relative to the Lodge Route, and most of the Lodge Route disengagements occurred near the lodges, which was not part of the Campground Route.

Landscaping & Maintenance

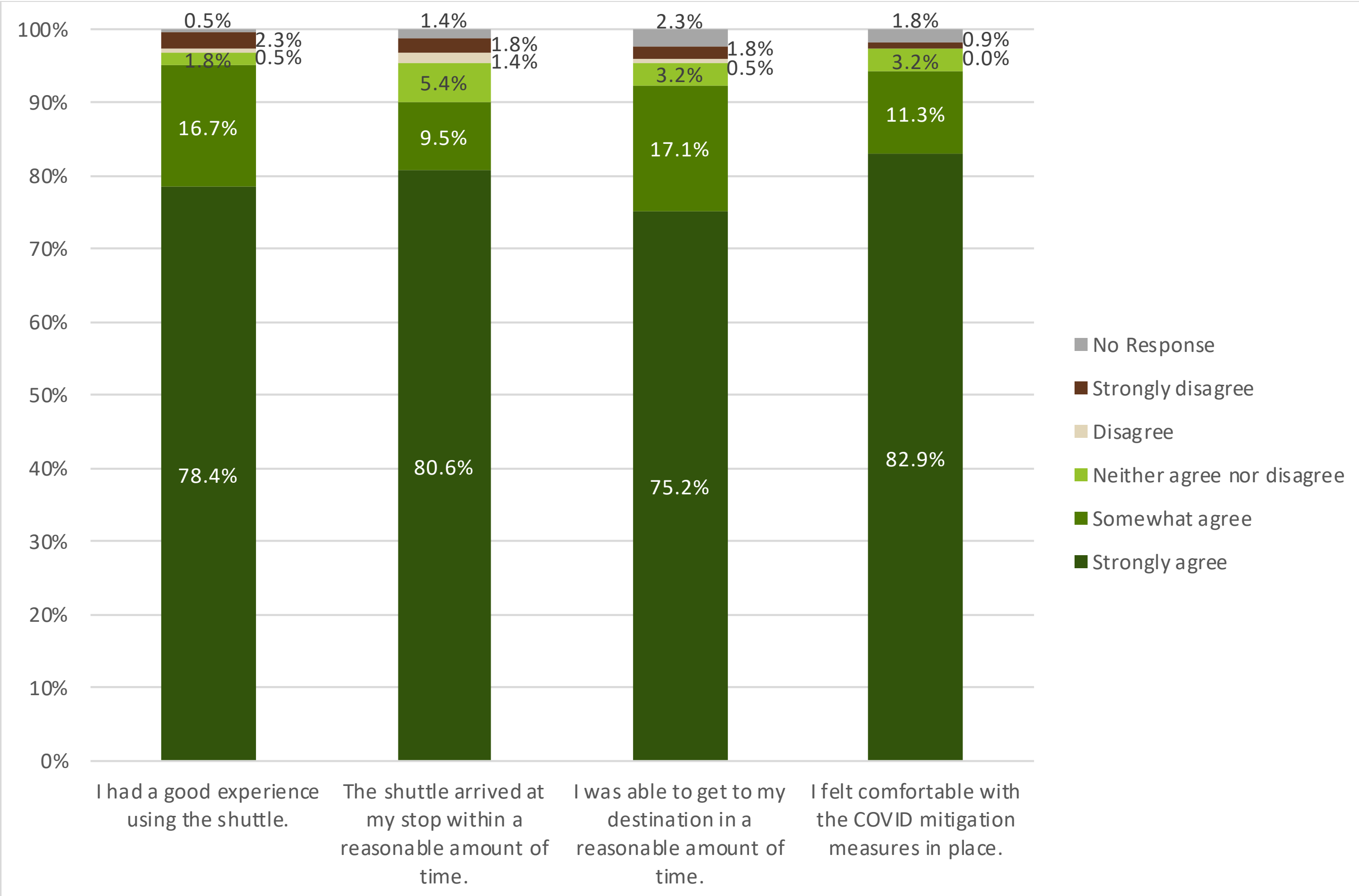
Prior to launch, the pilot team had identified the need for trimming nearby low-hanging tree branches, however, roadside vegetation and undergrowth caused additional challenges. The shuttle's sensors and ADS detected roadside vegetation, causing the shuttle to slow, stop, or disengage. As a result, additional landscaping maintenance was required.

2.3.2.3 Visitor Experience

The pilot cannot be fully evaluated without understanding the visitor experience on the shuttle. The survey results are the primary source of data on visitor experience, and although the survey response was low (2–4 percent), the insights from the survey still provide valuable feedback on visitor experience.

The survey had four questions that gauged visitor satisfaction with the shuttle, where respondents could select an answer on a five-point Likert scale from "Strongly Agree" to "Strongly Disagree" with each of the four statements. The survey responses for these questions is shown in Figure 20. Overall, the respondents strongly agreed with all the statements, indicating that they had a good experience with the shuttle, that their journey took a reasonable amount of time, and that they felt safe with regard to the COVID-19 mitigation measures. All statements had more than 90 percent "Somewhat" or "Strong" agreement. The statement that had the lowest level of overall agreement was "the shuttle arrived at my stop within a reasonable amount of time," with 90 percent either indicating "Somewhat" or "Strong" agreement. Although the third statement, "I was able to get to my destination in a reasonable amount of time" had the lowest level of "Strong" agreement (75 percent), the overall agreement level was still 92 percent due to respondents "Somewhat" agreeing.

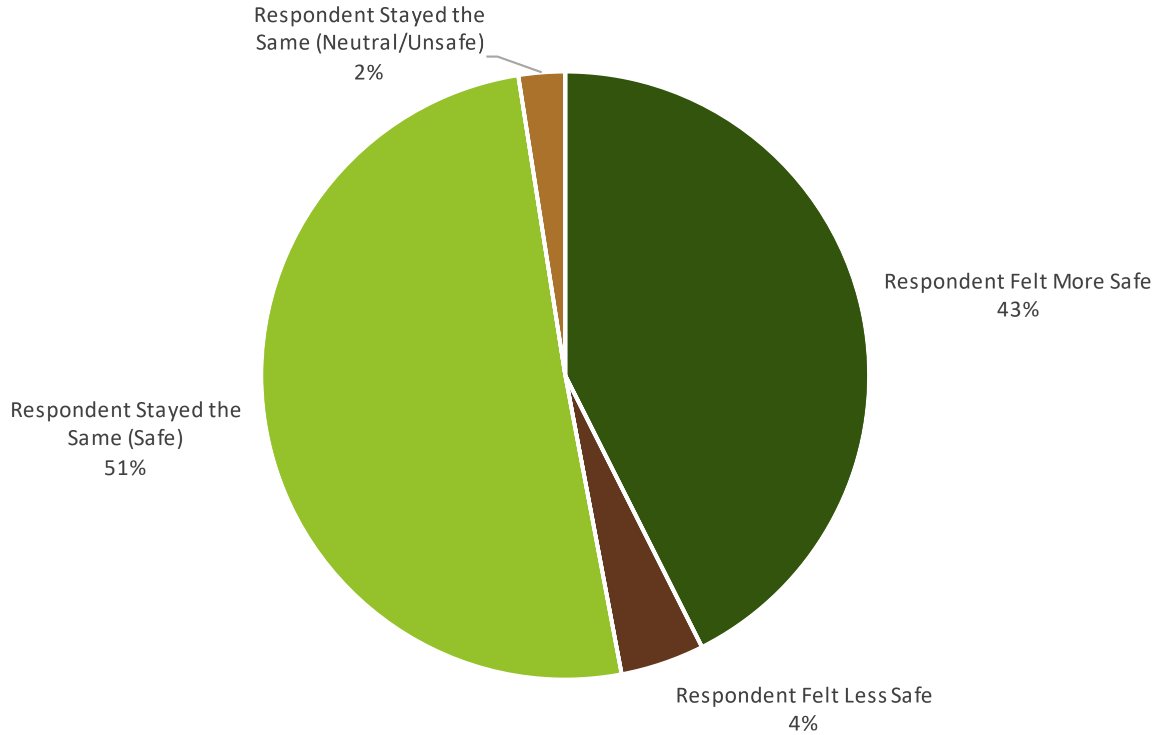
Figure 20: Survey Responses for Agree/Disagree Statements



Source: MSU and U.S. DOT Volpe Center

Respondents also indicated that they felt the automated shuttle was a safe experience. The survey asked respondents how safe they felt with automated shuttles both before and after riding the shuttle, and although the majority of respondents felt "somewhat safe" or "very safe" even *prior* to riding the shuttle (92 percent), there was an increase in the perception of safety *after* experiencing riding the shuttle (98 percent felt "somewhat safe" or "very safe"). Only nine respondents felt "less safe" after riding than the shuttle than they did before, and only five respondents who felt unsafe before riding the shuttle still felt the same level of safety after riding the shuttle. Figure 21 shows how respondents' opinions changed after riding the shuttle.

Figure 21: Survey Responses for Shuttle Safety After Riding the Shuttle



Source: MSU and U.S. DOT Volpe Center

Respondents also had the opportunity to include an open-ended comment about their experience with regard to safety. Some respondents left comments reinforcing their feeling of safety, but most of the respondents who provided an open-ended remark had a negative comment related to safety. The small number of more negative comments had a general theme of noting the technology limitations with the operator needing to manually stop the vehicle in certain circumstances.

> **"I felt safe riding the shuttle with an attendant. I'm unsure of what my opinion would be if the shuttle was truly automated."**

> **"Abrupt and jerky stops when it senses something in the road."**

> **"It's new, it got stuck a few times and needed human assistance."**

> **"I didn't feel unsafe but the shuttle went up on the curb and hesitated at the four way [stop]."**

When considering the visitor experience, it is also worth understanding whether visitors perceived the shuttle to be filling a transportation need or to serve as an attraction in-and-of itself by providing a new experience to visitors. The survey asked whether respondents rode the shuttle specifically to get to their destination or whether they were primarily motivated by just having a fun experience. The survey results indicated that most people rode it solely for a fun experience (75 percent), with only a small percent riding it specifically to get to their destination (2 percent) and some using it for both purposes (12 percent). The remaining respondents either did not respond to this question (9 percent) or selected "Other" and entered in a text response (1 percent). Anecdotal evidence from the shuttle attendants indicates that perhaps a greater percentage of riders were riding the shuttle to get to a specific destination than the survey results would suggest. This observation may reflect a possible response bias, in that people who took the shuttle for fun were more likely to respond to the survey, but it is unclear how large of a difference there may be.

While the initial plan for service had involved regular service intervals (headways), in practice the operators did not always work to preserve headway on the service. Frequently, shuttles would dwell at Canyon Village until they were full. As a result, the shuttles would bunch up. In at least one case, riders that had been dropped off in the campground were left waiting for a long time for one of the shuttles to return to pick them up. This lack of consistent headways may have been a factor in reinforcing usage of the shuttle as a fun experience rather than to get to a specific destination.

Finally, the survey asked visitors whether they would like to see more automated shuttles in national parks and allowed visitors to leave an open-ended response about whether they would ride the shuttle again. Over 83 percent of respondents agreed either "Somewhat" or "Strongly" with the statement that they would want to see more automated shuttles in national parks, with only 2.3 percent (5 respondents) "Somewhat" or "Strongly" disagreeing. Similarly, over 96 percent of the 152 open-ended responses indicated willingness to ride the shuttle again. It is worth noting that many of the open-ended responses remarked on aspects of the service that were unrelated to the automated technology (for instance, the electric power reducing emissions, the general concept of a shuttle reducing congestion, and the number of shuttles and other passengers).

> **"I would love to see shuttle vehicles available throughout the park. I also would love to ride one in an urban setting."**

> **"I would [ride] it again but there needs to be more work done to know when and how the shuttle will be there."**

> **"The shuttle was definitely in the development phase. I would definitely be interested when it is more fully developed. It should help reduce some of the congestion and parking difficulties around some of the more popular areas within national parks."**

2.4 Lessons Learned

Throughout the pilot process, the NPS learned many lessons. The aim is to put these lessons into practice for any future automated shuttle pilots, and in some cases, they may also apply to other types of emerging mobility pilots and projects. In addition, the lessons learned from this pilot apply beyond the NPS and may provide invaluable insights for future automated shuttle deployments for other potential deployers in other settings.

2.4.1 Contracting

Contracts set the stage for pilot projects—not only do they secure vendors who provide plans, vehicles, staff, and other materials, but they also lay out the roles and responsibilities of both the vendor and the other partners on the project. Ultimately, the quality and form of the contract will have a great influence on how the work is carried out and the ultimate success of the pilot. Lessons learned related to contracting include:

- **Seek additional technical expertise on new technologies during the contracting phase to build context and details into the contract.** NPS staff noted that once they started managing the contract, they realized that some details were missing. They suggested that for future pilots of emerging technologies, more engagement early in the process with staff or external contacts who have technical expertise and experience could be useful to provide context and determine how to incorporate that insight into the contract.

- **Be specific about partner obligations.** NPS staff indicated that the initial statement of work (SOW) was very broad. More details about partner obligations (e.g., specific tasks, roles, and responsibilities) would have been helpful. For instance, NPS staff noted that maintenance of trees and removal of snow within the shuttle's right of way was not initially spelled out as an NPS responsibility in the SOW.
- **Strongly and clearly identify data needs and formats in solicitation documents.** In addition, it may make sense to create a separate list to clearly differentiate between items that would be considered required and additional data elements that are desirable but not absolutely necessary. NPS staff expressed a desire for more consistent and thorough data sharing from Beep. Beep noted that given changes to operating systems and platforms, all data elements that were requested may not be available. Maintaining two lists would allow proposers to verify that they can meet all of the requirements while providing flexibility to include some of the optional items in proposals.
- **Consider the various contract mechanisms available and how the choice of a particular approach will affect how a project is executed and managed.** Given the number of deliverables and specific outcomes expected from the pilot, project staff believe that a performance-based contract would have been better suited to the specific needs of the shuttle pilot than a fixed-price contract. Going forward, the NPS could potentially consider performance-based contracts for automated shuttle pilots and other types of emerging mobility pilots.

2.4.2 Planning

Operational planning is critical to ensure that pilots can be executed safely and efficiently. Detailed planning also ensures that onsite and remote staff can respond to unexpected problems that may arise throughout the pilot period. Lessons learned related to planning include:

- **To the extent possible, maintain consistent staffing from all project partners throughout the pilot period. In cases where staffing changes are required, consider how documentation and training procedures can assist with providing continuity.** NPS and Beep staff agreed that staff turnover resulted in some miscommunication and loss of institutional knowledge. Project partners can ensure a greater consistency and reliability of operations if a core group of staff are involved from the beginning of the pilot to its conclusion. It is important to recognize that some staffing turnover may not be avoidable; in that case, thorough documentation and onboarding or training may help with the transition.
- **Identify staff, stakeholders, and subject matter experts early on and include them in all stages of planning and contracting.** Some stakeholders and subject matter experts were not included in project discussions from the beginning of the planning process. Creating opportunities for a wider group of staff to be engaged in the planning process may help ensure that more unanticipated operational obstacles are identified. In addition, working with vendors who have less experience with government contracts, and who may be less familiar with standard clauses and protocol, processes, and policies, reinforces the importance of involving all relevant parties in early planning discussions to help identify potential issues and provide clarification.
- **Make timelines clear and build in buffer time to allow for unexpected delays.** Route selection took longer than initially anticipated due to the range of activities occurring in Yellowstone National Park (e.g., maintenance, visitor service, and law enforcement). Building in additional buffer time for each task would have been helpful. Additionally, NPS and Beep staff noted that walking the route with stakeholders, subject matter experts, and pilot staff would have been preferred over a review of maps and site plans. However, this was not possible due to the snow on the ground at the time of planning. An earlier walk-through of potential routes (e.g., in the fall of 2020) would have increased the situational awareness for all project partners and reduced the number of unexpected operational obstacles.
- **Gather information needed to understand environmental and operational conditions early on in the process and ask for additional clarification where needed.** While NPS provided substantial information on operational

conditions (e.g., cellular connectivity, distances, and weather conditions), and Beep conducted some research on environmental conditions beforehand, Beep staff noted that it would have been useful to have additional details about weather conditions, distances between major locations, cellular signal coverage, driving conditions (e.g., location and frequency of major wildlife crossings), and Wi-Fi availability. All partners agreed that once planning began, collaboration was clear and effective, but more communication about project details early on would have been helpful. Potential methods for ensuring that vendors have adequate information for planning and understand what will be needed to execute a pilot project could include pre-award meetings or requiring specific plans related to conditions (e.g., plans for staff travel, data transfer methods, and how to conduct preparation activities and operate the shuttles in a variety of common weather conditions).

