Utah Autonomous Shuttle Pilot

Final Report

April 2021

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Executive Summary

The Utah Autonomous Shuttle Pilot, a collaboration between the Utah Department of Transportation (UDOT) and the Utah Transit Authority (UTA), provided passenger service at eight locations across Utah over a 17-month project period. Each location was served for varying periods of time, ranging from a few days up to eight weeks. Operational and performance data were collected at each site, as were ridership numbers and passenger feedback. These findings, along with interviews with the project team and site partners on lessons learned and recommendations, form the basis of this Final Report.

The Utah Autonomous Shuttle Pilot (see Figure 1) enabled residents and local transportation stakeholders to experience emerging Connected and Automated Vehicle (CAV) technology and form a better understanding of the types of use cases and opportunities this technology could provide in the coming years. The project met the following six goals agreed upon by the project team:

1. Expose the public to CAV technology and provide an educational rider experience for policy influencers, transit customers, and residents who are interested in the technology.
2. Assess the viability of the shuttle as a potential solution to creating first/last mile connections.
3. Understand the operational characteristics and constraints of the shuttle to help inform potential permanent operations in a transit network.
4. Interact with the public to assess opinions and attitudes about vehicle automation and the desirability of automated shuttles in the transport network.
5. Test the capability and readiness of the automated shuttle to communicate with traffic signal infrastructure using Vehicle to Infrastructure (V2I) communication.
6. Research and understand the factors that influence passenger and pedestrian trust in automated vehicles.

Figure 1: The Shuttle and Signage Along a Deployment Route

The Utah Autonomous Shuttle, an EasyMile EZ-10 Gen2 automated vehicle, visited eight locations during the project period:

1. **Utah Driver's License Test Track**, a state-owned testing site in West Valley City.
2. **Canyons Village**, a convention center in Park City, during the American Association of State Highway and Transportation Officials (AASHTO) Spring conference.
3. **Station Park**, a mixed-use development in Farmington.
4. **1950 West**, the location of several State of Utah office buildings in Salt Lake City.
5. **University of Utah**, in Salt Lake City, where the shuttle visited on two separate deployments.
6. **Utah State Capitol**, the state capitol building grounds in Salt Lake City that the shuttle visited for a short route demonstration and for a separate, short static demonstration.
7. **Mountain America Expo Center**, a convention center in Sandy.
8. **Dixie Convention Center**, a convention center in St. George.

Having the automated shuttle at different locations throughout the state allowed 6,878 riders to experience the technology firsthand, in addition to countless others who saw or interacted with the shuttle but did not ride. Riders were also asked to take a survey. Based on the 822 survey responses, nearly all riders (98%) felt safe on board. In addition, 95% stated that they think automated shuttles could complement public transit, and 95% had a more positive attitude toward automated vehicle technology after riding (see Figure 2).

Communication strategies employed by the project team included setting up a project website and email address, hosting two distinct kickoff events, and having staff on site at each deployment to answer questions and monitor the shuttle's operations. Videos of the project were created to introduce riders to the technology and eventually to summarize the project findings. Broad coverage of the automated shuttle by local media improved the visibility of the

Figure 2: Project Results

project. Project ambassadors at the shuttle stops gathered additional rider feedback through a digital survey taken on tablets provided by UTA.

This project created many learning opportunities for the project team, including the current state of CAV technology, the adaptability of automated shuttles as public transportation, and the ability of public agencies to integrate technologies into existing transit services. The project team learned the best types of environments for automated shuttles as well as the level of interest from local communities. These insights will help shape the next steps UDOT and UTA take in their CAV programs.
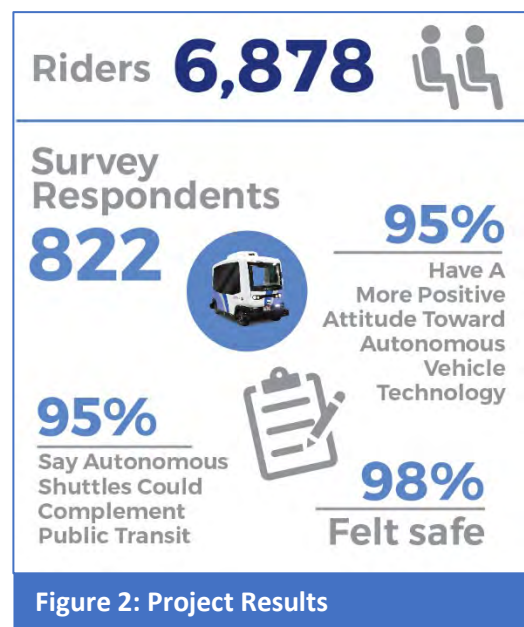
Challenges included securing the necessary government approvals, balancing the needs and priorities of many project stakeholders, overcoming the limitations related to CAV technology itself, and getting real-time data on the vehicle's location. There was one notable incident when a passenger was injured due to an abrupt stop by the vehicle. There were also challenges with service availability due to maintenance issues with the shuttle because there was only one vehicle available for the project.

This project demonstrated that CAV technology provides a safe option to educate the public on an emerging technology. And the research showed that experiencing the technology firsthand increased riders' understanding and trust of automated vehicles.

Project successes included the fostering of strong partnerships between project stakeholders and the cultivating of interest and enthusiasm from the public. In addition, the project demonstrated the ability to use automated shuttles as a first/last mile alternative and to successfully test connected vehicle components of an automated shuttle. There were also valuable lessons learned about the infrastructure and other support needs of CAVs.

The project team learned that given the current state of the technology, the most suitable operational characteristics of a permanent shuttle route would be a dedicated right-of-way with nearby storage and charging stations. For this project, a staff member was always on board the shuttle, but for a permanent deployment to be financially viable, operations with remote staff monitoring would be needed.

1   Introduction

In recent years, automated shuttles have been deployed in various jurisdictions across the country to enable local governments to understand the opportunities and limitations of this technology firsthand. These experiments have introduced the local public to CAV technologies and explored how they may be able to help address current and future transportation needs.

This project was a collaboration between the Utah Department of Transportation (UDOT) and the Utah Transit Authority (UTA). The project team deployed and evaluated an EasyMile EZ-10 Gen2 automated shuttle, shown in Figure 3, at multiple venues across the State of Utah over approximately 17 months.

This Final Report describes the details of the Autonomous Shuttle Pilot Project and presents the lessons learned for both local stakeholders and other jurisdictions that are considering pursuing similar pilot projects. In addition, it lays out preliminary recommendations for additional potential use cases for this technology. For the purposes of this report, the project is being referred to as the Utah Autonomous Shuttle Pilot.

Figure 3: The Utah Autonomous Shuttle

1.1   Project Goals and Motivation

Interest, development, and investment in CAV technology have been growing across the nation, including in Utah. With these trends, it is important to prepare Utah residents for emerging mobility options that will likely one day become commonplace.

Every year, UTA conducts a benchmarking survey to gauge public opinion across a representative sample. In recent years, this survey has included tracking perception of UTA's efforts to "innovate transportation services and use new technology, such as self-driving vehicles." The spring 2020 survey found that awareness of these efforts increased from 16% to 27%, likely because of the Utah Autonomous Shuttle Pilot. The survey also asked about support for UTA's innovation work, and that increased slightly from 59% to 61%. Additionally, UDOT commissioned focus groups to get a sense of the public's understanding and acceptance of automated vehicles. On average, participants' perceptions and likelihood of purchasing a CAV decreased slightly after learning more about CAV technology, likely because discussion sparked questions they had not thought of previously. However, when asked to identify the potential benefits of CAV technology, participants most frequently cited safety as the greatest benefit. Participants also cited convenience, efficiency, environmental benefits, and economic benefits of CAV technology.

As demonstrated in other locations, automated shuttle pilot projects help expose and educate both the public and agency staff on automated shuttles and other CAV technologies. This exposure can facilitate better understanding and acceptance moving forward. UDOT's and UTA's desire to address the gap in exposure and familiarity with CAV technology provided motivation to bring an automated shuttle to Utah and to demonstrate it to as many audiences as possible.

This project had multiple sets of goals, summarized as follows:

1. Expose the public to CAV technology and provide an educational rider experience for policy influencers, transit customers, and residents who are interested in the technology.
2. Assess the viability of the shuttle as a potential solution to creating first/last mile connections.
3. Understand the operational characteristics and constraints of the shuttle to help inform potential permanent operations in a transit network.
4. Interact with the public to assess opinions and attitudes about vehicle automation and the desirability of automated shuttles in the transport network.
5. Test the capability and readiness of the automated shuttle to communicate with traffic signal infrastructure using Vehicle to Infrastructure (V2I) communication.
6. Research and understand the factors that influence passenger and pedestrian trust in automated vehicles.

1.2 Project Team

One of the major factors leading to the success of this pilot project was solid and consistent collaboration between the two primary project partners of UDOT and UTA. Both agencies brought complementary strengths to the partnership, such as expertise in implementing transit services, the ability to navigate state-level guidance on emerging technologies, an understanding of the CAV technology, shaping long-range planning and research, and relationships with local decision-makers and potential site partners.

This collaboration was supported by various site partners and vendors and consultants. Each project partner's roles and responsibilities included:

- **UDOT:** As the contract holder for this deployment, UDOT procured the shuttle and contracted with EasyMile for the lease. UDOT was responsible for coordinating with stakeholders, preparing physical routes for the shuttle prior to deployment at each site, including any infrastructure modifications, and assisting with daily operations. UDOT operates a connected vehicle network in Utah and was responsible for the testing of the V2I communications capability of the shuttle within that network.

- **UTA:** As the regional transit agency serving Ogden, Salt Lake City, Provo and surrounding urban cities and towns (locally known as the Wasatch Front region), was interested in exploring ways to enhance transit services and customer experience, specifically by using CAVs for first/last mile transit connections. UTA participated in planning the project, oversaw the service development, conducted rider surveys, and supported daily operations through its office of Innovative Mobility Solutions (IMS).

- **Site partners:** Each deployment location was considered a project partner, as they agreed to store and charge the vehicle on site and provide any other support needed to enable operations within their jurisdiction. Site partners helped with public education and outreach and provided other support as needed.

- **Vendors and Consultants:** The following vendors and consultants were engaged by the project partners:
  - **EasyMile:** A low-speed automated shuttle provider contracted to demonstrate their vehicle, the EZ-10, in multiple venues across the state, including on-site and remote staffing required to support operations.
  - **Horrocks:** A civil engineering, planning, and design services firm contracted by UDOT to support public involvement, stakeholder outreach, and media relations.
  - **WSP:** An engineering professional services firm contracted by UDOT and UTA to support planning and documentation for the project, including this Final Report.

- o **University of Utah Applied Cognition Lab:** A part of the university's Department of Psychology, this group studied the factors involved in public trust of an automated vehicle.

1.3 Terms and Definitions

The following terms are used throughout this report to describe the technology being piloted:

- **Automated vehicle (AV):** A vehicle that uses onboard sensors, such as cameras, radar, and light detection and ranging (LiDAR) and software to take over some, but not all, of the driving function from the human driver. If the vehicle has a high level of automation where the human is not needed, it is often referred to as an automated or driverless vehicle.

- **Automated shuttle:** A low-speed, electric, shared vehicle with a capacity of approximately 6-20 passengers that can operate independently on a predetermined path under certain conditions and with human oversight.

  - o Early project documentation referred to the vehicle that this project piloted as an "autonomous shuttle" or "AV shuttle." Based on the current capabilities of the vehicle, trends in industry language preference, and for consistency with other similar projects, usage shifted to the term "automated shuttle" as a more accurate descriptor for this Final Report. The term Utah Autonomous Shuttle Pilot is still referenced throughout this report when referring to the actual project name.

- **Connected vehicle (CV):** A vehicle that is equipped with a wireless communication device that allows it to share information with other vehicles, other travelers, and roadside equipment such as traffic signals.

- **Connected and automated vehicle (CAV):** A vehicle that employs both automated and connected technologies. These two technologies work together cooperatively to further enhance the safety benefits offered by each, as follows:

  - o While automated vehicles are expected to improve vehicle safety by limiting the impact of human error, connectivity enables additional safety benefits, as vehicles can then gain context beyond what a regular driver would know or have the ability to perceive visually.

  - o Similarly, while connectivity can enable alerts and warnings to a driver-operated vehicle, deploying these messages on an automated vehicle can streamline the links between information, decision-making, and action.

- **First/last mile:** The travel segments at the beginning and end of a trip made by public transit that connect a traveler between the transit network and their origin or destination.

- **Levels of automation:** Society of Automotive Engineers (SAE) International, a standards-setting industry association of automotive experts and technologists, has developed a scale of driving automation, ranging from Level 0 to Level 5, shown in Figure 4. Level 0 indicates that the vehicle uses no automation of any kind, while Levels 1 to 4 have varying levels of abilities that can assist drivers on specific tasks and/or in certain conditions. Level 5 indicates that the vehicle can perform all driving tasks under all conditions. The automated shuttle piloted for this project is generally considered to employ Level 4 automated vehicle technology.

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS

5 **FULL AUTOMATION**
These cars can operate entirely on their own in all conditions without any human driver presence. It will be several years, at least, before vehicles with this capacity are available.

4 **HIGH AUTOMATION**
These cars can operate without a human driver in certain environments. An example of this level is an automated. Low-speed shuttle, which operates without a human operator but can only operate along specified routes in ideal conditions.

3 **CONDITIONAL AUTOMATION**
These cars can handle many "dynamic driving tasks" in defined locations and conditions, but cannot handle all scenarios. These systems still need human intervention in some conditions, but do not require the human to be constantly monitoring the driving conditions. Vehicles with Level 3 automation are not yet commercially available.

2 **PARTIAL AUTOMATION**
These cars handle forward and lateral motion support, like automated braking, lane keeping, and lane changing. A few of today's automobiles have these features. The human driver must still pay attention to driving conditions.

1 **DRIVER ASSISTANCE**
These cars handle forward motion support, like automated braking and acceleration. Adaptive cruise control is an example. Many of today's cars have this level of automation.

0 **NO AUTOMATION**
There are no automated features in the vehicle.

Figure 4: Levels of Automation Diagram

2   Project Overview

Most previous automated shuttle deployments have been conducted at a single location, whether it be for a week-long demonstration at a convention or other event or, as is becoming increasingly more common, a longer-term pilot project addressing a local transportation need.

The Utah Autonomous Shuttle Pilot was different, as it did not have one primary service location, but instead was brought to multiple locations throughout the project period. This allowed many groups of stakeholders to see and experience the technology. It also allowed the project team to assess its suitability in a larger number of use cases and environments. However, this did create logistical challenges as well. How these challenges were overcome, what locations were able to be served, and lessons learned from the project setup process are summarized in this section.

2.1   Overview of the Shuttle

The vehicle used for this project is the EasyMile EZ-10 Gen2, shown in Figure 5. The EZ-10 is a low-speed automated shuttle designed by the French company EasyMile, with the primary intended use case of providing public transit services for first/last mile applications. It is a Level 4 automated vehicle that can operate on fixed, repeated routes. It does not have a steering wheel or pedals but is equipped with a wireless handheld control unit that staff can use if necessary. Specifications of the vehicle are provided in Table 1.

Figure 5: Back of the EZ-10, Showing the License Plate Reading "Utah AV"

Table 1: EZ-10 Specifications

Vehicle Dimensions (l x w x h)	**13.2 ft** x **6.6 ft** x **9.4 ft** (4.02 m x 2.00 m x 2.87 m)
Vehicle Weight	**4,475 lb** (2,030 kg)
Maximum Load Capacity	**2,205 lb** (1,000 kg)
Maximum Passenger Capacity	**12** (6 seated, 6 standing)
Speed Range	Up to **12.5 miles/hour** (20 km/hour)
Advertised Battery Range	**8-14 hours** (depending on conditions)

To support this shuttle, EasyMile provided two on-site staff members as well as additional remote support. The two on-site staff members had the titles Chief Operator and Deployment Engineer. They were responsible for vetting sites before selection; designing feasible routes and programming them into the shuttle; and setting up, managing, and operating the shuttle itself. For the duration of this deployment, a designated staff member was required to be on board the shuttle whenever it was operating to monitor how it functioned and to intervene if necessary. The onboard person was also responsible for safety, which was a primary consideration for the project. Both the Chief Operator and the Deployment Engineer were certified by EasyMile to take this role. For consistency throughout this Final Report, whoever is in the onboard operator role is always referred to as the "Host," regardless of their official title or other responsibilities.

2.2 Project Setup

UDOT began considering a shuttle pilot project in late 2017 and had early conversations with various interested parties in November of that year. A rough deployment plan was drafted, and documents describing deployments in other states were collected and reviewed. As the idea of a pilot project began to take shape, it was clear that an early use case for an automated shuttle was to integrate with a public transit network. UDOT and UTA began discussions about a pilot project in January 2018. Although the two agencies had different objectives for a pilot project, there was clear overlap in those objectives and a shared desire to collaborate on the project. Coordination began in earnest by May of 2018, including some early meetings with potential deployment sites, a visit to a deployment site in Las Vegas, and discussions with potential shuttle vendors.

By late summer of 2018, the UDOT/UTA team had determined that operating the shuttle at multiple sites, each with different users and demographics, would provide the best opportunity to meet the goals outlined in Section 1.1 as well as maximize the learning potential. The team created a short list of shuttle sites, discussed partnering and financial arrangements, and developed a preliminary budget. Since neither agency intended to purchase or own a shuttle long-term (UDOT had no need beyond the project and UTA anticipated that vehicle technology would advance before a shuttle would be put in permanent service), a decision was made to negotiate a short-term lease with the constraints and considerations described in the next section. This overall project timeline is summarized in Figure 6.
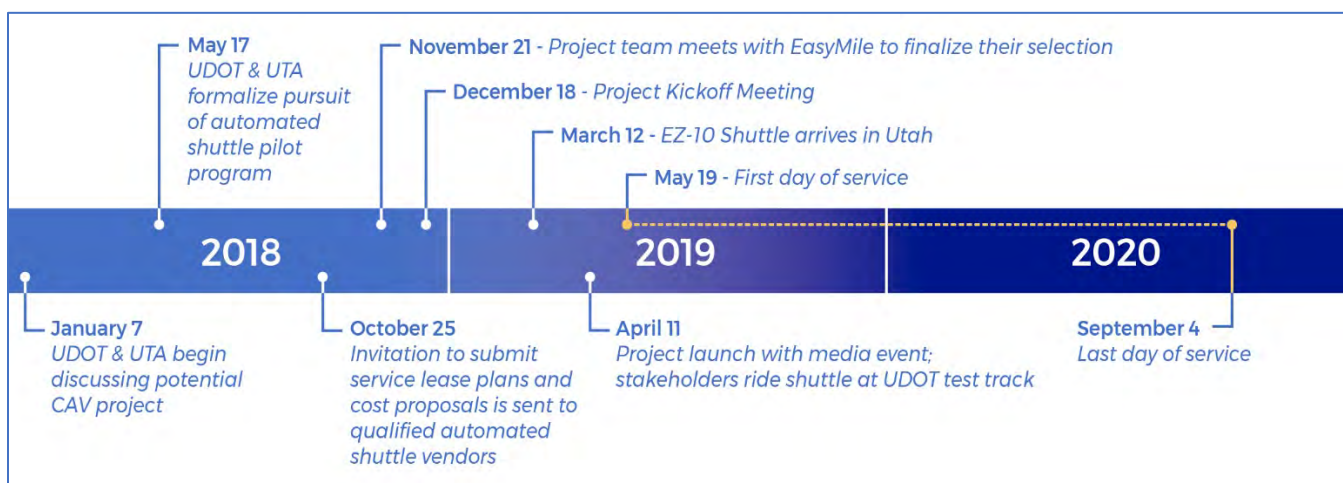

Figure 6: Project Schedule

2.2.1   Procurement

Once UDOT and UTA had established the program concept to address the goals presented in Section 1.1, the next step was to find a vendor that would be able to support these goals within the confines of the current regulatory environment. The project team understood that there were a limited number of qualified vendors available.

UDOT researched procurement methods in consultation with UDOT's Procurement Manager. Options discussed included competitive bid, sole source, and trial procurement. Given the uniqueness of the shuttle, the desire to only lease the vehicle, and the intent to have the vendor operate and maintain the vehicle, UDOT opted for the trial procurement method. This method would have also accommodated the possibility of using a second vendor if needed.

UDOT's trial procurement process allows UDOT to try out a product for a limited time (up to 18 months), subject to certain limitations. On September 26, 2018, UDOT issued an "Invitation for Trial Demonstration Deployment of an Autonomous Shuttle," seeking interested vendors. This request included a cost proposal. After assessing the current capabilities, past performance, and costs of vendors who responded to the invitation, the project team selected EasyMile.

One of the major benefits of EasyMile's proposal was that they were the only vendor that included a full-time staff member in Utah, referred to as the Deployment Engineer. While other pilot projects throughout the nation have taken on more tasks internally, UDOT and UTA thought it would be best for the vendor to completely cover maintenance and provide this full-time staff member due to the complexity of this deployment, particularly the numerous site setups. EasyMile also offered options for different levels of maintenance and support, as well as costs for each of these packages. At the time, this was the first deployment that EasyMile operated directly, rather than contracting with an operations entity for on-site staffing.

Because the Deployment Engineer was also responsible for vehicle maintenance, planning for future site deployments, and other project management tasks, this individual would not be available to serve as the Host at all times the shuttle would be in operation. Therefore, the project team needed another individual to be able to step in as a Host and share the duties. UTA had planned to dedicate a part-time staff member for this purpose who would be trained by EasyMile. Not having any prior experience with automated vehicles or jobs to support them, it made sense for UTA to leverage EasyMile's expertise in this area. Therefore, the decision was made to have EasyMile hire an additional staff person for the project, a full-time Chief Operator, and increase their contract to cover the additional cost. This allowed the project to launch closer to the original schedule while still allowing for UTA staff to experience the project firsthand in other ways.

2.2.2   State Regulatory Compliance

State governments have jurisdiction over the safe operation of vehicles on their roadways, including setting and enforcing speed limits, licensing drivers and vehicles, and placing restrictions on roadways. Most state laws require, either explicitly or implicitly, that a human driver operate a vehicle. Typically, changes to state statutes and rules are needed for automated vehicles to operate on public roads.

In 2016, *HB 280: Autonomous Vehicle Study* passed unanimously in Utah and was signed into law by Governor Gary Herbert on March 23, 2016. This bill directed the Department of Public Safety to study and make recommendations regarding the best practices for regulation of automated vehicle technology on Utah highways. It also stated that agencies should encourage the testing and operation of automated vehicles within the state, and permitted them to contract with a person for the purpose of testing automated vehicles.

In 2017, *HB 257*, which sought to establish an automated vehicle task force to recommend a strategic vision for automated vehicles and any proposed legislation, was introduced but did not pass.

In 2018, *HB 371: Autonomous Vehicle Amendments* intended to enable the testing and operation of automated vehicles on Utah roads. It passed the House Transportation Committee but was pulled from consideration on the House Floor to address some concerns brought forth by the insurance industry and others. During the interim, a multidisciplinary group met several times to refine the bill. This group was comprised of representatives from the state legislature, UDOT, other state agencies, the insurance industry, auto manufacturers, transportation service providers, and various other interested parties.

In 2019, the refined bill, now called *HB 101: Autonomous Vehicle Regulations*, passed unanimously and was signed by the Governor on March 29, 2019. Less than two weeks later, on April 11, 2019, the shuttle began operating in the state. Per this legislation, a special permit for automated driving systems was not required, and the shuttle could operate on Utah roads with or without a human driver.

2.2.3   Federal Regulatory Compliance

The EasyMile shuttle (and several similar shuttles from other manufacturers) does not meet Federal Motor Vehicle Safety Standards (FMVSS) because it lacks many of the required features that are common in other passenger vehicles, such as a steering wheel, rearview mirrors, or air bags, and it has not been evaluated for its crash test performance. Because of this, specific approval to operate the shuttle was required from the National Highway Traffic Safety Administration (NHTSA) for each deployment site. This process included EasyMile submitting a Site Assessment Report (SAR), which NHTSA then either approved or sent back for modifications. An SAR contains the following information:

- Route overview, including a route map, location overview, and defined purpose of the route, as well as how it will travel to and from its overnight storage and charging location.
- Key information, such as the type of road, speed limit, and anticipated maximum travel speed of the shuttle.
- Risk analysis of specific locations along the route that cause concerns, including how these risks will be mitigated.
- Station locations and layouts, including signage to indicate routes, boarding locations, and locations where the shuttle route crosses roads and sidewalks.
- Project requirements, such as insurance and stakeholder engagement, and how these requirements will be met prior to deployment (or have already been met).
- Operations rules that will be followed, such as monitoring for weather conditions that will trigger a service suspension, having a Host on board the vehicle, and performing testing prior to deployment.

Over the project period, the project team learned through experience, as well as EasyMile's guidance, what types of environments and mitigating actions would be required to obtain NHTSA approval. A NHTSA form defined the operational conditions that require a waiver from FMVSS requirements. Following that guidance, EasyMile prepared the SAR that documented the operational characteristics of each proposed deployment location. EasyMile helped the project team understand what venues and operating conditions NHTSA would be most likely to approve.

UTA's Civil Rights Compliance Office is responsible for evaluating the impact of major service changes on minority and low-income populations. While this demonstration project could have been considered to constitute a major

change, pursuant to Federal Transit administration Circular 4702.1B, UTA opted to exempt this demonstration project from the requirements to conduct a Title VI analysis since the shuttle did not operate at any one site for more than 12 months. The project team will keep Title VI needs in mind for any future plans.

UTA's Civil Rights Compliance Office is also responsible for ensuring that its service complies with the Americans with Disabilities Act of 1990 (ADA). The ADA prohibits discrimination and requires equal opportunity and access for people with disabilities. The shuttle vehicle and the demonstration project in general must be accessible to people with disabilities to comply with the ADA. To this end, the project invitation asked shuttle vendors about desired accessibility features, including an automatic wheelchair ramp, stop announcements, and wheelchair securement options. The EasyMile EZ-10 Gen2 shuttle has an automatic wheelchair ramp and Q'Straint wheelchair securement straps. The project team also reached out to stakeholders in the disability community to get their feedback on these features and any others that may be desired and engaged UTA's Committee on Accessible Transportation (CAT).

2.2.4   Insurance

The contract with EasyMile included insurance for the shuttle, the shuttle Deployment Engineer, the property the shuttle operated on, and passengers. The terms of the insurance were reviewed by UDOT's Risk Management Group, UTA's legal staff, and the State of Utah's Division of Risk Management. The project team recognized the importance of working with these groups and tapping their collective expertise to insure the vehicle properly and to assess any exposure gaps for both UTA and the State of Utah. The State Division of Risk Management provided support when negotiating and affirming provisions of the EasyMile policy to work with individual site partners. Since the State of Utah almost exclusively self-insures, there was one instance where the State stepped in to provide a Certificate of Insurance, addressing one specific aspect of a particular coverage under a separate line item. Despite assurances that the primary policy already covered the needed feature, the State further backed the project team by preparing this specific coverage feature to satisfy the site partner.

2.2.5   Vehicle Branding and Wrapping

After the vehicle was delivered, a local vendor with prior experience working with UTA created the design of the vehicle wrap and then ultimately applied this design to the shuttle itself. A number of alternatives were considered. The selected design, shown in Figure 7, was intended to be consistent with the design scheme and logo for the project and to ensure consistent branding and familiarity with the project. The colors were also selected to mimic the blue tones in the UDOT and UTA logos, as a bridge between the two primary project partners. It also had reflective components for safety, and materials were selected for longevity, based on the length of the project.

Figure 7: Vehicle Wrapping Design

Figure 8 shows the process of installing the vehicle wrap. Window clings were also added to the vehicle at each site to provide additional information. This included logos of site partners and other venue advertising, to both provide passengers information on the local area and also demonstrate the partnership between UDOT, UTA, and the site owner.

Figure 8: Wrap Installation

2.3 Budget and Costs

The base cost of this deployment was $400,000 to lease a shuttle and operate it in Utah. This cost included EasyMile's full-time Utah Deployment Engineer and other management staff time. However, there were many additional costs that were also essential to the success of this project, including the outside studies and public and media relations efforts. This cost of the vehicle lease, media efforts, and other related items were budgeted on the Fiscal Year 2019 UDOT CAV budget. A separate CAV program line item included budget for related research studies. UTA also allocated a budget of $90,000 toward this project for operations and logistics, funded through its normal budgeting process for operations. UTA's budget included the other on-site staff member, the Chief Operator.

During the project period, fares were not collected, and the service was free to the public. The actual total cost of the automated vehicle demonstration project, all included, was approximately $987,000, broken down as follows in Table 2. These costs do not include the value of the time that UDOT and UTA employees spent on the project.

Table 2: Project Costs

Item	Approximate Actual Cost
Setup and Documentation	$22,000
Shuttle Lease	$400,000
Outreach, Site Planning, Operations, and Engineering Support	$232,000
Public Trust Research	$197,000
Signage and Miscellaneous Charges	$21,000
Final Report	$25,000
Operations and Logistics	$90,000
Total	**$987,000**

Many of these expenses were one-time costs, and some were not necessary for deployment but rather to meet project objectives, enhance the service provided, and/or provide greater understanding of the technology and lessons learned. True deployment costs would only include the shuttle lease; signage and miscellaneous charges; operations and logistics; and a portion of the outreach, site planning, operations, and engineering support costs, with an estimated total of approximately $627,000.

A variety of in-kind contributions from local jurisdictions and private partners were provided to support this project, including:

- Access to and usage of storage and charging facilities.
- Informing local stakeholders of the project through existing communication channels.
- Supporting research and outreach efforts, including any on-site staff logistics support.
- Input into the preparation of promotional and informational materials.

