First in Flight, First in Automation:

NCDOT and NPS Pilot an Automated Shuttle at the Wright Brothers National Memorial

Joshua Cregger, Kendall Mahavier, Amalia Holub, Elizabeth Machek, Travis Crayton, Rahi Patel, Stephanie Sudano, Amanda Good, Katie Wong, and Steve Suder

FINAL REPORT — May 2022

DOT-VNTSC-NPS-22-02
WRBR 361/180195

Prepared for:

National Park Service
Washington Support Office
Washington, DC

North Carolina Department of Transportation
Integrated Mobility Division
Raleigh, NC

U.S. Department of Transportation
Volpe Center

Notice

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE ***(DD-MM-YYYY)***	**2. REPORT TYPE**	**3. DATES COVERED** ***(From - To)***
2022-05-06	Final Report	

4. TITLE AND SUBTITLE
First in Flight, First in Automation: NCDOT and NPS Pilot an Automated Shuttle at the Wright Brothers National Memorial

5a. CONTRACT NUMBER
Inter-Agency Agreement 51VU16A100

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
John A. Volpe National Transportation Systems Center
55 Broadway, Cambridge, MA 02142-1093

8. PERFORMING ORGANIZATION REPORT NUMBER
DOT-VNTSC-NPS-22-02

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Park Service
Washington Support Office
1849 C Street NW, Washington, DC 20240

10. SPONSOR/MONITOR'S ACRONYM(S)
NPS

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
WRBR 361/180195

12. DISTRIBUTION / AVAILABILITY STATEMENT
This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Through its Emerging Mobility Program, the National Park Service (NPS) implemented an electric, automated shuttle pilot at Wright Brothers National Memorial in partnership with the North Carolina Department of Transportation (NCDOT). This pilot, dubbed the "Connected Autonomous Shuttle Supporting Innovation" (CASSI), ran from April to July 2021 with a single automated shuttle provided by EasyMile and operated by Transdev. The CASSI shuttle served over 3,300 riders on more than 800 trips over the course of the pilot. The CASSI shuttle faced some operational challenges, with a significant number of disengagements and service suspensions stemming from relatively common weather events. Survey results indicated overall satisfaction with the pilot, although most riders rode the shuttle primarily for a fun experience rather than to get to their destination. The NPS and NCDOT also learned many lessons throughout the course of the pilot, on topics such as contracting, planning, and accessibility.

15. SUBJECT TERMS
Automated shuttle, Automated Driving Systems, Wright Brothers National Memorial, pilot, evaluation, emerging mobility technologies, visitor experience

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** ***(include area code)***
Unclassified	Unclassified	Unclassified		52	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI

Acknowledgments

The planning, development, operation, and evaluation of this automated shuttle pilot was a collaborative effort, involving input from multiple agencies, organizations, and disciplines. The following individuals contributed to the success of this initiative:

- **North Carolina Department of Transportation - Integrated Mobility Division:** Stephanie Sudano, Sarah Searcy, Julie White, Ryan Brumfield
- **North Carolina Department of Transportation - Highway Division 1:** Sterling Baker
- **North Carolina Department of Transportation - Transportation Mobility and Safety:** Kevin Lacy
- **North Carolina Department of Transportation - ADA/Title IV:** Mark Whisenant, Garrick Witherspoon
- **National Park Service - Washington Support Office:** Steve Suder, Wayne Emington, Mike Caldwell, Jennifer Proctor, Ina Hysi, Jeremy Buzzell, Adam Kelsey
- **National Park Service - Region:** Lee Edwards
- **National Park Service - Park:** Michael Colopy, Scott Dowd, Michael Barber, David Hallac, Tim Akers, Darius Collins, Melvin Walston, Elizabeth Hudick
- **Public Lands Transportation Fellow:** Charlie Gould
- **Kimley-Horn:** Amanda Good, Katie Wong
- **U.S. Department of Transportation Federal Highway Administration:** Lewis Grimm, Colleen Fletcher, Usman Ali, Karyn Vandervoort
- **U.S. Department of Transportation Volpe National Transportation Systems Center:** Joshua Cregger, Kendall Mahavier, Amalia Holub, Elizabeth Machek, Travis Crayton, Rahi Patel, Eric Wallischeck

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1. Introduction

The National Park Service (NPS) aims to proactively introduce emerging mobility technologies through collaborative partnerships and pilot deployments while upholding the dual mission—visitor experience and resource protection—of the National Park System. The vision of North Carolina Department of Transportation (NCDOT) is to become a global leader in providing innovative transportation solutions, including advancing alternative transit and mobility solutions. With these goals in mind, NPS and NCDOT sought to collaborate to bring the first automated shuttle to a national park site.

This project was completed in the middle of the global COVID-19 pandemic. Several challenges were overcome to ensure the success of the effort. Although visitation numbers fluctuated at National Park Service units across the United States, visitation remained strong in many units, including at the Wright Brothers National Memorial. This site consists of several outdoor attractions, allowing it to remain a popular destination for vacationers enjoying nearby beaches and other amenities.