- **Consider the implications of housing accommodations and their proximity to the pilot site.** Given the length of the pilot, it is important to ensure housing for shuttle operators is close to the route and the organization running the pilot is aware of the distance and travel needs for shuttle pilots to travel back-and-forth from the shuttle route to their housing. Shuttle operators stayed on trailer sites within the park during the TEDDY pilot; however, it was an approximately 30-minute drive from the trailer sites to the location where the shuttle pilots started their day. Initially there was confusion in communicating to the vendor that the trailer sites were not close to the shuttle route. When the vendor's staff arrived on site, they realized a vehicle would need to be rented for the shuttle operators to commute to and from the shuttle site. This caused added expenses and stress with coordinating shuttle operator schedules.
- **Look for opportunities to reduce redundancy in planning documents and clearly convey expectations in terms of what they should include.** Between the safety plan, operations plan, staffing plan, data collection plan, and other deliverables, there was substantial overlap, which resulted in redundancy in some cases and missing information in other instances. Fewer deliverables, with sample formats provided, could have greatly improved the quality of the information collected. For example, the vendor did not have a good understanding of NPS expectations for the safety plan, and as a result, multiple rounds of revisions were necessary.

2.4.3 Communications

Open and prompt internal communication, as well as communication between partners, ensures that all parties involved in planning, operations, and oversight of the pilot have timely information related to important project developments. Clear communication to the public is also necessary to ensure visitors have the information they need to access alternative transportation options safely and enjoyably. Lessons learned related to communications include:

- **Involve communications staff at all levels early on.** Public affairs teams from NPS and Beep began meeting weekly once the project was awarded. An open, understanding environment was created for staff to discuss important messaging issues. This allowed all project partners to effectively communicate both internally and externally.
- **Have dedicated project staff on the ground during the pilot project.** A successful feature of the pilot was the presence of the Public Lands Transportation Fellow (PLTF), who monitored the project on behalf of the NPS. Thanks to the long deployment period, and the fact that the PLTF was not an NPS employee, he was able to build relationships with the Beep personnel and share information with the project team that would otherwise have been missed. He also had the flexibility to assist field staff with project-related tasks when they were not in the area, including setting up the shuttle stops, and engaging with visitors.
- **Develop a thorough communications plan that addresses all items related to the project scope.** Beyond covering interpretation to the visitor (i.e., explaining the shuttles and providing additional context on the pilot), communications plans should clearly delineate team responsibilities and tasks, and detail aspects related to meetings, notes, and forms. A wider scope of the communications plan could have helped reduce some of the other problems that the TEDDY pilot faced.

2.4.4 Technology

Emerging technologies present opportunities to enhance visitor experience, accessibility, resource protection, and safety. Understanding the capabilities and limitations of these technologies is one of the primary purposes of automated shuttle pilots. Lessons learned related to technology include:

- **Understand the level of maturity of the technology and expect disruptions caused by environmental conditions and technical malfunctions.** During the pilot, there were multiple service suspensions caused by weather conditions, battery issues, and other incidents. As a result, rather than 100 days of operation, there were only 74 days with some level of service, including 38 days with both shuttles in full service, 20 days with one shuttle in full operation and the other shuttle in partial or no operation, and 16 days with only partial service from one or both shuttles. While operating, the shuttles also had many disengagements, particularly in areas where they were more likely to encounter pedestrians or other vehicles. While such performance may not be acceptable for a mature service, learning about issues related to operation of shuttles was a valuable benefit of the pilot.
- **Plan for additional landscape maintenance activities.** Shuttle sensors were disrupted by roadside vegetation and undergrowth. While NPS and Beep planned for the removal of low-hanging tree branches, the operational challenges caused by roadside vegetation were unexpected. NPS staff noted that future pilots should be aware of the potential need for increased landscaping maintenance along shuttle routes.
- **Place charging infrastructure close to the shuttle route.** NPS initially committed to providing charging stations at the shuttle storage garage only, but later had to add charging stations at a second location closer to the route to enable midday charging. The additional charging location close to both routes was critical to the efficient operation of the pilot.
- **Plan for redundancies in obtaining and transferring data.** Teams planning pilot projects may want to consider using multiple ways to collect, save, and transfer key data elements. Due to connectivity issues, the vendor was unable to transfer data directly from the park and had to ship physical hard drives back to its office in order to download data. In addition, disengagement data suffered from both spatial inaccuracies (due to weak signals) and loss of data for the month of June 2021 (due to a system error). Redundant systems may have allowed for higher-quality spatial data and prevented the loss of some disengagement data.
- **Consider an array of technologies to find options that best suit the needs of the park.** ADS are not limited to those used in low-speed automated shuttles—there are an array of ADS-equipped vehicle types and use cases that have been developed and piloted across the country and around the world. In terms of passenger service, companies have developed systems that use light-duty passenger vehicles, medium-duty minibuses, and heavy-duty city transit buses. Outside passenger transportation, companies have developed ADS-equipped vehicles and devices for last-mile goods movement, which may also be applicable to park environments. In some cases, automation may not be a necessary part of research or of a desired service. Depending on the needs of a park, there may be other transportation technologies that make sense to pilot instead of an automated shuttle.

3. WRIGHT BROTHERS NATIONAL MEMORIAL AUTOMATED SHUTTLE PILOT

The NPS identified the Wright Brothers National Memorial as a potential location for an automated shuttle pilot in 2019 due to both its symbolism and site characteristics. When the North Carolina Department of Transportation Integrated Mobility Division (NCDOT IMD) put out a statewide call for applications to host a pilot of its Connected Autonomous Shuttle Supporting Innovation (CASSI) program in early March 2020, the NPS team thought the partnership would align with the agency's vision of testing automated shuttle technologies at an NPS site and applied in spring 2020. NCDOT recognized the opportunity to partner with the NPS and the benefits of the location at the Wright Brothers National Memorial from the outset.

After delays related to the COVID-19 pandemic, the NPS and NCDOT decided on a spring 2021 timeframe and worked together to develop an agreement. EasyMile was NCDOT's selected vendor for the CASSI project, and CASSI was the first user of a third-generation EasyMile EZ10 shuttle piloted in the United States. EasyMile was responsible for mapping the routes for the shuttle and providing operations. Transdev provided onboard safety operators and manage operation of the shuttle for EasyMile throughout the duration of the pilot. The costs of leasing the automated shuttle from EasyMile and operating it for the pilot were split evenly between the NPS, using Federal Lands Transportation Program funds and NCDOT funds.

The partners involved in the CASSI pilot included:

- North Carolina Department of Transportation (NCDOT)
  - Integrated Mobility Division
  - Highway Division 1
  - Transportation Mobility and Safety
- National Park Service (NPS)
  - Wright Brothers National Memorial Park (as a unit within the National Parks of Eastern North Carolina)
  - Department of the Interior Region 2 (formerly the Southeast Region)
  - Washington Support Office (WASO)
- United States Department of Transportation (U.S. DOT)
  - Volpe National Transportation Systems Center (partnership coordination, pilot planning, evaluation)
- Vendors
  - EasyMile (shuttle provider)
  - Transdev (shuttle operator)
  - TransLoc (automatic vehicle location)

The pilot project required extensive logistics planning and coordination at all stages—from pre-planning to implementation to evaluation. Within the NPS, the team included the Washington Support Office (WASO), the Region 2 Office, and National Parks of Eastern North Carolina office, which manages Wright Brothers National Memorial. For this pilot of CASSI, the NCDOT team included the Integrated Mobility Division, Highway Division 1, and the Transportation Mobility and Safety Unit. Throughout the duration of the partnership between the NPS and NCDOT, an interdisciplinary team held weekly progress and coordination meetings. An agenda was prepared and meeting notes were distributed afterwards with action items clearly identified. This project team included the NPS, NCDOT, EasyMile, Transdev, and the

U.S. DOT Volpe Center. The Volpe Center provided technical assistance to the NPS at all stages of the Wright Brothers National Memorial automated shuttle pilot, including conducting the pilot evaluation.[28]

3.1 Pilot Overview

The CASSI automated shuttle pilot demonstration—the first of its kind on any recreational Federal lands in the country, together with the TEDDY pilot at Yellowstone National Park—operated from April 20, 2021, through July 16, 2021.[29] The shuttle traveled on a roughly 1.5-mile loop through Wright Brothers National Memorial. The schedule for shuttle operation included service five days a week (Monday through Friday) between 10:00 a.m. and 4:30 p.m.[30]

3.1.1 Setting

Wright Brothers National Memorial is located in Kill Devil Hills, North Carolina. The Memorial, dedicated to the first powered airplane flights by Wilbur and Orville Wright in December 1903, received 482,192 visitors in 2021.[31] Visitors can park in the main parking area near the Visitor Center and walk to the monument or drive onto Wright Brothers Memorial Loop, where additional parking is available. The Wright Brothers Monument is located at the top of a hill surrounded by the Memorial Loop. Visitors can walk up the hill to the monument or see the Wright Brothers sculpture at the southern end of the Memorial (Figure 22).

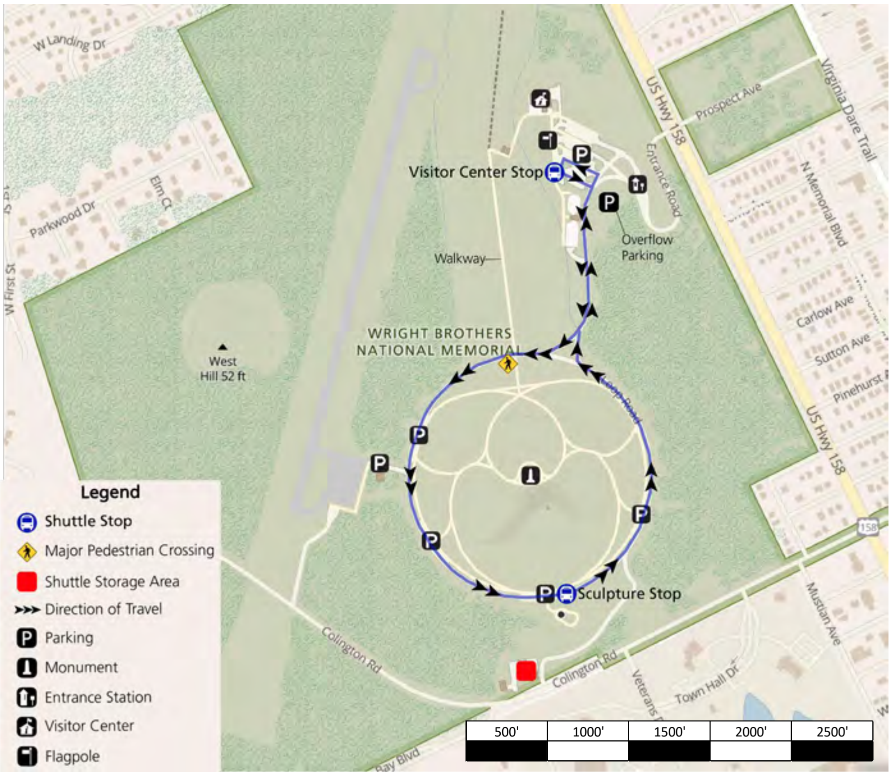
[28] U.S. Department of Transportation Volpe Center. (2021). *National Park Service Emerging Mobility*. https://www.volpe.dot.gov/transportation-planning/public-lands/national-park-service-emerging-mobility.

[29] NPS Autonomous Vehicle (2021). https://www.nps.gov/wrbr/learn/news/autonomous-vehicle-pilot-wright-brothers-national-memorial.htm; NPS News Release: State Transportation, National Park Service Officials Mark a Milestone in Launch of Self-Driving Shuttle (2021). https://www.nps.gov/wrbr/learn/news/state-transportation-nps-officials-mark-milestone-in-launch-of-self-driving-shuttle.htm

[30] Note: A 30-minute lunch break for the safety operator was built into this schedule. The shuttle did not operate during this period. There were interruptions to service that sometimes resulted in paused shuttle operations.

[31] Wright Brothers National Memorial Annual Park Recreation Visitation (1904-Last Calendar Year) (2021). https://irma.nps.gov/stats/ssrsreports/park%20specific%20reports/annual%20park%20recreation%20visitation%20(1904%20-%20last%20calendar%20year)?park=wrbr

Figure 22: Map of Wright Brothers National Memorial CASSI Shuttle Route



Source: NPS

3.1.2 Routes

The first step in the route selection process was for NCDOT to coordinate with NPS and conduct an online review of the proposed routes. From this review, NCDOT could determine generally whether a route met key specifications such as posted speed limit threshold, general sky visibility for GPS connectivity, sight distances at intersections, and center line grades.

The next step occurred in December 2020, when representatives from NCDOT and EasyMile visited Wright Brothers National Memorial to gather detailed information on the proposed shuttle routes. The site visit also provided an opportunity for NPS park staff to ask questions and discuss potential challenges for a pilot. EasyMile sent one of its EZ10 shuttles to the site, and the EasyMile representative slowly drove it around the site in manual mode, collecting data with the shuttle’s cameras and other sensors. The EasyMile representative brought the recorded data back to the EasyMile office, where additional engineers viewed the route and compiled a site visit report (SVR). The SVR identified the key points of interest and the likely mitigations for any identified needs. The report also included key operational specifications such as weather limitations, charging limitations, and other general expectations.

The next report, the site assessment report (SAR), documented a more detailed review of the site by the EasyMile team and included a full risk analysis for each route segment. It showed general sign placement, designated whether signs were for informational or localization purposes, identified which trees would need to be trimmed, and recommended changes to traffic flow, such as adding stop controls or yield signs.

3.1.3 Vehicle Specifications

The CASSI vehicle was an EasyMile EZ10 3rd Generation (Gen 3) shuttle.[32] The EasyMile EZ10 shuttle has four wheels and is approximately 12.9 feet long, 6.1 feet high, and 9.0 feet wide.[33] When empty, it weighs approximately 3,750 lbs. The shuttle was equipped with various sensors (e.g., lidar, radar, and camera units) and an automated driving system (ADS) capable of operating at SAE automation Level 4,[34] indicating that the vehicle's ADS was "fully responsible for driving tasks within limited service areas."[35] For safety purposes, and as required by the National Highway Traffic Safety Administration (NHTSA), a trained operator was always on board while the shuttle was operating, and they could switch the shuttle to "manual mode" and take over when necessary. The shuttle was programmed to stop at all crosswalks and stop signs and to proceed only once the operator determined that it was safe to do so. This required the safety operator to push a button once the crosswalk or intersection was clear, returning the shuttle to automated mode and allowing it to continue on the route.

While the EasyMile website lists maximum capacity of its shuttle as twelve passengers, to ensure that all passengers could wear a seatbelt and in order to follow appropriate COVID-19 safety precautions, fewer passengers were permitted on board.[36] During the pilot, the CASSI shuttle was limited to a maximum of six occupants (i.e., five passengers plus the safety operator). For passengers from the same household, five passengers were permitted to ride. For passengers from different households, three passengers were allowed to ride at one time. The safety operator explained this limitation to potential riders and monitored ridership.

Figure 23 and Figure 24 show the interior and exterior of the shuttle. The shuttle was equipped with a built-in automated accessibility ramp that the safety operator could deploy when necessary (Figure 25). In addition, safety operators could lower the floor of the shuttle (kneeling the shuttle) to allow for easier boarding of visitors with limited mobility.

[32] For more information on the EasyMile EZ10 shuttle and its specifications, see: EasyMile EZ10 Passenger Shuttle. https://easymile.com/vehicle-solutions/ez10-passenger-shuttle
[33] University of South Florida Center for Urban Transportation Research (2018). "Campus Automated Shuttle Service Deployment Initiative" https://www.cutr.usf.edu/usfcampusshuttle/
[34] For more information on levels of automation, see SAE J3016 "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles" available at: https://www.sae.org/standards/content/j3016_202104/
[35] NHTSA Automated Vehicles for Safety. https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety
[36] EasyMile EZ10 Passenger Shuttle

Figure 23: Interior View of the Shuttle

Source: U.S. DOT Volpe Center

Figure 24: Shuttle at the Visitor Center Stop

Source: U.S. DOT Volpe Center

Figure 25: The Shuttle with Its Ramp Deployed at the Sculpture Stop

Source: NPS

3.2 Site Modifications

3.2.1 Shuttle Stop Signage

NPS staff placed sandwich board signs to indicate where shuttle stops were located and to provide guidelines and information about riding the shuttle (Figure 26). Signs included a reversible “open/closed” plaque to let visitors know if the shuttle was in service. The signage also notified visitors that:

- The shuttle ran on a 15-minute schedule (headway) when operating;
- The shuttle was first-come, first-served; and
- Face masks were required to be worn on board (in compliance with COVID-19 safety measures).