2.4 Engagement and Outreach

UDOT hired a communications team, Horrocks Engineers (Horrocks), to lead the outreach/engagement for the project. The outreach team, with support from UDOT and UTA, developed a strategic Communications Plan, a Crisis Communications Plan, and a Venue Engagement Tactics Plan as the overarching documents to guide outreach and engagement efforts.

A Communications Plan was created initially to identify outreach goals and to establish the strategies and tactics to be utilized to accomplish the goals. The plan identified key audiences and included methods to be used to communicate to the public and to gather feedback, including a project website and branding, media relations, social media content, and outreach materials (onboarding video, vehicle wraps, handouts, window clings, etc.). Once the Communications Plan was finalized, the team used the plan as a guide for implementation throughout the project. The outreach team was also flexible and adapted to new needs as they arose.

As a result of the communications planning, the initial work focused on developing foundational tools that were central to all outreach and engagement with the public. The following details some of these key areas of focus.

The team developed key messaging for the project as a whole and then segmented project messaging for both UDOT and UTA, as shown in Figure 9. The key messaging was critical to ensuring that all project partners were communicating in a consistent manner.

Autonomous Shuttle Messaging and Supporting Information

High-level UDOT Key Messaging

UDOT continues to be at the forefront of connected and autonomous vehicle development and implementation and is currently researching how solutions like the autonomous shuttle and other driverless technology can support our main goals of safety, mobility and quality of life.

High-level UTA Key Messaging

UTA wants to explore ways to meet the travel needs of individuals and enhancing community accessibility through safe, reliable and innovative services. Autonomous and connected technology could be a great solution for transit needs and this pilot will provide us with the opportunity to learn more about the possibilities.

Overall Project Key Messaging with Supporting Information

Partnership Messaging:
UDOT and UTA are constantly looking for innovative and efficient ways to improve transportation in Utah.
- Connected and autonomous vehicles are the future of transportation and together we are exploring the best opportunities to leverage this technology for our state.
- UDOT and UTA are partners in bringing the autonomous shuttle to Utah.

Safety Messaging:
Testing driverless transportation technology, such as the autonomous shuttle, will help us identify more opportunities to improve safety by decreasing the possibility for human error.
- The autonomous shuttle operates at 15 miles per hour and follows a pre-determined route. It also reacts in real-time to other vehicles, pedestrians and any obstacles that intervene in its path.

National transportation safety statistics indicate human error is responsible for 94 percent of crashes. Eliminating human error will save millions of lives.

Access and Mobility Messaging:
Driverless vehicles, including autonomous shuttles, can help improve access and provide increased mobility to meet the needs of our communities. This shuttle pilot will help us evaluate the benefits of utilizing autonomous shuttles as part of our transit system as well as other possible applications.
- This technology can help provide mobility to individuals who aren't able to drive themselves, including those with disabilities and other individuals that don't have the ability or desire to drive.
- In the future, an autonomous shuttle may complement our transit system as first and last mile connections.
- This technology may also have application on university campuses, in shopping districts, at ski resorts, in our canyons or in our state and national parks.

Figure 9: Key Messaging

A mood board, as shown in Figure 10, was created to help direct the branding process, and UDOT and UTA discussed the possibility of naming the shuttle. Based on many considerations, the team concluded that the project would be branded as the "Autonomous Shuttle Pilot Project."

Figure 10: Mood Board

A project website, www.avshuttleutah.com, was set up by UTA's contractor, WSP (see Figure 11). WSP created the design based on established branding for the project and content provided by UTA. The website was created as the main outreach tool for the public to obtain information on the project. On the website, users could gather facts about the project through text, graphics, an informational video, and frequently asked questions. They could also find details on past and future deployment locations, links to social media channels, contact information for the project team, links to submit a comment, or the Autonomous Shuttle Pilot Project Survey. The website and social media channels were updated regularly by the communications team.

Figure 11: Project Website

To assist in reaching the project's goals of education to the public, an informational video was created as part of the Communications Plan. The video was 1 minute and 45 seconds long and provided the reasons why UDOT and UTA decided to launch the project, information about the automated shuttle and the project, contact information, and how the public could provide feedback. This video was played on the shuttle while passengers were on board to keep key messages consistent. During some deployments, the video was not played because it was longer than the shuttle route between stops. The video was also located on the project website and played in booths at various deployment locations.

Obtaining feedback from the public was done through a number of strategies. The website included various ways the public could provide feedback to the project team, including a survey, comment submission, project email, and social media channels. The comments that came through the website were directed to the UTA customer service department. Comments received were then filed at UTA under "innovative mobility" and flagged for the project team to see. A project email, info@avshuttle.com, was set up, and project team members had access to the email account to provide responses to any comments that required feedback. Section 5 discusses public feedback in more detail, including the survey results and results of the rider trust research conducted by the University of Utah.

The project had two kickoff events, one at the Utah Driver's License Test Track and another at Station Park. The project team decided it was best to have two opening events to serve different purposes.

The first event, which was held on April 11, 2019, was a media event at the Utah Driver's License Test Track. A media advisory was sent out to local media inviting them to the event. During this event, there was an official press conference with UDOT and UTA leadership and Lt. Governor Spencer J. Cox (see Figure 12). Lt. Governor Cox participated in the event and was the first official person to ride the shuttle. Lt. Governor Cox also demonstrated confidence in the technology by simulating a distracted pedestrian walking in the path of the approaching shuttle and letting it brake and not hit him.

Figure 12: KSL News Story from Kick-off Event
(Left to Right: UDOT Executive Director Carlos Braceras; Utah Lt. Governor Spencer J. Cox; UTA Board Chair Carlton Christensen)

The goal of this event was to garner media coverage to introduce the pilot project to the public prior to its first public deployment. The media were able to ride the shuttle, gather b-roll footage of the shuttle, and interview key spokespeople. The outreach team did considerable work for this event from coordinating logistics to developing key talking points and media documents, including a press release as shown in Figure 13. This event resulted in expansive media coverage from the main news outlets in Utah.

Figure 13: Launch Press Release

The second kickoff event was hosted at Station Park on June 13, 2019, which was the first deployment where the public had the opportunity to ride the shuttle. This event was structured as an open house and was attended by state and local elected officials. This event was conducted throughout the day to accommodate schedules of elected officials and to accommodate shuttle capacity. Members of the media were also present at the open house. UDOT and UTA representatives were able to speak with attendees directly about their motivations for this project. The goal of this event was to introduce the automated shuttle to the public, showcase the connectivity to transit and the multiple uses it had at Station Park, and create awareness of the project.

In between these two kickoff events, there was an event with the Utah Transportation Commission and the UTA Board, where employees and stakeholders were invited to experience the shuttle so they could better understand the project.

Before the shuttle was deployed, a Venue (site) Engagement Tactics Plan was developed to outline steps for a successful deployment and partnership with each venue and to maximize exposure and engagement with the public (see Figure 14 and Figure 15 for examples of outreach materials).

This plan outlined communication channels to leverage through each venue, such as newsletters, email distribution lists, and social media channels. For example, the outreach team was able to work closely with Station Park to provide content for their social media channels, e-newsletter, and website. This outline served as a checklist for the team to ensure all needs were met for each individual venue and was modified to fit each unique site. Some of the engagement tactics and outreach strategies in this plan included:

Figure 14: Outreach Poster

- Conduct a site visit with both the site partner and project team to determine informational signage needs, develop a route map, and finalize consistent messaging and other project details.
- Canvass local business, if necessary, with a notification flyer.
- If an email list of site users (employees, residents, etc.) is available, develop an email newsletter template to advertise the service and solicit survey responses.
- Develop and deploy on-site signage and brochures.
- Update the website and social media channels with venue-specific content.
- Determine a strategy for media outreach in the venue area.
- Set up photography and video needs, including drone footage and any on-site interviews.

Figure 15: Outreach Brochure

Some sites were at more centralized locations, where people walking by or looking out the window may have noticed the shuttle and decided to ride, while other sites were farther out of the way and required potential riders to know the shuttle was in the area in order to seek it out.

In either case, informational signage was included along and near the route to alert other drivers of the presence of the shuttle as well as to attract potential riders (particularly when labeling station locations). To design these signs, the communications team worked with the communications personnel at the site on placement, and the project team also vetted the signs with the management and logistics teams at each location. Typically, the signage at deployment locations included directional information, stop locations, anticipated travel times, operational days and times, a QR Code to the project website, a route map, and shuttle rider rules. Sign templates and examples can be found in Appendix A.

Station Park was the first venue to plan for, and the entire team learned quickly that there were more signage needs than originally anticipated. The outreach team also assumed a key role in ensuring that a high level of communication and integration was happening between the venue and the project team.

To further on-site engagement and education at most sites, Ambassadors were stationed at high-traffic shuttle stops (see Figure 16). Ambassadors were generally college-aged engineering interns, UTA customer service representatives, and other project team members who were not trained to operate the shuttles. They stood at a signed kiosk to engage potential riders, encourage alighting passengers to fill out the survey, and answer questions while the shuttle was underway (including on how long it may be until the shuttle returned). The main attributes of a successful Ambassador were enthusiasm and interest – they required very little

Figure 16: Ambassadors at the 1950 West Site

training, as they did not need to operate the shuttle itself and were able to direct passengers to the on-site EasyMile staff for any more technical questions. Ambassadors provided a valuable and complementary public engagement role that noticeably increased ridership. Additional detailed information regarding the Ambassador's role and setup of the shuttle boarding area can be found in the Communications Plan[1].

Lastly, using the footage obtained at each deployment site, videos of the project were created for use at conferences and to create a final end-of-the-project summary video, as shown in Figure 17. This video is complementary to this report and can be found at the following website: www.avshuttleutah.com.

Figure 17: End-of-Project Video

Most of the outreach and engagement was during the first few months of the project. Fewer outreach and media efforts were done as the project progressed. Throughout the 17-month deployment of the shuttle, 74 known articles and other media were written about the project. A list of these articles is provided in Appendix B. Most media coverage of the project was positive or objective, generally noting the upcoming locations and the futuristic

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[1] This plan is external to this report. Contact UDOT for questions at transportationtechnology@utah.gov.

nature of the project and stating the facts after the passenger incident at 1950 West. More information on that incident can be found in Section 6.1.6.

Social media strategy included developing content for UTA, UDOT, and the site partners' available channels. During the initial site coordination, the outreach team identified which social media channels each site used and if they were willing to share customized content there. A social media content spreadsheet was developed where content and visuals were shared between UTA and UDOT. When one agency posted, the other agency was prompted to retweet or share on their channel. The project implemented the use of the hashtag #avshuttleutah for tracking social media engagement and encouraged the public use of the hashtag by including it on all printed outreach materials.

Each deployment site offered opportunities for nontraditional, one-on-one outreach. At the Station Park deployment, first responders were offered the opportunity to perform an emergency simulation involving an automated vehicle. During the 1950 West deployment, the project team partnered with the Utah School for the Deaf and the Blind to demonstrate the benefits of automated vehicles for those with disabilities and allowed them the opportunity to interact with the vehicle firsthand. While at the University of Utah, the outreach team partnered with the School of Communications to have students perform person-on-the-street-type interviews, which were then assembled into a short video made for social media.

The outreach team also developed a Crisis Communications Plan. This is referenced in Section 2.6.

2.5 Operations

Operating characteristics at each site are described in Section 3. This section summarizes overall operational characteristics that applied to all deployment sites.

2.5.1 Operations Plans

Prior to project launch, the project team created Standard Operating Procedures (SOP), a Safety Management Plan, an Evaluation Plan, and other enabling documentation. This included an Incident Response Plan that is described in more detail in Section 6.1.6. These documents were created in partnership with UDOT, UTA, EasyMile, and other stakeholders and presented during a series of Tabletop Exercises hosted by UTA prior to the first service launch. The agenda for the Tabletop Exercises, as well as outlines for the other enabling documents, are included in Appendix C. They, along with existing EasyMile training manuals, guided how operations and maintenance were conducted throughout the pilot project.

2.5.2 Shuttle Host

Although the shuttle requires no driver, an onboard Host is required to initiate and terminate manual controls, monitor the vehicle, and interact with the riders. For this project, the Host role was performed by either the Chief Operator or Deployment Engineer employed by EasyMile. Hosts were extremely valuable to help with the riders. They were friendly, knowledgeable, and technologically savvy. They provided a lot of education to those who rode the shuttle and were able to share some technical information, but did so in a way the riders could understand. The Hosts were not the Ambassadors, but they were able to share information on how technology like this will help make transportation safer, better, and cleaner.

Hosts also helped reduce the uncertainty of riding an automated vehicle. Having the Hosts on board made riders feel better that there was someone there who could override things or take charge if needed, adding a level of comfort.

Data about the numbers of riders, trip times, operating times, and other notable features were collected during operations both manually by the Host and automatically using vehicle-based sensors and equipment. Survey responses were solicited from passengers using a tablet or by directing them to the website. If there was an Ambassador on site, they managed the survey tablet. In cases where Ambassadors were not present, the Host also solicited feedback from passengers using the tablet survey or directed them to the website.

2.5.3   Cleaning and Maintenance

EasyMile was fully responsible for any needed repairs as well as routine maintenance and cleaning. There were a number of maintenance issues during deployment, which EasyMile responded to using both on-site and remote support as needed. As would be expected with any vehicle, there were both minor and significant repairs needed during the 17-month project period. One type of issue was related to sensor failures – in some instances the shuttle was able to continue to operate, but in others the sensors were critical to the safe operation of the vehicle so it was necessary to suspend operations until a new sensor could be installed. Since EasyMile's United States headquarters are in the neighboring state of Colorado, overnight shipping of critical parts was facilitated with ease and service was usually back in operation quickly. Specific maintenance instances are presented in the site summaries in Section 3.

The shuttle also needed to be kept clean. For external cleaning, including the sensors, the shuttle was hosed off and manually washed with a wet cloth, as commercial car wash brushes can cause damage to the sensors. The vehicle generally stayed clean, as there weren't many insects or dirt splatter due to the low speed the vehicle travels. However, the shuttle was still washed prior to being introduced at each new venue so it could be introduced as a clean and shiny automated vehicle. For internal cleaning, Hosts were equipped with glass cleaner, cloths, and a broom to keep the inside fresh and tidy during operations. See Section 6.2.5 for information on new protocols in response to COVID-19.

2.5.4   Transportation, Storage, and Charging

The shuttle was transported between sites using a U-Haul trailer, as shown in Figure 18 on the next page. Transportation was included as a unit price in the contract with EasyMile, as the project team did not want to assume any risk in loading and towing the vehicle. This unit price was valid for all trips under 50 miles – the only trip that exceed this threshold was St. George, for which the shuttle was transported by a professional transport service in a hard-shell shipping trailer. A photo of this shipping trailer and other photos of storage and charging locations is included in Appendix D.

EasyMile staff would drive the shuttle up onto a utility ramp, leaving the sensors with about an inch of clearance from the wheel wells on the sides of the trailer. Bubble wrap was put around the sensors while the shuttle was transported to the sites to provide further protection for the sensors.

Each site needed to have a secure storage and charging location, some of which were outdoors and others were indoors. These locations had to be negotiated with each site owner, and in most cases they had to move their own equipment and/or disrupt other maintenance operations to accommodate temporary use by the shuttle. Since the shuttle requires 10 feet of vertical clearance, most traditional parking garages, with only 8 feet of clearance, are not suitable for storage.

Many types of outlets could be used for charging (leading to different charging speeds), and UDOT provided a variety of charging adapters. To maintain charging efficiency, all charging locations had to maintain an overnight temperature of 40° Fahrenheit or higher, so sites with outdoor storage locations were scheduled for summer

deployments. A separate charging study was also conducted with Idaho National Labs. They supplied an in-line charge meter to collect data on electric vehicle charging characteristics to contribute to a broader study they are working on. The results of that data collection have not been finalized as of the time of this report and are outside the core project goals.

Figure 18: U-Haul Used to Transport the Shuttle Between Sites

Once the project was complete, the shuttle continued to be stored in a UDOT garage at EasyMile's request. On December 11, 2020, the shuttle was transported to Denver, Colorado, to EasyMile's facility. It was transported in a truck, shown in Figure 19.

Figure 19: The Shuttle Leaving Utah

2.6 Emergency Response

At many sites, the project team hosted a familiarization training exercise for local emergency responders (see Figure 20).

These demonstrations showed the safety features of the shuttle and how to shut off the electric battery power in the event of an emergency. Some emergency responders were uncertain of the shuttle in general, and others had specific feedback to provide.

For example, the Farmington City Fire Department was curious to see how the shuttle would work with their emergency vehicles and how much space they would need between them and the ambulance or fire truck. They determined that the ladders needed more room

Figure 20: The Emergency Responder Familiarization Training Exercise

than was available in the right-of-way along the route, as the shuttle would automatically pull up behind the fire truck or ambulance and not know to leave enough room for pulling out the ladder or stretcher. To mitigate this, emergency responders placed a cone approximately 40 feet behind the fire truck or ambulance, which would effectively stop the shuttle and provide the emergency vehicle with enough room (see Figure 21).

Figure 21: Emergency Responders Testing how the Shuttle Would Work with Emergency Vehicles

Another operational concern was that the shuttle would view any emergency vehicle as an obstruction and not be able to identify flashing lights to pull over. This was mitigated by having the Host perform a manual intervention whenever there were emergency vehicles in the area.

UDOT and UTA both recognize the importance and value of utilizing the Incident Command System (ICS) under the Federal Emergency Management Agency's (FEMA's) National Incident Management System (NIMS) framework. Project team members trained and fluent with ICS set out to integrate the shuttle operations at each

venue with incident management and contingency planning. This helped ensure uniform interactions with local emergency response personnel by adopting the use of the Incident Action Plan and ICS forms. The project team named the plan as an Event Action Plan (EAP), but it identified all the same key elements as in an Incident Action Plan that could be quickly transferred to any commonly trained emergency response community. An EAP was written for each venue and a signed review process was conducted with UDOT, UTA, and EasyMile. All three entities had to agree to "Go/No-Go" for each venue before operating.

Conducting Tabletop Exercises at the beginning of the project helped form a risk approach to anticipating potential problems and mitigations and built awareness among the agencies in advance as to who was responsible for handling different parts of a unified and coordinated response.

An additional key support feature was the willingness of the UTA Police Chief to pledge statewide security and investigative support anywhere the shuttle was deployed in Utah. Utah laws support ease with sworn Peace Officers to have basic unilateral authority across the state. UTA Police have several operating agreements and excellent relationships across all jurisdictions within their present area of operations, and they have additional experience with transit vehicles. This ensured one agency would oversee necessary investigation of any incident and would not need to repeat a new learning curve in every municipality. UDOT could further call on the Utah Department of Public Safety and the Utah Highway Patrol to support this project in a similar manner, if needed.

To address the logistics and operations during a crash or a safety-sensitive situation, the outreach team created a Crisis Communications Plan[2], part of which is shown in Figure 22. This plan was created to provide a coordinated system and response to guide the project team in communicating clearly and efficiently with key audiences if a crisis arose. This plan outlined key audiences/stakeholders (both internal and external), notification to the core team, contact information for key players, identification of crisis levels, and response tools for each level. This document also had example scenarios the project team could reference for identifying the crisis level and response strategies and tactics. Prior to the pilot project launching, the Crisis Communications Plan was distributed and discussed with the project team to ensure that the process and roles in a crisis were understood. The project team enacted the Crisis Communications Plan during the deployment at 1950 West. More information on that event can be found in Section 6.1.6.

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[2] This plan is external to this report. Contact UDOT for questions at transportationtechnology@utah.gov.
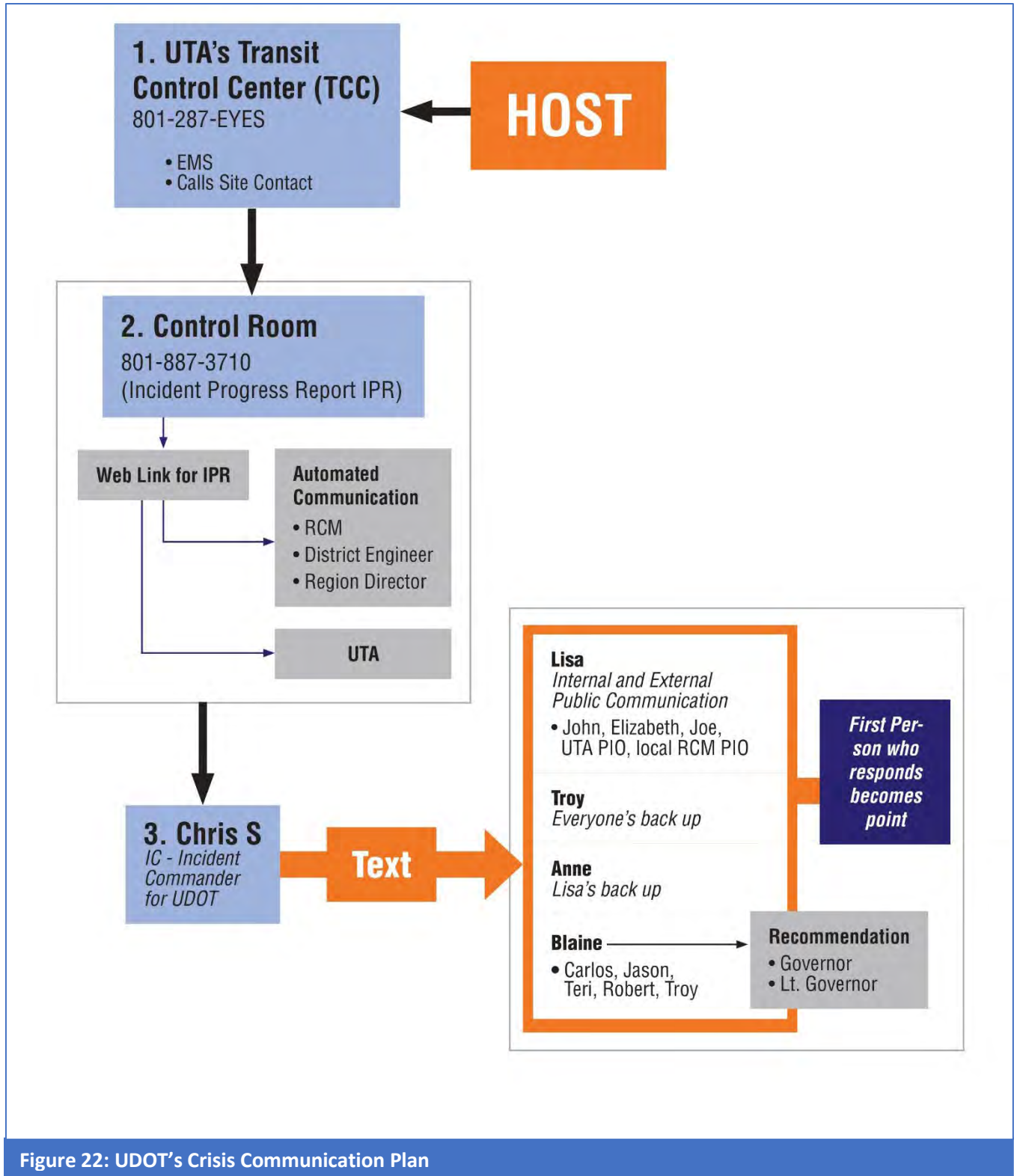
Figure 22: UDOT's Crisis Communication Plan

3 Project Deployments

The shuttle was deployed for 11 demonstrations at 8 unique locations across the State of Utah (the location at the Utah Driver's License Test Track was for the launch event, so it is not included in Figure 23). Most locations were within Salt Lake City and the surrounding Wasatch Front area (Ogden, Salt Lake City, Provo and surrounding urban cities and towns), with the exception of one demonstration in St. George, a city approximately 300 miles south of Salt Lake City. The dates the shuttle was operating at each location as well as the deployment type and average daily ridership, if available, are shown in Table 3. The goal for every site was to achieve an average daily ridership of 100 passengers.

Figure 23: Stylized Deployment Site Map

Table 3: Summary of Deployment Demonstrations

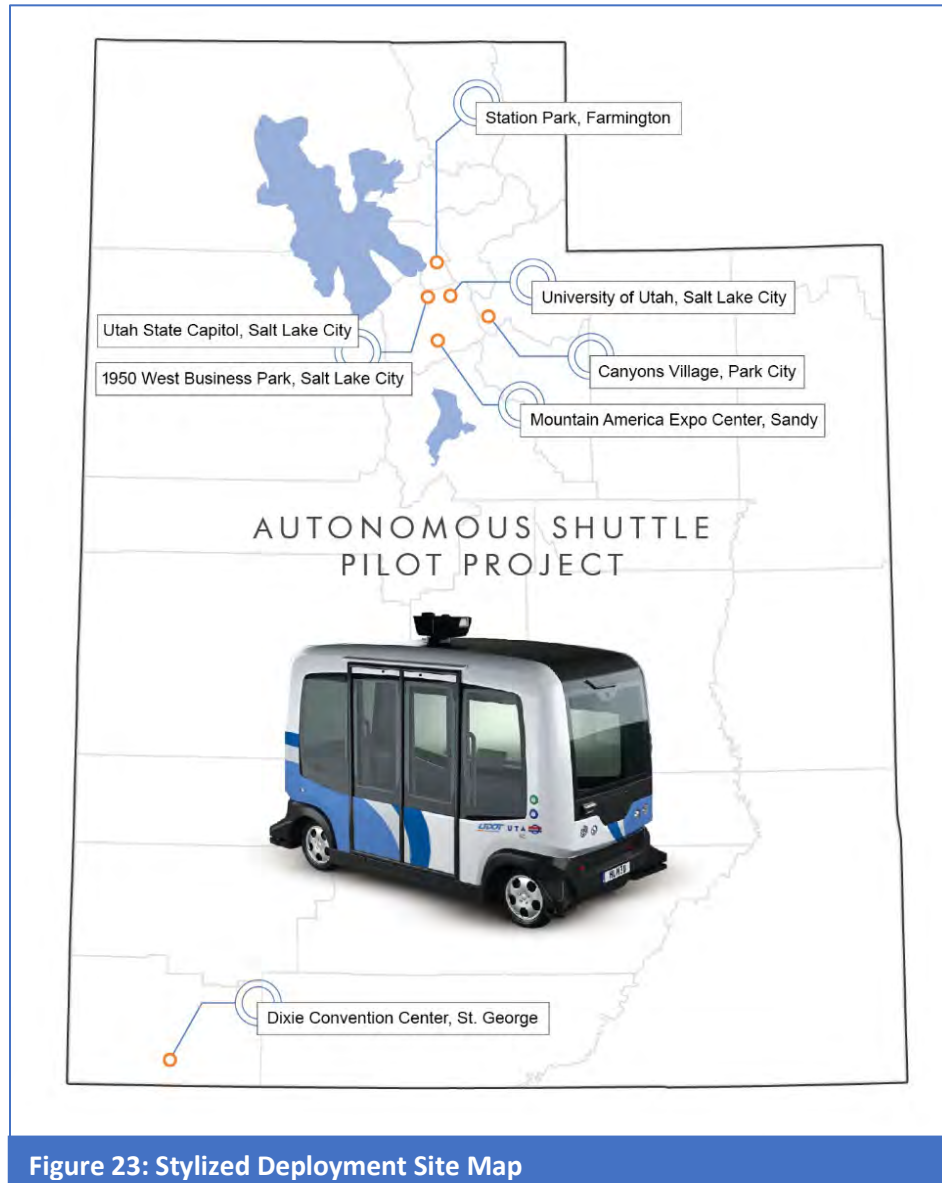| Location	Dates	Deployment Type	Avg. Daily Riders
Utah Driver's License Test Track	Apr. 11, 2019	Testing/training/ press event	n/a
Canyons Village	May 20 – 23, 2019	Resort/convention center	38
Station Park	Jun. 13 – Jul. 6, 2019	Retail/ entertainment	124
1950 West	Jul. 15 – Aug. 2, 2019	Business park/ accessibility	48
University of Utah	Aug. 19 – Sep. 27, 2019	University/user research	49
Utah State Capitol	Oct. 16, 2019	Public awareness/ policy	n/a
Mountain America Expo Center	Oct. 26, 2019 – Jan. 20, 2020	Convention center	103
Dixie Convention Center	Feb. 11 – 13, 2020	Convention center	114
Utah Driver's License Test Track	Feb. 28, 2020	V2I testing	n/a
Utah State Capitol	Mar. 3, 2020	Public awareness/ policy	n/a
University of Utah	Jul. 6 – Sep. 4, 2020	University/user research	6

The original intent was to serve these locations all within a year-long project period. However, due to unforeseen circumstances, including a Federally mandated NHTSA service suspension, the beginning of the COVID-19 pandemic, and the longer-than-expected time required at each site for the logistics of site planning, mobilization, and on-site route testing, this period was extended, with suspensions of service, to seventeen months, from April 2019 to September 2020.

While no significant infrastructure changes were made for this temporary pilot project, some minor investments did need to be made. All sites were generally in urban areas with trees, streetlights, and other objects that the shuttle's navigation system could use for reference, but the shuttle still required the installation of temporary localization signage along the route in some locations to provide additional reference points. These were not standard signs, so some effort was required to design the signs and install them successfully. In addition, one site, Mountain America Expo Center, required a minor sidewalk modification in the form of a concrete slab being installed to straighten out the path along the route. The goal of automated shuttles today is generally to run on pre-existing roadways, as it is not realistic to get roads built or significantly modified for a project period, but it is worth noting that some investments are still necessary.

With so many sites being considered, planning for the future sites had to begin while operations at a previous site were still being conducted, or in some cases still being set up. Planning for each site included applying for an NHTSA waiver as well as working with the site owner to establish a presence and an outreach strategy to promote the shuttle, dates, and operating times. The overall lead time and various tasks required for this process are shown in Figure 24.