1.1 North Carolina Department of Transportation Program Goals

As part of its continuing commitment to innovation and improving transportation, NCDOT launched a new venture in 2019: the Connected Autonomous Shuttle Supporting Innovation (CASSI). Work first began in early 2019 and has evolved over time and through experience into a multiyear pilot program. Through the CASSI project, North Carolina communities and NCDOT have gained experience with microtransit and automated driving systems (ADS) technology. This pilot has continued to evolve, helping to inform and educate both the public and the NCDOT.

There are several manufacturers of automated shuttles, including EasyMile, Local Motors, and Navya. Nearly all automated shuttle services also include an onboard safety operator to assist riders and take control of the vehicle if necessary. NCDOT worked with many shuttle manufacturers to navigate the launch of an automated shuttle in North Carolina, ultimately partnering with EasyMile for the launch. Prior to piloting the EasyMile shuttle with NPS, NCDOT previously used it at North Carolina State University and the Transportation Summit, which was held in Raleigh, North Carolina on January 8-9, 2020.

1.2 National Park Service Program Goals

The National Park Service (NPS) Emerging Mobility Working Group, an interdisciplinary group of staff and subject matter experts from across the NPS and United States Department of Transportation (U.S. DOT), works to identify, research, and assess the use of emerging technologies on NPS lands. In addition to research, policy solutions, and program development, the NPS is assessing the implications emerging technologies have for resource protection, safety, equity, emissions, and visitor experience.[1]

Over the last few years, several automated shuttle manufacturers and operators have approached the NPS 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.

The Wright Brothers National Memorial is the site of the first successful powered human flight, conducted by Wilbur and Orville Wright in 1903. It is also the site of the first demonstration of an automated shuttle on recreational Federal land as documented in this report. The title of this report, "First in Flight, First in Automation," honors the Wright Brothers National Memorial's legacy of transportation innovation and advancement.

The CASSI automated shuttle pilot at Wright Brothers National Memorial was one of two such pilots conducted at an NPS site in 2021. The other automated shuttle pilot took place at Yellowstone National Park from June through August 2021.[2] The overarching NPS goals for both pilots were to:

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

The NPS is in the process of publishing an evaluation report covering much of the content in this CASSI-focused report alongside details about the Yellowstone pilot, as well as a comparative analysis of the two pilots on the NPS Emerging Mobility webpage.[3]

[1] NPS Emerging Mobility (2021). https://www.nps.gov/subjects/transportation/emerging-mobility.htm
[2] NPS Yellowstone Automated Shuttle Pilot (2021). https://www.nps.gov/yell/learn/management/automated-shuttle-pilot.htm
[3] The NPS Emerging Mobility webpage can be accessed at: https://www.nps.gov/subjects/transportation/emerging-mobility.htm.

1.3 Partnership Coordination & Logistics

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 the CASSI 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 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, 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.[4]

1.4 Route Selection and Development

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.

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

2. Pilot Overview

2.1 Route and Vehicle Specifications

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.[5] 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 1).

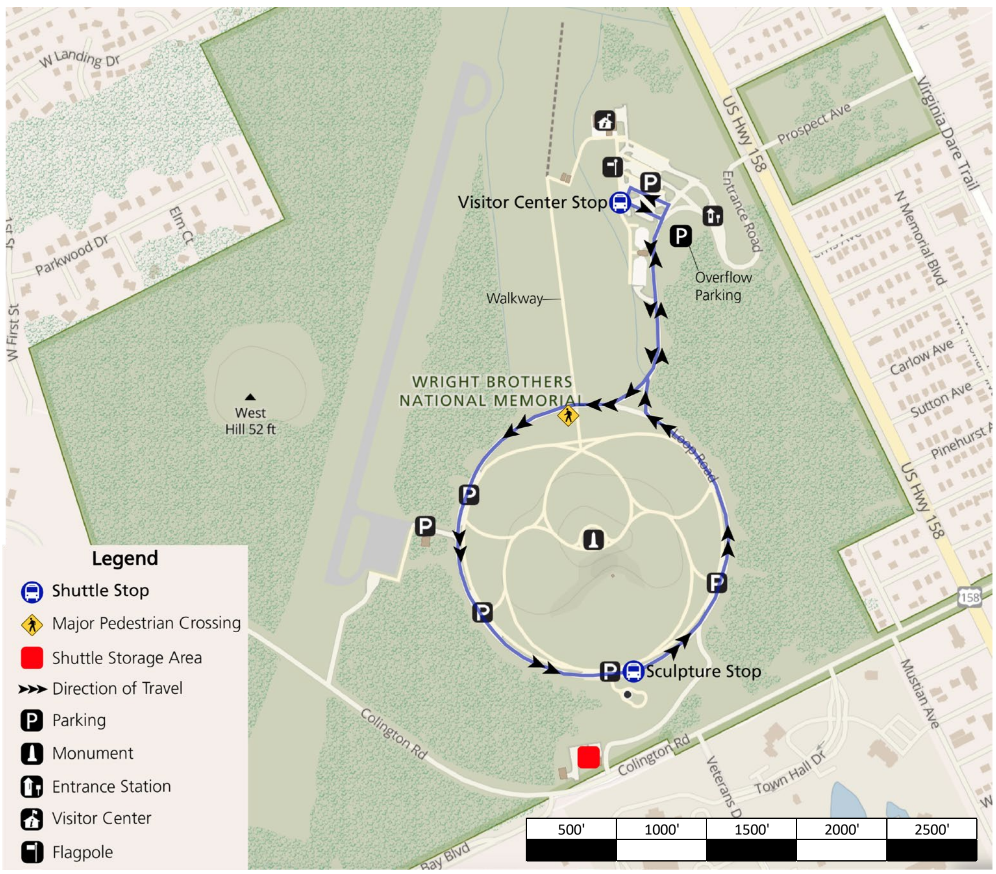

Figure 1: Map of Wright Brothers National Memorial CASSI Shuttle Route
Source: NPS

[5] 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

The CASSI automated shuttle pilot demonstration—the first of its kind on any recreational Federal lands in the country—operated from April 20, 2021 through July 16, 2021.[6] 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.[7] Prior to entering service each morning, the shuttle would go through a warmup run to ensure that systems were properly operating.