Figure 26: Signage at the Sculpture Stop (left) and at the Visitor Center Stop (right)

Source: U.S. DOT Volpe Center

3.2.2 Storage and Charging Shed

Requirements for the shuttle storage included a secured location for overnight parking, availability of charging equipment, and a covered location not subject to temperatures below 40 or above 95 degrees Fahrenheit. The pilot occurred in a mild season in which these temperature limitations could be met, so no climate control equipment was required. NPS staff oversaw upgrades to an existing shed onsite to ensure that the shuttle could be safely stored (Figure 27). The operator manually navigated the shuttle from its service route to the storage shed before and after service hours ended, as well as any time when midday charging was required. The storage shed was located approximately 0.35 miles from the sculpture stop (see site map, Figure 22).

Figure 27: Shuttle Storage Garage Exterior (left), Interior (center), and Charging Equipment (right)

Source: U.S. DOT Volpe Center

3.2.3 Localization Signs

EasyMile informed project partners that localization signs needed to be installed along the shuttle route for the duration of the pilot. These vertical reference signs served as known location markers to improve the shuttle's localization capability (Figure 28).[37] The markers helped create the 3D virtual map that the shuttle used—along with its GPS system—to identify its precise location along the route.[38]

Figure 28: The Four Localization Signs Installed Along Shuttle's Route

Source: U.S. DOT Volpe Center

[37] The signs would appear as vertical elements in the shuttle's lidar scans, and the ADS could measure the vehicle's distance from the signs and compare it to its internal map as a way of improving localization.

[38] NVIDIA Developer DRIVE Labs (2020). https://developer.nvidia.com/blog/drive-labs-how-localization-helps-vehicles-find-their-way/

3.2.4 Accessibility Ramp

The shuttle's accessibility ramp required a minimum three-foot-long section of curb (or elevated paved surface) for deployment. Such a curb did not exist at the sculpture stop, so NPS staff rented and installed a free-standing platform and wheelchair ramp at this location. The width of the initial platform was not sufficient to accommodate deployment of the accessibility ramp while also providing enough room for wheelchair maneuverability while on the platform, so the platform had to be enlarged, both of which are shown in Figure 29.

Figure 29: Accesible Ramp and Platform Installed at Sculpture Stop

Source: U.S. DOT Volpe Center

3.3 PILOT EVALUATION

3.3.1 Data Collection and Methodology

This evaluation used a mixed-methods approach, relying on quantitative statistics, survey data, and qualitative interviews with relevant stakeholders. There were several sources of data available at varying levels of granularity and frequency. For more precise details on the data provided, please refer to Appendix B: Data Tables.

3.3.1.1 Data Sources for Evaluation

Weekly Operator Reports: The first source of data was operator-recorded data provided to the evaluation team weekly from Transdev. Data was provided in spreadsheet form and contained several variables related to the weekly operations of the vehicle. A typical day would yield three reports in the spreadsheet—a morning report that the operator recorded at the beginning of service, a midday report (typically prepared during the operator's lunch break), and an evening report recorded at the end of service. Data included ridership numbers, trip counts, weather data, battery charging information, the service availability, manual disengagements, ramp deployments, and any general comments from the operator. If service was suspended at any point on a given day, then there may not be three reports for the day, but rather a note indicating when and why service was suspended.

Monthly Disengagement Report: The second data source was a monthly report detailing the vehicle's automated mode disengagements provided by EasyMile. The reports detailed the date, time, and location of every disengagement, as well as the weather conditions, speed of the vehicle, and the cause of the disengagement. The categories of "obstacle," "system," "e-stop button" (an emergency stop button that a passenger could push), and "operator" were listed as causes for disengagements. The monthly disengagement report also provided data on circumventions and provides summary graphs for some of the data that is available from the Transdev report.[39]

Monthly Operational Reports: The third source of data was monthly operational reports provided to the evaluation team by EasyMile, which presented key performance indicators for the month. Data included speed, mileage, battery consumption, outside temperature, and the percentage of time spent in automated mode. Values were presented as the average for the month, along with charts showing the approximate values for each day.

Rolling Visitor Survey Responses: The fourth data source was a visitor survey. Individuals who rode the automated shuttle were encouraged by safety operators to take the survey. The survey asked respondents about topics such as how safe they felt in the vehicle, whether the shuttle took them to their destination in a reasonable amount of time, why they rode the shuttle, and whether they would ride again. Several questions were multiple choice, but there were also open-ended responses for certain questions. The survey received 273 responses in which the respondent answered at least one survey question. The survey was approved through OMB (OMB control number 1090-0011). The full survey questionnaire is provided in Appendix A: Survey Questionnaire .

The survey was promoted to CASSI riders via a QR code on a printed brochure provided to all visitors entering the park during days of shuttle operation. QR codes that directed shuttle riders to the survey were also posted on the CASSI vehicle, on shuttle stop signs at the visitor center and sculpture locations, and on stickers handed out to visitors.

Visitation Numbers Report: The fifth data source was visitation numbers provided to the evaluation team by park staff. This report detailed the number of visitors to the park on any given day; this is an estimated value calculated by taking the number of vehicles entering the park and multiplying by four occupants.

[39] A circumvention is when the operator of the shuttle switches from automated mode to manual mode to drive around an obstacle.

3.3.1.2 Other Operational Data

In addition to the data sources used for evaluation, NCDOT collected, managed, and used the following data:

NCDOT Smartsheet: Daily operating hours, passenger counts, safety operator, and onsite NPS and NCDOT staff observations were recorded to allow quick observation of trends or issues that needed to be addressed.

NCDOT Deployment Diary: A SharePoint file was used to document situations and instances where collaborative troubleshooting and/or problem solving were used to address issues.

NCDOT Intermittent Observations: NCDOT team members visited and rode the shuttle throughout the pilot to monitor performance of the shuttle and vendors.

3.3.1.3 Site Visits

Members of the evaluation team also visited the site from June 22–24, 2021 and conducted informal interviews with the safety operator, park staff, and NCDOT staff about the pilot. The evaluation team rode the shuttle and observed it in operation. This anecdotal evidence is also used to inform the findings of this report.

3.3.1.4 Data Limitations

There are several limitations to the available data. One such limitation is the low survey response rate. The survey received 273 responses, of which 263 came from people who rode the shuttle. This is a relatively low response rate of only 8 percent given the 3,380 passengers on the shuttle across the pilot period.[40] A survey response rate of at least 50 percent would have been ideal, while a response rate of at least 20 percent would have enabled greater confidence in the findings. While the responses that were received are invaluable to this evaluation, the low response rate may mean that responses are not reflective of the entire population of riders.[41] An additional survey limitation is the lack of demographic data, which would have been helpful in understanding the characteristics of those who rode the shuttle. The survey collected broad age-range data, but it did not collect other demographic information, preventing any comparisons across race, gender, or more specific ages. The survey was also subject to Federal regulations regarding government-run surveys to speed the review and approval process. This required the survey to be limited to 10 or fewer questions, to limit collecting demographic data, and requiring the first page to consist of a long waiver.

The survey response rate was initially low. As the pilot progressed, the project team made a concerted effort to encourage more survey participation, including the creation of "I Rode the CASSI Shuttle" stickers for passengers. The stickers were distributed by the safety operator and included a QR code for passengers to access the survey. The distribution of the stickers increased the survey response rate considerably. Figure 30 shows the design of the sticker.

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[40] If you consider that the 3,380 estimate is not unique passengers, as many people may have ridden the shuttle in both directions and accordingly were double counted, the response rate would increase, however even a 16 percent response rate is still low.

[41] This idea is known as *non-response bias*, where those who respond to a survey are different in some fundamental way from those that do not respond. Often, those who respond to a survey have extreme opinions (either positive or negative) while more neutral individuals will not respond.

Figure 30: CASSI Shuttle Sticker with QR Code

Source: NPS

Another limitation is that passenger data was not available on a per-stop level. When evaluating a transit service, the data ideally should exist on a per-stop level. Having passenger data available per-stop offers much more detail on the use of the shuttle over the course of the day. The project team discussed the collection of this data early on, and chose to not to collect per-stop data, as it would have required manual collection by the safety operator. There was a concern that collecting the data could take too much time and that potential confusion would negatively impact accuracy of the collection. Other types of data that would have been beneficial on a per-stop level include the time of arrival and departure, average speeds, and dwell times (dwell times were not available at all in the data). These data would have allowed for more robust analyses of vehicle performance, on-time performance, usage, and more. Since this data would have been manually collected by the safety operator, compilation of this level of data was not practicable.

Additionally, the shuttle service was suspended from June 30 through July 8, 2021 due to an issue with the shuttle's battery. The loss of several days of ridership also reduced the available data for analysis. However, as is the case with pilots, this situation provided an important opportunity to assess issues involving the shuttle technology.

3.3.2 Data Analysis

The shuttle was scheduled to run on weekdays from April 20, 2021 through July 16, 2021, for a total of 64 days of operation. However, due to multiple service suspensions caused by battery issues and weather conditions, the shuttle ran for 46 days with complete service, 8 days with partial service, and complete suspension of service for 10 days.[42] In total, the shuttle took 809 roundtrips and carried 3,380 passengers (see Table 2).

Table 2: Overview of CASSI Operation

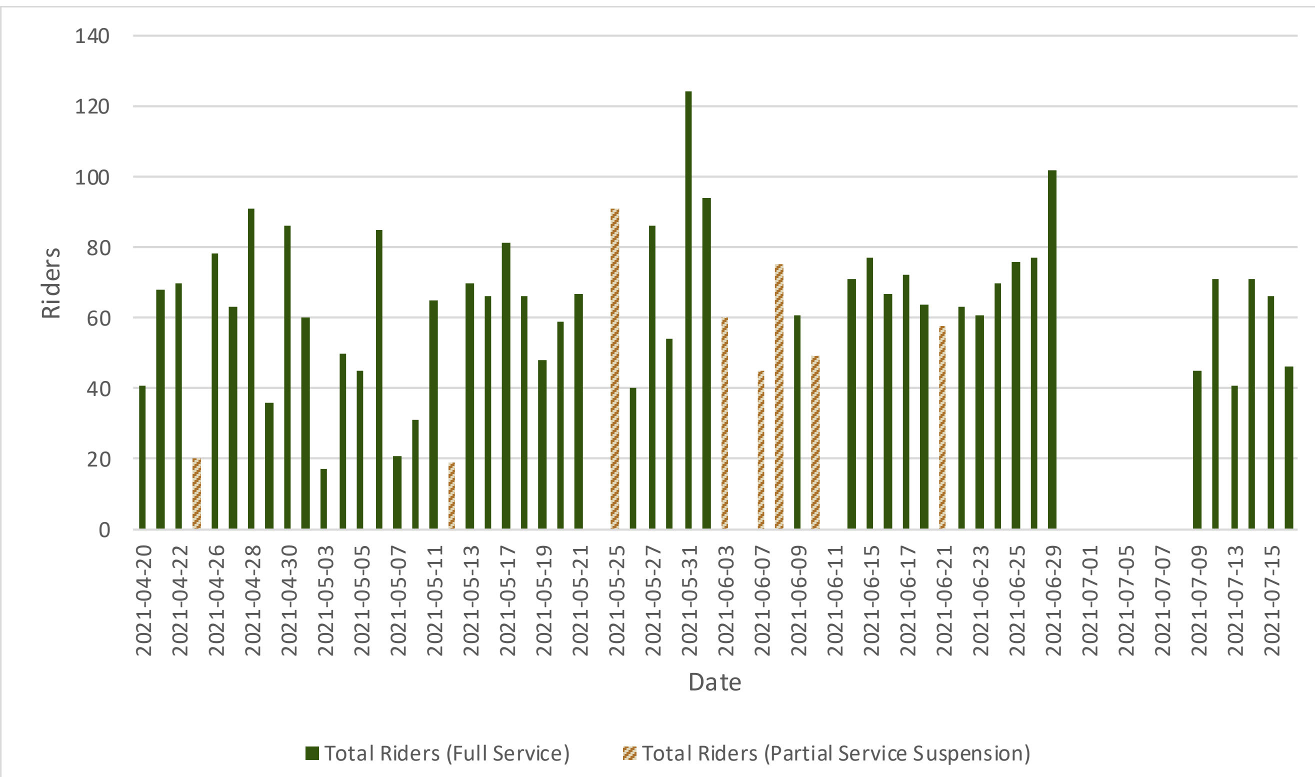
Category	Scheduled	Actual
Number of Days in Operation	64	54
Hours of Operation	384	279
Number of Roundtrips	N/A	809
Number of Passengers	N/A	3,380

Source: Transdev and U.S. DOT Volpe Center

3.3.2.1 Ridership

The number of riders varied considerably over the course of the pilot, even when accounting for service suspensions. As Figure 31 shows, the number of riders ranged from over 120 to below 20 on days with full service. Some of the days that had partial service suspensions had more riders than some of the other days which had full service. The average number of riders per day for days in which the shuttle was fully operational all day was 64.4.

Figure 31: CASSI Shuttle Riders per Day April-June 2021



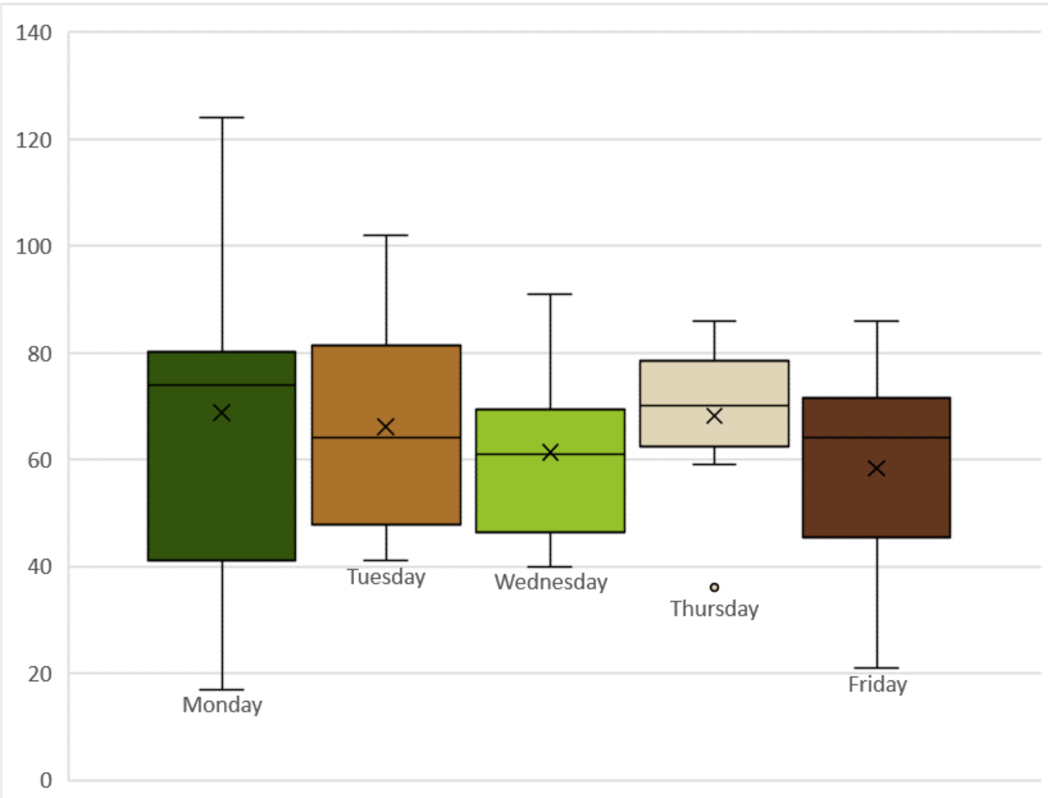
Source: Transdev and U.S. DOT Volpe Center

With 3,380 total passengers and 809 total trips throughout the pilot, the shuttle carried approximately 4.2 riders per roundtrip. There was almost no variation in the average riders per roundtrip between the morning and afternoon shifts, although the afternoon shifts saw more riders and trips overall, likely due to that shift being longer. Another possible

[42] Throughout the analysis, particular focus is paid to days of full operation. Days of partial service vary significantly in terms of hours operated and limiting the days of full operation allows for more consistent cross-comparison across days.

explanation for the ridership variation across shifts could be different levels of park visitation throughout the day. There was some variation by day of the week, with Mondays having approximately 10 more riders than Fridays on average; however, it is unclear why this would be the case.[43] Figure 32 presents a box-and-whisker chart for the ridership data on each day of the week.[44]

Figure 32: CASSI Shuttle Riders by Day of the Week, Full Service



Source: Transdev and U.S. DOT Volpe Center

As previously noted, due to COVID-19 safety precautions, the shuttle was limited to carrying between three and five passengers depending on whether they were from the same household. Accordingly, the average of 4.2 riders per trip is reasonable given that restriction. The visitation data also suggests that a low percent of visitors rode the shuttle, but this again seems reasonable based on the limitations. On days of full operation, an average of 2.7 percent of total park visitors rode the shuttle, with a peak of 5.3 percent and low of 0.9 percent.