Deployment Preparation Timeline

WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14

Create the SAR (1-2 weeks)   NHTSA approval (1-2 months)   Physical Infrastructure Modifications (2-3 weeks)   Site Set Up

Figure 24: Deployment Preparation Timeline
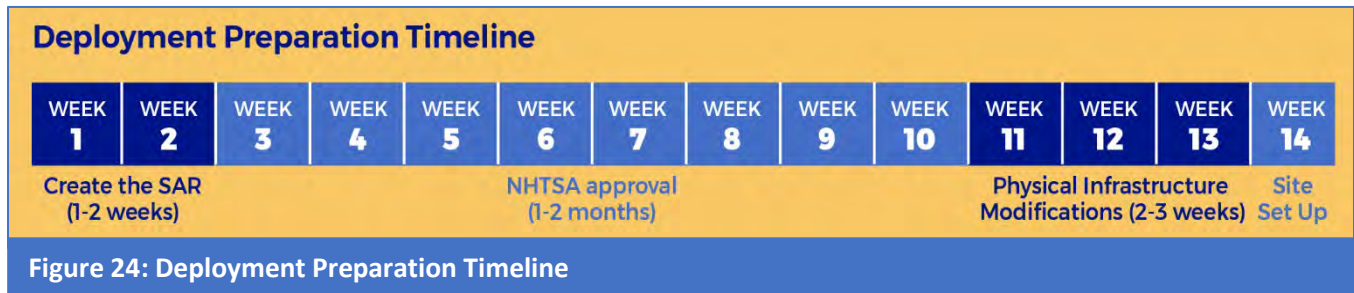
Multiple feasibility studies for future sites were also being conducted in parallel at any time. Having two dedicated EasyMile staff on site – a Deployment Engineer and a Chief Operator – as well as support from both UDOT and UTA allowed the many intersecting tasks to be completed. This arrangement is what made it possible to serve eight sites, as this would have been even more challenging if staff were remote and needed to travel for the on-site support necessary for route configuration at any new location.

3.1 Utah Driver's License Test Track

Site Statistics

Service Dates	Apr. 11, 2019	Feb. 28, 2020
Route Length	0.44 miles	
Max. Operating Speed	10.1 mph (4.5 m/s)[3]	

The shuttle was first deployed at UDOT's Test Track, a Driver's License Division facility across the street from the UDOT headquarters building where the shuttle was initially stored for initial testing prior to any deployment that involved members of the public as passengers. This deployment also served as a training opportunity for shuttle Hosts and Ambassadors and as an initial press event to create media

Figure 25: Pedestrian Demonstration with Lt. Governor Cox at the Test Track

coverage that would promote the first public deployment just a few weeks later (see Figure 25). Figure 26 shows the shuttle route used for testing and the press event, including the parking area and rider loading location.

The second time the shuttle was deployed at the Utah Driver's License Test Track was to test its wireless, connected vehicle communication capabilities. For this testing, a wireless communication system, using a dedicated short-range communication (DSRC) roadside unit (RSU) radio, was installed at the intersection on the Test Track. The EZ10 shuttle already had a DSRC onboard unit (OBU) installed as standard equipment. The shuttle, operating in automated mode, passed through this intersection while the OBU received and used messages defining the state of the traffic signal from the RSU. Results of this testing are presented in Appendix E.

The intent of the testing was to determine if the shuttle could use the Signal Phase and Timing (SPaT) message from the traffic signal to make decisions about movements through the intersection. The testing was performed at this site because none of the routes at the other sites involved movements through a signalized intersection, and the team wanted to test this capability in a low-risk situation. This testing was successful: the shuttle and roadside equipment communicated as expected. Prior to testing at this site, UDOT performed preliminary verification tests in a parking lot at the UDOT Region 2 offices using a trailer-mounted RSU.

UDOT also successfully tested vehicle-to-vehicle (V2V) communications using a UTA bus while the shuttle was operating at 1950 West, as described in Section 3.4.
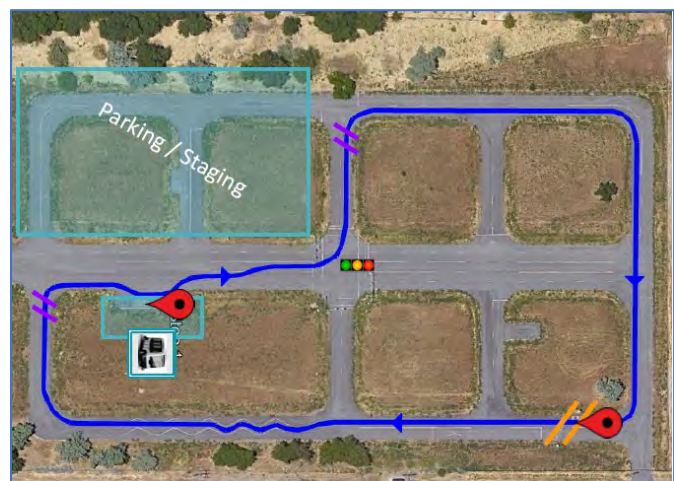

Figure 26: Utah Driver's License Test Track Route (Image from Google Maps)

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[3] The shuttle is programmed on an SI system of units, and the equivalent United States conversion is shown.

3.2 Canyons Village

Site Statistics

Service Dates	May 20 - 23, 2019
Route Length	0.58 miles
Max. Operating Speed	11.2 mph (5.0 m/s)
Frequency	10 to 15 minutes
Total Service Days	4 days
Ridership	151
Ramp Deployments	8
Surveys Conducted	76

Figure 27: Shuttle at Canyons Village

The first deployment on public roads of the shuttle in Utah was at Canyons Village, near Park City, during the American Association of State Highway and Transportation Officials (AASHTO) Spring conference (see Figure 27). Canyons Village is a ski resort hotel in a mountainous location with steep terrain. The shuttle was available to the public but was not promoted outside of AASHTO and the conference facility.

Other than rider counts and feedback, all other metrics were not reliable enough to be recorded at this site. This led to the understanding that operational data and reports should be established prior to running passenger service, as was done at subsequent locations.

The route, shown in Figure 28 on the next page, was shortened from early ideas to facilitate the process of getting NHTSA approval. Operating hours were 12 p.m. to 6 p.m., with a break between 3 p.m. and 3:30 p.m., for all four days of service. Battery use was sufficient for the hours of operation and performed well and as expected, with an average of 10% used per hour. The eight ramp deployments at this location were all for demonstration purposes.

The two main challenges at this site were route set-up and weather conditions. For route set-up, this site's terrain was difficult to map and required a lot of set-up and planning relative to the short length of the deployment – the project team spent about four weeks of set-up to run four days of service. Even once the route was fully programmed, a problem was encountered with slope, and LiDAR sensors consistently required a manual override to safely proceed through a T-intersection. In addition, construction and shifting lanes along the route required reprogramming the shuttle route, which temporarily interrupted service delivery.

The weather was cold and wet with a recorded high of 48 degrees Fahrenheit and a low of 39 degrees Fahrenheit. Each day saw medium to heavy rain, hail, or snow that interfered with automated operations and interrupted shuttle service at times. Service was paused on May 21, 2019, for a rain/hailstorm and on May 23, 2019 for snow. This likely contributed to the low average daily ridership of 38 riders, which was below the goal of 100 per day.

While operating in poor weather conditions, the shuttle was limited by LiDAR detections of rain and snow and from water dripping off LiDAR housings. The system interpreted these water droplets to be obstacles. There were also instances when the sun coming out caused steam to rise from the roadway, which the LiDAR detected, preventing the shuttle from operating in automated mode. However, it had no issue with traction on wet, slushy,

and muddy roads. The heater was lightly used because sunlight helped warm the vehicle's interior through the many windows on the shuttle.
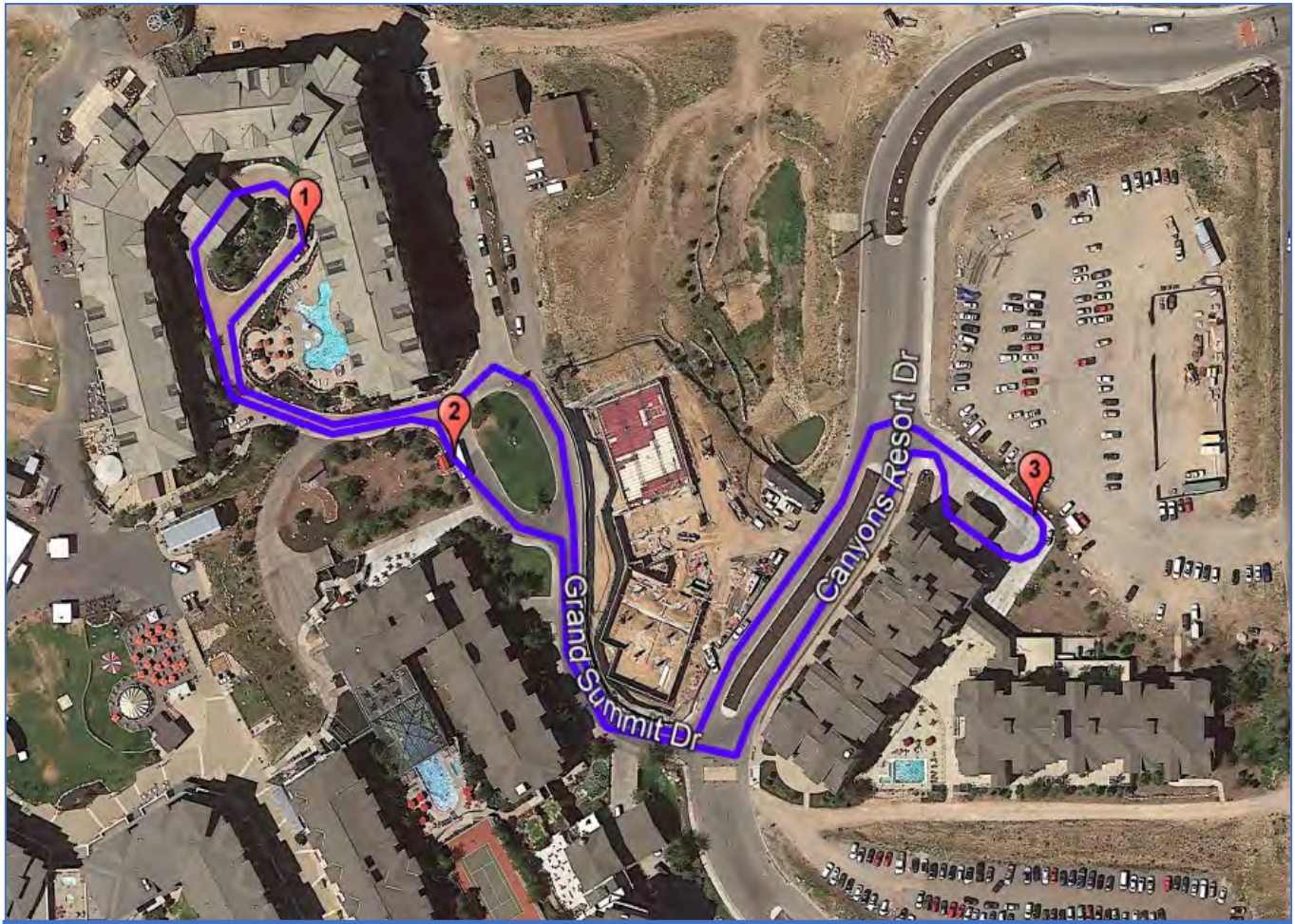

Figure 28: Canyons Village Route
(Image from Google Maps)

3.3 Station Park

Site Statistics for Station Park

Service Dates	Jun. 13 - Jul. 6, 2019
Route Length	1.1 miles
Max. Operating Speed	10.1 mph (4.5 m/s)
Frequency	15 to 20 minutes
Total Service Days	21 days
Total Miles Traveled	357 miles
Total Hours Served	114 hours
Ridership	2,613
Ramp Deployments	36
Surveys Conducted	343

Figure 29: Shuttle at Station Park

The first major, publicly promoted deployment was at Station Park, a large shopping center in the City of Farmington (see Figure 29). Station Park is a mixed-use development with both big box and boutique retail, entertainment, office space, and some residential space. This deployment ran Monday to Saturday, 12 p.m. to 6 p.m., for 21 service days total.

The route, shown in Figure 30 on the next page, was served at a low average speed. This increased travel time, but the low speed allowed the area to maintain a pedestrian-friendly atmosphere. Over the course of the deployment, the shuttle had no notable safety concerns other than one near miss when a skateboarder tried to hold onto the rear of the shuttle while it was moving. On June 22, 2019, the wheelchair ramp became inoperable when a passenger accidentally hit the ramp button while the shuttle was running its route, causing the ramp to try to extend and not be able to, which caused a fuse to be blown. The shuttle was out of service for 100 minutes and then ran without the ability to deploy the ramp for the remainder of that day and for several more days before the issue was resolved. The ramp was repaired by EasyMile on June 25, 2019, and the shuttle and ramp were then fully back in service.

Of all sites, this location had the highest proportion of riders who stated that they used the shuttle to connect to transit, at 16%. This makes sense because Stop 1 was located at a UTA FrontRunner commuter train station, and the shuttle provided first/last mile connections to that station within Station Park. As an example, the shuttle team observed that one passenger boarded the shuttle carrying a bag of groceries and a gallon of milk and was grateful for this alternative to walking while carrying a heavy load from the grocery store.

Station Park already has other alternatives for first/last mile connections, including a trolley bus and shared electric scooters. However, the trolley bus has too large of a turning radius to serve the route the shuttle served, and instead operates more on the periphery of the site. The electric scooters are not as useful for people carrying loads, and there are liability issues with allowing them on the private property of Station Park.

The private nature of the site also required additional liability insurance for the shuttle, which was handled by the project team prior to launch.

If the shuttle had been at this location for longer, it is likely that more routine trips such as the one for the person carrying groceries would have occurred. However, for the short duration of the demonstration, most riders were there primarily to experience a self-driving vehicle. Rider curiosity was high, and Hosts answered questions almost non-stop. Staffing Ambassadors at most stops encouraged people to wait for the shuttle and have their questions answered prior to boarding or after riding. However, these Ambassadors were not able to know the shuttle's location once it was out of sight and could not respond to questions about when the shuttle would return to the stop. This led to the motivation for a live tracking app, which was implemented at a future site of similar size, the University of Utah.

The weather was generally pleasant for this deployment, with a recorded high of 92 degrees Fahrenheit and low of 65 degrees Fahrenheit. The team reported weak air conditioning and shortened battery life as the air conditioning system was running most days. On June 20, 2019, a mix of wind, rain, and blowing flower petals triggered the LiDAR detectors and caused an emergency stop, and service was paused for 45 minutes. On July 4, 2019, rain caused a service suspension for 20 minutes.

This site was selected mainly due to its low-speed roads, its potential for significant public contact, its convenient location to charge and store the shuttle (shown in red at the left end of the route in Figure 30), and its connection to UTA bus and FrontRunner services. Physical site set-up included adding signs for localization, pedestrian and driver warnings, and wayfinding. These mitigations simplified the environment somewhat, but the complexity of the environment, including temporary construction activities, cars sticking out too far from their parking spot, crowded streets, and high pedestrian volumes, still required frequent manual disengagements.

Figure 30: Station Park Route

3.4 1950 West

Site Statistics

Service Dates	Jul. 15 - Aug. 2, 2019
Route Length	1.1 miles
Max. Operating Speed	11.2 mph (5.0 m/s) Lowered to 8.9 mph (4.0 m/s)
Frequency	8 to 10 minutes
Total Service Days	14 days
Total Miles Traveled	232 miles
Total Hours Served	72 hours
Ridership	677
Ramp Deployments	9
Surveys Conducted	64

Figure 31: Shuttle at a Bus Stop at 1950 West

The shuttle was demonstrated at 1950 West North Temple in Salt Lake City, the location of several State of Utah office buildings (see Figure 31). Service was provided Monday through Friday, 11 a.m. to 5:30 p.m., with a break between 2:30 p.m. and 3:30 p.m. Service originally extended to 6 p.m. but had to be shortened due to battery life issues. The route is shown in Figure 32 at the end of this section. This site was selected mainly due to its low-speed roads, light traffic, and connection to UTA buses and TRAX services on North Temple street. This site had one of the best storage locations, an outdoor, secured parking spot with other vehicles in the state's fleet. During early planning, the team attempted to extend the shuttle route farther south to get closer to North Temple Street, but a suitable turn-around spot for the shuttle could not be found.

Because this site included the work locations of many state employees, the project team was able to market the project through some state resources. This included sending notifications of and information about the project as well as surveys through the email list of the location.

This site was the location of the most notable incident during the project. On July 16, 2019, the shuttle was operating in automated mode at a speed of 11 mph when an obstacle crossed the shuttle's path. This caused the shuttle to make an abrupt emergency stop, resulting in a minor injury to a passenger. At the time of the stop, the passenger was not sitting squarely in the seat. The abrupt stop pushed the passenger out of the seat, and his face hit the door hardware. Service was immediately suspended while the incident was investigated, and the project team enacted their Crisis Communications Plan that was shown previously in Figure 22. Service resumed the next day along with new safety measures, including lowering the maximum speed from 12 mph to 9 mph, adding new warning signs and lights, and adding adhesive tape strips on the seats to make them less slippery. This incident and the corresponding response are discussed further in Section 6.1.6.

This site had the most known media coverage, with 26 news stories logged during the deployment, mostly related to the incident on July 16, 2019. Survey results show that 94% of respondents felt safe riding the shuttle, and 14% used it to connect to transit.

The Utah Division of Services for the Blind and Visually Impaired is located along the route at Stop #1 (see Figure 32 on the next page). Members of this community were engaged to help both EasyMile and the project team learn more about whether the current accessibility features of the shuttle met their needs and what additional features would be helpful. Through this engagement, the project team learned that people who are blind or have low vision usually expect to hear a transit vehicle approaching to know they should begin to get ready for their ride. However, because this shuttle is electric, it was too quiet for them to hear. While the internal audible announcements were helpful once passengers were on board, electric vehicles may need to add external sound to their vehicles for safety and directional guidance.

In addition, transit riders who are blind rely on both automated and personal wayfinding guidance, including bus drivers who could notify them of sidewalk hazards (i.e. wet paint, construction nearby). This type of guidance would be very difficult to implement for an automated shuttle with no onboard staffing support. In addition, a participant noted that the Braille on the shuttle's ramp push buttons said "door" instead of "ramp."

The weather was hot with a recorded high of 98 degrees Fahrenheit and a low of 82 degrees Fahrenheit. The team reported weak air conditioning and shortened battery life due to the heat. After being plugged in all night at the outdoor storage location, six times the shuttle started its day with a battery reading of less than 90%. Twice the shuttle required mid-shift breaks to recharge the battery. The team suspects that temperatures higher than 80 degrees Fahrenheit or 90 degrees Fahrenheit could have been a contributing factor. To help diagnose the problem, the team installed a charge meter to receive better data going forward.

Some impromptu testing of the shuttle's wireless, V2V communications systems occurred during operations at this site. As part of a separate project, some UTA buses were equipped with DSRC OBUs, and these buses would occasionally operate along North Temple Street. These buses would periodically detect messages being broadcast by the shuttle's OBU and log them. These messages were noted and reviewed, but no specific action was taken based on this data.
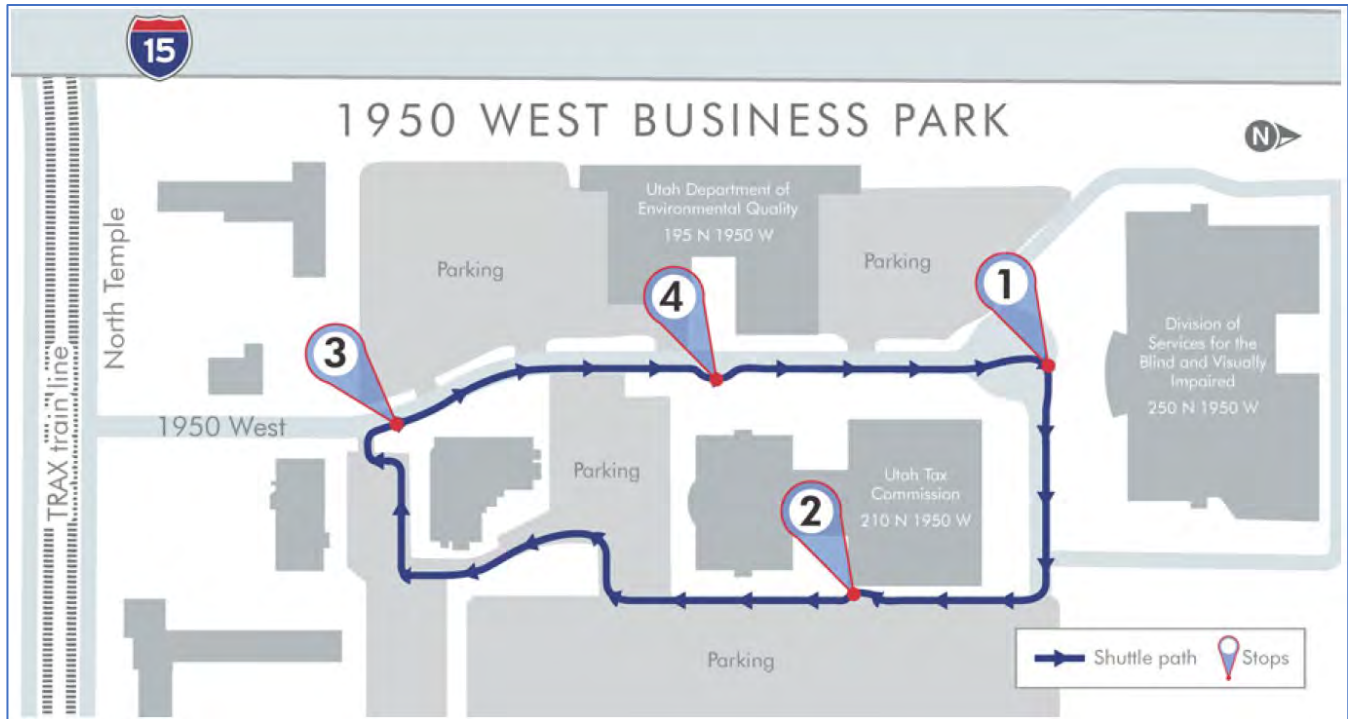
Figure 32: 1950 West Route

3.5 University of Utah

Site Statistics

Service Dates	Aug. 19 - Sep. 27, 2019	Jul. 6 - Sep. 4, 2020
Route Length	0.5 miles	
Max. Operating Speed	8.9 mph (4.0 m/s)	5.6 mph (2.5 m/s)
Frequency	10 to 20 minutes	
Total Service Days	22 days	42 days
Total Miles Traveled	377 miles	249 miles
Total Hours Served	121 hours	250 hours
Ridership	1,073	266
Ramp Deployments	1	0
Surveys Conducted	55	0

Figure 33: Passenger Boarding at the University of Utah

The first time the shuttle was stationed at the University of Utah was in the summer of 2019 (see Figure 33). The route, shown in Figure 34 at the end of this section, was served from 12 p.m. to 6 p.m. Monday through Friday. This site was technically desirable due to its low speed limits, wide vehicle-friendly dedicated roads (open only to other transit vehicles and some contractors), and connection to UTA TRAX. However, it was not an especially useful route for students because it was not on the main pedestrian path connecting to Legacy Bridge and TRAX. This contributed to lower-than-expected ridership, which motivated the project team to watch pedestrian foot traffic during commute hours to help identify future route locations.

This was a challenging site for the automated system for several reasons. Vehicles and bicyclists often cut too close, slowing down or halting the automated shuttle. On August 29, 2019, one shuttle passenger was inadvertently hit by a bicyclist as she exited the vehicle. These types of traffic hazards were anticipated and mitigated as much as possible in the set-up phase before service began. At times, the Host hit the emergency stop button in advance to avoid more abrupt braking by the shuttle making an emergency stop. In addition, unanticipated construction on the route forced re-mapping of the route, and construction dust caused emergency stops.

Weather was warm and mostly pleasant with a recorded high of 97 degrees Fahrenheit and a low of 69 degrees Fahrenheit. On September 10, 2019, operations were suspended for nearly an hour due to rain. Thanks to indoor overnight storage, the battery performed well.

One lesson learned was not to launch at a university during the first week of classes, or any other period with significant travel demand, because it is too hectic to meet this demand while the route is still being validated. In this case, unfortunately, at the same time as awareness of the shuttle's presence on campus grew, maintenance issues had to take the shuttle out of service. In total, there were four performance issues during this six-week deployment:

- On August 26, 2019, the shuttle battery died and was replaced the same day.

- On September 11, 2019, the team noticed a slow-speed issue. The shuttle was taken out of service on September 12, 2019, and transported to UDOT's garage to troubleshoot and make repairs. The team discovered that the rear differential had failed, caused by overloading the rear drivetrain due to automated braking on a relatively steep slope (13-14%) from the charge station to the service route. (Note that there were never passengers on board for this section, and a grade this steep would not have been approved for a passenger-carrying route due to the implied extra load).
- After replacing the rear differential on September 13, 2019, new issues surfaced. These took several days to diagnose and were ultimately resolved by replacing the rear failsafe brake.
- On September 25, 2019, the door motor burned out and was replaced the next day.

In total, the shuttle was out of service for seven full and four partial days the six weeks it was on campus. This led the project team to understand the need to set proper expectations for new technologies. Especially with just one shuttle and no spare, if there is a maintenance issue or the vehicle is out of service for any reason, the entire project is on hold. Several demonstration opportunities with on-campus and other groups had to be cancelled, and many potential riders were missed, but eventually the shuttle was brought back into service.

Survey results at this location indicated that 96% of passengers felt safe and 11% used the shuttle to connect to transit. A handful of riders became regulars, riding three or more times in a single day because it aligned with their schedules and destinations. The shuttle easily accommodated passengers and their bikes when there was room. Per project objectives, this site eventually started providing real-time shuttle information using EasyMile's GPS location data feed, as is discussed further in Section 6.1.5.

In addition to passenger surveys, detailed studies of rider trust and the role of the Host were conducted during the University of Utah deployments. These studies are discussed in more detail in Section 5.3, and full research reports are included in Appendix G. The first phase of this study was based on rider interactions during the first University of Utah deployment.

The second time the shuttle was at the University of Utah was during the summer of 2020. Because this period was both during summer break and during the COVID-19 pandemic, both demand and ridership were much lower than the first deployment, but valuable testing was still able to be conducted. Field data was gathered during this second deployment for the second phase of the rider trust studies. See Figure 35 for a map of the route.
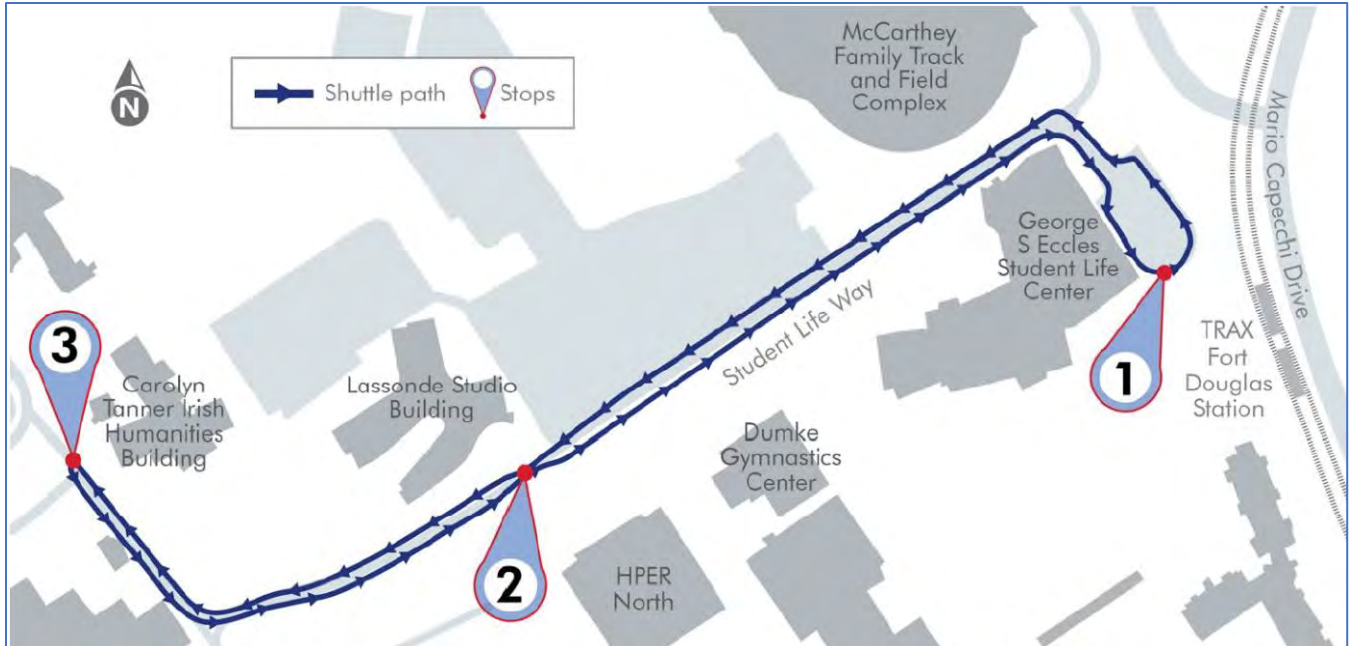
Figure 34: University of Utah – First Deployment Route

Figure 35: University of Utah – Second Deployment Route

3.6 Utah State Capitol

Site Statistics

Service Dates	Oct. 16, 2019	Mar. 3, 2020
Route Length	0.16 miles	n/a
Max. Operating Speed	6.7 mph (3.0 m/s)	n/a

Figure 36: Site Setup at the Utah State Capitol

The shuttle was brought to the Utah State Capitol twice during the project. There was interest to bring the shuttle to the Capitol first, in March 2019, but shipping time, customs, and other delays precluded this from happening. Instead, it was first demonstrated on October 16, 2019, during a pre-session legislative committee day to increase public awareness of the shuttle, particularly for legislators, and to bring emerging CAVs further into the policy discussions happening at the state level (see Figure 35). The shuttle followed a simple route (see Figure 44 on the next page) in front of the Capitol building on a non-motorized vehicle path. Signs were placed in the House and Senate office buildings, and certain committee meetings included an announcement of the presence of the shuttle.