The CASSI vehicle was an EasyMile EZ10 3rd Generation (Gen 3) shuttle.[8] The EasyMile EZ10 shuttle has four wheels and is approximately 12.9 feet long, 6.1 feet high, and 9.0 feet wide.[9] 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,[10] indicating that the vehicle's ADS was "fully responsible for driving tasks within limited service areas."[11] 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.[12] 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.

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[6] 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

[7] 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.

[8] For more information on the EasyMile EZ10 shuttle and its specifications, see: EasyMile EZ10 Passenger Shuttle. https://easymile.com/vehicle-solutions/ez10-passenger-shuttle

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

[10] 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/.

[11] NHTSA Automated Vehicles for Safety. https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

[12] EasyMile EZ10 Passenger Shuttle.

Figure 2 and Figure 3 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 4). In addition, safety operators could lower the floor of the shuttle (kneeling the shuttle) to allow for easier boarding of visitors with limited mobility.

Figure 2: Interior View of the Shuttle
Source: U.S. DOT Volpe Center

Figure 3: Shuttle at the Visitor Center Stop
Source: U.S. DOT Volpe Center

Figure 4: The Shuttle with Its Ramp Deployed at the Sculpture Stop
Source: NPS

2.2 Site Modifications

2.2.1 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 5). 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,
- Ridership on 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 5: Signage at the Sculpture Stop (left) and at the Visitor Center Stop (right)
Source: U.S. DOT Volpe Center

2.2.2 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 6). 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 1).

Figure 6: Shuttle Storage Garage Exterior (left), Interior (center), and Charging Equipment (right)
Source: U.S. DOT Volpe Center

2.2.3 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 7).[13] 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.[14]

[13] 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 an compare it to its internal map as a way of improving localization.
[14] NVIDIA Developer DRIVE Labs (2020). https://developer.nvidia.com/blog/drive-labs-how-localization-helps-vehicles-find-their-way/

Figure 7: The Four Localization Signs Installed Along Shuttle's Route
Source: U.S. DOT Volpe Center

2.2.4 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 8.

Figure 8: Accesible Ramp and Platform Installed at Sculpture Stop
Source: U.S. DOT Volpe Center

3. Pilot Evaluation

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.

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.[15]

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 the United States Office of Management and Budget (OMB) (OMB control number 1090-0011). The full survey questionnaire is provided in Appendix: 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

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

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.

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.

3.1.3 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.

3.1.4 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.[16] 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

[16] 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.

were received are invaluable to this evaluation, the low response rate may mean that responses are not reflective of the entire population of riders.[17] 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 9 shows the design of the sticker.

Figure 9: 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

[17] 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 times, those that respond to a survey have extreme opinions (either positive or negative) while more neutral individuals will not respond.

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.

3.2 Data Analysis

The shuttle was scheduled to run on weekdays from April 20 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.[18] In total, the shuttle took 809 roundtrips and carried 3,380 passengers (see Table 1).

Table 1: 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

3.2.1 Ridership

The number of riders varied considerably over the course of the pilot, even when accounting for service suspensions. As Figure 10 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.

[18] 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.