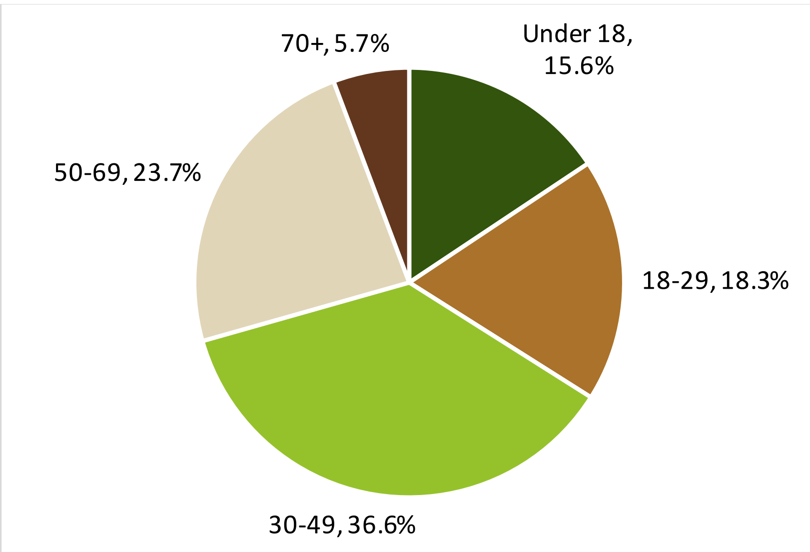
The data also indicated that there were 193 total ramp deployments overall, and an average of 4 deployments per day (on days of full service). Unfortunately, the rider survey did not directly ask passengers if they needed mobility assistance or required ramp deployment, and there is no indication in the data whether these passengers found the shuttle to be easily accessible. It is also worth noting that the park staff were unaware of any wheelchair users utilizing the shuttle. The ramp was likely deployed to make boarding easier for elderly individuals or others with limited mobility (but who were not wheelchair users). It is promising that the shuttle ramp was deployed multiple times for passengers,

[43] Visitation data suggests that Mondays and Fridays had similar numbers of total visitors throughout the pilot. It may be the case that the difference in ridership by day of the week is just due to random chance, particularly given the small sample of days.
[44] The "box" part of a box-and-whisker graph shows, essentially, the middle 50 percent of the data. The "whiskers" that extend out from the box show the range of the bottom and top 25 percent of the data. Any dots that lay beyond the ends of the whiskers show outliers. The line through the box shows the median, and the X indicates the mean.

but without more insight into the experience of the passengers, it is difficult to evaluate how the passengers perceived the usefulness of the ramp deployments.

The survey responses do provide some insight into the age of riders. Figure 33 shows the survey respondents by age. The results show that the plurality of riders (36.6 percent) were between 30 and 49 years old, with the next largest group being riders between 50 and 69 years old (23.7 percent). It should be noted that some age groups may have been more likely to respond to the survey than others, which could contribute to bias in the survey results

Figure 33: CASSI Survey Respondents by Age



Source: NCDOT and U.S. DOT Volpe Center

3.3.2.2 Vehicle Performance

As previously noted, the shuttle ran in full operation for 46 days of the planned 64 days of service, with 8 days of partial service and 10 days of complete service suspension.[45] This section describes vehicle performance as it relates to speed, battery usage, impacts of weather, and disengagements.

Speed

Although the shuttle is capable of a maximum speed of 25 mph, the anticipated maximum speed during the pilot was 10 mph.[46] The shuttle's average speed during the pilot was around 5.2 mph (8.4 km/hr) and the maximum speed reached was 9.5 mph (15.3 km/hr).[47] This low speed of the shuttle was expected, as the automated technology is still under development, and low speeds are safer for operation with mixed traffic at this time.

The shuttle's low speed appeared to encourage other vehicles on the road to try to pass or overtake the shuttle. Park staff noted early on that some vehicles were trying to pass the shuttle when it was stopped at a particular pedestrian crossing, which created an unsafe environment for both pedestrians and the shuttle operation. These occurrences took place during the first week of the pilot. The project team met to observe the crossing and plan changes to the traffic pattern and shuttle operation.

[45] Partial service suspensions occurred on 4/23, 5/12, 5/25, 6/03, 6/07, 6/08, 6/10, and 6/21. Full service suspensions occurred on 5/24, 6/04, 6/11, 6/30, 7/01, 7/02, 7/05, 7/06, 7/07, and 7/08.

[46] EasyMile Safety Report (2020). https://easymile.com/sites/default/files/easymile_safety_report.pdf

[47] Average speed when the shuttle doors are closed. May include speeds while from driving to and from storage as well as speeds from when the shuttle is stopped but the doors are closed.

The shuttle had been stopping at the crosswalk, instead of moving through when no pedestrians were waiting. EasyMile altered the safety operator's practice at this location. In addition, the decision was made to change the "no passing" message to motorists and allow passing on the roadway while the shuttle was in motion—similar to typical traffic management. This reduced conflicts at the pedestrian crossing. The lower speed of the shuttle is acceptable and expected for a pilot. However, for a permanent shuttle service, it would be preferred to have the shuttle operate at speeds closer to those of the rest of the traffic on the road.

Battery Usage

The shuttle experienced an average daily energy consumption of around 18.0 kWh throughout the pilot, but this was not consistent over time. Days in the month of July had a much higher average battery consumption (27.4 kWh) than days in the month of May (15.0 kWh)—this change in energy consumption was likely due to increased use of air conditioning during warmer months.

The initial battery charging plan was to charge the vehicle only at the beginning and end of the day, not during the service period. Because the shuttle consumed more electricity than expected (increasing the electricity costs needed to operate the shuttle), this plan had to be modified to charge the battery during the middle of the day. This change reduced the overall time in operation.

Additionally, the shuttle was taken out of service entirely for several days near the end of the pilot to service the battery. Over half of all service suspensions were due to battery issues, for a total of eight service suspensions. These challenges with the battery did influence visitor experience, as one survey respondent noted that they were only able to take the shuttle one-way, stating:

> **"The battery got down to 15% so we were not able to return to our destination."**

Weather Impacts

The shuttle ran primarily in warm, dry weather conditions (e.g., no rain, typical temperatures between 70 °F and 80 °F, and slow winds). Fewer than 15 days of service were noted as having light, moderate, or heavy rain, and the average temperature was approximately 73 °F. The coldest days dropped down to just below 50 °F, and the hottest days had temperatures around 90 °F. The shuttle did operate on some relatively windy days, with the highest recorded wind speed noted as 25 mph, but most days consisted of significantly lower winds.

Although much of the pilot occurred in relatively calm weather, there were seven service suspensions caused by weather. Days of heavy rain caused partial or total service suspensions, either because the route was too wet after the rain or because the shuttle could not operate in the inclement weather conditions. It is worth noting that there were times in which the data indicates that the shuttle was able to operate in light or moderate rain conditions; while service may not have been suspended during those conditions, in some cases rainfall caused increased disengagements and increased use of manual operation. Significant rainfall and roadway ponding pose a challenge for the automated technology, and more permanent usage in year-round service would require a shuttle that is capable of operating in inclement weather conditions or the use of a conventional "fill in" vehicle to provide rides when the automated shuttle could not operate.

Disengagements

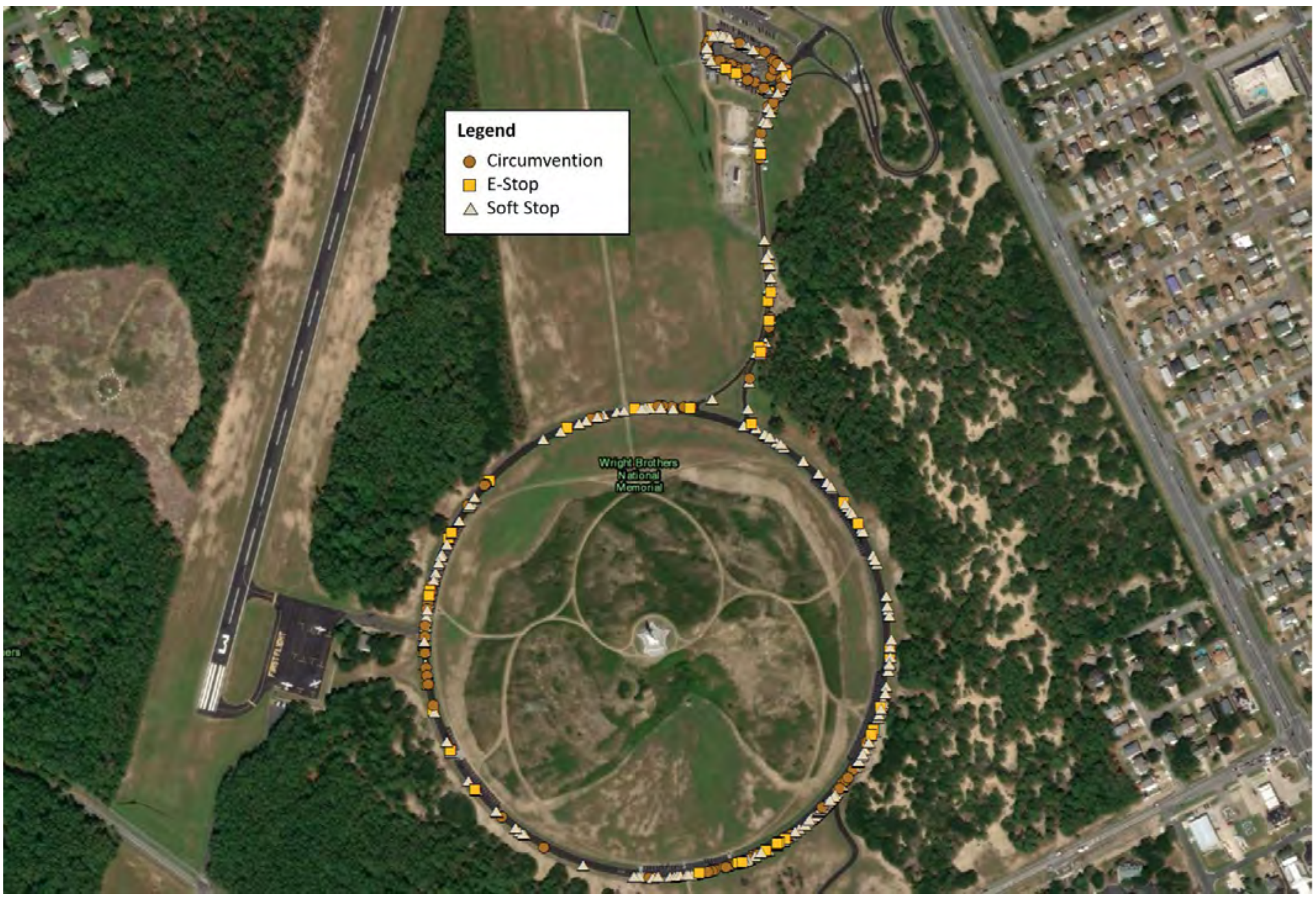
The vehicle experienced numerous disengagements throughout the pilot, with a total of 82 e-stops, 410 soft stops, and 128 circumventions.[48] This was an overall total of 620 disengagements. If only days of full service are included, there were 489 total disengagements, with an average of 1.3 e-stops per day, 7.4 soft stops per day, and 2.0 circumventions per day.[49] This data can be seen in Table 3, and the disengagements are plotted on the route in Figure 34.

Table 3: Average and Total Shuttle Disengagements by Type

Type of Disengagement	Total (All Days)	Total (Days of Full Service)	Average (Per Day of Full Service)
All Stops	620	489	10.63
E-Stop	82	59	1.28
Soft Stop	410	339	7.37
Circumvention	128	91	1.98

Source: EasyMile and U.S. DOT Volpe Center

Figure 34: Map of CASSI Shuttle Disengagements



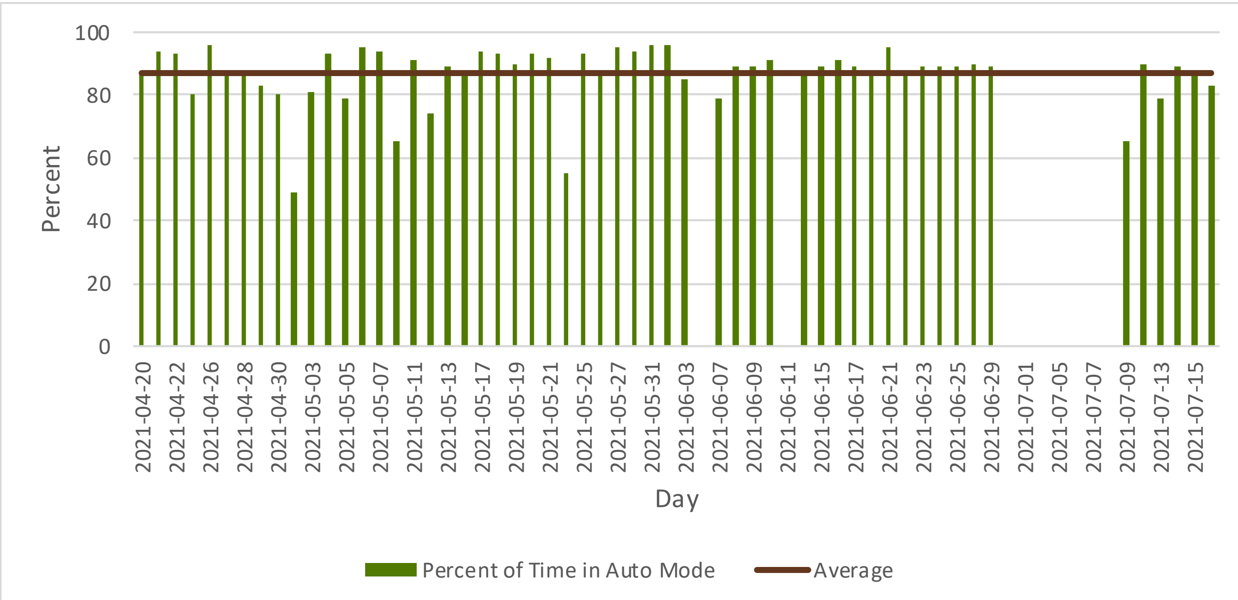
[48] An "e-stop" is a stop triggered either manually by the operator using the button inside the vehicle or automatically by the vehicle computers when an obstacle gets too close. A "soft stop" is triggered either manually by the operator on the operator panel or automatically by the vehicle computers when an obstacle is identified ahead in the shuttle's future path; this stop is made more gradually than an e-stop. A "circumvention" occurs when the operator switches from automated mode to manual mode to manually drive around an obstacle.

[49] As previously noted, it is beneficial to compare solely days of full service as these days are roughly equivalent in terms of service hours—days of partial service are more varied.

Source: EasyMile and U.S. DOT Volpe Center

Even with the numerous disengagements, the vehicle operated primarily in automated mode. An average estimate across the pilot suggests that the shuttle was driving in automated mode around 87 percent of the time. This is promising, but also indicates that the automated technology is likely still far off from not requiring a safety operator to be onboard the shuttle. Figure 35 shows the percentage of time spent in automated mode plotted by day. Due to service suspensions, not all days have data.

Figure 35: Time Spent in Automated Mode



Source: EasyMile and U.S. DOT Volpe Center

Landscaping & Maintenance

During the pilot, it was discovered that weeds growing within 1.5 feet of the roadway interfered with the lidar sensors on board the shuttle, causing the shuttle to repeatedly slow, stop, or disengage at multiple points along its route. Park staff then mowed the grass as frequently as every three days to address the issue (Figure 36 and Figure 37). Park staff noted that this frequency of mowing is not sustainable in the long term. In addition, before the pilot began, several tree canopies were trimmed in the northwest area of the circle to not interfere during the pilot. These trees and related vegetation were monitored during the concurrent growing season.

Figure 36: Weeds Sticking Out into Roadway, Which Caused Shuttle Disengagements

Source: U.S. DOT Volpe Center

Figure 37: Signage Warning Visitors That Lawn Mowing is in Progress

Source: U.S. DOT Volpe Center

Multimodal Conflicts

The shuttle was required to navigate a high-volume, mixed pedestrian and vehicle traffic area when it passed through overflow and main parking areas to access the visitor center stop. The high amount of multimodal activity in this area presented challenges for the shuttle. Occasionally, tour buses and vehicles with trailers parked in spaces that were too small, causing them to extend into the roadway. In these situations, either the shuttle automatically disengaged from automated mode or the safety operator did so. Then the shuttle proceeded along the route in manual mode. For cases in which vehicle owners were present, shuttle operators would ask them to move their vehicle out of the roadway to prevent the problem from reoccurring.