The second time the shuttle was at the Capitol, on March 3, 2020, was during a transit demonstration day hosted by UTA. The shuttle and several UTA buses were on display on the front plaza of the Capitol. The event was intended to focus on transit and the role of UTA in moving the public. This was a static display; the shuttle did not move or offer rides since the plaza was filled with other transit vehicles on display. Also, this event was during the NHTSA suspension, which the project team was advised of on February 25, 2020, during which time NHTSA required all EasyMile passenger services nationwide to be put on hold while an incident at another site was reviewed. The protocol for static displays was to have the doors open and the project video playing on board. Display boards and easels with specifications were stationed near the shuttle. The communications team, as well as the Deployment Engineer and Chief Operator, were on site to answer questions.
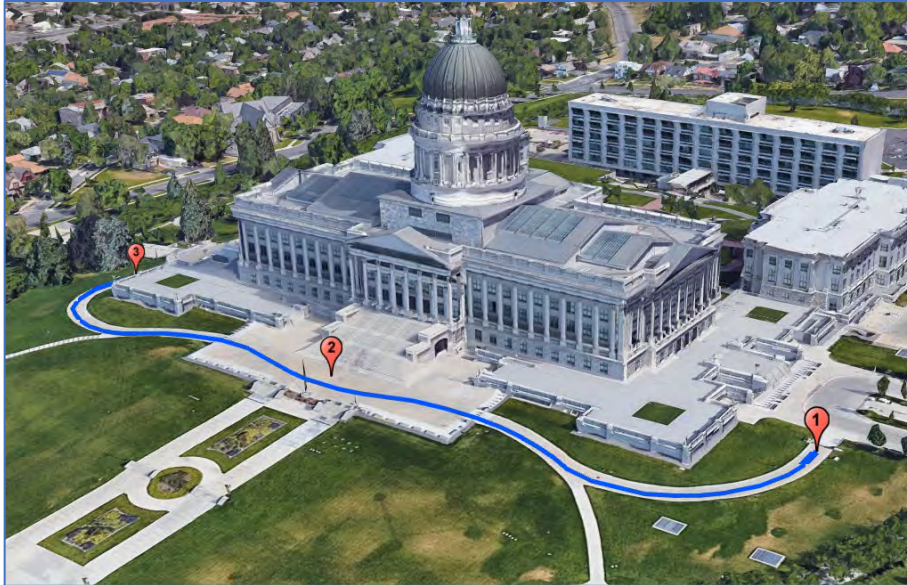
Figure 37: Utah State Capitol Route
(Image from Google Earth)

3.7 Mountain America Expo Center

Site Statistics

Service Dates	Oct. 26 2019 - Jan. 20, 2020
Route Length	0.5 miles
Max. Operating Speed	5.6 mph (2.5 m/s)
Frequency	10 to 15 minutes
Total Service Days	17 days
Total Miles Traveled	103 miles
Total Hours Served	103 hours
Ridership	1,756
Ramp Deployments	8
Surveys Conducted	77

Figure 38: Temporary Tire Tracks on Alignment at Mountain America Expo Center

The shuttle was next located at Mountain America Expo Center in Sandy, a conference facility that hosts a broad variety of exhibits and shows (see Figure 37). Between October 1 and October 25, 2019, the shuttle was parked inside the exhibit hall and available only for display because securing NHTSA approval for this site took longer than expected. People were still excited to step inside and learn about the vehicle.

The route was approved and fully set up in time for an event on October 26, 2019. During the rest of its time at the Expo Center, the shuttle was in service on this route for 17 days, corresponding to various events, including a car show and the annual UDOT conference. Operating hours varied for each event. The route, shown in Figure 38 on the next page, was an out-and-back route operated in "elevator" mode, where the shuttle only reverses direction without turning around. The only other location where the shuttle was operated in this way was the Utah State Capitol. The route at the Expo Center was operated entirely on sidewalks and all points along the route were potential crosswalks. Therefore, the shuttle ran at drastically reduced speeds and yielded through high pedestrian traffic zones. This, along with the high number of stops along such a short route, led to the low average speed, even compared to other sites.

This site offered easy public access to demonstrate the shuttle at a variety of events and for different demographics. The route was desirable due to its relatively wide sidewalks free of other vehicles. When operating, this was primarily a demonstration route that picked riders up and brought them back to where they started. It still performed well from a ridership perspective. Occasionally, customers would use the shuttle to get closer to their parked car or to the TRAX station about 500 feet from the last shuttle stop. The TRAX station was accessed by about 3% of surveyed shuttle riders.

This was not a technically challenging site, but the project team still had to make some safety mitigations. For example, because one section of the route was too narrow for the shuttle, the edge of a gravel planter box had to be paved over with concrete. This poured concrete pad is shown in Figure 37 as the slightly lighter-colored trapezoidal concrete near the planter to the left of the tire tracks.

The weather was generally mild or cold during this deployment, with a recorded high of 58 degrees Fahrenheit and a low of 25 degrees Fahrenheit. On October 27, 2019, medium snowfall caused five obstacle emergency stops and a 3-hour suspension of service. On January 10, 2020, during a private safety training exercise, packed snow and ice caused the shuttle to slow down, but the vehicle was still able to complete its route. Thanks to overnight storage in a heated garage, the battery performed well at this location.

The shuttle's ramp was inoperable due to a mechanical issue for 8 of 17 days, though the shuttle continued operations during this time. There were no other notable maintenance issues. Once the team started operating at the Expo Center, the shuttle was available for service every day at this site.

One interesting observation at this site was how closely the automated shuttle followed its trajectory due to its geolocalization. As shown previously in Figure 37, temporary tire tracks clearly marked the vehicle's route after running on the same sidewalk path for just a few weeks.

Figure 39: Mountain America Expo Center Route

3.8 Dixie Convention Center

Site Statistics

Service Dates	Feb. 11 - 13, 2020
Route Length	0.6 miles
Max. Operating Speed	8.9 mph (4 m/s)
Frequency	10 to 15 minutes
Total Service Days	3 days
Total Miles Traveled	29 miles
Total Hours Served	25 hours
Ridership	342
Ramp Deployments	0
Surveys Conducted	42

Figure 40: Shuttle Presentation at the Dixie Convention Center

The Utah Autonomous Shuttle Pilot was transported down to St. George in early February 2020, providing service from 11 a.m. to 5 p.m. for three days at the Dixie Convention Center (see Figure 39). The route, shown in Figure 48 on the next page, was a relatively simple route with light traffic that resulted in the highest level of automated operations of all sites. This site was attractive with easy access to the public and done in conjunction with a Transportation Expo. The route was technically desirable due to its low speed, lightly trafficked roads, and limited interactions with pedestrians.

This was not a technically challenging site, but the project team still made safety mitigations. The shuttle ran at drastically reduced speeds and yielded at pedestrian traffic zones. Additional traffic control was added to keep the route to one lane at a point where the road usually split into two lanes, creating a safer and simpler operating environment for the shuttle. This was possible because it was a low-traffic area where the street dead-ended at a city park.

Although this demonstration was outside UTA's service area, the safety Event Action Plan had any incident calls going to UTA's Transit Communication Center (see Figure 22 for more detail on the communications protocol). UTA police would then have notified emergency dispatch in St. George.

Weather did not interfere with the operations at St. George. Days were sunny and dry with highs between 55 degrees Fahrenheit and 63 degrees Fahrenheit. Due to indoor overnight storage and mild temperatures, the battery performed well. Battery use averaged 5% per hour, lower than at other sites where it was generally closer to 10% per hour due to higher heater and air conditioning use.

There were zero performance or mechanical issues during this three-day deployment, and all hours of service were provided as planned. Based on the surveys collected, all respondents (100%) felt safe. Due to the nature of this being a demonstration route, 0% of riders stated they connected to transit. While there was a St. George bus stop nearby, the automated shuttle route was primarily used by conference attendees to experience the technology rather than for transportation.

Demonstrating the automated shuttle can help communities plan for more advanced transportation options. Local stakeholders, including invited local officials and student groups, valued being able to experience the technology firsthand. St. George stakeholders and the public in general were highly receptive and welcoming of automated vehicle technology. The project received excellent media exposure on this short deployment. During its short time in St. George, the shuttle was promoted favorably in the local news media and local online journals. Many members of the public heard about the shuttle through these sources and came to the project site to ride it. St. George is a smaller metropolitan area, and because the shuttle was there for a shorter period of time, there was generally a higher level of excitement than there had been at other sites.
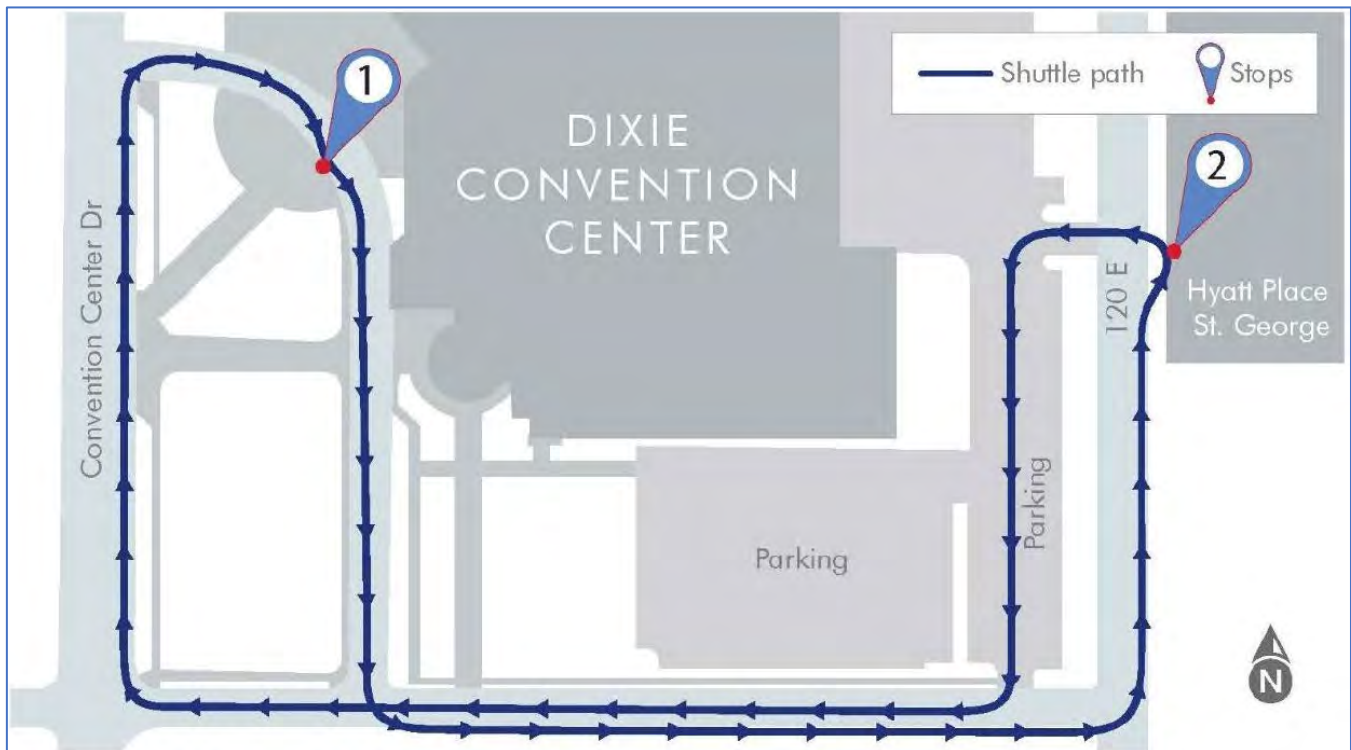

Figure 41: Dixie Convention Center Route

3.9 Deployment Locations that Were Considered but Not Implemented

The shuttle reached an ambitious number of locations within its project period in Utah, but there were still additional locations that were supported by both the project team and the local community that were ultimately not able to be served. This was primarily due to timing and resource constraints, but in some cases the use case, route, and/or environment were not suitable for the current state of the technology. Potential sites were assessed based on how they addressed the following criteria:

- 80-100% private roads
- Shares the road with other vehicles
- Low speed (< 25 mph) route
- Signalized intersection (V2I, DSRC)
- Avoids residential streets
- Easily accessible to the public
- Compelling customer market
- Connects to train or bus rapid transit (first/last mile connection)
- Estimated UTA weekday boardings

The candidate site most heavily evaluated but not ultimately achieved was Thanksgiving Point in Lehi. This was primarily due to timing, with the Thanksgiving Point deployment planned to begin during the nationwide NHTSA suspension and then the COVID-19 pandemic. Instead, the project team focused on safely completing research and operations at the University of Utah.

The project team was also interested in exploring a hospital as a use case to demonstrate. Significant effort went into pursuing a service at the very large Intermountain Medical Center campus in Murray. The potential site partners were supportive of the idea, but already had their own shuttle running, so this shuttle would support existing operations rather than create a new link. As the site was assessed and its conditions were matched with the current limitations of the shuttle, it became clear that the desired route was not currently feasible, and this location was therefore ultimately not pursued. The main limitation was the need to cross a signalized intersection.

A similar challenge occurred at two other medical facilities, one of which was in St. George. The routes considered workable weren't a good fit for actual demand and flow of users, and the real needs were on higher speed and higher traffic roadways outside the capabilities of the shuttle.

Another challenge was finding a suitable temporary storage location near each deployment site, particularly during the winter months where indoor storage is required, largely because of charging limitations. Existing parking garages are not always suitable as some have height limits as low as 7 to 8 feet, while the EZ-10 shuttle requires 10 feet of vertical clearance. For longer-term deployments, a storage facility could be built, but this investment could not be justified for such short-term deployments.

Many additional communities, such as the cities of Vineyard and Ogden, were very interested in exploring ways in which the automated shuttle could be demonstrated within their jurisdictions. While timing and resource constraints and/or the lack of a suitable route precluded all potential sites from ultimately being served, many were assessed over Google Maps or with a site visit, allowing the project team to learn more about future opportunities and what to look for in sites that are ideal for first/last mile and other types of automated shuttle services.

4   Project Evaluation

Data was collected over the course of the project at all deployment locations across the state. During the procurement period, potential vendors were asked to "describe what operational data (travel path history, logs of occupancy during the trips, logs of speeds and braking, video imagery inside or outside of the vehicle, etc.) [they] can make available to [UTA] for our research and evaluation purposes." EasyMile agreed to provide the data presented in this section.

Collected data included operational data, such as odometry readings and the number of disengagements, which was automatically collected by EasyMile's various vehicle systems and shared with the project team. Anecdotal data reported by Hosts, Ambassadors, and other on-site staff as well as survey responses were also collected at each site.

4.1   Technology and System Performance

One of the major reasons UDOT and UTA chose to bring an automated shuttle to Utah was to be able to assess its performance firsthand. Table 4 on the next page summarizes the results of this study across all sites.

Table 4: Service Statistics

Days in Service	119 days (123 days[1])
Average Daily Duration	6 hours, 5 minutes, 58 seconds
Total Hours in Service	686 hours, 11 minutes, 0 seconds
Total Distance Traveled	1,346.55 miles
Maximum Operating Speed	11.2 mph (5.0 m/s)
Total Ridership	6,727 riders (6,878[1])
Average Ridership per Hour	12.2 riders/hour
Ramp Deployments	62
Average Battery Usage Rate	9.25% / hour
Average Maximum Allowable Time in Service	8.91 hours
Total Estimated Cost of Electricity	$159.40
Average Cost of Electricity per Hour	$0.22/hour
Average Energy Consumption	1.36 kWh/mile
Disengagements[a]	2,792 disengagements
Disengagements/Mile	2.07 disengagements/mile
Manual Switches[b]	1,203
Soft Stops[c]	1,219
Obstacle Emergency Stops[d]	370
Button Emergency Stops[e]	0
Approximate Total Cost	$987,000
Approximate Capital and Operating Cost[2]	$627,000
Average Cost/Boarding	$91.16
Average Cost/Mile	$465.63
Average Cost/Hour	$913.75

Notes

[1] Summary statistics do not include Canyons Village, as not all statistics were able to be measured at this site. Values in parenthesis include Canyons Village.

[2] Includes vehicle lease, signage, operations, and all other costs not related to research and assessment.

Definitions

[a] Disengagements – Any interruption in automated driving, whether by the operator or the safety control.

[b] Manual Switches – Operator intervention that involves the operator physically turning the key-switch to "manual" in order to take over control with the remote control unit (RCU).

[c] Soft Stops – Operator-triggered function to slowly coast to a stop. Used for non-emergency situations.

[d] Obstacle Emergency Stops – An autonomous, calculated stop triggered by the safety control to avoid an interaction with a detected obstacle.

[e] Button Emergency Stops – There are three emergency stop buttons inside and two emergency stop buttons outside the shuttle that an operator, passenger, or bystander can press to stop the shuttle. These are used to stop the shuttle from moving due to a safety concern that is not apparent to the onboard safety control unit.

These results are assessed in more detail throughout Section 6. However, it is worth noting at this point that due to the nature of a pilot project, many of these metrics are not representative of what would be expected for a longer-term deployment. This is especially true for the cost breakdowns, as a short-term shuttle lease is more expensive per period than a longer-term lease or purchase, especially considering the high set-up costs for each of the many deployment sites and the amount of downtime the shuttle experienced as a result, which led to lower utilization than could have been experienced in a consistent, long-term deployment at a single site over a similar lease period.

4.2 Staff Feedback

Interviews were conducted with UTA and UDOT staff members that were either directly involved with this project or who were representative of departments that may have a larger role in automated shuttle projects in the short or long term. This feedback led to many of the lessons learned outlined in Section 6. In addition, surveys were conducted with key site partners and with EasyMile.

Most site partners were able to ride the shuttle themselves. For those who rode the shuttle, there was initial excitement due to the novelty of the experience, but many stated that their ride was overall somewhat unexciting – safe, but boring. As riders, they were impressed by the precision of the shuttle's path, as it did not vary over the service period at that site. However, they did note how slow the shuttle was and that it would become more appealing to specific use cases once it can reach a higher speed.

At UTA, stakeholders who were able to ride the shuttle expressed appreciation that the transit agency was looking at innovative ideas. There are benefits to piloting a new technology even if it cannot be put into service immediately, because it can lead to lessons learned and interest in other technologies and services. There was also excitement about beginning to have dynamic conversations on what the next phases of the technology will look like and seeing how that could be incorporated into what UTA offers today.

Some UTA drivers provided negative feedback through UTA's social media channels because they were worried that this was the first step in taking their jobs away. UTA's position on this topic is that automated shuttles will be a complement to the services already being provided. Adding an automated shuttle is intended to increase the number of riders on buses and trains, and thereby in the overall transit system, by assisting with the first/last mile and helping fill that missing connection.

5 Survey Results and Public Feedback

As noted elsewhere in this report, the project team actively sought feedback from the public about this shuttle project and about vehicle automation in general. Gathering this feedback was in direct response to one of the six key project goals, "Interact with the public to assess opinions and attitudes about vehicle automation and the desirability of automated shuttles in the transport network." This section summarizes those efforts and findings.

When reviewing the survey results in this section, it is important to note that with opt-in surveys and most data collected at shuttle demonstration sites, respondents are more likely to have favorable attitudes toward automated vehicle technology or at least have an existing interest and awareness of automated transportation, since they have voluntarily arrived at the project site and agreed to respond to the survey. Results are therefore likely to be more positive in nature than a survey of the general public, but there are still valuable insights that can be added by the firsthand experiences of this subset of the population.

5.1 Passenger Experience

Two surveys were conducted during the project period to better understand the passenger experience. The first survey was conducted by tablet in person at each deployment site. Tablet survey responses were collected with QuickTap software. Generally, the survey was answered by riders as they alighted the shuttle and were greeted by an Ambassador carrying a tablet. This survey received 789 responses, 708 (90%) of whom stated they had ridden the automated shuttle. The questions included in this survey are presented in Table 5.

Table 5: Tablet Survey Questions

Questions for Riders Only	Questions for All Respondents
Was this your first ride in an autonomous vehicle?	Do you think autonomous vehicles can make travel safer?
Did you transfer to or from a bus or train?	Do you think that autonomous shuttles could complement public transit?
Where did you ride the shuttle?	Are you looking forward to having autonomous vehicles on roadways in the future?
Do you have a more positive attitude toward AV technology after your ride?	What if anything, makes you hesitant about including autonomous vehicles in transportation? *(Optional)*
Please rate your ride:	Are you a resident of Utah?
Did you feel safe?	What is your age group?
Would you feel safe in the shuttle without a human attendant on board?	

The other survey was conducted online and was more general in nature. This survey was aimed at the general public, whether they had a chance to ride the shuttle or not. Online survey data was collected using UTA's Open UTA software for public involvement. This survey received 33 responses, much lower than the on-site survey, demonstrating that direct rider engagement is a more effective strategy for collecting responses from the public. Questions varied slightly between the two surveys, and responses were tracked separately. Questions asked in the online survey are shown in Table 6.

<p align="center">**Table 6: Open UTA Survey Questions**</p>

Open UTA Survey
Are you aware that this shuttle is a fully automated, self-driving vehicle?
Do you think autonomous vehicles can make travel safer?
Are you looking forward to having driverless vehicles on roadways in the future?
Do you think that autonomous shuttles could complement public transit?
What, if anything, makes you hesitant about including autonomous vehicles in transportation? *(Optional)*
Any other comments? *(Optional)*
Are you a resident of Utah?
What is your age group?

5.1.1   Summary of Responses/Quantitative and Qualitative Analysis

The two surveys received a total of 822 responses and collected both quantitative and qualitative data. The quantitative data demonstrates respondents' overall comfort with automated vehicle technology and general understanding of how an automated shuttle can serve as a first/last mile solution. The three strongest positive responses were:

- **98%** felt safe
- **95%** think that automated shuttles could complement public transit
- **95%** have a more positive attitude toward automated vehicle technology after riding

Looking deeper into the results of the surveys, one of the project's goals was to interact with the public to learn if the presence of a shuttle would influence their decision to use transit. This was explored through the following two survey questions:

- Do you think that autonomous shuttles could **complement public transit**? Nearly all people (95%) surveyed said yes. Riders see the potential of a low-speed shuttle to complement transit as a first/last mile solution. This finding should encourage UTA to continue planning for automated vehicles as a future transit mode.
- Did you **transfer** to or from a bus or train? Transferring was not an option for many people because only three of the seven unique public deployment sites were connected to a transit stop. However, the shuttle spent 80% of its days at these three sites, and many of the other sites were also relatively close to transit options if not directly connected. Overall, few riders (13%) used the shuttle as a first/last mile connection. The other riders were mostly using it for the novelty of the experience. Usually, the shuttle ran for a few weeks at each site, and transit riders typically need time to learn about new options and adjust their travel routines. The project team noticed that when the shuttle was at a location for longer, more people started finding ways to use it in their everyday lives and there were more repeat passengers. This finding should encourage UTA to locate future automated shuttle tests at transit hubs and for longer timeframes.

During the Utah Autonomous Shuttle Pilot, a human Host was always present on the vehicle. This person was capable of taking over control of the vehicle and periodically found it necessary to do so, as noted by the number of disengagements. In the long term, the idea behind vehicle automation is to remove the human operator entirely. One of the questions posed to riders was whether they would be comfortable riding without that human attendant. For a no-operator shuttle to be successful, riders must be comfortable using the service. Most riders (82%) indicated that they would feel safe without the human attendant. This positive finding suggests that a no-operator scenario should be evaluated further in future deployments. Further studies analyzing the rider attitude about not having an attendant are discussed in Section 5.3. An evaluation of whether a no-operator deployment is physically practical at the eight deployment sites in this project is discussed in Section 6.3.1.

The surveys also asked respondents an optional qualitative question, "What, if anything, makes you hesitant about including autonomous vehicles in transportation?" A total of 407 participants (50%) answered this open-ended question. The top three themes that emerged were: (1) Nothing, (2) Other Drivers, and (3) Technology/Vehicle Concerns. A sampling of comments across these themes follows.

Theme 1. Nothing: Comment speaks positively about automated shuttle or automated vehicle technology

Future is looking better.

Nothing bothers me about them. I think they would ultimately make the roads safer.

Nothing, we need to get infrastructure and legislation to allow faster implementation.

Theme 2. Other Drivers: Comment mentions wariness of human-operated vehicles

Really, what concerns me most are the cars around the automated vehicle driving disrespectfully. I think it is because they see it as a machine and don't need to worry about offending a vehicle without a driver.

Other drivers not obeying traffic laws, making the automated vehicles have problems.

Human drivers getting distracted.

Theme 3. Technology/Vehicle Concerns: Comment refers to the vehicle's slow speed or performance limits

The vehicle can't think and make decisions like humans.

There are simply too many technological hurdles that still need to be overcome before this technology can be fully implemented.

It is a bit slow and might cause congestion.

A word cloud (see Figure 41) was prepared to process the hundreds of open-ended comments. The word cloud illustrates the main themes and the wide variety of responses, with font sizes roughly indicating the popularity of each word.

Figure 42: Word Cloud Graphic Created from Survey Answers on Hesitance towards Automated Vehicles

According to the Hosts and Ambassadors, the sites where they heard the most positive feedback were Station Park and the University of Utah. Many passengers at these sites stated that they were glad that the service was there and that it added to the other services provided. At the University of Utah, there were many riders who were studying technical fields who asked technical questions about the shuttle and the technology, which the project team was happy to answer.

5.2 Broader Public Reaction

There was no formal solicitation of non-rider feedback as part of this project, beyond allowing people who did not ride the shuttle to still answer the survey. Out of all survey respondents that took the tablet survey on site and did not ride the shuttle (a total of 81 responses):

- 62% said they thought that automated vehicles can make travel safer.
- 79% responded that they think that automated shuttles could complement public transit.
- 68% said they were looking forward to having automated vehicles on roadways in the future.

For the Open UTA survey that was available to anyone online, regardless of whether they rode or even saw the shuttle, for the same questions (and a total of 33 responses):

- 76% said they thought that automated vehicles can make travel safer.
- 88% responded that they think that automated shuttles could complement public transit.
- 76% said they were looking forward to having automated vehicles on roadways in the future.

This is much lower than responses to the same questions for the tablet survey for those who said they rode the shuttle, where (with a total of 708 responses):

- 94% said they thought that automated vehicles can make travel safer.
- 97% responded that they think that automated shuttles could complement public transit.
- 92% said they were looking forward to having automated vehicles on roadways in the future.

This demonstrates that there is a gap between those who were willing to ride the shuttle and who generally have more favorable views of the technology, and those who chose not to. It also supports the finding that when people personally experience the shuttle, they have a higher opinion about vehicle automation. However, the majority of respondents in all cases still had favorable views of the technology. Beyond survey results, while there were no formal protesters as there have been for some other projects, some people walking by and declining a ride just waved it off or made snide remarks.

In addition, there were some people who expressed hesitance of the technology prior to riding the shuttle, but were eventually willing to do so. Anecdotally, these people became more comfortable after experiencing a ride firsthand. Once on board the vehicle, they noted that interacting with the shuttle was more familiar and less mysterious than they had been expecting.

A notable piece of verbal feedback from people who chose not to ride, particularly at Mountain America Expo Center, was that they were interested in the technology generally, but that the application at hand was just for show and not actually useful for them. This was in the context of a simple route that was just for demonstration purposes, outside a conference that likely had many other attractions going on. The lesson from this feedback is that future deployments should strongly consider designing shuttle routes that meet realistic passenger needs, especially for longer-term deployments.

5.3 Rider Trust Studies

The Utah Autonomous Shuttle Pilot provided an opportunity to conduct unique research into rider trust of automated vehicles and the role of the Host. The project team partnered with the University of Utah Applied Cognition Lab – Center for Driving Safety and Technology to conduct rider trust studies during the pilot project.

A number of polls have been conducted over the years to ask whether people are comfortable riding in an automated vehicle. Responses have generally indicated a lack of trust in these vehicles, but it is noteworthy that most of the respondents have neither ridden in an automated vehicle nor seen one in operation. The Utah Autonomous Shuttle Pilot allowed for a detailed study to be conducted among actual riders.

This study was conducted in two phases. In both phases, field work was performed while the shuttle was deployed at the University of Utah. In the first phase, conducted between August 19 and September 27, 2019, riders' opinions were gathered through surveys, and rider behavior was assessed using video footage in the vehicle. Results suggested that the experience of riding the shuttle resulted in a more positive experience and confidence; trust was increased. However, unexpected emergency stops experienced during the ride negatively impacted rider trust. The research also indicated that interactions with the Host increased rider trust and that the Host filled other valuable roles. These roles included helping with boarding and providing information about the vehicle operations.

All the phase one research included a visible Host on board the vehicle. Since the presence of the Host likely impacts the attitudes of the riders, phase two focused on evaluating those attitudes when a visible Host is not present. Phase two research was conducted in August 2020. A series of riders were evaluated through surveys, interviews, and video observation with a visible Host on board. A second set of riders were evaluated with the Host disguised as a regular rider, and the results were compared. Rider trust is impacted by the expectations of the rider, regardless of whether the vehicle operates in a safe manner. Results of the phase two research suggest that automation is very effective at meeting those needs. There was no significant difference between the attitudes of riders with a Host present and those with a disguised Host relative to vehicle capability, response to traffic conditions or obstacles in the pathway, feelings of comfort, and safety. Riders did appreciate that the Host made them feel welcome, provided operational information, and helped communicate the shuttle's intended movements to travelers outside of the shuttle. These results provide valuable insights to automated vehicle developers and operators.