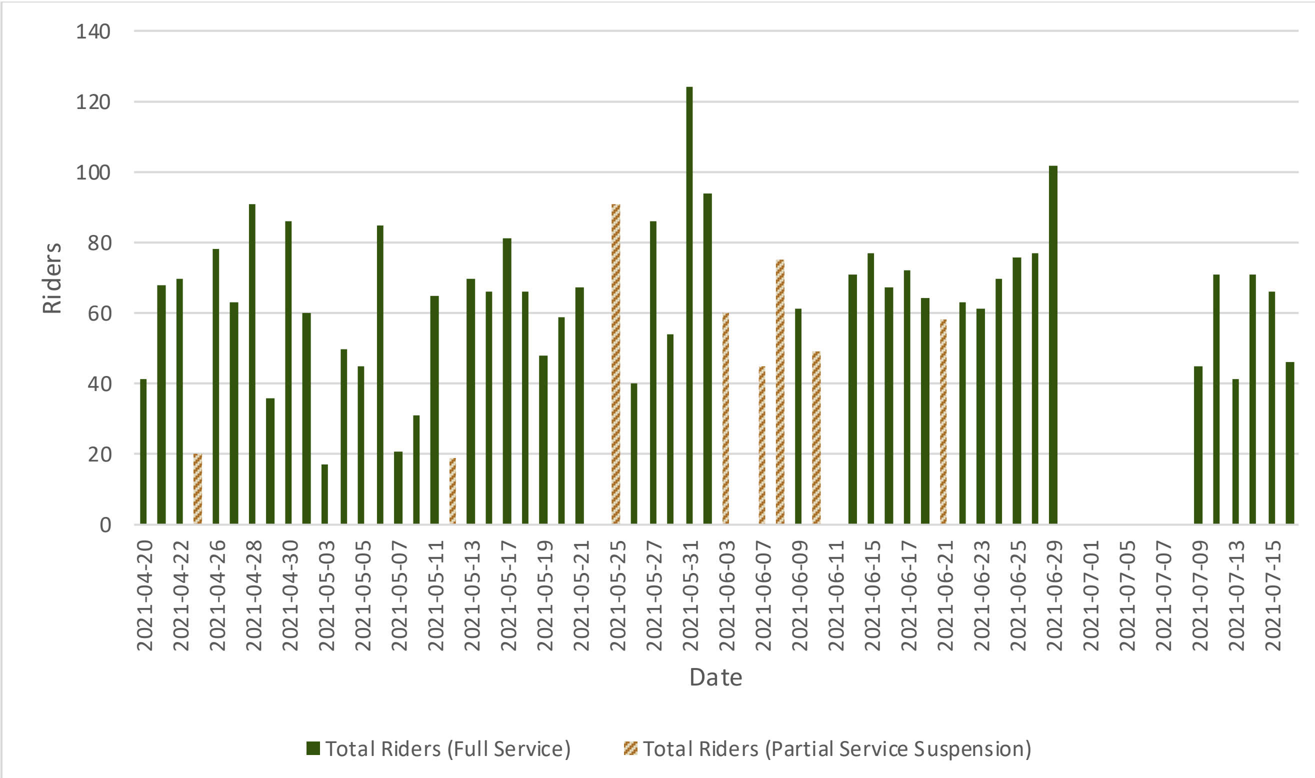

Figure 10: CASSI Shuttle Riders per Day April-June 2021
Source: Transdev and U.S. DOT Volpe Center

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 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.[19] Figure 11 presents a box-and-whisker chart for the ridership data on each day of the week.[20]

[19] 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.
[20] 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.

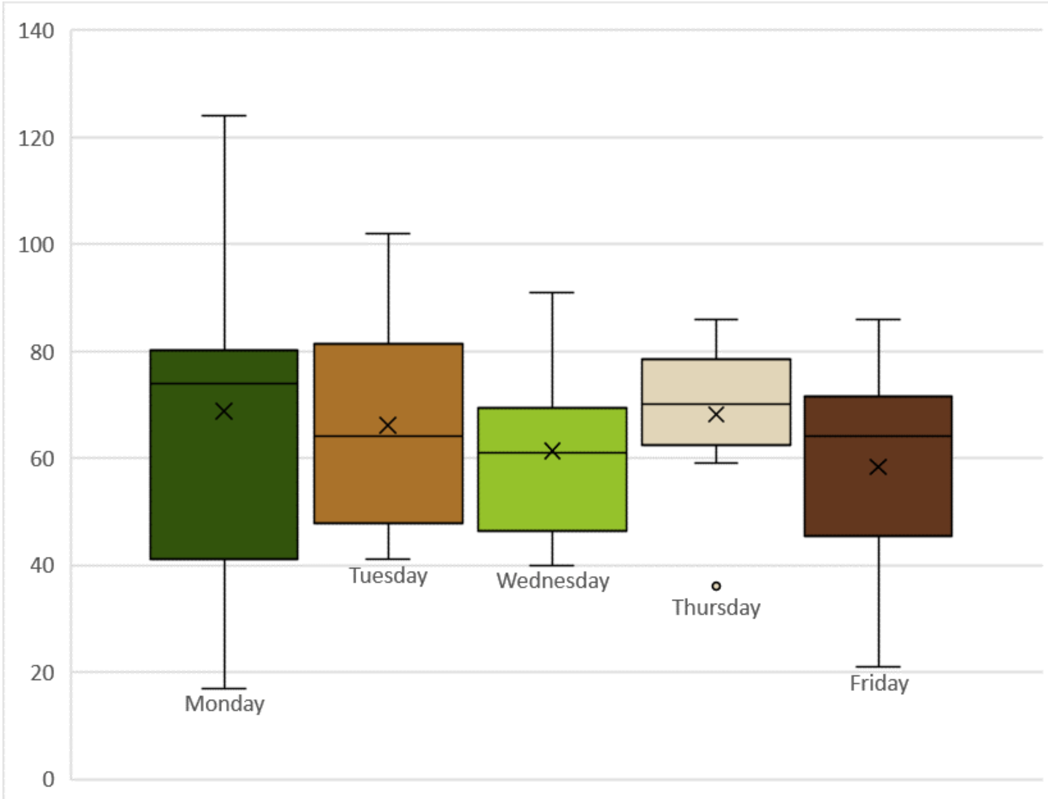

Figure 11: CASSI Shuttle Riders by Day of the Week, Full Service
Source: Transdev and U.S. DOT Volpe Center

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, 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 12 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.