The disengagement data shows that 22.9 percent of all disengagements (e-stops, soft stops, and circumventions) occurred in the main parking area. This is a relatively high percentage given that the parking area represents a small portion of the overall distance (less than 9 percent of the total route length) traveled by the shuttle in a single loop. Circumventions, in particular, had a high rate of occurrence in the parking area (32.0 percent of all circumventions occurred in the parking area). This finding, however, is expected. Given that much of the route is either one-way traffic or separated traffic where vehicles tend to make predictable movements, it is reasonable that more disengagements occurred in the parking area, where vehicles and pedestrians are significantly more likely to be present and to make unpredictable movements.

Operator Interaction

All soft stops recorded in the disengagement data are noted as being caused by the safety operator. It is unclear if this was a reporting error; if accurate, the 410 soft stops may not reflect issues with the automated shuttle technology but rather the cautiousness of the safety operator. Operators may have preemptively triggered soft stops in fear of possible collisions rather than relying on the automated shuttle's own safety technology.

When the NPS evaluation team conducted their site visit, they observed that the operator would sometimes switch the shuttle to manual mode in anticipation of possible safety concerns. This practice was not always implemented throughout the pilot, given that some days have very few recorded disengagements; however, it still indicates that a portion of the disengagements may have been due to a high degree of caution on the part of the operator rather than an issue with the automated shuttle technology. This could be further explained by the high number of different safety operators utilized during the pilot, as some safety operators may have been more comfortable with the vehicle and its capabilities than others.

3.3.2.3 Visitor Experience

The pilot cannot be fully evaluated without understanding the visitor experience on the shuttle. The survey results are the primary source of data on visitor experience, and although the survey response rate was low (8 percent to 16 percent), the insights from the survey still provide valuable feedback on visitor experience.[50] The survey had four questions that gauged visitor satisfaction with the shuttle, where respondents could select an answer on a five-point Likert scale from "Strongly Agree" to "Strongly Disagree" with each of the four statements. The survey responses for these questions can be seen in Figure 38.

Overall, the respondents "Strongly Agreed" with all the statements, indicating that they had a good experience with the shuttle, that their journey took a reasonable amount of time, and that they felt safe regarding COVID-19 mitigation measures. The statement with the highest level of disagreement was "the shuttle arrived at my stop within a reasonable amount of time," with 7.3 percent disagreeing or strongly disagreeing. Even in that case, the results show that the majority of visitors taking the survey (nearly 90 percent) agreed with the statement.

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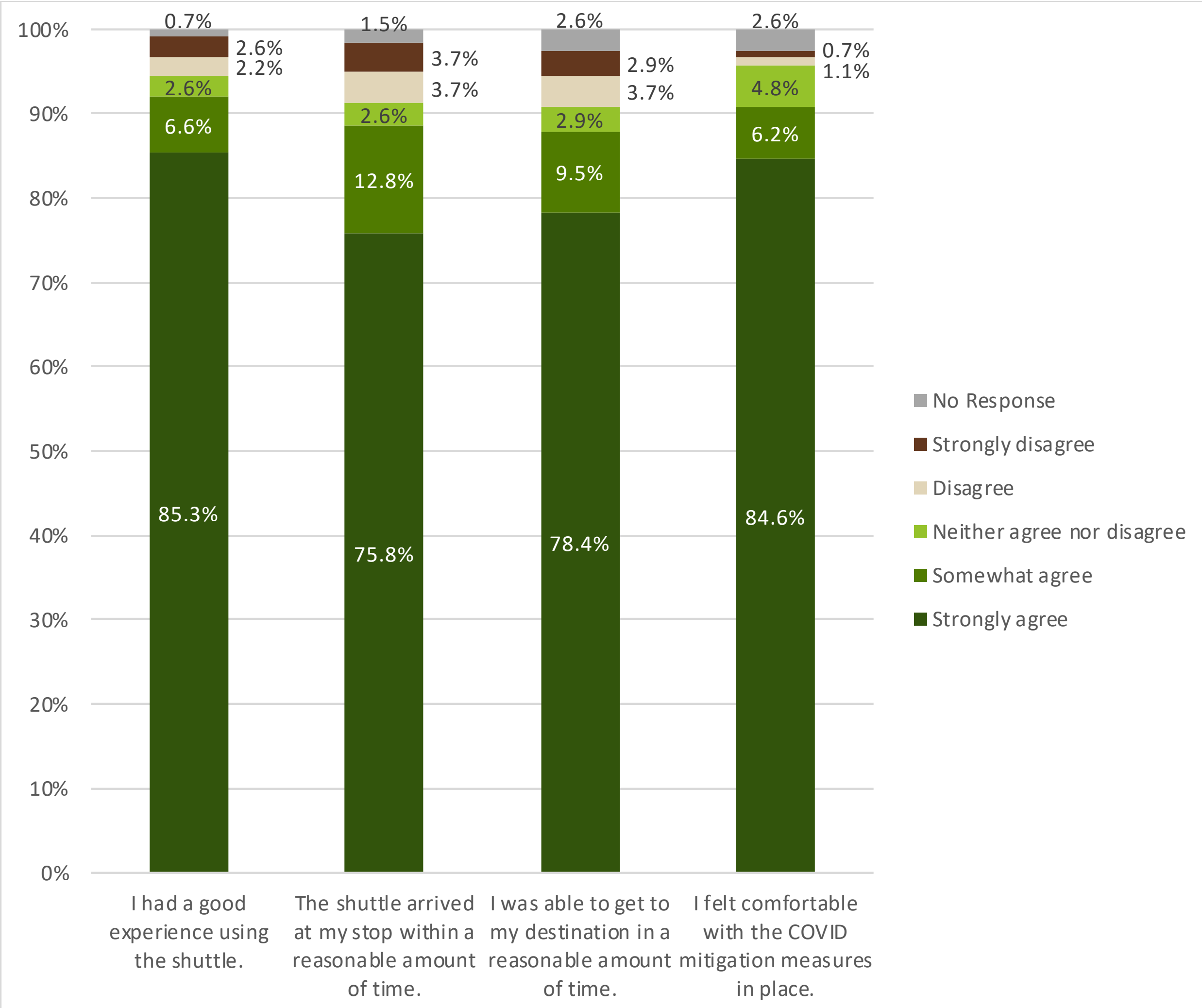
[50] See the Data Limitations section for an explanation of the response rate calculation.

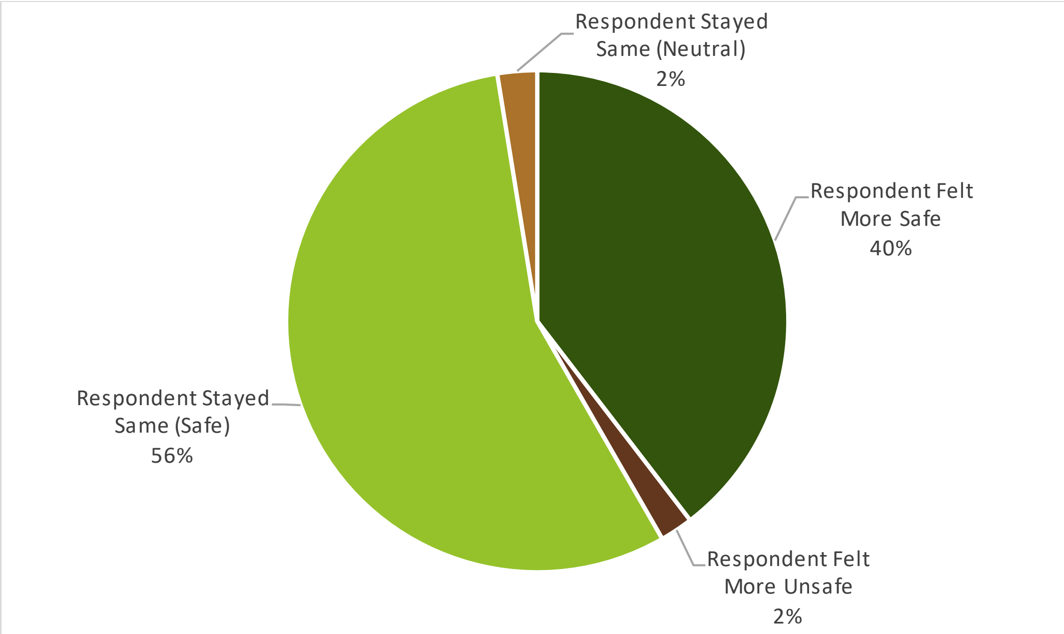
Figure 38. Survey Responses for Agree/Disagree Statements



Source: NCDOT and U.S. DOT Volpe Center

Visitors also indicated that they felt the automated shuttle was a safe experience. The survey asked respondents how safe they felt with automated shuttles both before and after riding the shuttle, and although the majority of respondents felt “somewhat safe” or “very safe” even prior to riding the shuttle (70 percent), there was an increase in the perception of safety after experiencing riding the shuttle (86 percent felt somewhat safe or very safe). Only 5 respondents felt more unsafe after riding than the shuttle than they did before, with all other respondents either feeling safer or the same as they did before riding the shuttle. Figure 39 shows how respondents’ opinions changed after riding the shuttle.

Figure 39. Survey Responses for Shuttle Safety After Riding the Shuttle



Source: NCDOT and U.S. DOT Volpe Center

Respondents also had the opportunity to include an open-ended comment about their experience with regards to safety. Several respondents left comments reinforcing how safe they felt, but there were also some negative comments. The small number of negative comments had a general theme of noting the technology limitations with the operator needing to manually stop the vehicle in certain circumstances. Some of those comments included:

> *"Emergency stop with no apparent reason was very abrupt."*

> *"Not unsafe but I felt it impractical with the current technology limitations. ... Someday when these flaws are fixed I will have more confidence."*

> *"It was amazing!!!! Felt safe."*

> *"I did not feel unsafe at all. The shuttle felt safer than a diesel powered bus."*

When considering the visitor experience, it is also worth understanding whether visitors perceived the shuttle to be filling a transportation need or to serve as an attraction in-and-of itself by providing a new experience to visitors. The survey asked whether respondents rode the shuttle specifically to get to their destination or whether they were primarily motivated by just having a fun experience. The survey results indicated that the majority of people rode it solely for a "fun experience" (62 percent), with only a small percent riding it specifically to get to their destination (7 percent) and the remaining using it for both purposes (32 percent).

Finally, the survey asked visitors whether they would like to see more driverless shuttles in National Parks and allowed visitors to leave an open-ended response about whether they would ride the shuttle again. Over 94 percent of respondents either "Somewhat" or "Strongly Agreed" with the statement that they would want to see more driverless shuttles in National Parks, with only 1.9 percent (5 respondents) "Somewhat" or "Strongly Disagreeing." Similarly, 97 percent of the 123 open-ended responses indicated a willingness to ride the shuttle again. There is some indication that visitors' experiences on the shuttle were heavily influenced by the operator, with several responses specifically calling out operators by name as a positive aspect of their ride. In the small number of responses given where the respondent indicated they would not ride the shuttle again, the primary reason given was the low speed and long wait time. Some of the comments included:

> *"I would ride because it's easier when you are less able to walk."*

> *"My kids loved it, the driver was very knowledgeable and fun! He knew a lot about the site as well as about the vehicle!"*

> *"Yes, but the speed and quantity of vehicles needs to increase to be more useful."*

> *"No. Because it is extremely slow and talkative."*

Overall, the survey results indicated a generally positive visitor experience for those who rode the shuttle. However, as previously indicated, there were some responses that indicate areas of improvement for future pilots. The areas that had the most negative responses were the timeliness and speed of the shuttle.

Overall Visitor Reactions

In addition to the survey data, visitor experience was also observed through staff interactions with visitors and the evaluation team's site visit. These observational experiences are noted in the following subsections. Park staff reported positive visitor reactions to the shuttle. In the early days of the pilot, staff noted that some visitors came to the Wright Brothers National Memorial site specifically to ride the shuttle. Visitors were particularly excited about the shuttle's connection to the Wright Brothers' legacy of transportation innovation. Park staff did not report hearing any negative comments about the shuttle.

Visitor Questions

Some visitors were confused about where the shuttle would take them. Visitors would sometimes ask park staff if the shuttle would take them to the top of the hill (where the monument is located). Visitors with limited mobility were particularly interested in learning if the shuttle could take them to the monument, since the walk up the hill is steep. Other common questions were about the frequency and reliability of the shuttle. Confusion about the shuttle's frequency and operational status often stemmed from the fact that operators did not always remember to change signs at stops from "open" to "closed." As a result, visitors sometimes queued at the shuttle stops when the shuttle was not in service.

Formal Complaints

Two formal complaints were filed with the park during the pilot period. One complaint was lodged by a visitor with limited mobility who boarded the shuttle at the visitor center stop and alighted at the sculpture stop. The shuttle dropped the visitor off, but then returned to the storage shed after it began to rain. The individual was not able to walk back to the visitor center on their own and had to ask for a return ride back from another visitor.

Another complaint was filed by a visitor who regularly walked on the Loop Road in the roadway and not on the grass. The shuttle approached this visitor from behind as it traveled on its route. The visitor expected the shuttle to pass, as other motorists typically would. However, the shuttle would not overtake the visitor, since the person was designated as an obstacle in the roadway by the shuttle's ADS. As a result, the shuttle slowly followed the visitor around the Loop

Road. NPS staff later installed a sign asking pedestrians walking in the roadway to step off the shoulder to allow the shuttle to pass (Figure 40).[51]

Figure 40: Notification Sign to Pedestrians Indicating That the Shuttle Will Not Pass Them in the Roadway

Source: U.S. DOT Volpe Center

[51] See Visitor Management for signage details.

3.3.3 Other Barriers and Challenges

This section describes additional challenges that the pilot faced. Those challenges included multimodal conflicts, visitor information challenges, and potential challenges getting buy-in from park staff.

3.3.3.1 Multimodal Conflicts

Most visitors walked through the Memorial by starting at the visitor center and continuing south down the walkway toward the Wright Brothers Monument. Pedestrians must cross a marked crosswalk across Memorial Loop to walk toward the Monument (see site map, Figure 22). Drivers attempted to pass the shuttle as the shuttle yielded to pedestrians in the crosswalk, creating an unsafe environment for the pedestrians and the shuttle operation. Park staff resolved this issue by placing orange cones, an MUTCD-compliant crosswalk sign, and a custom sign instructing drivers not to pass at crosswalks (Figure 41 and Figure 42).[52]

Figure 41: Signage Instructing Drivers Not to Pass Shuttle at Crosswalks

Source: U.S. DOT Volpe Center

[52] FHWA Manual on Uniform Traffic Control Devices (2009). https://mutcd.fhwa.dot.gov/htm/2009/part2/fig2b_02_longdesc.htm

Figure 42: Cones and Signage Placed at High-Traffic Pedestrian Crossing

Source: U.S. DOT Volpe Center

The general layout of roads and pathways of the Wright Brothers National Memorial represents a number of potential conflicts and interactions between vehicles and pedestrians. Park staff were able to resolve several of the associated challenges for the shuttle during the pilot with temporary solutions, but these solutions may need to be reevaluated or altered to support a long-term shuttle service.

3.3.3.2 Visitor Information

Some issues related to signage at the shuttle stops were reported by park staff. Signage (Figure 43) was lacking some relevant information, which led to some visitor confusion about the CASSI's frequency, route, and rules. The following items were observed at the shuttle stops:

- Signs stated that masks were required onboard but did not inform visitors that masks were available on the shuttle. Some visitors returned to their vehicles to grab masks or walked away from the shuttle stop because they did not have masks with them.
- The QR code which linked to the online CASSI tracker was too small and easy to miss. As a result, many visitors did not know they could track the shuttle's location in real time.
- Visitors were observed queuing for the shuttle even when it was not in service due to the operator's lunch break or inclement weather. This often occurred because the operator did not change the operating status sign from "open" to "closed."

Figure 43: Signage at Visitor Center Stop Displaying an "Open" Status

Source: U.S. DOT Volpe Center

3.3.3.3 Buy-In

Initially, NPS staff were hesitant to move forward with this project because of the uncertainty involved in an automated shuttle pilot of this nature. Park staff anticipated increased visitor management needs and the added workload of dealing with operational issues. However, few of these concerns materialized. Park staff were, overall, enthusiastic about the pilot after the shuttle had operated for a few weeks.

3.4 Lessons Learned

Throughout the pilot process, the NPS learned many lessons. The aim is to put these into practice for any future automated shuttle pilots, and in some cases, they may also apply to other types of emerging mobility pilots and projects. In addition, the lessons learned from this pilot apply beyond the NPS—they may provide invaluable insights for future automated shuttle pilots for other potential deployers in other settings.