The research reports from both phases of this work are included in Appendix G.

6   Lessons Learned and Recommendations

This project team discovered and documented many lessons learned and made recommendations for future automated shuttle service opportunities. The feedback summarized in this section was obtained through discussions with the project team and core partners as well as via a form and spreadsheet the project team set up to track issues as they occurred. The idea behind this form was that a project team member could pull out their phone while on site and easily and immediately record a thought that should be analyzed further in the future. This form was useful and was used by the project team on occasion, but a simpler version may have been better and used more often.

6.1   Challenges

This project faced many headwinds and challenges during the project period, resulting from both external and internal factors. These challenges had an impact on the project schedule, passenger experiences, and the responsibilities of the project team. While none of these challenges ultimately hindered the overall success of the pilot project, they are worth assessing in more detail, particularly before presenting recommendations for future opportunities.

6.1.1   Government Approvals

Operating a motor vehicle on Utah roads requires vehicle registration and insurance, so the project team engaged the Utah State Tax Commission Division of Motor Vehicles (DMV) vehicle registration process prior to the first deployment. Since the shuttle does not fit within the usual registration categories, the DMV staff had to meet with the project team to establish specific vehicle codes and characteristics and explain the contracting and leasing relationship with EasyMile. The team initially wanted to name the shuttle and have the license plate reflect that name. Once it was decided to not have a name, a personalized license plate reading "UTAH AV" was decided on instead. The DMV staff were able to accommodate the project team's registration and issue the requested personalized license plate.

On the Federal government side, the 35-day Federal government shutdown of 2018 to 2019 hindered the ability of the project team to obtain NHSTA approval for the first site by the time the project was originally supposed to launch in April 2019. This shutdown was entirely outside of the project team's control, and it added significant uncertainty for planning a project launch at the beginning of the project. Ultimately it delayed the project by approximately a month, which was added on to the end of the contract.

When the federal government resumed, the project team waited for the NHTSA review process to catch up on the backlog of approval requests. NHTSA's involvement reviewing each site was a unique and important safety oversight feature of the project. The project team members had to remain flexible while NHTSA was also learning how to shape the safety review needed for this new and emerging technology. Within NHTSA during the time of project approval requests, changes in oversight delegation roles sometimes added time in the review and multilevel approvals process. In some cases, the project team had to communicate directly with NHTSA to prioritize reviews for key venues that had significant calendar scheduling sensitivity. The typical approval time ranged from four to eight weeks after the Site Assessment Report (SAR) was submitted.

NHTSA's approval process was also temporarily halted after a passenger incident at another EasyMile deployment in Columbus, Ohio. This incident led to NHTSA requiring a nationwide shutdown of all passenger service by EasyMile. While NHTSA was reviewing the incident to determine when EasyMile service could be restarted, the COVID-19 pandemic began. The project team consequently had two sets of changes to implement, responding to

both NHTSA safety recommendations and new health/cleaning guidelines plus reassuring UTA and UDOT leadership that it was prudent to resume service with modifications. Altogether, these factors meant there was no passenger service between February 25 and July 5, 2020. On July 6, 2020, service was restarted for the final nine weeks of the contract with new protocols in response to COVID-19 (see Section 6.2.5).

6.1.2   Balancing Priorities

There were many advantages for UDOT and UTA to pursue this project together instead of having two separate undertakings. Being able to work together on finding locations, developing communication strategies, and learning about the vehicle made the process easier for both agencies. Moreover, combining UDOT's expertise in CAV technology, traffic management, and road infrastructure with UTA's knowledge of customer needs, daily operations, and vehicle performance standards meant the project team was well equipped to plan and oversee the project. However, there had to be compromises from both entities in order to meet the goals they brought to the project, and some approval items took longer because they had to go through both executive teams. Overall, the benefits outweighed the disadvantages, especially given the nature of a pilot project.

It was a valuable and productive approach for UDOT and UTA to rotate the shuttle across eight locations within a relatively short period of time, given the goals of this project. However, doing so brought many logistical challenges to overcome, and a less ambitious plan (with fewer locations over the same period of time) would likely be a better approach for most agencies.

For other agencies deciding where and how long to deploy a shuttle, the focus should be on the goals of the project and how a deployment location (or multiple) might address these goals. For example, if a project's goal is to increase exposure to a technology or see how an automated shuttle operates in different environments, having it rotate across multiple different locations for a short duration each serves that goal. However, if the goal is to see how this technology would serve as a more permanent transportation option, for example addressing certain specific first/last mile needs, then having a longer deployment at fewer sites, or just one, would better meet that goal.

If both goals are of interest, increasing the overall project length would allow for the benefits of both strategies to be realized. This includes being conservative with schedule and time estimates, especially for planning and site approvals. Having a vendor confirmed at least six months prior to initial deployment would help, as they could then actively be involved in the setup and approvals process. For multiple sites, providing at least a three-month lead time for each site deployment, even for short-term demonstrations, is essential. If multiple sites will be served, setting distinct criteria for accepting sites that consider the lead time required, political and other external considerations, and the desire to reach out to new audiences will help streamline the process of site selection and make sure the goals of the project are met.

After the launch of shuttle service, the project team received many requests from government officials, site owners, and conference planners to have the shuttle brought to their site. Because of the constraints of site planning, most of those requests had to be turned down. Having a clear timeline and approval criteria at the beginning of the project would have made those conversations easier.

There were many tasks that needed to be completed before launching at any site, which made it difficult to look back and review successes during the project period. Looking back, it would have been more beneficial to do more follow-up directly after the shuttle was at a site to get feedback when the learnings were still fresh, rather than

needing to move focus immediately to the next site and then circling back after all site deployments were complete.

6.1.3   Vehicle Technology Limitations

As others who have piloted automated shuttle technology have noted, these vehicles are continually advancing but still have significant limitations, including:

- Low speed, capped at a maximum of 12 mph.
  - o This is due to the conservative nature of the automated vehicle system rather than a limitation of the vehicle itself, as the vehicle can travel faster but is not programmed to do so at this time while the automated vehicle system is still under development and evaluation.
- Inability to move around obstacles without human intervention.
  - o The vehicle is designed to stick to its trajectory.
  - o It looks like a bus, but it runs like a train on a virtual track.
- Requires frequent disengagements for human control.
- Battery life, particularly when the air conditioning system is being utilized.
- Programmed stop locations that need to be adjusted after initial route setup to enhance passenger comfort and ramp landing area.
- Sensitivity to landscaping.
  - o There is a need to mow grass, trim trees, or similar landscaping maintenance more often, as changes in vegetation growth were sometimes identified by the shuttle as potential hazards, causing it to slow down.
- Need for signs or other objects to support vehicle localization, especially in areas with few existing structures.
  - o The signs take a significant amount of effort to deploy and clean up on each service day.
  - o Having more signs on site than a project team anticipates using is a good strategy to ensure that if more signs are needed, there is no significant delay in acquiring them.
- Weather limitations.
  - o Weather can limit both the ability of the vehicle to operate and in identifying suitable storage and charging locations.
  - o The shuttle can have problems operating in windy or dusty conditions as well as other previously known weather limitations such as rain and snow.
- Challenges with interactions with other vehicles and pedestrians.
  - o Vehicles or pedestrians cutting close meant the shuttle would slow down or stop.
  - o Abrupt close calls resulted in sudden emergency stops.
- LiDAR detections on slopes can limit the ability to detect actual objects, especially at grade changes and transitions to flatter or steeper slopes where the LiDAR detects pavement surfaces ahead and the algorithms identify the pavement as an obstacle.
- Sensitivity of LiDAR system algorithms can cause the shuttle to stop for minor obstacles, including rain droplets and snowflakes.
  - o In general, the filtering software used to determine what the LiDAR sensors have detected is not advanced enough to prevent abrupt stops for tumbleweeds, insects, and other minor obstacles. This creates an unacceptable safety risk at higher speeds, but is functional and safe at lower speeds of 5 mph or under.

- The time it takes to transition back from manual to automated mode (approx. 30 seconds).
- Although rare, there can be interference with localization if there are live TV feeds nearby.

EasyMile and other automated shuttle vendors are actively striving to resolve many of these limitations, but the timing on when a more sophisticated product could become available is currently unclear.

Within these limitations, the shuttle needs a very simple environment to run safely. Private roads with low speeds and not much through traffic are the best environments, ideally on an entirely dedicated right-of-way. Other environments that have suitable routes are not always a good fit with interacting with the mobility and function of existing users. For example, parking lots do provide lower speeds, but also additional challenges, especially from larger vehicles that stick out of a normal parking stall or related to traffic coming from many different directions. It is important to note that expectations need to be set for both site partners and passengers that the technology is safe but not quite as capable as they may hope or expect.

Unlike other transit vehicles that return to a garage for storage and maintenance, the shuttle needs to be stored on site very close to its route. Agencies planning to deploy automated shuttles need to consider how to provide maintenance, repair, cleaning, charging, and other services to vehicles at remote locations. This represents a major shift in their normal logistics and operations. Usually, the shuttle is driven manually to its storage location, but this route could also be programmed in if it were short enough and within technological capabilities. For now, accessing the storage location in automated mode would probably mean having a dedicated lane and/or educating other drivers that the automated shuttle has the right-of-way.

Overall, the automated shuttle drove itself almost the entire time it was moving. When Hosts needed to step in, they would pause operations to let something happen and then restart in automated mode rather than driving manually for a stretch, which kept the proportion of automated operations by distance traveled high (at over 99%) but may have caused a higher number of disengagements.

6.1.4　Accessibility

The automated EZ-10 ramp, shown in Figure 50, was deployed for both demonstration purposes and to allow passengers to board the automated shuttle when they needed it. The ramp facilitated the boarding of passengers in wheelchairs, with walkers, or with other mobility impairments. Feedback was solicited from the UTA Committee for Accessible Transportation (CAT) at Station Park. In addition, the National Federation of the Blind (NFB) and The Utah Council of the Blind (UCB) participated in an open house with a group of people who are blind or have impaired vision at the 1950 West site.

Figure 43: Ramp in the Deployed Position

Based on lessons learned on this project and previous transit experience, UDOT and UTA have the following recommendations for future vehicle design:

- Ramps should have a raised edge at least 1.5 inches high for riders with visual impairments and canes, per United States Department of Transportation ADA Specification 49 CFR §38.23(b)(5).
- External stop announcements are needed for riders with visual impairments.
- A two-strap wheelchair securement system would be preferred. It would be even better if it were automatic.
- The ramp slope should be made less steep, especially because infrastructure constraints preclude the ability of the shuttle to be able to "kneel" at some stops, which made it challenging for some riders to step into and out of the shuttle and was uncomfortable for those in a wheelchair to use the steep ramp. The slope of the ramp was especially problematic in locations where there was not a raised curb alongside the travel path for the ramp to land on.
- Internal stop announcements should be stop-specific, rather than the generic announcements.
- Ramp deployments should be automatically logged.
- The external Braille button was incorrect, reading "door" instead of "ramp." Verification of internal and external Braille for redundancy and accuracy should be implemented in future vehicle designs.
- The vehicle is too quiet, given that it is an electric vehicle and riders with visual impairments are used to being able to hear the approach of, for example, a 40-foot diesel bus. Suggest a distinct, consistent artificial engine sound, particularly for station approaches.

- The ramp needs to be kept very clean to be functional. Hosts dusted it off often, but there were still a few issues with the ramp being out of service during the project period because of dirt in the ramp mechanism. A less sensitive ramp would lead to less downtime for maintenance and repairs.

Overall, with these limitations, the EZ-10 shuttle is accessible, but not ADA-complaint. EasyMile is working on improving these features, but it is still worth noting as the need has been reinforced through stakeholder engagement for this project.

6.1.5   Real-Time Data

The project team had originally wanted real-time shuttle location data to be a project requirement. However, EasyMile was not originally able to access this data because it was handled through a third party and the firewall would get in the way. Meeting this requirement ended up taking months to address, and during this time there was a struggle on how to keep people informed of the shuttle location and arrival times. If they could not see it, riders were not sure when the shuttle would be back. Even when an Ambassador was there to help, they were not always able to communicate with the Host. The project team tried radios and walkie-talkies to enable conversation between Ambassadors and Hosts, but sometimes there was no service. Hosts ended up using their own personal cell phones to communicate with the Ambassadors. They were cautious about this because they did not want the passengers to feel that the Host was distracted, but it generally worked. This was still limited, however, because if there was an issue with the shuttle, the Host would be busy trying to fix the situation and did not have time to also communicate with the Ambassador.

Real-time information was eventually provided at the final University of Utah route, as shown in Figure 43. This information could be accessed by Ambassadors, Hosts, and all members of the public with Transit App or Google Maps installed on their personal devices.
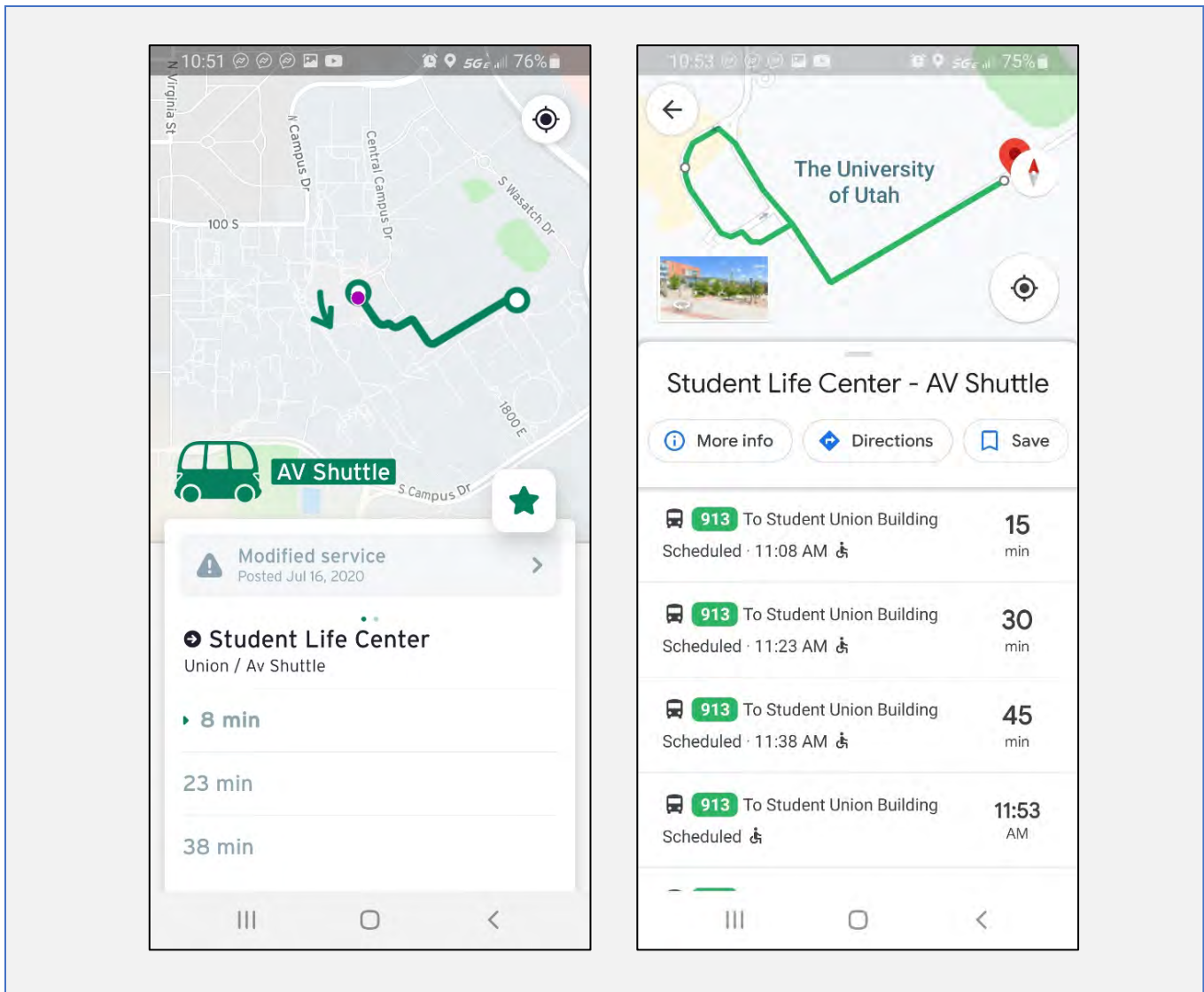
Figure 44: Real-Time Location Information on the Transit App and Google Maps

6.1.6 Passenger Incident

As mentioned in Section 3.4, a passenger was slightly injured at the 1950 West site when the automated shuttle made an abrupt stop and the passenger slid out of their seat. As soon as the incident happened, the Host stopped the vehicle and attended to the passenger's needs. UDOT and UTA put the Crisis Communications Plan (as shown previously in Figure 22) and the Incident Response Plan (see Figure 52) into action. EasyMile then reviewed the system data log and the onboard video to assess what happened and to verify that the sensors and drive system did not malfunction. This incident occurred in the afternoon, and shuttle service was suspended for the rest of the day. Members of the project team also met with the Host and the injured passenger the next day to share concern for their well-being and review what happened.
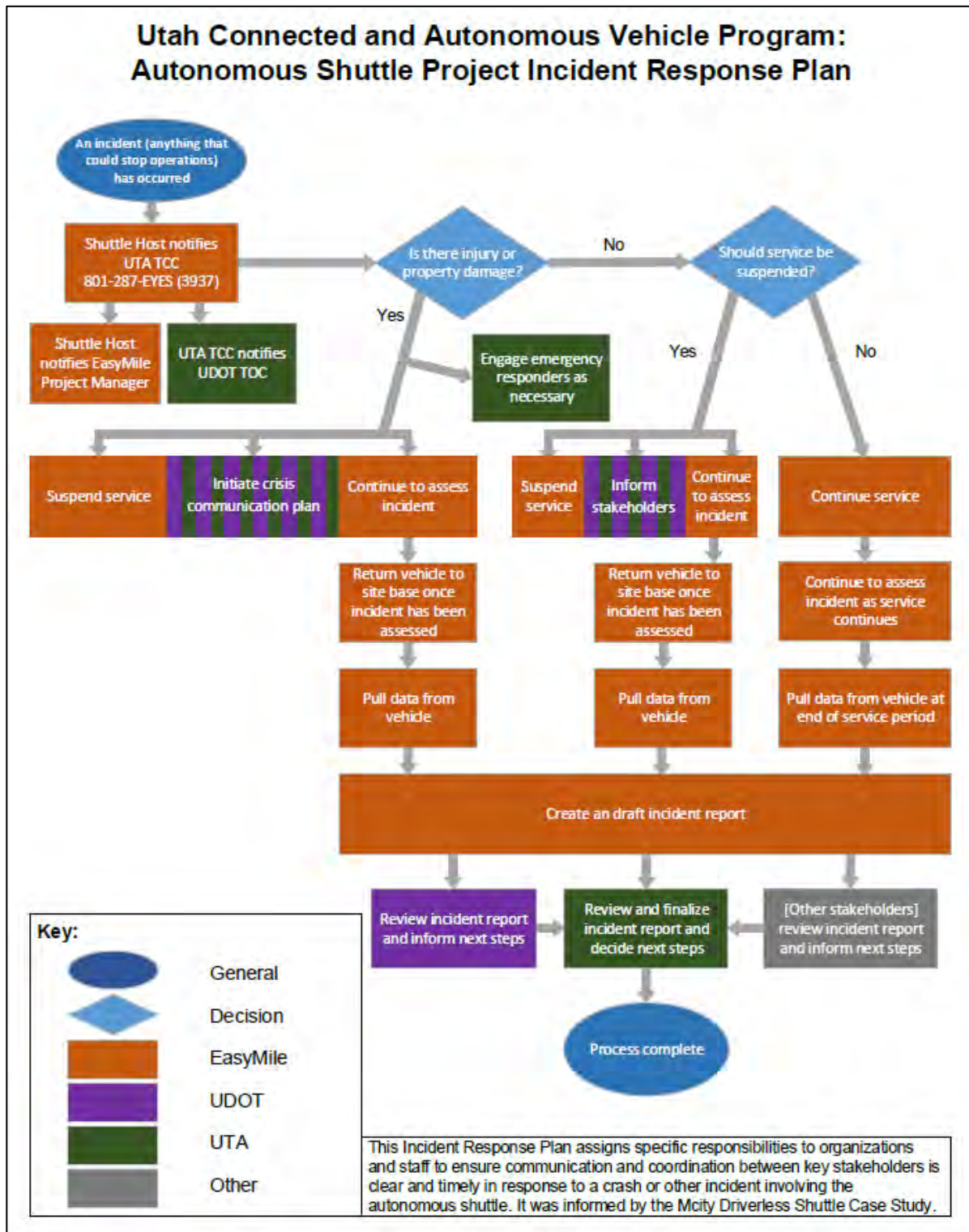
Figure 45: Incident Response Plan

The project team tested the shuttle on the route without passengers to ensure there were no underlying issues, and none were detected. By noon of the following day, service had restarted with new procedures and new signs in place.

This proactive strategy allowed the project team to identify the issue and implement new operating procedures to prevent the occurrence of a repeat incident. In addition, the project team prepared talking points before the media reached out. When the media did reach out, the project team invited them to visit the site to see that the shuttle was already safely running again, demonstrating that they were proactively managing and assuring the public of the shuttle's safety features.

Mitigations that went into place include:

Figure 46: Seatbelts and Less Slippery Seating Surfaces Installed on the Shuttle

- The Host began instructing riders on the proper seating position, encouraging the use of rear-facing seats and keeping both feet on the ground even while seated.
- The maximum shuttle speed was reduced from 12 mph to 10 mph.
- A new warning sticker was added to the shuttle for passengers and other drivers to see, stating that the shuttle may abruptly stop on short notice.
- Higher-friction seating surfaces were added to the seats so they would be less slippery. These surfaces, essentially white sticky tape, are shown in Figure 45. This figure also shows seatbelts that were added to the vehicle later, after a similar incident occurred at a different automated shuttle deployment in Columbus, Ohio.

Nearly all automated shuttle emergency stops (90%) happen at low speeds of 1 to 5 mph and are hardly noticed. An emergency stop at a higher speed can impact riders, and in this case the shuttle emergency stopped while moving at 11 mph. One thing the project team learned through this incident was that while the automated shuttle is good and consistent in stopping when it needs to, it faces more challenges in filtering and differentiating between, for example, a leaf and a bird and not stopping when it does not need to. This is an aspect of the technology that should improve and get better over time, but for now the vehicle sometimes stops abruptly. In this case, the vehicle did what it was supposed to do, just not for the right reasons.

Another major challenge is communication. When a human-driven vehicle stops abruptly, the driver is there to tell you why it stopped, but the shuttle cannot do that in all cases. EasyMile can pull the logs and see the detected obstacles, but that is not available immediately and may not fully answer the question of why it stopped.

Another recommendation for future vehicle design that came out of this incident is a second-level audible warning that tells of a sudden stop and/or can alert other vehicles to avoid impending collisions. The second use case would require more of a horn and not the same trolley bell that currently exists.

6.1.7   Service Availability

Service availability compares the amount of time that service is scheduled to the amount of time it can actually operate. For the automated shuttle, overall it was available around 89% of the time it was scheduled. However, this varied across locations, with 99% availability at Station Park and 86% at 1950 West. In St. George, the shuttle was available 100% of the time because weather was favorable, the deployment was just a few days, and there were no maintenance issues. At the University of Utah, availability was just 76% of the time because of multiple maintenance issues. Service availability was not tracked at the other deployment sites.

To maintain reliability, transit service generally should be available at least 95% of the time. The automated shuttle did not quite get there, even with a much simpler environment and much more attention than most of UTA's buses.

Availability is generally reduced due to maintenance needs, inclement weather, or labor issues (i.e., a driver does not show up when they are scheduled). The first two reasons were the primary causes for the lower availability during the Utah Autonomous Shuttle Pilot. Availability was especially hindered by only having one shuttle and no spare.

Having a Deployment Engineer on site meant that maintenance issues could be responded to more quickly, but they often were still not a same-day fix, especially when software updates were involved or specialized parts were needed. This is similar to UTA's experience with electric buses. While electric vehicles fail less often, when they do fail it is usually both hardware- and software-related and not an easy or quick fix.

Another challenge was maintaining the full scheduled day of service within the limitations of the battery. When the EZ-10 battery reaches 15%, it can no longer be operated in automated mode and must be driven back to the storage location and charged. While this is important to ensure the shuttle is not stranded, a lower threshold would have allowed higher service availability, particularly at Station Park where an additional 10% (down to 5%) would have been sufficient to provide the additional hour of service needed to maintain the full-service hours on hot days with high air conditioning usage. The heater did not use as much battery as the air conditioning, in part because the many windows allowed sunlight to warm the cabin. This benefit may be reduced in other locations with less sunny winters or when service is provided during nighttime hours. There were also times when the shuttle did not fully charge overnight, so the shuttle started out the day at a disadvantage.

Weather limitations of current automated shuttle technology have been well documented in other pilot projects, most notably in Minnesota. The Utah Autonomous Shuttle Pilot did not plan for as many operations during the winter. When it did operate in the winter, snowstorms in Utah are generally short, so often the team would simply pause operations until the storm had passed. If snow happened during the final two hours of the shift, they would end service for the day.

6.2 Successes

Beyond overcoming the challenges that were faced, this project experienced many successes that enabled it to proceed, while still providing the project team with opportunities for lessons learned. The Utah Autonomous Shuttle Pilot met all six goals originally identified by the project team. The project successes are briefly described in this section.

6.2.1 Partnerships

As has been mentioned throughout this report, the strong partnership between UDOT and UTA was essential to the success of this project. However, other partnerships were valuable as well. The project team received a high degree of interest and cooperation from potential site partners throughout the state and worked with many groups of people to make these deployments happen. This included partnerships with other public agencies as well as private partners, enabling the shuttle to be exposed to a broad cross-section of the public and resulting in a large number of riders. The stakeholders listed in Appendix F were integral partners and contributed to the success of this project. These successful partner relationships suggest that there may be many more opportunities for public-private partnerships to enable services like these in the future. If there had been more time in the project schedule, the project team would have desired to serve even more sites and stay at some of the sites for longer.

Another essential partnership was with EasyMile. Pilot programs like this one help not just the public agency learn about the technology, but also help companies like EasyMile learn about what clients want and improve their technological offerings accordingly. EasyMile uses learnings across sites to determine what can be improved, what features clients need, and how this matches with what is feasible within their product development plan. EasyMile uses this feedback to directly influence what is next in their road map. Software updates are released approximately every six months and are sent out to every deployment site at that time. Some of these updates, particularly related to sensor calibration, were even implemented during the project period in Utah, and the Deployment Engineer and other on-site staff noted the enhanced capabilities these improvements provided.

One example in particular where EasyMile has improved the shuttle in response to client feedback is accessibility. EasyMile has taken feedback from clients and used it to make changes. They now have a kit to add rails to make the ramp ADA-compliant.

6.2.2 First/Last Mile Connections

Three deployment sites directly connected UTA's train and bus services to destinations, and another two were close to transit but not close enough to effectively facilitate a connection. At the three that connected directly to transit, an average of 15% of riders used the shuttle to connect to transit: 16% at Station Park, 14% at 1950 West, and 11% at the University of Utah. At the two that did not really facilitate a connection, an average of 5% of riders used the shuttle to connect to transit: 8% at Canyons Village and 3% at Mountain America Expo Center. This demonstrates that an automated shuttle can be effectively used as a first/last mile option when the route is connected to established transit service.

In Section 5.1, it was noted that 95% of the shuttle riders surveyed believe that an automated vehicle shuttle can complement regular transit service, and 79 to 88% of non-riders surveyed also believe this. In addition to the measured transit connections mentioned above, these survey results indicate that the public supports this type of enhancement to transit service.

At the Dixie Convention Center, 0% of riders connected to transit. Similar survey data was not collected at the Utah State Capitol, though it is possible that some riders at that location connected to transit, nor was it collected at the Utah Driver's License Test Track, where transit was not an option.

If the shuttle had been at any of these locations for longer, it is likely that more routine trips would have occurred, as there were already repeat riders within these short project periods. However, for the short duration of each

demonstration, most riders were there primarily to experience a self-driving vehicle and came to the site specifically for that purpose.

6.2.3   Connected Vehicle Technology (V2I Testing)

One of the original goals of the project was to test the capability of the shuttle to wirelessly communicate with traffic signals using Vehicle to Infrastructure (V2I) technology. This capability was tested in a UDOT parking lot with a portable signal controller and roadside unit, shown in Figure 54, and then further demonstrated at the UDOT Test Track, where a fixed traffic signal was used to send stop and go commands to the shuttle's onboard unit. These tests were successful. Descriptions of the testing and the results are included in Appendix E.

Figure 47: Portable Traffic Signal Controller and Roadside Unit

6.2.4   Signage

Signage was deployed at all deployment sites to advertise the presence of the shuttle, increase safety by alerting other drivers and pedestrians to its presence, and provide localization indicators to aid shuttle navigation. These signs included sandwich boards, additions to existing bus stop signage, and traditional street signs that were temporarily placed on the roadside. Since the shuttle does not read the text on the signs, the new localization signs did not need text on them, but the project team felt that appropriate text could provide both localization to

the shuttle and information to drivers and pedestrians. Many of the small, temporary informational signs, such as the sandwich boards, had to be installed daily. While it was sometimes a hassle to put up this signage every morning and take it down every evening, the signage did increase awareness, as intended.