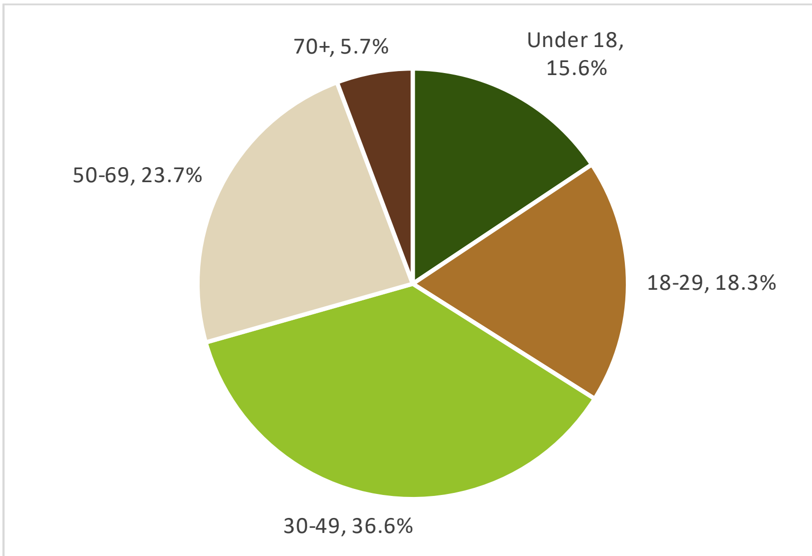

Figure 12: CASSI Survey Respondents by Age
Source: NCDOT and U.S. DOT Volpe Center

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

3.2.2.1 Speed

Although the shuttle is capable of a maximum speed of 25 mph, the anticipated maximum speed during the pilot was 10 mph.[22] 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).[23] 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

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[21] 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.
[22] EasyMile Safety Report (2020). https://easymile.com/sites/default/files/easymile_safety_report.pdf
[23] 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.

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.

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..

3.2.2.2 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."

3.2.2.3 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.

3.2.2.4 Disengagements

The vehicle experienced numerous disengagements throughout the pilot, with a total of 82 e-stops, 410 soft stops, and 128 circumventions.[24] 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.[25] This data can be seen in Table 2, and the disengagements are plotted on the route in Figure 13.

Table 2: 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

[24] 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.

[25] 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.

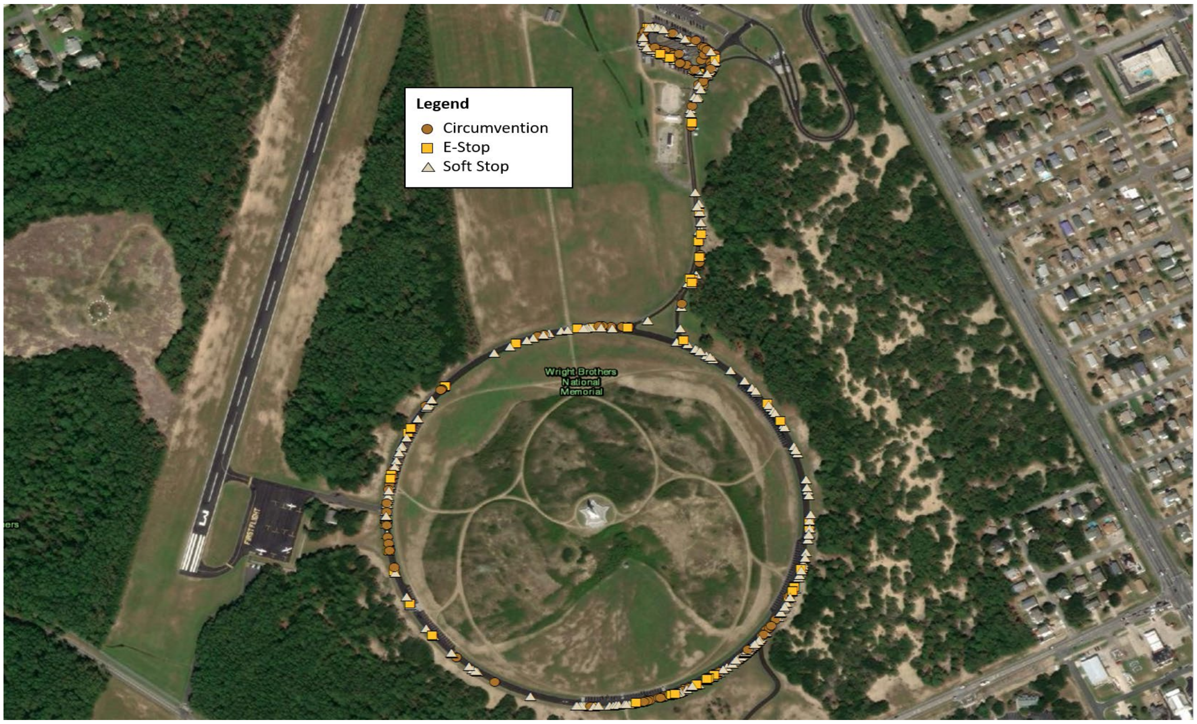

Figure 13: Map of Disengagements
Source: EasyMile and U.S. DOT Volpe Center

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 14 shows the percentage of time spent in automated mode plotted by day. Due to service suspensions, not all days have data.