3.4.1 Contracting

Contracts set the stage for pilot projects—not only do they secure vendors who provide plans, vehicles, staff, and other materials, but they also lay out the roles and responsibilities of both the vendor and the other partners on the project. Ultimately, the quality and form of the contract will have a great influence on how the work is carried out and the ultimate success of the pilot. Lessons learned related to contracting include:

- **Understand expectations of the pilot technology and impacts to service.** Unforeseen circumstances can be expected to arise when testing a new technology. A clear understanding of the nature of the pilot is essential to manage expectations. For example, it would be beneficial to include a section in the contract with the vendor to address the impact to, or loss of, service due to a technology issue, such as a malfunctioning battery.
- **Ensure that replacement parts are readily available and that maintenance staff can quickly address technology malfunctions.** EasyMile was planning to phase out its current accessibility ramp supplier in 2022. This meant that, had the ramp had malfunctioned and replacement parts were needed, acquiring those parts would have been difficult. During the course of the pilot, the battery did malfunction. Battery technicians in France had to be consulted, prolonging resolution of the battery problem and extending the service disruption. Ensuring that replacement parts and maintenance staff are able and required to address technology malfunctions efficiently is critical for minimizing service disruption and maintaining a safe, high-quality service.
- **Identify all funding obligation processes early and maintain open communication until approved.** Conversations regarding the funding source and obligation process should be identified and communicated early in the project. The process for obligating those funds should be clearly understood and noted within the agreement. All points of contact should be included within these discussions early and frequently.

3.4.2 Planning

Operational planning is critical to ensure that pilots can be executed safely and efficiently. Detailed planning also ensures that onsite and remote staff can respond to unexpected problems that may arise throughout the pilot period. Lessons learned related to planning include:

- **Involve all subcontractors during the planning process.** Transdev, the primary operator and party responsible for staffing the onboard safety attendants, was not involved in early project planning conversations. As a result, the NPS, NCDOT, and EasyMile developed plans that Transdev was required to implement. This presented some challenges early in the pilot, when issues arose due to shuttle operators having a limited degree of knowledge of operations and planning efforts established prior to launch.
- **Establish a plan for on-site oversight throughout the project period.** Even though much of the project was managed remotely, establishing a plan for on-site supervision throughout the project was critical. Shuttle operators did not have regular supervision, so it could be difficult to verify if agreed-upon procedures were being followed correctly. Implementing a plan for frequent site visits or planning for an on-site project member to oversee the project can help ameliorate these challenges.
- **Identify and mitigate potential safety concerns before operations begin.** As part of the project, the team conducted a risk assessment to evaluate potential hazards associated with the project, determine whether any

mitigations were required, and develop a matrix of mitigation measures clearly assigning responsibility for further action. While it may not be possible to anticipate all potential hazards, risk assessments can help identify possible conflict points before operations begin and reduce the risk of safety issues arising. For example, while the potential for pedestrian conflicts was identified in the risk assessment (and mitigated with reduced shuttle speed at crossing locations, educational brochures, and site signage), the safety hazard created by drivers attempting to pass the shuttle when it stopped at a crosswalk to yield to pedestrians was unanticipated and had to be resolved during the project.

- **Ensure consistent operating procedures among shuttle operators.** Shuttle operators did not always act consistently. Some operators failed to switch the operating status signs at shuttle stops from "open" to "closed," which caused confusion among visitors. Some operators did not kneel the vehicle for older riders as NCDOT and the NPS requested. One operator did not initially know how the kneel function worked and attempted to operate the shuttle while it was still in a kneeled position. Contracts with service operators could specify the guidance that operators should receive when being trained to operate an automated shuttle (e.g., when to kneel the vehicle, when to deploy the accessibility ramp, and when to intervene in a possible safety conflict) to help ensure consistency in operations.
- **Maximize time for mapping, testing, training, and other planning.** A schedule for mapping, testing, and operator training should be clearly defined and accepted by all parties. The schedule should include adequate time to identify any issues well in advance of the start of passenger service. This schedule should be included in the contract and, if mapping takes less time than originally planned, the remaining time should be allocated toward additional testing and operator training.
- **Include NPS staff in the mapping process.** EasyMile staff had to return to the site after initial mapping was completed because the new accessibility ramp installed at the shuttle stop was not considered. This requirement could potentially have been avoided by having NPS staff included in the initial mapping process.
- **Consider recruiting operators locally to help reduce turnover.** While hiring local operators may be desirable, it may not always be possible. Transdev advertised for onboard safety operator positions locally, but ended up bringing in operators from distant locations to staff the pilot. Multiple operators were hired for the pilot since few people were willing to spend time away from home for the duration of the entire pilot. Lower turnover could allow fewer operators to be involved, making it easier to establish consistent operating practices. Fewer operators with longer work periods could also enable each operator to become more familiar with the technology, possibly eliminating issues related to consistency in operating procedures. Furthermore, the restrictions and uncertainty surrounding the COVID-19 public health emergency made hiring local operators for the CASSI shuttle more difficult.
- **Develop a plan for service interruptions.** While service interruption was addressed in the risk assessment (e.g., if weather conditions or technical issues result in a suspension of shuttle service), planners did not anticipate the event of a visitor getting stuck due to a service suspension. For instance, it may be necessary to establish a sweep process or provide for a backup conventional vehicle to transport stranded visitors if the automated shuttle is unable to operate or taken out of service. The intent of a service interruption plan would be to establish a consistent set of procedures to make sure visitors are not waiting at stops or stranded if the shuttle can no longer operate.
- **Improve the quality and placement of information provided at vehicle stops.** For the CASSI pilot, signage at the shuttle stops was lacking some pertinent information, which led to some visitor uncertainty about the service's frequency, route, and rules.

3.4.3 Communications

Open and prompt internal communication, as well as communication between partners, ensures that all parties involved in planning, operations, and oversight of the pilot have timely information related to important project developments. Clear communication to the public is also necessary to ensure visitors have the information they need to access alternative transportation options safely and enjoyably. Lessons learned related to communications include:

- **Establish early communication with park superintendents.** Park superintendents may have specific preferences for project elements. Establishing earlier dialogue with superintendents to identify preferences could help streamline planning and ensure these considerations are incorporated upfront.
- **Standardize procedures for operators to communicate service disruptions and operational information with NPS staff.** Some operators routinely used their radios to notify park staff about service disruptions and lunch breaks. This allowed park staff to answer visitor questions about the shuttle accurately. In cases when operators were inconsistent in radio communications with park staff, it was more difficult to relay service information to visitors.
- **Involve public affairs staff at all levels early on.** For the CASSI pilot, public affairs staff at the park, regional, and WASO levels were required to be involved in project publicity. Engaging these individuals and connecting them with each other early in the planning process helps streamline planning efforts and allows for communications strategies to be developed with sufficient time.
- **Communicate frequently and divide roles clearly to establish a strong foundation for a working partnership.** The NPS and NCDOT established roles for project implementation early in the planning process. Frequent communication through weekly meetings (which included representatives from the NPS, NCDOT, EasyMile, and the Volpe Center) was also critical to project success. Weekly meetings were used to review survey data, address operational issues, and exchange general project updates.

3.4.4 Technology

Emerging technologies present opportunities to enhance visitor experience, accessibility, resource protection, and safety. Understanding the capabilities and limitations of these technologies is one of the primary purposes of the automated shuttle pilots. Lessons learned related to technology include:

- **Be prepared to address visitor confusion, which may result from unexpected vehicle behaviors.** In the case of the CASSI pilot, the shuttle's safety protocols prevented it from passing pedestrians, forcing the shuttle to slowly follow them around the route. Ultimately, this issue was addressed by adding signage noting this behavior and asking pedestrians to exit the roadway to allow the shuttle to pass (refer to Figure 40).
- **Expect disruptions caused by environmental conditions and plan for additional landscape maintenance activities.** CASSI's on-board sensors were more sensitive than park staff initially anticipated. While this meant that the vehicle drove more cautiously, the quality of service was reduced because the shuttle would frequently disengage, while the reason for the disengagement was not always immediately clear to operators or park staff. Light rain, weeds growing near the roadway (refer to Figure 36), and even small insects were noted as causes of sensor disruptions and disengagements.

3.4.5 Evaluation

Compiling visitor feedback and assessing the quality of data collection enables improvements in the planning and operation of similar future pilots. Lessons learned related to evaluation include:

- **Limit the length of visitor feedback surveys to expedite Federal approval (if necessary) and encourage visitors to complete them.** Surveys administered by or in partnership with the Federal government may be subject to

Paperwork Reduction Act clearance. Short surveys with 10 or fewer questions can be submitted as customer feedback surveys under an expedited OMB review process taking two weeks or less (about a month for the entire review process, including NPS review prior to OMB submission). Some questions may not be allowed under this process due to the customer feedback limitations.[53]

- **Consider all potential options when determining the best way to administer surveys.** There are many different tools and techniques available to administer surveys and analyze results. Consider providing options for both electronic and paper survey distribution. Also, consider different types of approval needed to comply with necessary Institutional Review Board guidelines and Paperwork Reduction Act clearance.
- **Plan strategies to increase survey response rates.** Survey response rates can be low, so considering ways to increase response rates early on is helpful. For example, stickers with the QR code for the survey were used at Wright Brothers National Memorial to encourage riders to fill out the survey, but these were not developed until later in the pilot.
- **Set expectations for data sharing and data limitations early on.** Data sharing can be challenging, even with requirements spelled out in the contract. For example, shuttle vendors do not tend to collect passenger counts automatically—they rely on their safety operators to collect these manually. This restricts data to aggregated counts rather than stop-level alightings and boardings, which poses limitations on the types of evaluation analysis that can be conducted. Providing partners with a template or exemplar data sets could improve data sharing.
- **Use a range of approaches to inform visitors.** Printed informational materials are helpful to educate visitors about the pilot, but visitors may not always read written materials provided to them. Deploying multimedia approaches to information through video or other means may inform a broader range of visitors about the pilot.

3.4.6 Visitor Experience and Visitor Management

Enhancing visitor experience and evaluating potential new opportunities for interpretation and mobility assistance were among the main goals of the automated shuttle pilots. Visitor management is also important to set expectations and provide information needed to use the service and interact with the vehicles. Lessons learned related to visitor experience and visitor management include:

- **Balance visitor experience and transportation needs.** While the small capacity of automated shuttles means that not many visitors are transported, the small capacity can provide an opportunity for a different type of visitor experience. Balancing the visitor experience with transportation needs when considering driving automation technologies will be an important consideration for the NPS going forward in evaluating and considering these services.
- **Identify signage needs and assign responsibilities for design, production, installation, and maintenance.** Park staff stated a desire for more professional signage throughout the pilot area. Project teams could deploy signage that displays information such as route schedules and times, headway information, stop locations, route maps, and informational messages.
- **Ensure that visitors have important information about vehicle stops, frequency, and other key details.** Service information is important for providing a safe and enjoyable visitor experience. As part of providing this information, it is important to anticipate when and where visitors will require direct engagement with park staff, and where they will be able to understand vehicle and route information without direct interaction. Prior to the start of the pilot, park staff expressed concern about potential visitor management issues. Staff were especially

[53] See Office of Management and Budget: A Guide to the Paperwork Reduction Act for more information.

concerned about the extra duties they would need to take on to support the shuttle pilot. However, most of these issues never materialized.

3.4.7 Accessibility

Emerging mobility technologies can provide opportunities for parks to enhance access to cultural and natural resources for visitors of various abilities. Lessons learned related to accessibility include:

- **Require the use of robust accessibility equipment with a good supply chain for replacement parts.** The supplier of the shuttle's on-board accessible ramp was not able to readily provide replacement parts for the ramp in the event of a malfunction. This made operators more reluctant to deploy the ramp. More robust equipment and a more reliable supplier could resolve this issue and allow operators to deploy on-board ramps as needed.
- **Use the shuttle's kneeling function for elderly riders and others who may need it.** While operators were instructed to use the kneel function for any rider who appeared to need it, park staff noted that some operators rarely used the kneel function. Clearer guidance about the use of the kneel function could help resolve this issue and ensure that riders can safely board and alight from the vehicle.
- **Design accessibility infrastructure in initial planning stages with input from all partners.** The ramp built at the sculpture stop was not anticipated during the mapping process. Thus, mapping was completed without the ramp structure included. EasyMile staff had to return after the ramp was constructed to fix the shuttle's approach to the sculpture stop and to ensure that visitors had enough clearance to use the ramp structure to board the shuttle. This step could have been avoided by considering the need for a ramp structure prior to the completion of the mapping process.

4. Comparative Analysis

While the automated shuttle pilots at Yellowstone National Park and Wright Brothers National Memorial had unique operational environments and characteristics, the two pilots do allow for some cross-comparison on key performance metrics. Both pilots had an overarching research objective of learning about the performance of automated shuttle technology in remote, recreational settings, and both shuttle pilots provide interesting insights into this research area. This section compares the results of the two pilots to highlight how several findings are cross-cutting, indicating that the findings of a particular pilot are not standalone but rather are indicative of larger trends in automated shuttle technology. Table 4 presents some of the key characteristics of the pilots.

Table 4: Comparison of Pilots: Planned Elements

Category	Yellowstone National Park (TEDDY)	Wright Brothers National Memorial (CASSI)
Operator	Beep	Transdev
Vehicle	Local Motors Olli	EasyMile EZ10
Number of Shuttles	Two	One
Operating Days	Seven days, Sunday–Saturday	Five days, Monday–Friday
Service Day	7:00 am – 9:00 pm (with two breaks)	10:00 am – 4:30 pm (with one break)
Planned Hours per Day	9 hours	5.5 hours
Number of Unique Routes	Two routes	One route
Route Miles	1.5 miles / 1.6 miles	1.5 miles
Number of Stops	Three / four	Two

Source: NPS and U.S. DOT Volpe Center

4.1 Ridership

Each pilot had high levels of ridership, given the characteristics of the pilot. CASSI had significantly fewer riders than TEDDY, but there was also only a single CASSI shuttle that operated for five days each week, compared to two TEDDY shuttles that ran seven days each week. Additionally, CASSI had passenger limitations due to COVID-19 restrictions that TEDDY did not.

Table 5: Comparison of Operations

Category	TEDDY	CASSI
Number of Days in Operation	74	54
Number of Trips	2,544	809
Number of Passengers	10,057	3,380
Average Passengers per Trip	4.0	4.2
Average Passengers per Vehicle per Operating Day	68.0	62.6
Average Trips per Vehicle per Operating Day	17.2	15.0

Source: Transdev, Beep, and U.S. DOT Volpe Center

Although TEDDY did have significantly more trips and riders in absolute terms, the two pilots were very similar in terms of per-trip statistics. CASSI had an average of 15 trips per day for a single shuttle, while TEDDY had an average of 17 trips per day for each of the two shuttles. Additionally, the passengers-per-trip averages were also very similar, at 4.0 and 4.2 for TEDDY and CASSI, respectively. This suggests that the two pilots actually had very similar outcomes in terms of ridership and trips, with TEDDY appearing to have more in the total counts due to the extra shuttle and the extra days and hours of operation.

4.2 Vehicle Performance

Although both pilots experienced overall success with respect to meeting their project goals, there were challenges in regards to vehicle performance. There were multiple days where the scheduled service was completely or partially suspended, due to reasons such as depleted batteries, inclement weather, physical or software issues with the shuttles, or other causes. At Yellowstone National Park, both shuttles were in full operation for the entire day during only 38 of the 74 days of the pilot and at Wright Brothers National Memorial, the shuttle was only in full operation for the entire day for 46 of the 54 days of the pilot.

These were pilot tests of automated shuttle technology, and neither pilot had the goal of the shuttles being in full operation for every planned hour of service. However, it is still important to note that these results indicate that automated shuttle technology is likely not ready for full-scale, long-term deployment in national parks. For the technology to be a feasible long-term service option, the frequency of service suspensions will likely need to be on par with or better than that of traditional non-automated shuttles with regular full-time drivers.

4.2.1 Battery Usage

All shuttles experienced challenges related to battery usage that caused changes to the original charging schedules for the two pilots. At Wright Brothers National Memorial, the operator's lunch break was extended to allow for midday charging, and Yellowstone National Park added another charging station closer to the route to be able to charge the shuttles during the day between shifts. The higher-than-expected rate of battery consumption was attributed in both pilots, at least in part, to significant use of air conditioning. Given that both pilots experienced the same battery-related challenges, it may indicate that it was not a problem related to a specific element of either pilot or to a particular vehicle platform, but rather is indicative of a broader issue with the capacity of the batteries currently used in automated shuttles. The batteries and electrical systems used in shuttles will need further improvements if they are to be competitive with traditional human-driven shuttle vehicle alternatives.