To design these signs, the project team reviewed options for traffic sign designs that conform to the Federal Highway Administration's (FHWA's) Manual on Uniform Traffic Control Devices (MUTCD). The project team engaged in a traffic engineering brainstorm effort to develop and decide on the message, shape, and color formats to use for the localization and street traffic warning signs. The FHWA Division Office advised against using any symbols, since those go through many levels of review and adoption, and encouraged the use of word messages instead. The warning signs for drivers read "WATCH FOR AUTONOMOUS SHUTTLE," with black letters on a yellow background in a diamond shape.

Designing the localization signs were somewhat more challenging. EasyMile specified a sign that was 5 feet in height and at least 24 inches wide, situated next to the roadway centered 10 feet above the roadway. These signs are only for the purpose of the shuttle using LiDAR to "see" waypoints along a route when there are not many vertical objects. The shuttle only needed to see the shape of the sign; the words and color are irrelevant to the LiDAR. Even though warning signs are usually limited to a diamond shape, except as specified, the project team decided to maintain the use of the warning colors of black letters on a yellow background on rectangular signs. These localization signs were deployed on low speed, low-volume streets, parking lot aisles, and mixed-use pathways. The project team came up with a message to fill the space of the needed dimensions, and the sign design made it fit to 60 inches tall by 30 inches wide. Tall Telespar poles were needed to make the height work, while maintaining proper clearance on the bottom of the sign. The localization signs read, "LOW SPEED SHUTTLE ROUTE-USE CAUTION."

For a permanent deployment, the project team would recommend revisiting the sign color scheme and conducting more evaluation to determine the best category to align the color scheme appropriately. Deployments in other states have used a variety of noncompliant signs for highway signage – some have used the guide sign white letters on a green background, and others have used motorist information signs with white letters on a blue background.

In addition to physical signs, information was relayed to riders using an onboard video and paper flyers that were offered to potential riders. Photos of station signage, roadway signage, onboard information, and paper flyers are included in Appendix A.

6.2.5   COVID-19 Response

Once service relaunched in July 2020, the team implemented a number of procedures in response to COVID-19. These procedures followed UTA's guidelines for COVID response and were similar to what UTA was doing for their other routes.

Under these new procedures, the shuttle was limited to four seated riders and no standing riders (other than the Host), to accommodate social distancing. Masks were required of all passengers and the Host, the windows were kept open whenever possible, and enhanced cleaning procedures were implemented – particularly for all touch points. This included the frequency of cleaning and how cleaning was conducted. Lastly, new signage was deployed to inform riders of these new procedures.

6.2.6   Public Perception and Overall Enthusiasm

As noted in the rider surveys, the public overwhelmingly felt comfortable with the shuttle, and those who did not ride it indicated that they were still excited for automation technology to become part of the transportation network. Site owners were uniformly excited and cooperative about this technology. This overwhelmingly positive response exceeded the expectations of the project team.

While there was no major pushback, there were some passersby who chose not to ride the shuttle due to apprehension about the technology as well as some unenthusiastic media coverage. As with any emerging technology, there will be a transition period, and it will take some time to build trust and buy-in for any longer-term pilot projects in the future. It was noted by some stakeholders that having an additional educational outreach plan prior to deployment may be beneficial to help ease any uncertainty the public may have.

Overall, most people were genuinely excited to board the automated shuttle. Ninety-two percent of riders had never been in an automated vehicle. People took selfies with the shuttle, and school children marveled at it. The media wanted to cover its debut. Hosts and Ambassadors were peppered with questions on how the technology worked. The advent of CAV technology is inspiring, and many people were enthusiastic about personally experiencing a self-driving vehicle for the first time. This made for a productive and enjoyable testing environment.

6.2.7   Insights into Rider Trust

As described in Section 5.3, detailed studies were conducted into the factors that lead riders to trust automated vehicle technology. These unique studies led to some new insights about the attitudes of riders, the role of the Host, and the factors that may cause the rider to trust the vehicle without a human attendant. Future deployments can build upon this research and help guide the industry toward shuttle service without a Host.

6.3 Future Pilot Project Recommendations

The variety of experiences provided by rotating the shuttle across multiple locations in Utah helped reveal the best types of environments and routes for a longer-term temporary or permanent deployment of an automated shuttle. It also maximized exposure of this technology to a broad cross-section of the public. This section presents the resulting recommendations to improve pilot projects and to turn them into full-service deployments. The biggest needs for a successful service, particularly if it is providing a first/last mile connection, are reliability, accessibility, and frequency so that service is consistently provided when it is planned to passengers with varying abilities without a long wait time. If these attributes can be ensured, automated shuttles could be included in the suite of options that a transit agency considers when implementing a new transit service.

6.3.1   Assessments of No-Operator Service

During the Utah automated shuttle deployments, there was always a Host on board the vehicle when riders were present. Having a Host on board adds cost to the service, making it less cost-effective. If a Host is always present, it is more practical from a cost perspective to use a conventional, nonautomated (and less expensive) vehicle for this service.

EasyMile was tasked with evaluating the feasibility of a no-operator (no-op) service at each of the deployment sites during the project. This effort identified the modifications that would be necessary at each site to enable a no-op service. These insights enabled the project team to better understand the potential for shuttle operations on a longer-term basis.

This type of service could be supported by teleoperation or a remote staff member who can see inside and outside the vehicle and step in if needed. Longer term, this remote staff member could be monitoring a small fleet of up to three shuttles at a time. Remote operations would be facilitated by wireless communications and onboard camera systems.

While EasyMile has deployed no-op service at other locations, all the sites in Utah were considered too complex to achieve no-op without modifications. The criteria to be no-op are very conservative and restrictive. Given the shuttle's current limitations, there are a lot of criteria that would need to be met, including:

- Dedicated right-of-way.
- Limited interactions with other vehicles.
- Shuttle has priority over other traffic.
- Prevention of obstructions from parked vehicles or delivery vehicles.
- Limited conflicts with pedestrians, bicyclists, skateboarders, and other travelers.
- No construction activities in the proximity of the travel path.

Unfortunately, these restrictions suggest that the most successful sites from a passenger service perspective are also the least likely to be no-op in the near future. Summaries of the assessments of each site are presented in Table 7.

Table 7: Site No-Op Assessments

Utah Driver's License Test Track	This site did not receive a formal assessment. While it is likely the closest site to being ideal for no-op, it is also the least useful site from a passenger needs perspective.
Canyons Village	This site did not receive a formal assessment.
Station Park	Not recommended by EasyMile without significant mitigation. Challenges at this site included: • Street design: close quarters, narrow lanes, sharp turns. • Ample parking: many obstructions and risks. • Demographics: mostly joy riders and not enough commuters.
1950 West	Not recommended by EasyMile without significant mitigation. Challenges at this site included: • Storage location: need secure, indoor storage space for charging. • Traffic uncertainty: clarify driving behavior using paint, road markings and signs. • Parked vehicles: landscaping and delivery vehicles often obstructed the shuttle's path.
University of Utah	Not recommended by EasyMile without significant mitigation. Challenges at this site included: • Congestion on Student Life Way: too many converging vehicles. • Improper/illegal parking: high interference. • Bicycles, skateboards, and scooters: zooming past the shuttle at close range is unsafe.

	• Construction: an unavoidable reality, but lack of communication caused service delays as the shuttle re-routed.
Utah State Capitol	This site did not receive a formal assessment, but given that it is on a separated path, it could be a viable candidate.
Mountain America Expo Center	This site did not receive a formal assessment, but EasyMile informally recommended that it could be a viable location.
Dixie Convention Center	This site did not receive an assessment because it was a pure demonstration deployment.

The ability of the shuttle to deviate several feet left or right along a route to avoid an obstacle would likely make no-op service much more feasible, even if this required remote support. If a no-op service were pursued in the future, there would likely still be a staff member on board at the beginning of a deployment to help educate riders on the automated shuttle and answer any questions they may have. This would be similar to an Ambassador role, and they would likely not need to be there long-term.

Not having a staff member on board could lead to safety concerns for some riders. An internal camera would need to be in place and monitored during operations to be able to stop the shuttle if a concern arose. In addition, there could be rotating staff members on board at times to increase comfort levels. They could move through the system as needed, both at station locations and onboard vehicles.

6.3.2   Cost Assessment

There were many costs involved in this project that would not be needed for a longer-term deployment, as they provided valuable research and outreach support, but that would not be necessary after a project and assessment period. Therefore, this section looks just at the capital and operational costs of a single shuttle to provide a comparison of the expense of implementing a new automated shuttle relative to the costs of more traditional transit service.

These estimates assume that the automated shuttle no longer requires a Host on board each vehicle at all times, though it is supported by a remote operator who is monitoring multiple shuttles. The total capital and operating cost are estimated to be approximately $400,000 for one automated shuttle running about 30 hours per week for the first year. Costs decline after the first year when only operational expenses apply.

The biggest cost is the approximately $230,000 purchase of the shuttle. This cost could change based on the vendor selected or changes in vehicle developments. Beyond the vehicle costs, in general, automated shuttles need very little infrastructure changes to operate in a simple environment – when there is a Host on board. Without a Host, more infrastructure changes would be needed. Finding an existing environment that meets the constraints of safely operating without a Host on board would be optimal from a cost perspective, as the costs to upgrade infrastructure would likely be high and possibly cost-prohibitive. Any infrastructure improvements required to enable operations without a Host, such as physically separating a lane or smoothing the road, are additional capital costs.

Operational costs are estimated at approximately $170,000 per year. This estimate consists of $60,000 per shuttle mainly for a full vehicle maintenance contract and software licenses and $110,000 in fixed labor costs that could be spread across two to five shuttles. The cost for charging the automated shuttle is assumed to be only $2 a day, based on project results.

A service performance analysis is presented in Table 8. Goals are targets based on UTA's actual data as of August 2020. Cost estimates are forward-looking, assume teleoperations are possible, and include only operating expenses; they do not factor in capital costs or one-time start-up expenses. Within these assumptions, automated shuttle operations could potentially provide first/last mile service at a lower cost per hour, cost per mile, and cost per rider than existing UTA services to complement existing bus and train routes. The project did not meet its goal of 100 riders per hour, so a suitable route would need to be identified for this goal to be met in the future. In addition, service availability and the proportion of operations that were automated were slightly lower than UTA's goal, so the technology would likely need to evolve before this scenario would be possible – especially since it assumes there is no Host on board. Lastly, the project had a goal of zero avoidable accidents, and there was one.

Table 8: Preliminary Service Performance Analysis

Metric	Utah Autonomous Shuttle Pilot		Goal
Efficiency and Effectiveness			
Cost per Hour	$22.61*	✔	$41.97 *(UTA system ongoing operating expenses, including wages and benefits)*
Cost per Mile	$1.79*	✔	$1.89 *(UTA system cost to maintain, fuel, and repair)*
Cost per Rider	$2.31*	✔	$5.88 *(UTA bus comparison)*
Avg. Daily Boardings	57	✖	100
Avg. Riders Per Hour	10	✔	10
Service Quality			
Service Availability	91.1%	✖	95.0%
Automated Operation	98.6%	✖	99.0%
Safety			
Avoidable Accidents	1	✖	0

Estimated future costs

6.3.3 Sustainability Potential

This section lays out different options to meet the costs presented in the previous section. The two primary ways to generate revenue service are through payments from passengers or funding from a partner, sponsor, or grant.

6.3.3.1 Fare Payment

For this pilot program, the project team was not able to test charging fees or fares to passengers, but this is a high-priority component to include in any future pilot projects in order to fully evaluate this type of service. The most likely method would be electronic fare collection using UTA's existing tap on/tap off electronic payment service. However, there would likely need to be other options, including cash paid off-board at a kiosk, for some passengers.

The revenue potential of fares is limited because transfers are free within the UTA system, so if an automated shuttle were deployed primarily to link riders to or from a transit station, there would not likely be a fare collected, as it would already be included in their original ticket.

A low fare could be implemented for a system that was primarily designed for passengers just wanting to make short trips, such as a circulator service. Downtown Salt Lake City has a free fare zone, so a fare would not be collected for any deployment within this area, but this would be possible in other areas.

6.3.3.2 Other Long-Term Sustainability Options

Deploying and attracting passengers to an automated shuttle service could be bundled with a campaign to encourage people to ride other UTA transit services. Encouraging this end-to-end transit usage will help areas continue to grow, help with parking constraints, and increase overall ridership and revenue for UTA.

There are many creative ways that UDOT and/or UTA could find partners to help invest in an automated shuttle service. There will likely be interest from private partners, and there will also need to be a local investment (city or county) component, or at least local buy-in and approval. Types of potential partners could include:

- Property developers – especially if they are engaged early on and can design their new properties to meet the constraints of automated shuttles.
- Universities – both to help students move around campus and to enable research.
- Utility companies – particularly for the electric vehicle component, as there are programs that help deploy charging infrastructure for electric vehicles.

Grants and pooled funding are also good options, but they tend to be competitive. In the long term, and to allow for grants and other Federal funding, a deployment would need to be compliant with:

- Americans with Disabilities Act (ADA).
- Federal Motor Vehicle Safety Standards (FMVSS).
- Buy America Act.
- Title VI of the Civil Rights Act.

The project did not need to be compliant with these items because it was a limited pilot operation and was funded with local funds, but these are important components for any future service. The EZ-10 shuttle in its current form is not compliant with any of these three standards because it is accessible but not fully ADA compliant, requires an exemption from FMVSS due to being designed from the ground up as a specially made automated vehicle, and is built at EasyMile's headquarters in France. Some other automated shuttles meet some of the requirements, and it is recommended that all vendors continue to strive to meet all four in order to be able to work with public transit providers on a longer-term basis in the future.

The potential of this technology is that while there may be higher capital costs, these would be offset by lower operating costs, both because the vehicles are electric and because they allow a reduced staff presence. This is similar to one of the reasons why trains can be more effective than buses, in that they allow a transit agency to carry more customers with fewer staff. Generally, finding funding for capital projects is less challenging than finding an ongoing source to fund operating costs, so shifting this burden could help UTA launch a service and then support it with existing operating funds.

UTA sees potential for automated shuttles to complement its transit network by serving first/last mile connections or 1-2 mile circulators that are unsuitable for regular bus routing. For example, routes that are short and repetitive, such as those with a total run time of 10 minutes, are boring for drivers but ideal for automated shuttle technology. These shorter routes would feed into UTA's existing transit system, providing access to more riders in more locations.

In general, a service will attract riders and be more sustainable if it runs for 12 months or more at a location. From previous transit experience, it usually takes about four months for businesses and residents to start using a new bus route after it is put into place, so it will likely take this long to really see the impact.

6.3.4   Future Locations and Use Cases to Explore Further

There are many potential future locations and use cases for automated shuttles in Utah. In general, high-level attributes of a good route include:

- A total distance of under 2 miles.
- Low traffic speeds and volumes and other characteristics of a simple traffic environment.
    - This may include a parking lot, though parking lots are also more complex and unpredictable in other ways, particularly when it comes to traffic behavior.
    - The ideal environment is a dedicated right-of-way, but other environments are possible with mitigations.
- Appropriate demand patterns.
    - High projected ridership, but not high enough for a larger transit project.
        - UTA's guidance for introducing a suburban bus route is at least 10 passengers per hour on average. The same threshold is recommended for supporting an automated shuttle deployment.
    - Anywhere that caters to people who go somewhere regularly, since it is a fixed, repeatable route.
    - An area with a high number of people with disabilities or older adults, or where walking may not be as attractive of an alternative for other reasons.
- Proximity to transit, but with ineffective pedestrian connections.
    - If an automated shuttle is being used to connect to transit, schedule coordination that includes real-time interventions will need to be implemented for it to be considered a seamless and attractive option.
- Demographic groups that are either more inclined to be interested in CAV technology and/or who have been overlooked in CAV outreach in the past.
- Less than 1 mile from an appropriate storage and charging location.

Many of these attributes could be incorporated or developed while a project team is still planning an automated shuttle project, making use of the lengthy startup time required from project conception through securing a vendor to vehicle delivery.

Once these attributes are met, the final two considerations are cost (is it worth it?) and need (is it the right thing to do?). In addition, having a partner – whether it be a public agency, a private entity, or both – would be hugely valuable in getting a project set up and building ongoing local support.

While only fixed stop service was piloted in this project, there is a definite interest in trying an on-demand service. Other challenges would need to be resolved, including defining the allowable service area, defining and gaining approval for multiple routes, setting up a system for requesting rides, and finding a suitable location for a rider to board and alight (especially if a host is not present in the shuttle).

6.3.4.1   Data, Information, and Equipment Needs of Potential Site Partners

The project team experienced eleven deployments at eight unique sites and are therefore very familiar with what is required to set up a deployment. This section summarizes those needs for other potential project teams.

Project teams should be prepared to make temporary adjustments at a site, with sufficient lead time that includes the following tasks:

1. Looking at a potential site in Google Maps (or similar) to identify any conditions that preclude a deployment from being possible, such as high-speed roads, steep hills, or insufficient pavement markings.
2. Performing a site walk with stakeholders and also using this opportunity as a pre-operations planning meeting.
3. Making any temporary infrastructure adjustments.
4. Determining where signs will be placed along the route.
5. Allowing the vehicle vendor to program their vehicle and calibrate it on the actual route.

Logistically, the equipment listed in Table 9 will facilitate this experience.

Table 9: Equipment Needs

Storage and charging	• A location within 1 mile of the route • Preferably indoors, especially if hot or cold weather is expected • A plug – any type will work, but this decision will impact charging time
Signage	• Informational signs • Warning signs • Localization signs • A variety of stands to place and hold the signs • A truck to transport the signs • A warehouse to store the signs Daily set-up of approximately one person-hour to set up and one person-hour to take down the signs is required if they are not able to be kept outside during non-service hours.

Other ground equipment	• Traffic control devices to use when needed • Tablets to solicit survey responses • Kiosk and/or umbrella, if there are Ambassadors standing outside • Cleaning supplies
If near an indoor location, such as a conference center	• Booths inside the venue with informational materials

The biggest things potential site partners want to know is the cost and the safety of the shuttle. They also want to know what, if any, infrastructure changes will be required, which has been discussed throughout this report and can be variable depending on the operational constraints. Potential site partners are also interested in ridership and cost-effectiveness, but this will depend on the demographics and characteristics of each site. They also value information on Federal and other guidelines and regulations to help determine whether their plan would be feasible.

6.3.5   Long-Term Planning Impacts

Through this project, the project team learned that there are many cases where opportunities to deploy automated shuttles are almost ideal but are missed out on by not getting involved early enough in the planning process. Because of this, automated shuttles and other CAV technologies need to be considered in ongoing strategic and long-term planning efforts today, to make sure environments and infrastructure are ready when the technology is.

One example is a pedestrian bridge or other pedestrian infrastructure. Pedestrian rights-of-way are almost large enough for the EZ-10 shuttle, but not quite. Knowing this, new pedestrian infrastructure could be standardized to enable vehicles like this one to safely share the right-of-way, especially while their speeds are comparable.

In addition, it would be ideal if new developments that are in the planning stages and may be open to the public in five years could incorporate and implement guidelines that are needed for CAVs into their projects. By incorporating this into the planning early on, there would be a smaller investment needed for when an automated shuttle or other similar technology could be deployed there once both the development and the technology are ready.

Automated shuttle projects should also begin to be included in long-range plans by Metropolitan Planning Organizations (MPOs) and other government agencies. It is critical that conversations are started with these MPOs on CAV technology to build awareness and see where the technology could be applied in various contexts throughout the region. In addition, including projects in an MPO's Long-Range Plan ensures they are eligible for certain funding programs.

7   Conclusions

The Utah Autonomous Shuttle Pilot ran from April 11, 2019, to September 4, 2020. It successfully served eight locations across eleven deployments during this time. Through the set-up, deployment, and analysis of these demonstrations, the project team addressed the six core goals introduced in Section 1 as explained in Table 10.

Table 10: Project Goal Assessment

	Goal	Assessment
1	Expose the public to CAV technology and provide an educational rider experience for policy influencers, transit customers, and residents who are interested in the technology.	Achieved. 6,878 passengers were able to experience the shuttle, and 91% of survey respondents were residents of Utah. Two demonstrations at the Utah State Capitol provided access to legislators.
2	Assess the viability of the shuttle as a potential solution to creating first/last mile connections.	Achieved. Multiple sites connected the first/last mile between existing transit services and site attractions, allowing 13% of shuttle demonstration riders to transfer. The shuttle could be a viable first/last mile solution at some locations, especially as the technology improves.
3	Understand the operational characteristics and constraints of the shuttle to help inform future potential permanent operations in a transit network.	Achieved. The project team learned that given the current state of the technology, the most suitable operational characteristics of a permanent shuttle route would be a dedicated right-of-way with on-site storage and charging.
4	Interact with the public to assess opinions and attitudes about vehicle automation and the desirability of automated shuttles in the transport network.	Achieved. Questions on these topics were included in the passenger survey, and results were generally positive. More effort could be done to reach out to communities that are not seeking out CAV technology to learn about their opinions on and needs of the technology as well.
5	Test the capability and readiness of the automated shuttle to communicate with traffic signal infrastructure using Vehicle to Infrastructure (V2I) communication.	Achieved. Testing at the Utah Driver's License Test Track demonstrated that DSRC communication and responses by the EZ10 shuttle are accurate and reliable if properly set up, with some limitations and approvals required.
6	Research and understand the factors that influence passenger and pedestrian trust in automated vehicles.	Achieved. Research by the University of Utah conducted in conjunction with this project suggested that riders who rode the shuttle more than once had more positive experiences and confidence in the technology, while those who experienced one or more emergency stops during shuttle operation were less trusting of the technology.

By conducting this pilot project, the project team and both agencies were able to meet these goals, forming a better understanding of CAV technology and starting to educate the public on the path forward. This pilot has already jump-started the conversation locally, with many site partners and members of the public now discussing the opportunities technologies like this can enable and the options it will provide for in the future.

Having the automated shuttle short term at multiple locations was good for exposure and for enabling comparisons between different environments. By doing the pilot project this way, there is now a level of experience locally to reference when talking about automated shuttles, rather than just speculation. However, looking forward, another rotational deployment like this one would not be recommended in Utah. Instead, further learnings would be best facilitated by operating an automated shuttle on a single, more permanent route for a longer period of time. This would allow passenger experiences and use cases to coalesce into more of a steady state and enable learnings on other potential challenges, like what happens when demand exceeds capacity or when year-round operations need to remain consistently available. Eventually, a dynamic route may be interesting to explore, but a fixed route would be more feasible in the short- to medium-term as a next step.

For any other jurisdictions considering pursing an automated shuttle pilot project, whether at one or many locations, this experience has shown that there is definitely value in learning by doing. The many challenges and permits and people to engage along the way led to an experience that helped both UDOT and UTA understand at the most basic level what it would take to get this type of service on the street, serving residents and visitors, and keeping the State of Utah actively engaged in shaping the future of transportation.
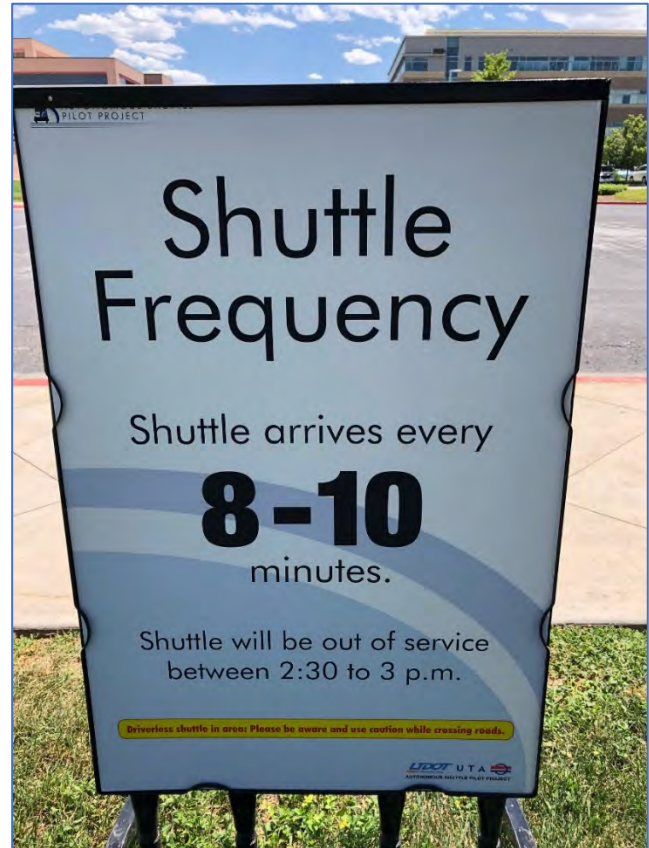
Appendices

A. Example Signage

Temporary signs with information about the shuttle route and frequency

Set-up of temporary signs at 1950 West

Roadside signs to alert other roadway users of the presence of the shuttle

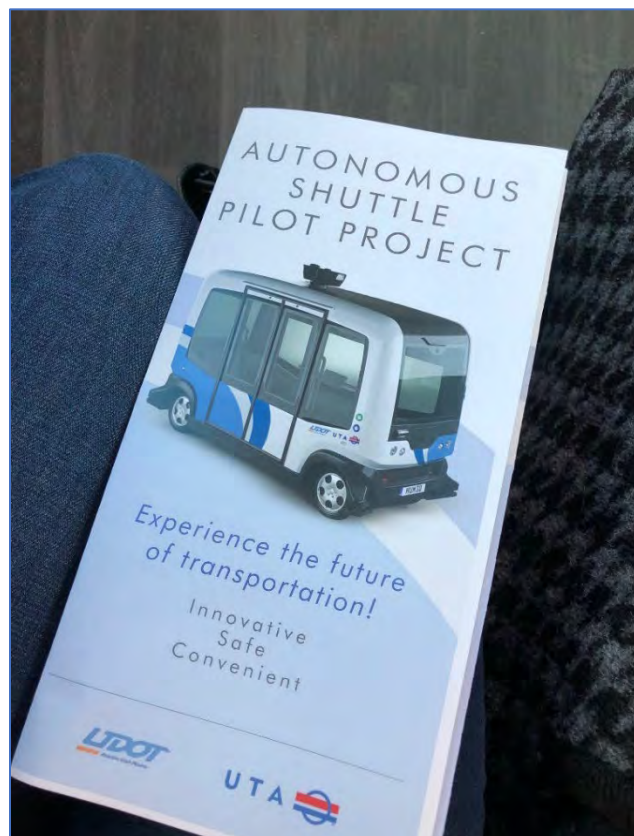Onboard screen showing current and next-stop information

Information Kiosk

Brochure that was provided on board

Brochure content

AUTONOMOUS SHUTTLE PILOT PROJECT

WHY ARE WE TESTING IN UTAH?

UDOT and UTA want to explore ways to meet the travel needs of individuals and enhance community accessibility through safe, reliable and innovative services. Autonomous and connected technology could be a great solution for transit needs. This year long pilot program will provide opportunity for the public to experience and better understand autonomous technology and to provide feedback as we shape the future of transportation in our state.

SITES

To maximize the opportunity for Utahns to interact with the shuttle, it will be deployed at a variety of locations throughout Utah:

Park City AASHTO Conference

Station Park - Farmington

Utah State Capitol

1950 West Office Park

Mountain America Expo Center

University of Utah

Intermountain Healthcare Center

St. George

We want your feedback!

Scan the QR code or visit www.avshuttleutah.com to fill out a survey and help us bring driverless vehicles to Utah!

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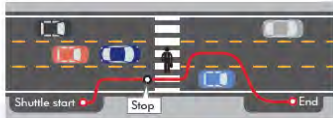
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AUTONOMOUS SHUTTLE PILOT PROJECT

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AUTONOMOUS SHUTTLE PILOT PROJECT

WHAT IS AN AUTONOMOUS SHUTTLE?

Autonomous shuttles are electric vehicles with capacity for 6 to 12 passengers. They do not have a driver's seat, steering wheel, pedals, or the other features usually associated with traditional vehicles. The driverless shuttle follows a pre-determined route but reacts to other vehicles, pedestrians, etc. in real time as they are encountered. See illustration below.

Shuttle start — Stop — End

SPECIFICATIONS

- Moves at speeds up to 15 mph
- Can hold up to 12 passengers
- Motorized ramp deploys for riders who have a mobility device

9 ft.
6.5 ft.
13 ft.

DOOR SIDE   FRONT   WINDOW SIDE

BENEFITS OF AUTOMATION

Safety:
94% of serious crashes are due to human error

Automated vehicles have the potential to save lives and reduce injuries.

Economic:
A 2018 survey shows that motor vehicle crashes cost Utah consumers

$268 million

Less driver error decreases accidents, which in turn saves the consumer money.

Efficiency & Convenience:
More connected and autonomous vehicles on the road can help increase driver efficiency/shared rides to decrease congestion.

driver efficiency & shared rides

congestion

Mobility & Access:
Connected & autonomous vehicles can improve access and increase mobility to meet the various needs of Utah communities.

FAQs

1. Where will it be located?
The autonomous shuttle will change locations every few weeks. All shuttle sites and routes are vetted and approved in advance by the Federal Government. For a complete, up-to-date list, visit www.avshuttleutah.com.

2. Is there a driver?
No, but the shuttle will have a person on board to serve as a host to answer questions and monitor operations.

3. Will the autonomous shuttle run in street traffic?
Yes. The shuttle will only drive in pre-designated locations on approved sites. It may operate on public roads and in low-speed traffic.

4. Is it safe?
Yes. The shuttle follows a pre-determined route, but reacts in real-time to other vehicles, pedestrians, etc. This is a Level 4 automated vehicle, meaning the vehicle is capable of performing all driving tasks within specific conditions (such as only in daytime, or within a specific neighborhood), with no expectation that a driver will be asked to intervene when the vehicle is operating in those conditions.