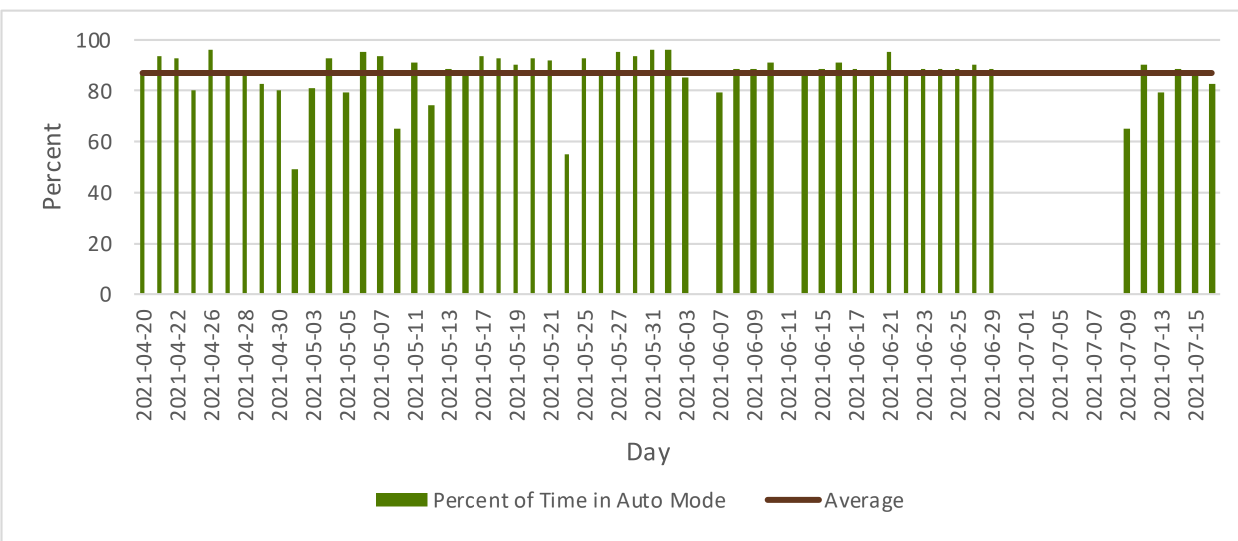

Figure 14: Time Spent in Automated Mode
Source: EasyMile and U.S. DOT Volpe Center

3.2.2.4.1 Landscaping

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 15 and Figure 16). 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 15: Typical Example of Weeds at Roadway Edge Causing Shuttle Disengagements
Source: U.S. DOT Volpe Center

Figure 16: Signage Warning Visitors That Lawn Mowing is in Progress
Source: U.S. DOT Volpe Center

3.2.2.4.2 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.

3.2.2.4.3 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.

3.2.3 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.[26] 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 17.

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.