4.2.2 Weather

Both pilots experienced service suspensions related to weather conditions, specifically from rain and other stormy weather conditions. This is a known challenge with automated shuttles—they are primarily able to run in fair, dry weather conditions, meaning that the technology would not be able to be deployed year-round in many locations in the United States. Until automated shuttles can operate in the same weather conditions as a traditional road vehicle, there will be limitations on their use as viable, long-term transportation solutions.

4.3 Disengagements

There were numerous disengagements for each shuttle. The two pilots recorded information on disengagements slightly differently, precluding a direct comparison of disengagements by type, but there are still useful ways to compare the disengagements. June disengagements data for TEDDY are missing, but TEDDY had two shuttles, operating all seven days of the week, with longer hours of operation each day, which would suggest that, all else being equal, TEDDY should have had more disengagements than CASSI. However, in practice, the CASSI shuttle had a much higher rate of disengagements than TEDDY shuttles did—the total number of recorded disengagements for TEDDY was only 478 for both shuttles combined, compared to 620 for CASSI with its single shuttle.

On days of full operation, the CASSI shuttle experienced an average of 10.7 disengagements per day and one of the two TEDDY shuttles experienced an average of 7.0 disengagements per day, while the other shuttle experienced an average of 6.9 disengagements per day. It is not clear in the recorded disengagement data why this would be the case, but observational data could suggest that the CASSI shuttle encountered pedestrians in the road more frequently than the TEDDY shuttles did, simply due to the nature of the respective sites and pedestrian movements, which could potentially be a reason for the disparity in disengagements. Other reasons could include differences in the automated technology used, specific characteristics of the route and surrounding landscape, or an increased tendency by CASSI operators to manually disengage the vehicle relative to TEDDY operators (e.g., related to different training instructions or standard operating procedures).

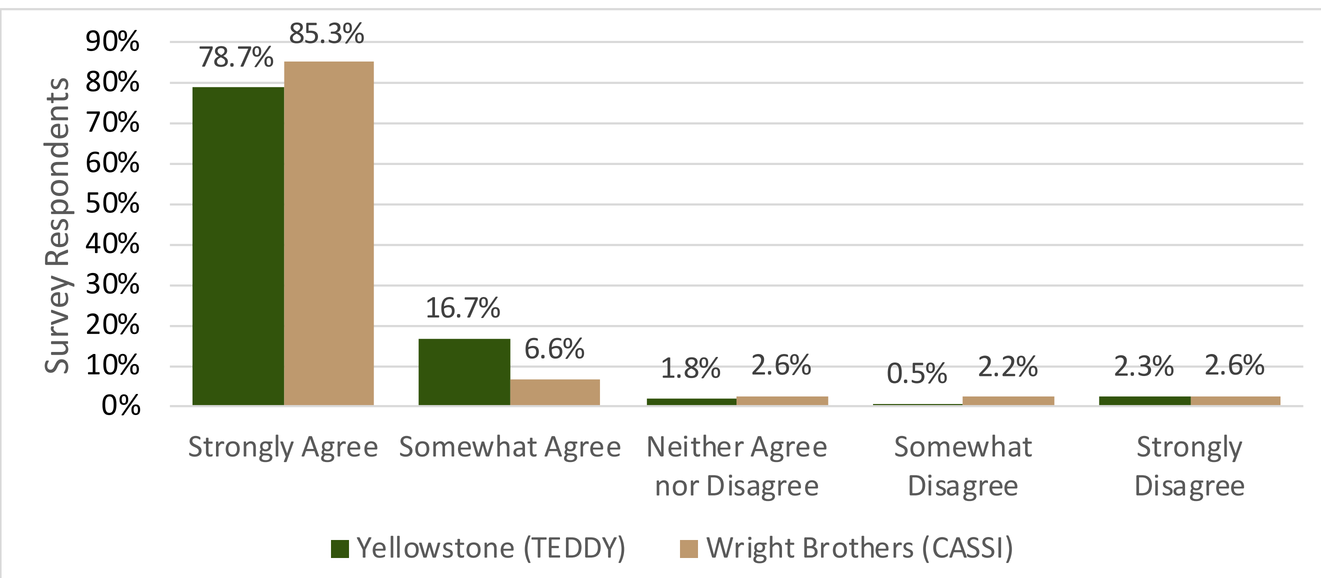
Although the rate and number of disengagements differed, both pilots experienced many of their disengagements in similar areas. There were disengagements on the open roadway portions of the routes relative to the portion of the route in parking areas, at high pedestrian crossings, and similar operational settings. This could be indicative that the automated technology works best in environments with simpler traffic flows where most movements are predictable. Conversely, the technology is more challenged in environments with increased pedestrian traffic and generally more unpredictable vehicle movements.

4.4 Visitor Experience

The survey used by both pilots was virtually identical, allowing cross-comparison of survey answers to gauge how visitor experience differed across the two pilots. Overall, there were very similar trends across both surveys for all survey questions, but there were some minor differences in the survey responses.

The first survey question asked respondents to rank how much they agreed with the statement: "I had a good experience using the shuttle." Both surveys indicated a high rate of agreement. The CASSI results saw a larger percent of respondents "Strongly Agree" with the statement (85.3 versus 78.7 percent), but TEDDY results saw a larger percent of respondents who either "Strongly" or "Somewhat Agreed" with the statement (95.4 versus 91.9 percent). The breakdown of responses for both pilots can be seen in Figure 44.

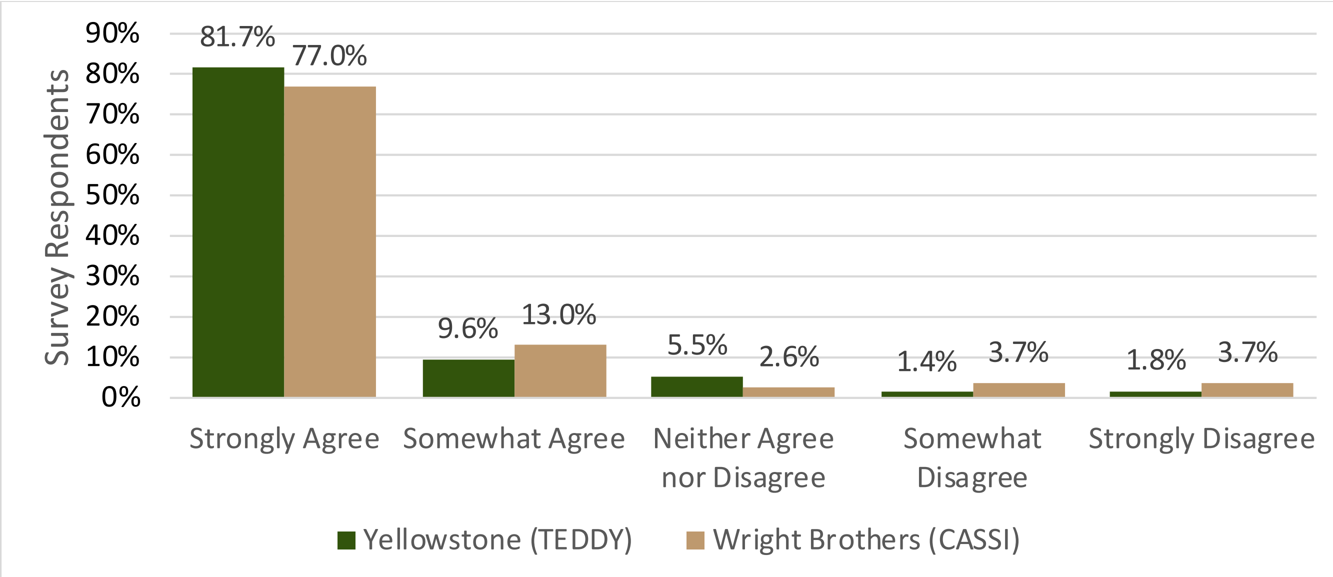
Figure 44: Survey Response Comparison: "I had a good experience using the shuttle"



Source: NCDOT, MSU, and U.S. DOT Volpe Center

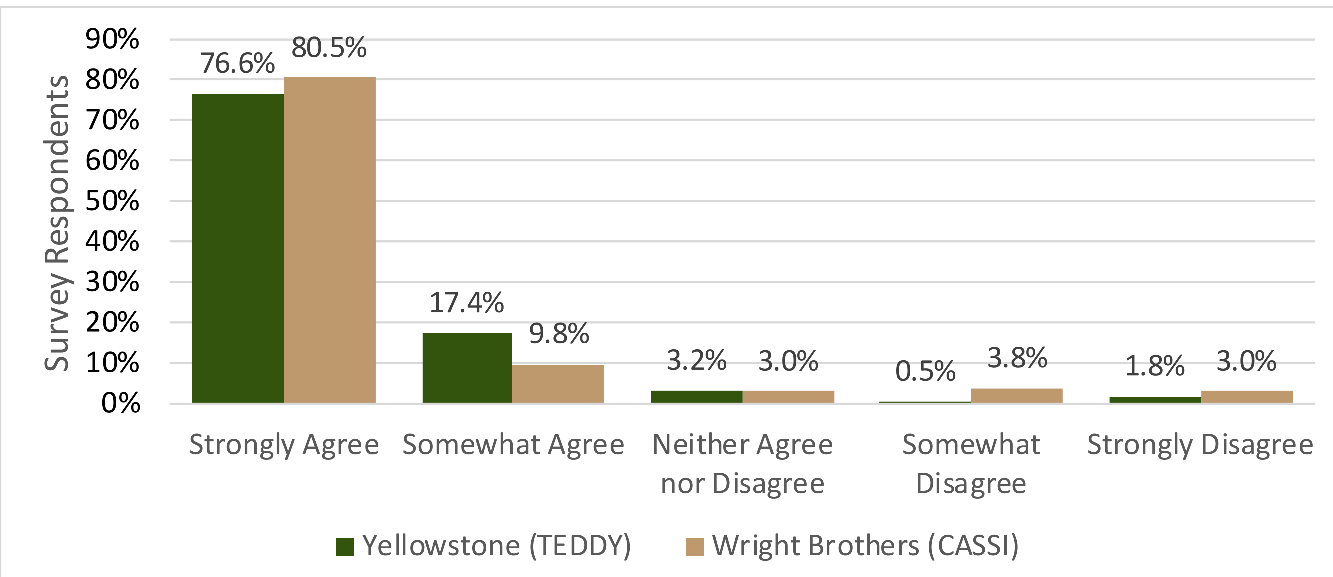
The next two questions asked about the timeliness of the shuttle, with the first statement relating to the origin stop and the second relating to the destination stop. For both pilots, there was greater agreement in regards to reaching the respondent's destination in a reasonable amount of time than there was in regards to the shuttle arriving at the respondent's stop in a reasonable amount of time. However, both pilots saw general agreement that the shuttles were timely. TEDDY respondents did have a higher rate of agreement with these statements, but CASSI still also had high levels of agreement. The comparison of responses can be seen for these two statements in Figure 45 and Figure 46.

Figure 45: Survey Response Comparison: "The shuttle arrived at my stop within a reasonable amount of time."



Source: NCDOT, MSU, and U.S. DOT Volpe Center

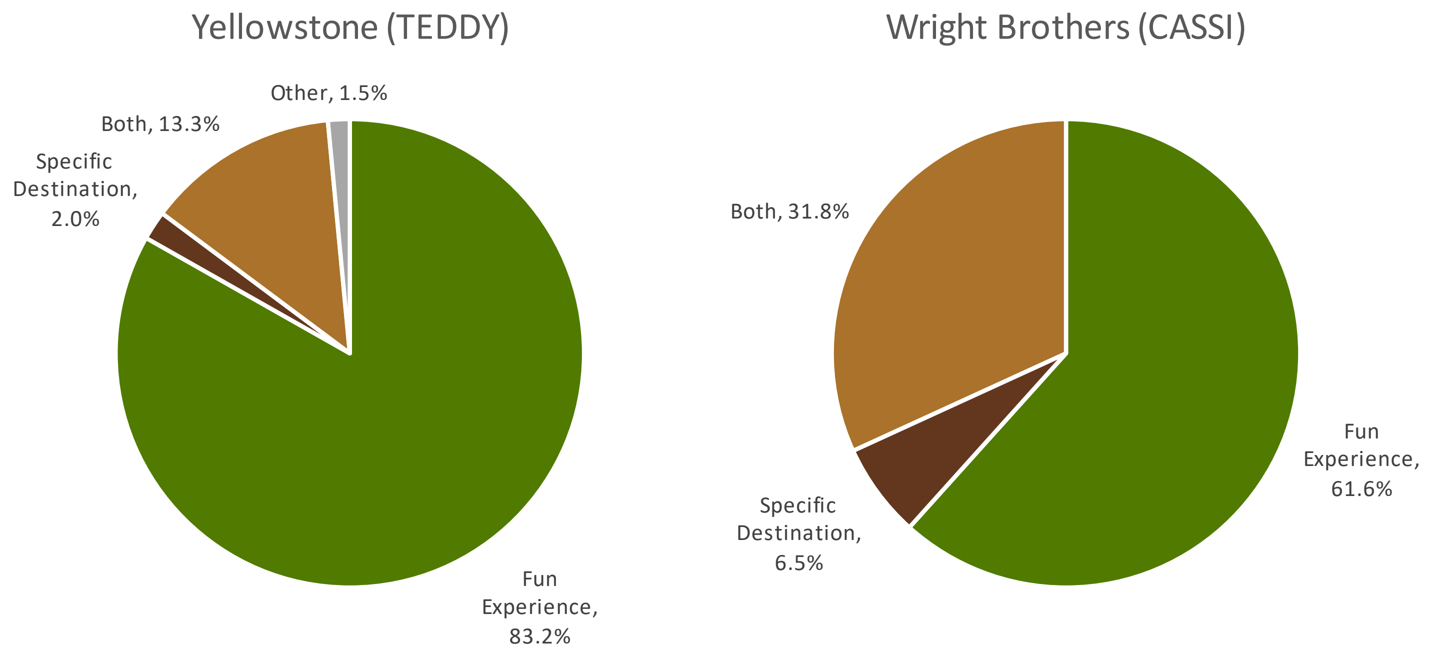
Figure 46: Survey Response Comparison: "I was able to get to my destination in a reasonable amount of time."



Source: NCDOT, MSU, and U.S. DOT Volpe Center

For both pilots, the majority of survey respondents took a shuttle ride primarily for a fun experience, but the percentage was far higher for TEDDY (83.2 percent) than for CASSI (61.6 percent). Similarly, CASSI had a slightly higher percentage of people taking the shuttle primarily to reach a specific destination (6.5 percent) compared to TEDDY (2.0 percent), with the remaining respondents riding for both purposes. This could indicate that the shuttle was filling more of a transportation need at the Wright Brothers National Memorial than at Yellowstone National Park, but it is difficult to say for certain.[54] The breakdown of responses can be seen for both pilots in Figure 47.

Figure 47: Survey Response Comparison: Purpose of Ride

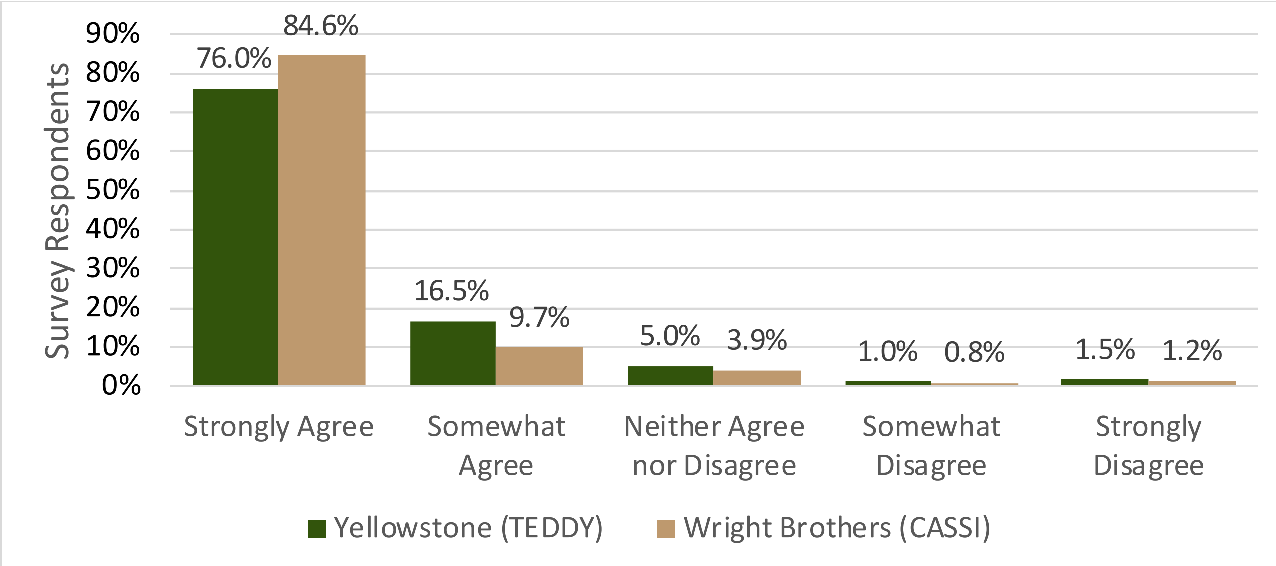


Source: NCDOT, MSU, and U.S. DOT Volpe Center

The final question common to both pilots asked if respondents would agree with the statement that they would like to see more automated shuttles in national parks. This was the only agreement statement for which the Wright Brothers National Memorial had a slightly higher percentage of “Strongly”/”Somewhat Agree” responses than Yellowstone National Park, with 94.3 percent “Strongly” or “Somewhat Agreeing” at the Wright Brothers National Memorial and 92.5 percent at Yellowstone National Park; however, these percentages are still very similar to each other. The breakdown of responses can be seen for both pilots in Figure 48.