B. Known Media Coverage

Date Published	Source	Headline
1/15/2019	Salt Lake Tribune	A no-driver shuttle is coming to Utah - as an experiment
1/15/2019	Fox 13	Self-driving shuttle to debut in Utah this year
1/15/2019	KSL	UDOT, UTA to pilot 'driverless shuttle' program along Wasatch Front
1/15/2019	971. ZHT	A driverless shuttle is coming to Utah
1/16/2019	Reddit	UDOT, UTA to pilot 'driverless shuttle' program along Wasatch Front
1/16/2019	The Association for Unmanned Vehicle Systems International (AUVSI)	Driverless shuttle project expected to launch in Utah next month
1/17/2019	UtahPolicy.com	New autonomous mobility era beginning in Utah
1/19/2019	Miami Herald	Driverless shuttle to make Utah debut at state Capitol
1/19/2019	KUTV	Driverless shuttle to make Utah debut at state Capitol
1/19/2019	The Telegraph	Driverless shuttle to make Utah debut at state Capitol
1/19/2019	U.S. News	Driverless shuttle to make Utah debut at state Capitol
1/21/2019	Industrial Equipment News	Utah Tests Driverless Public Shuttle Bus
4/11/2019	Channel 4	UTA, UDOT launch driver-less shuttle
4/11/2019	Deseret News	Utah joins national effort for self-driving transportation, tests autonomous shuttle
4/11/2019	Salt Lake Tribune	Utah gets a look at an automated shuttle that may signal a coming era of driverless travel
4/11/2019	KSL	Utah joins national effort for self-driving transportation, tests autonomous shuttle
4/11/2019	Daily Herald	Beep: A self-driving public transit shuttle may come to Utah County
4/11/2019	KUTV	Utah's first autonomous shuttle made its public debut, will travel throughout the state
4/16/2019	Daily Herald	UDOT receives $3 million grant to deploy high-tech road safety solutions
4/19/2019	AASHTO	UDOT - UTA Join Forces on . . . Autonomous Shuttle Pilot
4/20/2019	Salt Lake Tribune	Despite earlier vows that tax hike funds would go to improve buses and roads, $400K now going to a study that may advance a $1.2B TRAX expansion
4/22/2019	Standard Examiner	Driverless car to serve Farmington's Station Park

Date Published	Source	Headline
4/22/2019	U.S. News	Driverless Shuttle to Ferry Passengers Around Farmington Hub
4/24/2019	Government Technology	Self-Driving Cars Get the Greenlight Under New Utah Law
4/25/2019	Mass Transit Magazine	Self-Driving Cars Get the Greenlight Under New Utah Law
6/15/2019	Standard Examiner	State's driverless, robot shuttle debuts at Farmington's Station Park
6/17/2019	KSL	Driverless shuttle debuts at Station Park
6/17/2019	Deseret News	Driverless shuttle debuts at Station Park
6/20/2019	The Davis Clipper	Driverless Shuttle Moves Shoppers Through Station Park
6/23/2019	Deseret News	Letter: Autonomous shuttle: why?
7/18/2019	KUTV- SLC	2News at 4:30 PM (4:31 PM)
7/18/2019	KSTU-SLC (Fox13)	Fox 13 News at Nine (9:47 PM)
7/18/2019	KSTU-SLC (Fox13)	Fox 13 News at Nine Quickcast (10:01 PM)
7/18/2019	FOX13now.com	Man injured by self-driving shuttle in SLC
7/19/2019	KSL-AM (Radio)	2:18 PM
7/19/2019	KSL-AM (Radio)	12:27 PM
7/19/2019	KSL-AM (Radio)	11:59 AM
7/19/2019	KSTU-SLC (Fox13)	Fox 13 News at Nine (1:27 AM)
7/19/2019	KUTV 2	Autonomous shuttle presents challenge for first responders
7/19/2019	Deseret News	Utah driverless shuttle mishap doesn't slow 76-year-old state employee
7/19/2019	KUTV- SLC	2 News at 5:00 PM
7/19/2019	KSL-SLC	KSL 5 News at 6 (6:05 PM)
7/19/2019	KSL-SLC	KSL 5 News at 6 (5:13 PM)
7/19/2019	KSL-SLC	KSL 5 News at 10 (10:09 PM)
7/19/2019	KSL-SLC	KSL 5 News at 10 (10:14 PM)
7/19/2019	KSL News Radio	UDOT makes safety upgrades after autonomous shuttle accident injures man in Salt Lake City
7/20/2019	KSL.com	State employee badly bruises face when driverless shuttle abruptly stops
7/20/2019	KSL News Radio	Passenger badly injured when a driverless shuttle abruptly stops

Date Published	Source	Headline
8/9/2019	The Detroit Bureau	Utah Man Injured Riding in Autonomous Shuttle-Second injury attributable to shuttles in recent months
10/7/2019	KSL-SLC	KSL 5 News Today at 5 am (5:46 AM)
10/14/2019	City Journals	Driverless Shuttle, Nicknamed Tom, Now On Utah Roads
1/6/2020	Inside Unmanned Systems	Autonomous Shuttles: Rolling Toward Efficiency
2/7/2020	St. George News	Dixie Transportation Expo to highlight area projects, offer rides on Autonomous Shuttle Pilot vehicle
2/11/2020	KUTV-SLC (CBS)	2 News at 5am (5:59 AM)
2/11/2020	KUTV-SLC (CBS)	2 News This Morning at 6am
2/11/2020	KUTV-SLC (CBS)	2 News at Noon
2/11/2020	KUTV-SLC (CBS)	2News at 4 pm
2/11/2020	KUTV-SLC (CBS)	2 News at 5 pm
2/11/2020	KSL-SLC (NBC)	KSL 5 News at 6
2/11/2020	KUTV-SLC (CBS)	2 News at 6
2/11/2020	St. George News	Transportation Expo rolls into Dixie with free rides and a glimpse into future trends
2/12/2020	NPR Utah	KUER 90.1
2/12/2020	The Spectrum	Autonomous vehicles, more flights: Washington County unveils transport projects for future
2/12/2020	KUER 90.1	NPR Utah
2/12/2020	Community Education Channel (YouTube)	Autonomous Shuttle tested in St. George
2/13/2020	St. George News	Transportation Expo recap: Here's what you can expect for the future of getting around Washington County
2/13/2020	The Daily Utah Chronicle	Improving Utah's Transportation System
2/20/2020	KUER 90.1	Utah's First Autonomous Shuttle Arrives In St. George
2/25/2020	Fox 13	Federal agency brings driverless car pilot program in Utah to stop following passenger injury
2/26/2020	KSTU-SLC (FOX)	Fox 13 News at Nine
2/26/2020	Salt Lake Tribune	Feds halt autonomous shuttle testing in Utah, 9 other states after Ohio incident
7/7/2020	@TheU	Autonomous Shuttle now running
4/2/2021	AASHTO Journal	Technology Will Help Provide 'Barrier-Free Mobility'
4/9/2021	AASHTO Journal	AASHTO Offers Perspective On Automated Driving System Safety

C.   Project Document Outlines

Tabletop Exercise Agenda

10:00 – 10:25: Introductions and Project Overview
10:25 – 10:40: Review Safety Assessment Report (SAR) & Emergency Response
10:40 – 12:30: Scenario Walkthroughs
12:30 – 1:00: Lunch Break
1:00 – 2:00: Complete Tabletop Exercise / Review Safety Plan and Operating Plan Sections

Evaluation Plan Outline

1 Introduction
    1.1 Project Goals
    1.2 Project Objectives

2 Evaluation Metrics
    2.1 Relevant Metrics from IMS Strategic Plan
    2.2 Additional Metrics

3 Data and Methodology

4 References

5 Appendix: Autonomous Shuttle Evaluation Plan Meeting Notes

Operating Plan Outline

1 Introduction
    1.1 Purpose

2 System Description
    2.1 Organizations
    2.2 Venues
    2.3 Regulations
    2.4 Licenses and Permits
    2.5 Passenger Rights, Rules, and Responsibilities

3 System Management
    3.1 Autonomous Shuttle Personnel: Shuttle Hosts, Fleet Engineers, and Site Ambassadors
    3.2 Vehicle Maintenance and Safety Inspections
    3.3 Field Operations Validation

4 System Operations
    4.1 Unplanned Route Change
    4.2 Weather Event
    4.3 Disaster Preparedness
    4.4 Crash Response
    4.5 Incident Response
    4.6 Vehicle not Behaving as Expected
    4.7 Public Inquiry to UTA or UDOT Customer Service
    4.8 Policies on Young Passengers

Appendix: Autonomous Shuttle Tabletop Meeting Notes
Appendix: Other Supporting Documents for Reference

D. Storage and Charging Locations

Shuttle offloading – successful with flatbed tow on same level surface as container truck

Assembling the roof-mounted HVAC and sensor unit atop the shuttle

Long-distance, shell-protected transport for the St. George trip

Shuttle maintenance

Shuttle storage at Canyons Village

Shuttle storage at Station Park

Shuttle storage at 1950 West

Shuttle storage at the University of Utah

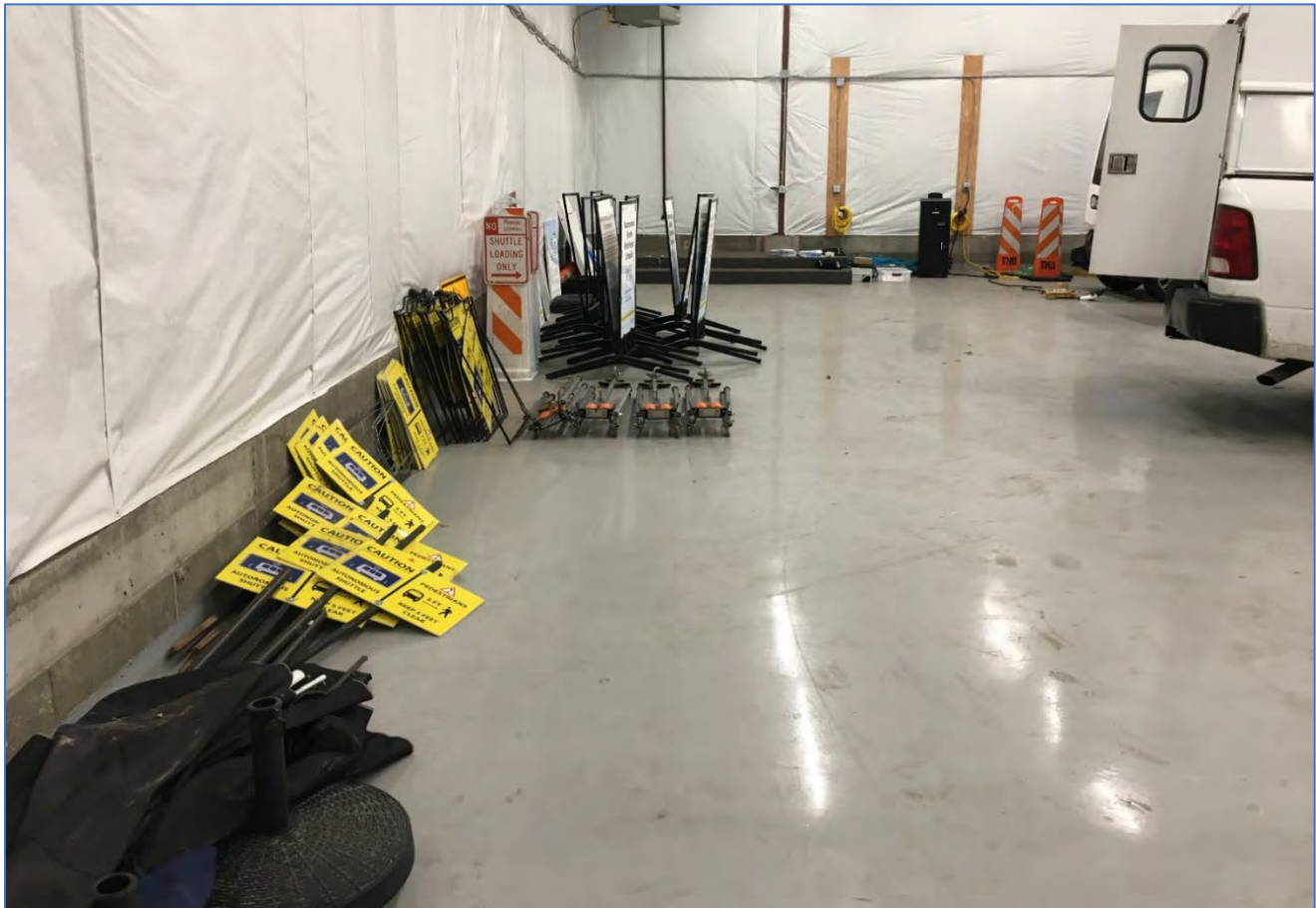Shuttle charging station at the University of Utah

Shuttle charging outlet access at the Mountain America Expo Center (50 amp, 220/240 V outlets for welding were commonly used in shops)

UDOT storage location

UDOT storage of vehicle equipment and signage

E. V2I Testing Summary

Intent

Understand and document the EZ10's capabilities to communicate with, take commands from, and send commands with connected vehicle Road Side Units (RSUs). Employ standard equipment and methods used for vehicle-to-infrastructure (V2I) wireless communications, including Dedicated Short Range Communication (DSRC) radios and messages standardized by SAE.

Identification

Vehicle: 　　　　　　　EasyMile EZ10 Gen2

Control Software version: 　　18.10R4

OBU: 　　　　　　　Neavia LaCroix – Dedicated Short Range Communication (DSRC)

RSU: 　　　　　　　Lear & Cohda – DSRC

Plan

1. Establish communication between On-Board Unit (OBU) and RSU(s)
     1.1. Messages to be sent (SAE J2735): SPaT, MAP, BSM
2. Setup, Test, and Document various intersection scenarios:
     2.1. Shuttle arrives to the intersection on a green and knows to proceed
     2.2. Shuttle arrives to the intersection on the yellow phase and knows to proceed based on proximity
     2.3. Shuttle arrives to the intersection on the yellow phase and knows it cannot clear the intersection and prepares to stop
     2.4. Shuttle arrives on a Red and stops, then proceeds on green
     2.5. Shuttle arrives to the left turn lane and proceeds on the left green arrow
     2.6. Shuttle arrives to the left turn lane and goes on permissive left
     2.7. Shuttle arrives to the left turn lane and is waiting for traffic, light turns yellow and waits appropriately for obstructions, then goes even though the light is now Red
     2.8. Shuttle arrive to the signal in flash mode and proceeds like a 4 way stop
     2.9. Shuttle arrives to a dark intersection and proceeds like a 4 way stop.
     2.10. Maybe a feature that tells the shuttle that a conflicting ped button has been pushed and to proceed at a slower speed through that crosswalk
3. Report

Report

Previous Works

The initial communication test during Summer 2019 at Station Park revealed that the EZ10 was broadcasting BSM, was communicating internally with its own OBU, but not receiving any SPaT or MAP packets from signalized intersections. This was thought to be because of mismatched PSID's in the messages but that was found not to be the case.

Establishing Communication

The first full round of testing was undertaken in a shed and parking lot at UDOT Region 2 using a portable trailer with a DSRC RSU, acting as a traffic signal. During this testing, it was discovered that there was communication both ways between the RSU and the OBU, but the OBU was discarding messages based on factors that categorize them as inaccurate / not safe to use. Although there were no messages being displayed real-time, a recording of a log of the activity (.pcap) was viewed with wireshark. This evaluation revealed that SPaT and MAP were being broadcasted by the RSU and received by the OBU, but not being considered because their timestamp was not corresponding with the time on the OBU.

The OBU uses GPS to know the current time based on its location. If messages from an RSU are time-stamped more than a couple seconds before the OBU timestamp they lose effectiveness. If they're more than 10 seconds older they will be discarded entirely by the OBU (This is an internal Neavia setting - to be confirmed 10 seconds - not sure if it's configurable). The RSU's and traffic signal controller were cloned from the Redwood Rd. and 2100S intersection in October, a location that has been successfully broadcasting SPaT and MAP for over two years. They were keeping time locally, so when they were booted up they were either recalling the last time they had before shutting down or starting over at the time they were cloned. On October 15th, 2019, the testing team was able to reprogram the startup procedure to include script that called time from a GPS modem. The times on the RSU and OBU were then in alignment and real-time messages were being accepted by the OBU.

(The original thought that the mismatched PSID's was causing no reception was false - the OBU is always accepting both ...8002 and ...8003 PSID's.)

How Does the EZ10 Make Decisions?

The EZ10 is using several data elements from the SPaT message, including the intersection ID, signalgroup, the eventstate of the signal group, and the time remaining in that particular eventstate. The EasyMile Deployment Engineer creates a trajectory that follows the desired lanes and programs in traffic signals and their associated stop bar locations. Each traffic signal along the trajectory is defined by the engineer with an intersection ID and which signal group to respond to. The EZ10 is not using GPS position to identify which lane it is in and which signal group it should comply with. Based on the speed of the vehicle and the acceleration limits built into the vehicle/trajectory, the EZ10 decides when to go through an intersection vs. when to stop in yellow light scenarios.

The EZ10 is able to broadcast signal request messages (SRM) which can request that an upcoming traffic signal provide early green or green extension to its normal signal cycle. This feature wasn't tested in this evaluation.

Test 1 - Imaginary Intersection at UDOT Region 2

Intersection 1 - Setup

The first configuration is a simulated intersection in the parking lot where the EZ10 makes left turns, as shown in the following figures.
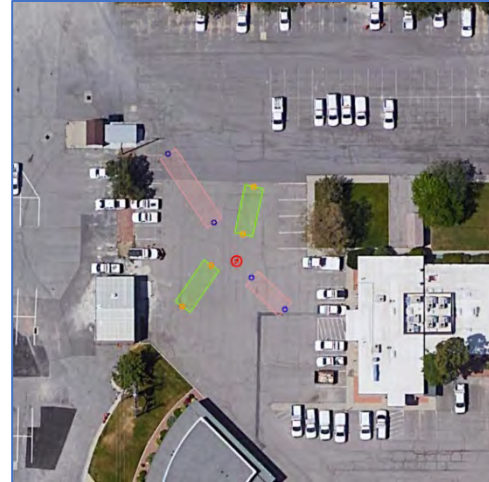
On the left is the EZ10 map and on the right is the signal controller map.

The Northbound left arrow is signalgroup6, the southbound left arrow is signalgroup2. The EZ10 is preconditioned by programming into the map which signal group to obey for each traffic signal on its route.

Intersection 1 - Protected Left Test

The EZ10 accurately interprets the condition of the traffic signal as messaged by the RSU and responds accordingly as such (the numbers in parentheses below indicate the test scenario defined in the plan defined earlier):

- (2.4) Stopping on red and proceeds on green
- (2.1, 2.5) Proceeding on green and green left arrow
- Continuing through on green
- (2.2) Continuing through on yellow with enough time remaining to make it through the intersection
- (2.3)Stopping on yellow when there is not enough time to make it through the intersection

Intersection 1 - Permissive Left Test (2.6, 2.7)

In this case, a yield is added after the traffic signal but before starting the left turn. This allows for a permissive left when the on-coming right-of-way lanes are clear.
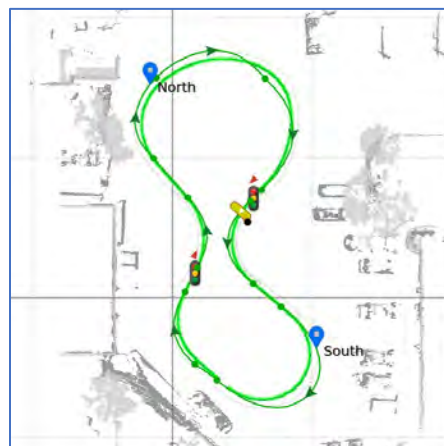
The yellow arrow after the traffic signal in the southbound intersection is an automatic OR operator granted yield.

Automatic Validation Permissive Left

Automatic validation in the EZ10 uses zones. This means the computer looks for LiDAR impacts within defined validation zones (defined by the deployment engineer) to determine if it can safely pass through a programmed yield. For example, to make a right turn from a driveway onto a street the deployment engineer would draw a virtual yield/stop bar and then define a zone that stretches a few hundred feet (length depends on speed of the roadway) down the oncoming traffic lane. If the zone contains no obstructions, as detected by LiDAR sensors, the vehicle will continue to roll through the virtual stop bar and proceed onto the road. If at any point before reaching the stop bar the EZ10 senses an object in the zone, it will decelerate at a rate to reach a halt at the virtual stop bar. When the zone is clear again, the EZ10 resumes. A flaw with this technique is that the EZ10 will stop for almost any LiDAR-detected object in the defined zone. It could be a dog running across the street, a cone, a parked car, etc. This means that when the light turns red and the oncoming traffic stops at their stop bar, they are parked in the detection zone as they are in an oncoming lane of traffic. The EZ10 will not proceed automatically. The operator will need to select the button to override the yield and continue through the intersection when he/she sees fit. The EZ10 does not incorporate object recognition or relative velocities which can be troublesome in situations like this. More robust LiDAR impact interpretations and stereo camera vision will solve this issue in the future.

The graphic below depicts a "validation zone" associated with a yield:

Intersection 1 - Flash Mode Tests (2.8)

If the signal controller broadcasts the same signal in flash mode as it would for a red light in a normally operating situation, the EZ10 will come to a stop and wait for a green light or offer the operator the chance to override the signal. If the traffic signal broadcasts any other special emergency message, it will likely not be understood by the EZ10. In a case where the EZ10 is unsure of what it is receiving it will behave as if the light is red and stop - just as it does when it receives no message (see Dark Mode Tests). The EZ10 should only proceed through an intersection if it clearly receives a message that the red phase is done and the green phase is active OR if the operator manually overrides the signal command.

Intersection 1 - Dark Mode Tests (2.9)

The Dark Mode test is performed by operating with the RSU switch off. The EZ10 behaved as if the intersection was always a red light. After a few seconds at the stop bar, the EZ10 screen gives the operator the option of

overriding the traffic signal. This allows the operator to behave as if the intersection were an all-way stop, proceeding through the intersection when it is their turn and the intersection is clear.

Test 2 - Physical intersection at West Valley Driver's License Division

Intersection 2 - Setup

The second test round was coordinated at the Utah Driver's License Test Track on February 28, 2020. The course has a signalized intersection with multiple lane options and an RSU that was provided and configured for the tests. The intersection at the Test Track is pictured below.
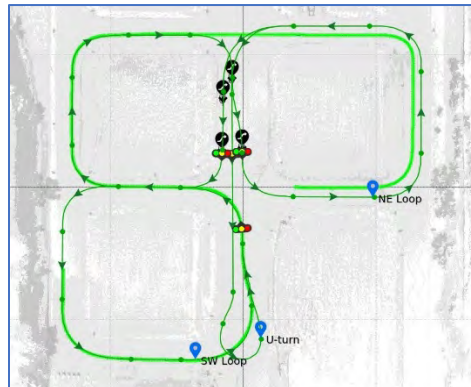
Intersection 2 - Performance

This configuration allowed the EZ10 to pass through the intersection from each direction and each available lane/group. The EZ10 circulated autonomously for over two hours, experiencing the following interactions:
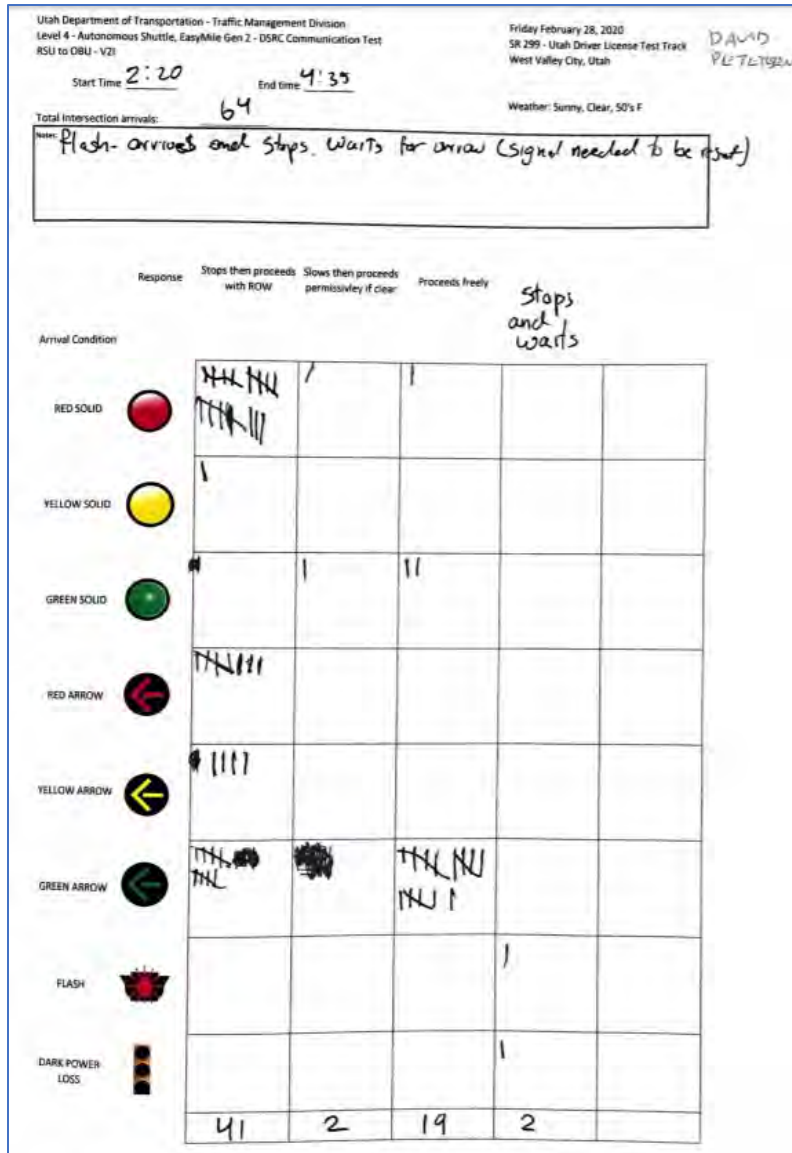
There was one instance during the setup phase where the EZ10 passed through a red light, without taking any command via DSRC because the deployment engineer (Colin), made an adjustment to the route on the EZ10 and forgot to replace a traffic light recognition zone while approaching the light. Without programming a zone in which to search for a DSRC signal and respond accordingly, the EZ10 will not recognize or respond to any signal. This makes the setup and route sign-off extremely important for any route with DSRC interaction.

The EZ10 accurately responded to the RSU signals but with only a capacity to recognize if the signal was go or no-go. Permissive passages are not possible in the current software version (18.10R5) because the only differentiation is go for green, and no-go for any other phase. Additional flexibility through an intersection is available with an operator on board and operator granted permissions, but not autonomously in the current software/sensor configuration.

Another limiting factor of the V2I software used by the shuttle is that it does not utilize information contained within the MAP message. This means that the deployment engineer must manually program how the shuttle

interacts with the intersection, such as where to stop when SPaT indicates a red light. Another example is that the shuttle needs to be programmed to know which signal group to obey for each interaction. This means, for example, in the left turn lane with a yellow left turn arrow and green ball in through-lanes, the EZ10 cannot recognize that both (more than 1) signal groups are relevant to the decision that must be made. In this situation the deployment engineer must choose which signal group to obey, which must be the left arrow, and cannot go through the left turn until the signal gives a "go" (green left arrow) for the defined signal group.

Capability is expected to increase as autonomous visualization and recognition increases. More phases and signal groups will be considered as the ability of the EZ10 to accurately analyze on-coming/competing traffic lanes increases.

Conclusion

The current software (version 18.10R5) capabilities for V2I communication and response by the EZ10 is accurate and reliable if properly set up. The automatic validation of traffic signals on public routes still requires additional approvals from within EasyMile and NHTSA and is still limited to very basic intersections with only one "go" phase in each approach/passage.

F. Stakeholder Interview List

A key component of the report development process was soliciting input from stakeholders who were directly involved in the deployment. These interviews informed the content of the report, especially the reflection on key challenges and successes and recommendations on how and under what conditions similar projects could be best pursued. The following individuals participated in this outreach, and their input and feedback is greatly appreciated by the project team.

Name	Project Affiliation
Chris Siavrakas	UDOT
Blaine Leonard	UDOT
Michael Sheffield	UDOT
Lisa Miller	UDOT
Rob Wight	UDOT
Jason Davis	UDOT
Shaina Miron Quinn	UTA
Jaron Robertson	UTA
Katie Matisohn	UTA
Nichol Bourdeaux	UTA
Hal Johnson	UTA
Lorin Simpson	UTA
Laura Hanson	UTA
Eric Callison	UTA
Kerry Doane	UTA
Kristin Buchholz	EasyMile
Colin Timm	EasyMile
Nate Ramsay	EasyMile
Anne Williams	Horrocks
Katie Williams	Horrocks
John Wayne Close	University of Utah
Chad Larson	University of Utah
Andrew King	University of Utah
J. David Anderson	Station Park
Karen Roundy	City of St. George
Adam Lenhard	City of St. George
Myron Lee	Dixie MPO
Naghi Zeenati	Utah Transportation Commission
Lindsay Mabry	WSP
Katie McLaughlin	WSP

G. University of Utah Rider Trust Research Findings

As described in Section 5.3, the University of Utah Applied Cognition Lab performed two studies on the development of rider trust and the role of the Host/Operator on the automated vehicle shuttle. The reports summarizing these research studies are included here:

Phase I: Rider Trust and the Role of the Operator in Automated Shuttles

Phase II: Trust Development in an Automated Shuttle with a Disguised Operator

Rider Trust and the Role of the Operator in Automated Shuttles

Amanda E. Carriero, Kaedyn W. Crabtree, Joel M. Cooper, Blaine D. Leonard
University of Utah

Automated, low-speed shuttles are being deployed to help solve the first-mile/last-mile problem in several cities worldwide. To achieve full automation, each of the roles and responsibilities of the operator must be considered. This research aimed to address how increased ridership, abrupt emergency stops, and the operator influenced the development of trust in riders. Surveys and video footage were collected from riders between the dates of Aug. 19th, 2019 and Sept. 27, 2019, as well as the operator on-board. Results suggested that increased ridership with the shuttle predicts more positive experiences and confidence in the technology. However, riders that experienced one or more unexpected emergency stops during shuttle operation were less trusting of the technology. In addition, we found that the backup operator actively worked to foster rider trust. These findings suggest that several challenges will need to be addressed in order to develop and maintain rider trust in low speed automated shuttles when an operator is no longer present.