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

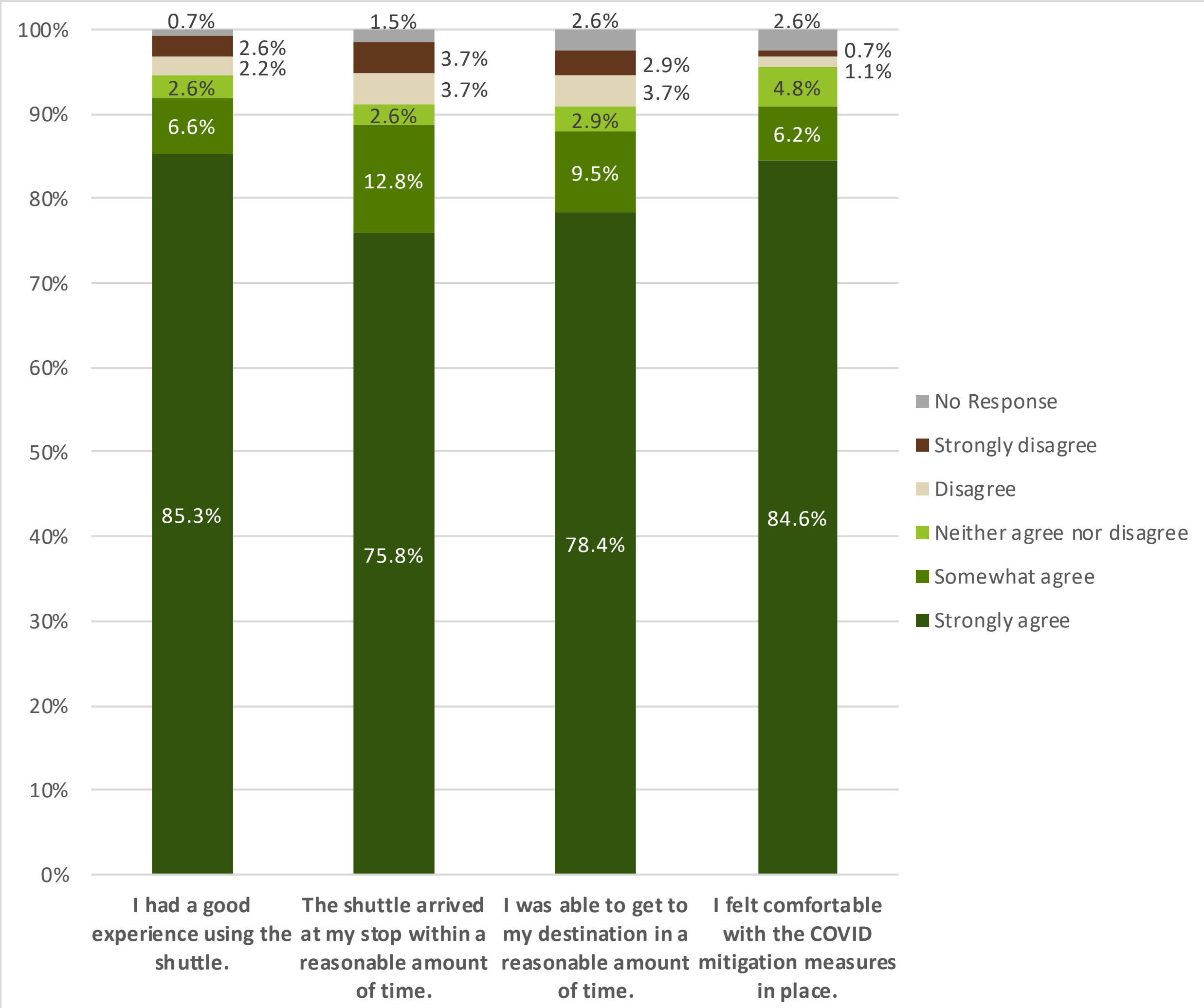

Figure 17. Survey Responses for Agree/Disagree Statements
Source: NCDOT and U.S. DOT Volpe Center

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 18 shows how respondents' opinions changed after riding the shuttle.

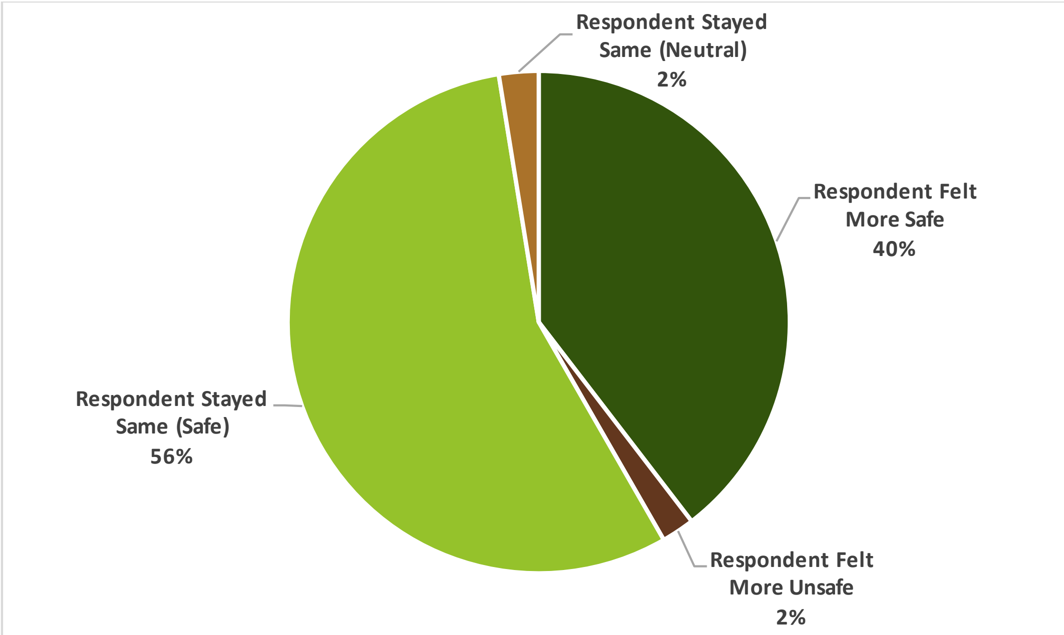

Figure 18. Survey Responses for Shuttle Safety After Riding the Shuttle
Source: NCDOT and U.S. DOT Volpe Center

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.

3.2.3.1 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.

3.2.3.2 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.

3.2.3.3 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 19).[27]

[27] See Visitor Management for signage details.

Figure 19: Notification Sign to Pedestrians Indicating That the Shuttle Will Not Pass Them in the Roadway
Source: U.S. DOT Volpe Center

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.

3.3.1 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 1). 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 20 and Figure 21).[28]

Figure 20: Signage Instructing Drivers Not to Pass Shuttle at Crosswalks
Source: U.S. DOT Volpe Center

Figure 21: Cones and Signage Placed at High-Traffic Pedestrian Crossing
Source: U.S. DOT Volpe Center

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

Some pedestrians walk along the side of the road, as there is no sidewalk along the road. A typical driver is easily able to avoid these pedestrians, but having pedestrians walking in the road creates a challenge for the automated shuttle technology. Park staff asked pedestrians to step off the road to allow the shuttle to pass by, but a small number of pedestrians indicated frustration with this practice.

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.

3.3.2 Visitor Information

Some issues related to signage at the shuttle stops were reported by park staff. Signage (Figure 22) was lacking some relevant information, which led to some visitor confusion about the CASSI route and the rules for riding. 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 22: Signage at Visitor Center Stop Displaying an "Open" Status
Source: U.S. DOT Volpe Center

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 been operating for a few weeks.