[54] The CASSI shuttle provided access to a primary resource (i.e., the Wright Brothers National Monument), while the TEDDY shuttle did not, and that difference would have likely influenced the reasons why visitors chose to ride the shuttle. Given that most visitors who encountered the TEDDY shuttle were not likely staying at one of the lodges or at the campgrounds, most visitors who chose to ride would have done so for the novelty of the experience and relatively few would have taken the shuttle to get to a specific destination.

Figure 48: Survey Response Comparison: "I would like to see driverless shuttles in more national parks"



Source: NCDOT, MSU, and U.S. DOT Volpe Center

4.5 OVERARCHING LESSONS LEARNED

As documented in the previous chapters on TEDDY and CASSI, there were many lessons learned during the two automated shuttle pilots. This section further distills those lessons learned into general considerations that could apply to other future pilots, whether they involve automated shuttles or other emerging transportation technologies. These lessons learned include:

- **Contracting:** Depending on the nature of the emerging technologies piloted, certain contracting mechanisms may be more appropriate than others. When possible, identify details and specifics before drafting the contract. Partner obligations and responsibilities must be clear, as well as what data will be collected and shared. A certain amount of flexibility can also be built into contracts and subcontracts to enable partners to resolve the unexpected situations that inevitably arise from novel technology pilots. Involving staff with technical and legal expertise early in the contracting process will also help to provide context, identify any missing pieces, and resolve agreement language.

- **Communications:** Early and regularly-scheduled communication between project partners is critical for successful pilot operations. Clear procedures surrounding communication, such as when operators should notify park staff of operational issues, can help ensure that all partners have shared expectations regarding communications in terms of roles, frequency, timing, and content. Presence of dedicated project-planning staff onsite throughout the pilot can help keep the project team informed, improve communications with contractors, and provide opportunities to implement changes as needed.

- **Planning:** Involving all subcontractors in the planning process from the beginning can help the parties identify and address safety and operational concerns before the pilot begins. Additionally, planning sufficient time for initial mapping and potential mapping revisions may be necessary. Recruiting shuttle operators locally may help reduce turnover for future pilots, while developing a thorough plan for service interruptions can ease uncertainty during operations. A service interruption plan could help establish a consistent set of procedures to make sure visitors are not waiting at stops or stranded if the automated shuttle service is suspended (e.g., through instituting a sweep process or having a backup conventional vehicle and driver maintain service if the shuttle is unable to operate). Finally, planning ahead with better design and placement of visitor information signage throughout the pilot area would assist with visitor management.

- **Visitor Experience and Visitor Management:** Planning and placing sufficient information about the shuttle service throughout the project area can help ensure that visitors are informed of shuttle frequency, the number of stops, stop locations, and other key details. Identifying responsibility for different elements of visitor information (such as signage and online information) and assigning staff to those roles during project planning stages can help ensure consistent and reliable information.
- **Technology:** As with any emerging technology, unexpected disruptions may occur. Shuttles in both pilots were affected by roadside vegetation and other site elements, such as wildlife and weather. TEDDY was also affected by weak GPS signals, which caused disengagements and inaccurate data collection. Shuttles in both pilots were also impacted by battery issues, from insufficient capacity to support a full day's operation to battery system failures. Establishing multiple charging locations (e.g., at overnight storage locations and somewhere near the shuttle route) and creating plans for other service disruptions can help contractors and park staff mitigate potential technology limitations. Planners should also consider the impacts of secondary technologies on the project, such as limited internet connectivity and its effect on transferring data and collecting survey responses.
- **Evaluation/Survey:** During the project planning stages, it may be helpful to identify strategies to improve survey response rates (e.g., assigning staff to randomly administer the survey to riders, printing stickers or other takeaway materials, or giving thought as to how to make web-based survey submissions easier in areas with limited cellular or Wi-Fi signals). Planners working on Federal projects can limit the length of visitor feedback surveys to expedite Federal approval through the Office of Management and Budget. Additionally, keeping surveys short may help increase survey completion rates.
- **Accessibility:** Planning for accessibility infrastructure (e.g., deployable onboard ramps or ramps installed at shuttle stops) during the initial stages of the project may help ensure that accessibility aspects are adequately addressed and reduce difficulty in adding accessibility features later in the project. By involving all project partners in the planning and design of mobility infrastructure, teams can better ensure compatibility between historic site guidelines and shuttle specifications. Building reliable accessibility infrastructure also involves ensuring that replacement parts are readily available in the event a component breaks and needs to be replaced. Shuttle kneeling or deployment of ramps could be more routinized to improve accessibility for all riders without requiring users to request accommodation.

5. Conclusion

Through its automated shuttle pilots and public-sector and private-sector partnerships, the NPS has gathered information, experience, and many lessons learned. NPS staff have grown both in experience and in preparation for ADS-equipped vehicles, with lessons that can be applied not only to future automated shuttle pilots, but also to other types of ADS-equipped vehicle pilots (e.g., privately owned personal vehicles or shared-ride service fleets) and other emerging mobility technology pilots.

The MOU between U.S. DOI and U.S. DOT on Transportation Innovation in the National Park System is an indicator of initiatives and expanded Federal collaboration to come. Rapid advancements in transportation technology and the development of new business models are transforming the transportation industry, with important implications for park congestion, visitor experience, equity, safety, and resource protection. These trends present both opportunities and challenges for the NPS, and proactive technology demonstrations in park operating environments will help the NPS understand the implications of these innovations, provide experience and lessons learned to aid in deployment, and assist with the management of park transportation systems in a manner that supports the NPS mission.

Results from these automated shuttle demonstrations will be used to inform future NPS work and to provide additional use cases for the automated shuttle industry. The TEDDY and CASSI pilots were useful in understanding how small, novel-design, low-speed automated shuttles, operating on a fixed schedule along a fixed route, can function in a national park setting. While some aspects worked well, many challenges were also identified. Further technological development will be needed before those technologies will be ready for broader use to provide regular service for national park visitors.

To further advance knowledge and understanding of ADS-equipped vehicle capabilities in its parks, the NPS may consider distinctly different use cases, vehicle formats, or technologies, rather than directly replicating the TEDDY and CASSI pilots. For instance, the NPS could consider pilots related to ADS-equipped vehicles providing on-demand, point-to-point services. The NPS could investigate the use of ADS in light-duty vehicles, cutaway buses, full-size transit buses, or other vehicle types, many of which are being developed and piloted elsewhere. Similarly, outside of transit-related service, there may be opportunities to test ADS-equipped vehicles for other applications, such as personal individual transportation, ride-hailing services, interpretive services, or goods delivery. Future pilots could also consider the use of ADS-equipped vehicles and other emerging technologies, such as connected vehicle applications.

While TEDDY and CASSI considered somewhat limited use cases, similar services and routes could apply to many different national parks and other Federal lands. In addition, some of the challenges, such as the GPS and internet connectivity limitations that hindered data collection and transfer in Yellowstone National Park, would also apply to many other park settings. When the technology is sufficiently advanced, the use of automated driving systems may help provide new services to visitors, especially in remote park settings where staffing is limited. Further pilot testing may be helpful in determining applicability of various vehicle technologies in different park settings, and, may be helpful should the NPS consider more permanent installations when technology capabilities, park needs, and site suitability align.

Through their commitment to work together, innovate, and make on-the-ground adjustments to address unanticipated issues, the NPS and its partners were able to successfully complete the first two automated shuttle pilots on any recreational public lands in the Nation, learn about the capabilities and limitations of current technology, and gain a better understanding into how visitors feel about the technology and its future in national parks. As the NPS looks to the future, it has gained perspective and insight that will help in addressing questions related to ADS-equipped vehicles, both in national parks and in other Federal lands across the country.

APPENDIX A: SURVEY QUESTIONNAIRE

This appendix presents the two survey questionnaires for the separate pilots.

TEDDY SURVEY QUESTIONNAIRE

1. Did you ride the driverless shuttle?

2. What is your age?
    - o Under 18
    - o 18-29
    - o 30-49
    - o 50-69
    - o 70+

3. On a scale from 1-5 with 1= strongly agree and 5= strongly disagree, please indicate your level of agreement with the following statements about your experience:

	Strongly agree 1	Somewhat agree 2	Neither agree nor disagree 3	Disagree 4	Strongly disagree 5
I had a good experience using the shuttle.					
The shuttle arrived at my stop within a reasonable amount of time.					
I was able to get to my destination in reasonable amount of time.					
I felt comfortable with the COVID mitigation measures in place.					

4. I boarded the shuttle at [dropdown menu listing park specific stops] and disembarked at [dropdown menu listing park specific stops].

5. On a scale from 1-5, with 1 = very safe and 5 = very unsafe, please indicate how safe you felt using driverless vehicles before and after riding the shuttle:

	Very safe 1	Somewhat safe 2	Neither safe nor unsafe/ No opinion 3	Somewhat unsafe 4	Very unsafe 5
BEFORE riding the shuttle, I felt that driverless shuttles are:					
AFTER riding the shuttle, I feel that driverless shuttles are:					

If you felt unsafe riding the shuttle, please tell us why: ___________________

Informative/Educational

6. On a scale from 1-5, with 1= excellent and 5 = very poor, please rate the quality of the information you received about the following while riding the shuttle:

	Excellent 1	Good 2	Fair 3	Poor 4	Very Poor 5
Driverless vehicle technology?					
The purpose of the shuttle pilot?					
Canyon area resource information and significance?					
Wayfinding and navigation?					

7. Did you ride the driverless shuttle **just for a fun** experience, or to **get to a specific destination**?
   - o Fun experience
   - o Specific destination
   - o Both
   - o Other:___________

8. If you had not taken the driverless shuttle, which of the following modes of transportation best describes how you would have traveled?
   - o Walk
   - o Bike
   - o Personal Vehicle
   - o Carpool
   - o Would not have taken the trip
   - o Other mode:______

9. On a scale from 1-5, where 1 = strongly agree and 5 = strongly disagree, please indicate your agreement with the following statement:

	Strongly agree 1	Somewhat agree 2	Neither agree nor disagree 3	Somewhat disagree 4	Strongly disagree 5
I would like to see driverless shuttles in more national parks					

10. Would you ride the shuttle again? Why or why not?

CASSI Survey Questionnaire

1. Did you ride the driverless shuttle?

2. What is your age?
   - o Under 18
   - o 18-29
   - o 30-49
   - o 50-69
   - o 70+

3. On a scale from 1-5 with 1= strongly agree and 5= strongly disagree, please indicate your level of agreement with the following statements about your experience:

	Strongly agree 1	Somewhat agree 2	Neither agree nor disagree 3	Disagree 4	Strongly disagree 5
I had a good experience using the shuttle.					
The shuttle arrived at my stop within a reasonable amount of time.					
I was able to get to my destination in reasonable amount of time.					
I felt comfortable with the COVID mitigation measures in place.					

4. On a scale from 1-5, with 1 = very safe and 5 = very unsafe, please indicate how safe you felt using driverless vehicles before and after riding the shuttle:

	Very safe 1	Somewhat safe 2	Neither safe nor unsafe/ No opinion 3	Somewhat unsafe 4	Very unsafe 5
BEFORE riding the shuttle, I felt that driverless shuttles are:					
AFTER riding the shuttle, I feel that driverless shuttles are:					

   If you felt unsafe riding the shuttle, please tell us why: ___________________

5. Did you ride the driverless shuttle **just for a fun** experience, or to **get to a specific destination**?
   - o Fun experience
   - o Specific destination
   - o Both
   - o Other:___________

6. If you had not taken the driverless shuttle, which of the following modes of transportation best describes how you would have traveled?
   - o Walk
   - o Bike
   - o Personal Vehicle
   - o Carpool
   - o Would not have taken the trip
   - o Other mode:______

7. On a scale from 1-5, where 1 = strongly agree and 5 = strongly disagree, please indicate your agreement with the following statement:

	Strongly agree 1	Somewhat agree 2	Neither agree nor disagree 3	Somewhat disagree 4	Strongly disagree 5
I would like to see driverless shuttles in more national parks					

8. Would you ride the shuttle again? Why or why not?

APPENDIX B: DATA TABLES

The tables below provide additional detail on the data elements provided to the evaluation team, included units, level of specificity, and the type of file in which the data was provided. Data for TEDDY can be seen in Table 6 and data for CASSI can be seen in Table 7.

Table 6: TEDDY Data Elements

Data Element	Units	File Type	Level of Specificity	Notes
Starting Battery Charge	%	Spreadsheet	By Shuttle, By Shift	-
Ending Battery Charge	%	Spreadsheet	By Shuttle, By Shift	-
Trips Operated	Count	Spreadsheet	By Shuttle, By Shift	-
Passengers	Count	Spreadsheet	By Shuttle, By Shift	-
ADA Passengers	Count	Spreadsheet	By Shuttle, By Shift	-
Scheduled Hours	Hours	Spreadsheet	By Shift	-
Actual Hours	Hours	Spreadsheet	By Shift	Not available for all shifts, particularly for the Lodge Route
Temperature	° Fahrenheit	Spreadsheet	By Day	Available from a nearby local station
Temperature	° Fahrenheit	Spreadsheet	By Shift	Available from Beep specific weather station, only available past 8/02
Weather Conditions	Description	Spreadsheet	By Day	Available from a nearby local station
Weather Conditions	Description	Spreadsheet	By Shift	Available from Beep specific weather station, only available past 8/02
Humidity	%	Spreadsheet	By Day	Available from a nearby local station
Humidity	%	Spreadsheet	By Shift	Available from Beep specific weather station, only available past 8/02
Shuttle Status	Text: Full/ Partial/Off	Spreadsheet	By Shuttle, By Shift	Text descriptions explaining shuttle status also available for some days
Disengagements	Count	Spreadsheet	By Disengagement	Each disengagement includes lat/long, route, shuttle, and the cause. Disengagements are also unavailable before 7/03
Speed	m/s	Email	By Shuttle, By Route	Top speed and average speed in motion
Incidents	Description	Email, PDF	By Incident	Qualitative description of the incident characteristics

Table 7: CASSI Data Elements

Data Element	Units	File Type	Level of Specificity	Notes
Battery %	%	Spreadsheet	By Shift	-
Battery % Before Charge	%	Spreadsheet	By Charge	-
Battery % After Charge	%	Spreadsheet	By Charge	-
Hours of Service	Hours	Spreadsheet	By Shift	Only available for some days/shifts
Service Availability	%	Spreadsheet	By Shift	% of time in operation – only available for some days/shifts
Ridership	Count	Spreadsheet	By Shift	-
Number of Trips	Count	Spreadsheet	By Shift	-
E-Stops	Count	Spreadsheet	By Shift	-
Disengagements	Count	Spreadsheet	By Disengagement	Each disengagement includes lat/long, cause, weather, and speed
Ramp Deployments	Count	Spreadsheet	By Shift	-
Precipitation	None/Light /Moderate /Heavy	Spreadsheet	By Day	-
Average Temperature	°Fahrenheit	Spreadsheet	By Day	-
Comments	Qualitative text	Spreadsheet	By Shift	Additional comments from the operator on the details of a particular shift
Average speed per day	km/h	PDF	Monthly	Daily estimates pictured on a graph, but only monthly average noted explicitly
Average commercial speed per day	km/h	PDF	Monthly	Daily estimates pictured on a graph, but only monthly average noted explicitly
Maximum speed in "AUTO" mode	km/h	PDF	Monthly	Daily estimates pictured on a graph, but only monthly average noted explicitly
Percentage of time in "AUTO" mode	%	PDF	Monthly	Daily estimates pictured on a graph, but only monthly average noted explicitly
Percentage of time in "AUTO" mode at non-null speed	%	PDF	Monthly	Daily estimates pictured on a graph, but only monthly average noted explicitly
Average battery consumption per day	kWh	PDF	Monthly	Daily estimates pictured on a graph, but only monthly average noted explicitly