4. Lessons Learned

Throughout the pilot process, the NPS and NCDOT 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 and NCDOT—they may provide invaluable insights for future automated shuttle pilots for other potential deployers in other settings.

4.1 National Park Service Lessons Learned

As part of the Wright Brothers National Memorial pilot, the NPS identified the following lessons learned.

4.1.1 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.

4.1.2 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.

4.1.3 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.

4.1.4 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:

- **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 19).
- **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 15), and even small insects were noted as causes of sensor disruptions and disengagements.

4.1.5 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.[29]

- **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.

4.1.6 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.

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

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

4.1.7 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.

4.2 NCDOT Lessons Learned

NCDOT has learned the following lessons through the pilot at the Wright Brothers National Memorial as well as previous usage at North Carolina State University and the Transportation Summit in 2020.

4.2.1 Policy

- An agency interested in piloting a low-speed automated shuttle in North Carolina will need to consider the North Carolina Division of Motor Vehicles (DMV) registration requirements for this type of vehicle.

4.2.2 Planning

- It is highly beneficial to conduct a risk assessment workshop prior to development and deployment. All knowledgeable parties should be included to properly identify, discuss, and propose mitigations to all identified risks.
- Provide operators with a very specific script to provide consistent messaging that the lead and partner agencies wish to communicate. Providing this script along with other forms of communication (brochure, kiosk, etc.) will help improve the rider experience. While the technology is advanced, people still interact with the shuttle operator, which can positively or negatively influence the rider's overall experience.
- Develop a detailed emergency response plan if the shuttle is involved in an incident. This should include all key agencies and contact information during all hours of operation. The plan should be available to the shuttle operator and provided to all emergency contacts.
- Plan for lead agency staff to stay onsite during programming and initial few days of observation to lead adjustments as necessary. Also plan for occasional trips to monitor vendor and safety operator services and overall operations.
- Rider feedback is very helpful. Promoting and incentivizing a rider survey increases participation, and the feedback is valuable as the pilot progresses and for further analysis. The survey must be brief, easily accessible, and available electronically (e.g., through a smartphone or web-based portal).
- COVID-19 considerations should include standard public transit practices, plus restriction of number of riders.

4.2.3 Operations

- Low speed shuttles can create frustration for motorists due to their low operating speed. Great care should be taken to communicate expectations to motorists through public outreach, signage, and clear messaging along the project corridor. In addition, route selection must take the observed speed into consideration.
- While it was preferable that the low-speed automated shuttle was fully ADA compliant, there were none available at the time of this project. The shuttle used for this pilot had the capability to kneel for easier access, plus an automated wheelchair ramp to provide additional accessibility.
- In the absence of solid "streetscape" along a route (such as structures or buildings or signs), additional signage will need to be installed so the vehicle sensors can track its location along the route.
- A robust training program for all involved partner agencies is essential for a successful pilot. This should include the host agency, partner agencies, onsite staff, local first responders, and possibly other stakeholders depending on the environment. Training should be tailored to the audience and role of each group. While vehicle manufacturers provide training, it is recommended for the lead agency to develop some of its own training as well, to ensure all parties are comfortable not only with the goals of the project but how they will be executed and the functions of the technology.
- A very well trained, knowledgeable, and engaging operator is essential for a successful pilot. This should not only include technical and operations training by the shuttle vendor, but also training by the lead and partner agencies about the route, area, purpose, etc. This can vary depending on the use case.

4.2.4 Technology

- The sensors on the shuttle can be very sensitive to unexpected items in the roadway or alongside the roadway. Maintenance of the roadway and road edge (e.g., free of debris, trimming of vegetation, etc.) is important to prevent emergency stops or vehicle slowdowns which can be unexpected to riders.

5. Conclusion

Through their partnership and automated shuttle pilot activities, NCDOT and the NPS have gathered information and many lessons learned. They have both grown in experience and preparation for ADS and other coming emerging mobility technologies, whether they be automated shuttles or other types of ADS-equipped vehicles.

NCDOT is also a willing partner to assist other States in their deployments of automated shuttles. This type of project requires complex logistics coordination, but the value from testing transportation solutions is great. NCDOT can aid any community on navigating the various steps of the process (including State and Federal rules), especially for the EasyMile shuttle used for the CASSI project and others investigated by NCDOT.

By being the first to register, title, and tag this new type of vehicle in North Carolina, NCDOT and NC DMV created a replicable process for additional similar shuttles. In addition, the experience of securing, registering, titling, and tagging the CASSI in North Carolina has brought attention to modifications that could be made to state laws and processes to support growth and innovation. This insight clarifies the road to increased autonomy in the fleet in North Carolina and beyond.

Through their commitment to work together, innovate, and make on-the-ground adjustments to accommodate needs that arose, NCDOT and the NPS were able to successfully complete the automated shuttle pilot, learn about the capabilities and limitations of that technology, and gain a better understanding of how visitors feel about the technology and its future in national parks. As the partners investigate the future, both have gained perspective and insight that will help them address questions related to ADS-equipped vehicles, both in North Carolina and in national parks across the country.

6. Appendix: Survey Questionnaire

The survey questionnaire for this pilot is produced below. The survey was approved through the Office of Management and Budget (OMB), and the OMB control number for the survey is 1090-0011.

1. Did you ride the driverless shuttle?

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