INTRODUCTION

Partially autonomous vehicles are more prevalent in current transportation for personal and public use than ever before. Cars with partially automated systems, are now available to everyday consumers (i.e. Tesla's Autopilot, Cadillac's SuperCruise, etc). Additionally, companies like Waymo have autonomous rideshare programs which make driverless taxis available to select consumers at will. In order to increase the public's exposure to autonomous vehicles, the Utah Department of Transportation (UDOT) in conjunction with the Utah Transit Authority (UTA), began a pilot program for an autonomous shuttle as a possible first-mile/last-mile solution in areas where the transportation solutions cannot service the commuter to their final destination. The autonomous shuttle in Utah, manufactured by EasyMile, can transport up to 12 passengers, but is constrained to limited access roadways and low speed environments (EasyMile, 2019). SAE levels of driving automation characterize low-speed, limited access Autonomous Shuttles as a Level-4 automated vehicle meaning it can drive autonomously in most conditions and does not require an interior steering wheel or gas pedals (SAE, 2019).

A better understanding of the evolution and development of rider trust and acceptance is needed in order to maximize the potential ridership of autonomous shuttles. Prior research suggests that several factors are critical for the development of trust in automated vehicles (Sanbonmatsu, Strayer, Yu, Biondi, & Cooper, 2018; Choi & Ji, 2015; Lee & See, 2004) and that trust is a vital factor for user acceptance (Balfe, Sharples, & Wilson, 2018). Critical factors for trust development include, reliability of the automation, emotive factors associated with experiencing automation (i.e attitudes, confidence, etc.), the ability and competence of the technology (Lee & See, 2004; Balfe, Sharples & Wilson, 2018) context in which the automation functions (Lee & See, 2004, Balfe, Sharples & Wilson, 2018) the predictability of the automation (Balfe, Sharples & Wilson, 2018), and trial and error experience (Zuboff, 1988). Based on these prior findings and applied to Automated Shuttles, we propose that trust is founded on *reliable, positive, contextually dependent, experience over time.*

Thus, general exposure to autonomous technologies over time is a requirement for the development of trust.

Several studies have looked at the development of trust in partially automated vehicles (e.g. Lee & Moray, 2004; Choi & Ji, 2015; Hoff & Bashir, 2015; Lee and See, 2004; Sanbonmatsu, Strayer, Yu, Biondi, & Cooper, 2018), fewer have looked at trust in autonomous shuttles (e.g. Motak, Neuville, Chambres, & Marmoiton, 2017; Madigan et al, 2016; Madigan et al, 2017). However, our review of the literature failed to find prior work that looked specifically at the role of the operator in autonomous shuttles and their influence on the development of rider trust. Currently, operators of autonomous shuttles are required to navigate around obstacles using a remote-control system that is similar to those used by operators of remotely controlled model cars and airplanes. Operators are also required to confirm decisions made by the automation in complex or heavy mixed traffic and to troubleshoot any technical difficulties the shuttle may experience. Operators also resume shuttle operation after emergency maneuvers or stops. Furthermore, in our initial investigations of operator behaviors we have found that operators routinely interact with riders and other road users in a manner similar to manually operated shuttles.

Together, these many duties and responsibilities of shuttle operators challenge the notion that these low speed automated shuttles are "driverless". In traditionally operated shuttles, drivers perform many tasks outside of simply driving, such as conversing with and educating riders, communicating with other road users (i.e. waving on other cars), and acting as an authority figure in order to provide a safe and comfortable atmosphere. These traditional roles of shuttle operators set the standard for rider expectations when using public transportation and in order for riders to trust automated shuttles these roles need to be handled by the automation, altered through changes in rider expectations, or made irrelevant through operational constraints of the shuttle.

Current Study

This research aims to address interrelated questions on the development of rider trust in partially automated shuttles.

First, how does the reliability and positivity of experience over time affect trust? To measure this, we collected surveys and video footage between the dates of Aug. 19th, 2019 and Sept. 27, 2019 from riders that took several trips in the autonomous shuttle. Based on the literature, we hypothesize that trust would increase with contextually bound, positive, reliable experience over time.

Second, how does the occurrence of unanticipated emergency stops (e-stops) affect rider trust? Currently, low speed autonomous shuttles routinely make unanticipated e-stops. We reviewed all e-stop data and flagged survey data for riders that experienced an e-stop.

Third, how does the presence of the operator shape and influence rider trust? To investigate this, we reviewed video footage of the operator and coded their various interactions with riders and other pedestrians and traffic (e.g. waving on cars, educating riders, manual navigation, etc.). The effect of the operator was also probed through surveys.

METHOD

Participants

Two hundred and thirty-six (236) individuals on the University of Utah campus who had ridden the autonomous shuttle participated in this research.
96 identified as female, 133 identified as male and 7 preferred not to answer. Participants ranged between 18 and 82 years old ($M = 26.35$, $SD = 12.24$). Participants were asked to complete a brief voluntary survey about the Autonomous Shuttle. Participants that took the survey were included in observational video coding along with the operator aboard the shuttle.

Shuttle operator entering EasyMile autonomous shuttle

Procedure

Data were collected at the University of Utah where the EasyMile Autonomous Shuttle was piloting a deployment route on their demonstration tour around the state. The shuttle was open to students, faculty, and other public. The shuttle route was approximately half a mile and was comprised of three stops taking about 15 minutes to complete a full loop. Data were collected over 4 weeks.
Interested riders completed surveys as they deboarded the shuttle. Upon completion of the short survey, riders were compensated through the choice of a cold drink and thanked for their time. At the start of each day a GoPro Hero 7 camera was placed inside the shuttle and throughout the day researchers monitored the battery life, and quality of the video.

Measures

Survey. The survey was given to participants via an iPad which included questions on demographics, ride information (duration of shuttle ride, etc.), and opinions/expectations regarding their experience with the autonomous shuttle. All opinion-based questions were answered via a 7-point Likert Scale (*1 = Strongly Disagree, 7 = Strongly Agree*) and addressed the role of the operator, comfort, interactions with other road users (cyclists, cars, pedestrians, etc.), and overall ride experience.

There were two versions of the surveys which framed intermixed positively and negatively framed questions to catch unthoughtful responses. Nine surveys with inconsistent responses were identified and excluded from analysis.
Each survey consisted of 16 questions that took between 1-5 minutes to complete. Seven survey questions related specifically to the shuttle experience; these were included in the analysis (see Table 1). Other questions were demographic or information in nature and were excluded from this evaluation.

Table 1
Positively framed post-rider questionnaire and identifying keywords. Survey responses were provided on a 1-7 point Likert scale where 1 was strongly disagree and 7 was strongly agree.

Keyword	Questions
Experience	My experience riding the shuttle was extremely positive.
Expectations	The shuttle operated in a manner that was consistent with my expectations.
Displays	If there was no operator, I feel my questions could be answered through the shuttle's interactive displays, signs and auditory messages.
Safety	If there was no operator, I would feel at ease being alone with other passengers.
Destination	I have complete confidence that this shuttle would get me to my destination in a timely manner.
Pedestrians	Pedestrians and other drivers clearly understand whether the shuttle is going to stop, turn, yield, etc.
Intervene	The shuttle operated smoothly without requiring the host on board to intervene.
Ride Number	Number of times a participant rode the shuttle
E Stop	E-stop data was collected from the shuttle service report to determine if a rider experienced an e-stop

Note. E-stop data and Ride Number were not collected from the questionnaire but were extracted from video footage and telemetric data from EasyMile.

Video. A GoPro HERO7 Black sports camera was mounted on the inside rear of the shuttle to capture continuous video and sound of the shuttle operator and all riders. The camera was visible to all riders. Video was analyzed only for the participants that took the survey and shuttle at least twice. In order to look at the effect of repeated ridership on trust, we identified 19 riders that completed at least 2 trips in the shuttle. Several classes of behavior, that we defined indicative of trust,

were coded from these videos to gauge whether and how repeated use of the shuttle affected user trust.

BORIS, A **B**ehavioral **O**bservation **R**esearch **I**nteractive **S**oftware was used to code rider and operator behavior (Friard, & Gamba, 2016). Keyboard letters were assigned to behaviors for researchers to quickly flag behaviors of interest (i.e., c = conversation). Every time the researcher saw a behavior they would click the key, noting the event with a timestamp in a .csv file.

Two types of behaviors were coded, state behaviors (i.e. behaviors that have a duration) and point behaviors (i.e. behaviors that occur at an instance). For state events, researchers would click the associated key for a behavior to start an event and hit the key again when that behavior ended. Researchers coded for multiple state behaviors in riders such as cell phone use, conversations, and ride duration (see Table 2). Research Assistants marked every instance where a rider was participating in casual (social media, texting, etc.) or novel (taking photos or videos of the shuttle) cell phone use. Conversations were coded by instances where the rider conversed with the operator. Three categories of conversation were addressed in our video coding: casual, shuttle information/questions, and predictor statements. Predictor statements were defined as anytime the rider exhibited knowledge of shuttle behavior and could either predict its' behavior or educate another person about its' behavior. These behaviors were coded by the duration of each conversation during their ride and compared to their total ride duration.

Table 2
Rider video coding scheme and keywords

Keyword	Video Coding Criteria
Casual	Rider engaged in casual conversations
Informational	Rider engaged in conversations about the shuttle
Casual Cell	Rider participated in casual cell phone activity (texting, social media, news, etc.)
Novel Cell	Rider participated in novel cell phone activity (taking pictures, videos, etc.)
Anticipatory	Rider made a comment that predicted the shuttle's behavior.

The operator's behaviors were also coded from the videos. We specifically looked at state and point behaviors that involved the operator manually controlling the shuttle or communicating with passengers and other road users. Conversations were coded as being casual or providing shuttle information. The operator's communication with other road users was also coded and included behaviors such as waving on a vehicle, or casually waving to a pedestrian. Instances where the shuttle operator initiated preemptive emergency stops (e-stops), which are cases where the operator made a decision to stop the shuttle before it would have made an autonomous emergency stop, were also coded. A final behavior that was coded were instances when the operator had to manually take control and navigate around obstacles.

RESULTS

Due to the heteroskedasticity of responses as well as "ties" in the results, Kendall's tau_b was used to compute all correlations (Kendall, 1945). An overview of the results from survey responses is shown in Figure 1. An overview of results from the video coding is shown in Figure 2 and Tables 3 and 4.
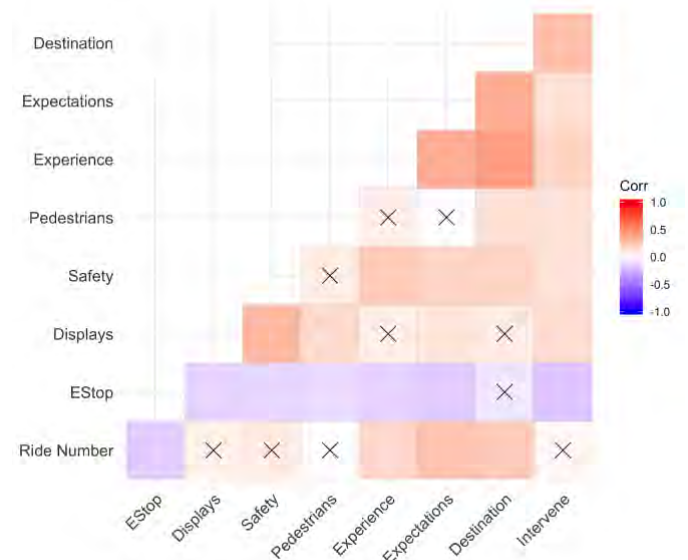
Survey

The results from the survey can be summarized by the categories of trust which we previously defined as: *positivity, reliability* and *experience over time*, as well as questions addressing rider interaction with the operator and e-stops (see Figure 1).

Questions regarding rider *positivity* and *experience over time* after riding the shuttle revealed that participants who more frequently rode the shuttle had a positive experience with the shuttle ($\tau b = .164$, $p = .008$), found the shuttle had met their expectations ($\tau b = .252$, $p < .001$), and had greater confidence that the shuttle would get them to their destination in a safe and timely manner ($\tau b = .216$, $p < .001$).

Survey questions regarding *positivity* and *reliability* after riding the shuttle found that riders who reported having a positive experience on the shuttle also reported that they felt the shuttle would get them to their destination in a safe and timely manner ($\tau b = .421$, $p < .001$) and that the shuttle operated smoothly without operator interventions ($\tau b = .183$, $p = .002$). Riders also reported feeling more safe if their questions could be answered by the shuttle's informational displays ($\tau b = .316$, $p < .001$).

Figure 1
Correlation of survey responses. The heat map below represents the correlation of effects in survey data. Cells with colors closer to red indicate a positive significant correlation while cells with colors closer to blue indicate a negative significant correlation. Cells with an "X" in them indicate no significant correlation.
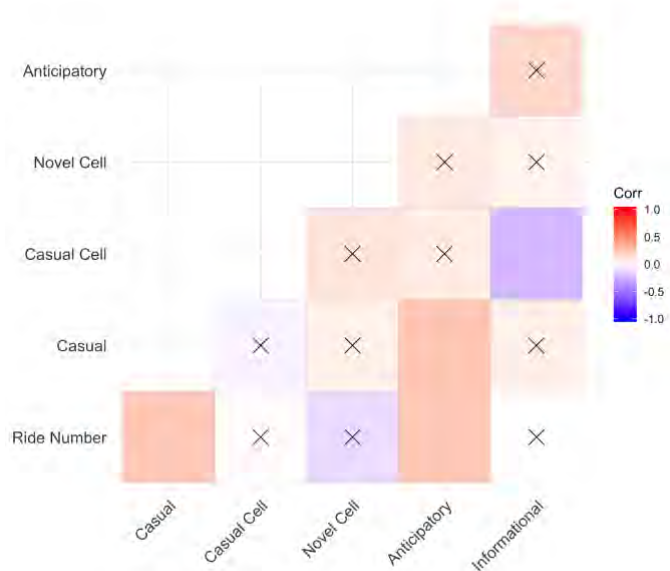

Note. See Table 1 for keywords.

E-stops

From the e-stop data and survey questions it was found that if an e-stop occurred during a trip, riders reported having a more negative experience (τb = -.148, p = .022) and they indicated they thought the shuttle operated inconsistently with their expectations (τb = -.169, p = .006). The presence of e-stops influenced riders to report less confidence that the shuttle's informational cues and displays could inform them of the shuttle's behavior (τb = -.135, p = .019). E-stops were also associated with lower confidence that other road users (i.e. pedestrians, drivers, etc.) understood the shuttle's intentions (τb = -.125, p = .031). Finally, riders that experienced e-stops reported that the shuttle required more intervention from an operator (τb = -.187, p = .002).

Video

Results from the video observations can be split into two categories, rider coding and operator coding.
Video from riders showed that participants who rode the shuttle more than once engaged in more casual conversations (τb = .229, p = .012) and made more anticipatory statements predicting the shuttle's behavior (τb = .228, p =.03). Casual conversations had a positive correlation with anticipatory statements (τb = .243, p = .014), meaning that as they spoke more casually, or were more relaxed, the more statements they made in predicting the shuttle's behavior (see Figure 2).

Figure 2
Correlation of observed rider behavior. The heat map below represents the correlation of effects in rider video coding data. Cells with colors closer to red indicate a positive significant correlation while cells with colors closer to blue indicate a negative significant correlation. Cells with an "X" in them indicate no significant correlation.

Note. See Table 2 for keywords.

Video coding results of the operator revealed that the largest portion of the operator's day was spent engaging in conversations with the riders related to the shuttle (Table 3). The percentage was calculated by summing the duration of each behavior per day and then dividing it by the number of total days (Table 3). Operators were also found to wave casually at other road users close to 30 times per day (Table 4). These results suggest the continued social role of the operator.

Table 3
Average duration of state behaviors per day

	Casual Convo.	Manual Control	Shuttle Info. Convo.
Average % of day spent	12.69%	3.01%	25.75%

Table 4
Frequency of operator point behaviors

	Pre-e-stop	Wave Casual	Wave Intentional
Average # of observations per day	5	29.05	3.5
Total	95	581	63

DISCUSSION

This study aimed to address three interrelated questions on the development of rider trust in low-speed autonomous shuttles. First, how does the reliability and positivity of experience over time affect trust? Second, how does the occurrence of e-stops affect rider trust? Third, how does the presence of the operator shape and influence rider trust? In general, we found that riders had a positive experience with the shuttle which increased with exposure. However, we also found that rapid emergency stopping (e-stops) had a very negative outcome on the overall rider experience. Analysis of the video data suggested that operators were very active in curating the experience of riders and that they still played a critical role in helping riders to feel more comfortable and trusting with the shuttle.

Prior research suggests that trust is developed through reliable, positive, contextually bound experience over time. Survey responses to questions targeting these various aspects of trust development suggested that more experience with the shuttle predicts more positive experiences, met expectations, and greater confidence in the technology. These findings suggest that in order for people to trust and use autonomous shuttles they must have repeated, positive experiences. Companies deploying autonomous shuttles should consider

ways to increase repeated ridership in order to ensure trust development.

Unanticipated rapid stopping (e-stops) were a somewhat common occurrence during our testing (M=4 per day). Survey results collected in this study suggest that riders who experienced at least 1 e-stop had more negative experiences and less confidence in the system's abilities. Prior research suggests that trust can only be developed from positive experiences, thus we can conclude that the occurrence of e-stops hinders the development of trust since they evoke negative experiences.

Currently, low speed shuttles require a backup operator to be present in the event of an unanticipated problem. In reviewing the video of operator behaviors, we found that operators remained very active in helping to develop and maintain rider trust. In fact, 38% of their day when riders were present in the shuttle was spent conversing with them, and over half of that time conversing was spent educating riders about the shuttle. The operator filled many other roles throughout their day that the automation did not fulfill, such as waving on other cars at a four way stop. In order to achieve successful trust development of driverless shuttles, autonomy must be able to fulfill these small, but crucial roles the operator conducts.

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Trust Development in an Automated Shuttle with a Disguised Operator

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Abstract

This paper explores differences in rider trust development in an automated shuttle when the safety operator was either visible or disguised. Autonomous driving technology is developing rapidly. New driverless shuttles are being developed, tested, and deployed to solve the first and last mile problem in public transit. Previous research has shown a general positive attitude towards automated shuttles, but little research has been done to examine how, and if, people will trust a shuttle without a human driver onboard to oversee operation. Studies show that trust is a necessary factor in order for public usage. Like operators in manually driven shuttles, automated shuttle operators perform many roles other than simply driving. The current study evaluated the development of rider trust in an automated shuttle when the operator was either visible or disguised. In the disguised condition, the operator also rode in the shuttle but dressed like a college student and pretended to ride the shuttle out of curiosity. In the visible condition, the operator completed all normal roles. A final exit question revealed that riders genuinely believed the disguise and felt as if they were in an unsupervised autonomous shuttle. Survey, open ended interviews, and video data were coded to determine the effect of the operator on rider trust development. Open ended interviews were evaluated using a thematic analysis approach which revealed several key themes for trust development as well as areas for improvements to foster utilization. Riders were generally quite positive overall about the way in which the automated shuttle fulfilled the traditional operator roles with some notable exceptions. Results indicated that several trust development factors were potentially deficient in the operator disguised condition but that reliable and actionable results can be obtained in either condition. Actionable and systematic recommendations for future development of rider trust are organized into a trust framework based on operator roles and potential solutions. These findings can be used by research or government institutions to improve the utilization of automated transportation systems.

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Introduction

Automation is increasingly prevalent in personal and public transportation. Consumer vehicles are now commonly available with technology that automates steering, braking, and acceleration (i.e. Tesla's Autopilot, Cadillac's SuperCruise, etc). More advanced systems can also change lanes, slow for traffic lights and stop signs, avoid front, side, and rear collisions, and detect pedestrians, animals, and other potential road hazards (Tesla Model Y, 2020). Additionally, companies like Waymo, Uber, and Lyft have begun rideshare programs which make driverless taxis available to select riders on demand. Riders may not, however, be ready or prepared for automated rideshare (Zhang, Roberts, & Goldman, 2019). In order to increase the public's exposure to autonomous vehicles, the Utah Department of Transportation (UDOT) in conjunction with the Utah Transit Authority (UTA), completed a pilot program in 2020 for a low speed, 12-passenger autonomous shuttle as a possible first-mile/last-mile solution. However, similar to most services, a safety operator was required to be onboard, clearly visible, and prepared to override shuttle behavior if necessary (Waymo, 2020; EasyMile, 2019). From a passenger perspective, the presence of a safety operator may weaken the authenticity of the automation experience and bias behavioral outcome measures (Distler, Lallemand, & Bellet, 2019). This research sought to probe rider behavior, acceptance, and trust development, in an automated shuttle in the absence of a clearly visible safety operator and to determine whether and how the presence of a visible operator affects result validity.

Several studies have looked at the development of trust in automated shuttles (e.g., Motak, Neuville, Chambres, & Marmoiton, 2017; Madigan et al, 2016; Madigan et al, 2017; Hilgarter & Granig, 2020). Previous research has shown that people generally have a positive perception of autonomous shuttles (Hilgarter & Granig, 2020; Salonen & Haavisto, 2019) however these conclusions are often drawn from naive survey respondents (Nordhoff, de Winter, Madigan, Merat, van Arem, & Happee, 2018) or riders that experience automation with a backup safety operator (Nordhoff, Winder, Payre, van Arem, & Happee, 2019; Zoellick, Kuhlmey, Schenk, Schindel, & Blüher, 2019). Several aspects of the rider experience are changed when a safety operator is not present and the findings from prior research on rider attitudes may not generalize to full vehicle autonomy where a backup safety operator is not present.

Trust in Automated Shuttles

Lee and See (2004) argue that automation can sometimes fail to reach its full potential if it is not trusted by users. Trust is required when a complete understanding of a system is impractical or impossible (Dzindolet, Peterson, Pomranky, Pierce & Beck, 2003). Rider trust is formed and strengthened with reliable, positive, contextually dependent, experience over time. (Madhavan & Wiegmann, 2007; Carriero, Crabtree, Cooper & Leonard, 2020). Prior research suggests that several factors are critical for the development of trust in automated vehicles (Sanbonmatsu, Strayer, Yu, Biondi, & Cooper, 2018; Choi & Ji, 2015; Lee & See, 2004) and that trust is a vital factor for user acceptance (Balfe, Sharples, & Wilson, 2018). Critical factors for trust development include, reliability of the automation, emotive factors associated with experiencing automation (i.e attitudes, confidence, etc.), the ability and competence of the technology (Lee & See, 2004; Balfe, Sharples & Wilson, 2018), context in which the automation functions (Lee & See, 2004, Balfe, Sharples &

Wilson, 2018), the predictability of the automation (Balfe, Sharples & Wilson, 2018), and trial and error experience (Zuboff, 1988).
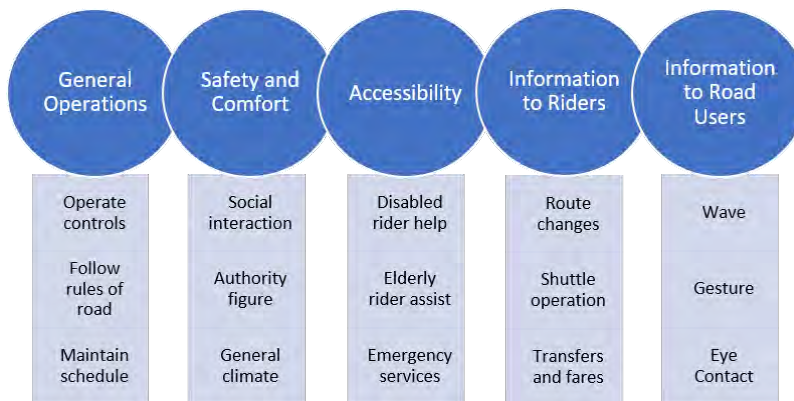

Figure 1. Roles of the operator and example tasks.

Several factors are likely to affect the likelihood that riders will utilize automated shuttles. However, many of these are identical or substantially similar to trust related factors in a manually driven shuttle or factors in public transportation use in general. Specifically, automated shuttles change factors in the rider trust equation that are associated with traditional operator duties and responsibilities. The focus of this paper is on those factors that are uniquely changed with an automated shuttle relative to a manually operated shuttle. The degree to which automated shuttles behave like manually operated shuttles is critical for the development of user trust (Madigan, 2016). In manually driven shuttles, operators fill several roles. In our prior research (Carriero, Crabtree, Cooper & Leonard, 2020) we obtained survey data on hundreds of riders. These data suggest that operator roles can be roughly organized into five distinct groups: General Operation, Safety and Comfort, Accessibility, Information to Riders, and Information to Other Road Users, see Figure 1.

General Operation: The most evident operator task is to drive the shuttle. And to do so in accordance with all local laws and norms, on a prescribed route, and on schedule.

Safety and Comfort: Operators often socially interact with riders, they also adjust climate controls, tailor driving maneuvers to the needs of riders, and fulfill several other minor roles which increase rider comfort and convenience. Operators are also available to call emergency services and otherwise come to the aid of passengers in need. Another important role of the operator is to act as an authority figure on board, which may impact the behavior of riders.

Accessibility: Operators regularly provide assistance to elderly and disabled passengers. Wheelchair riders look to operators for assistance with seat and floor latches and elderly riders may require operators to assist in finding and clearing a seat. Operators also assist those with visual or auditory disabilities who may need additional help to get necessary information like emergency protocols or announcements.

Information to Riders: Operators routinely communicate the intent of the shuttle with riders. This communication often includes route and schedule information, transfers, or other routine or nonstandard operations.

Information to Road Users: Communication is often verbal but can also include hand gestures and eye movements, smiles and nods. Operator communication helps to disambiguate intended shuttle maneuvers in tricky driving situations such as four way stops and crosswalks.

Rider trust is complex and multifaceted. Trust, as it relates specifically and uniquely to automated shuttles is grounded in the roles and responsibilities of the operator. In order for riders to trust automated shuttles, the many roles and responsibilities of operators need to be handled by the automation, altered through changes in rider expectations, or made irrelevant through operational constraints of the shuttle.

Current Study

In order to better understand the effect of a visible operator on trust development, participants were recruited to experience the shuttle in either an operator visible or operator disguised condition. Following each ride, participants filled out a set of questionnaires and completed an open-ended interview in order to evaluate operator roles, and trust factors. Several operator behaviors were coded in the visible and disguised conditions. Coding these behaviors served both means to provide further insight into the automation experience of each passenger, and a way to validate that the disguise of the operator showed differences in behavior between the two groups. In the operator disguised condition, our operator played the part of a curious student photographer, which given the early fall timing of the study, was a highly plausible occurrence. The disguised operator was instructed never to initiate conversation but was allowed to respond and interact with participants. This manipulation allowed us to address two specific research questions as well as several more general questions.

Q1: How do factors associated with the development of rider trust differ when a shuttle operator is visible versus disguised?

In the current study, we operationalize the potential for trust development through rider responses to survey and interview questions. The degree to which responses differ when the shuttle operator is clearly visible versus not, reflects a trust shift associated with the presence of the operator. Prior research suggests that reliance on automation requires users to trust that the automation will fulfill its operational roles. Thus, the foundations for trust development are reflected by the degree to which users feel that the automation fills the roles of the operator.

Q2: How did riders feel that shuttle automation fulfills traditional operator roles?

Several studies have looked at a variety of factors related to rider trust; none have done so from a systematic framework that evaluates the fulfillment of operator roles by automation. This framework uniquely looks at the sufficiency of automation in areas that are changed by the removal of the shuttle operator. In order to probe general rider sentiment, we combined all survey and interview responses from participants in both conditions to look for mean score shifts from a neutral response point.

Methods

Participants

Ninety-six participants ($N = 96$) were recruited from online ads, flyers, and word of mouth to ride the autonomous shuttle and participate in a verbal interview about their experience for a payment of $30. Fifty-nine identified as female, 36 as male, and one preferred not to answer. Participants ranged from 18-65 years old ($M = 33.09, SD = 13.92$). Participants rated their previous experience with autonomous shuttles using a sliding scale with 0 = no experience, 50 = some experience, and 100 = a lot of experience with an average score of 11.6. Those who had previously ridden the shuttle were excluded from the study in order to capture honest first impressions from the participants. Data collection occurred at the University of Utah campus from July 23rd, 2020 through August 7th, 2020 where the Easy Mile Autonomous Shuttle operated on a pre-programmed route which consisted of two stops. Participants were randomly assigned to begin their shuttle ride at either stop 1 or stop 2, and arrived every half hour. This shuttle was available to the public, but the number of riders was limited due to decreased traffic because of Covid-19.

Participants were randomly assigned to one of two conditions: participants in condition one rode the shuttle with a visible operator aboard the shuttle ($N = 48$) while participants in condition two rode with an operator who was disguised as a fellow rider ($N = 48$). The operator disguised condition occurred in the first week of data collection, and the operator visible condition during the second week.

Operator Disguised Condition

It was important to gather real reactions from participants as if there was no operator on the shuttle to understand genuine perceptions of riders' experience with a true "driverless" shuttle. The operator was disguised as a fellow rider, and a number of things were done to ensure the disguise was not revealed until the end of the trip. The shuttle operator was disguised to be a student photographer, wearing a camera bag and casual clothing. Current safety regulations require the operator to have a manual navigation controller strapped around their body at all times. To hide the controller, it was put in the camera bag (See Figure 3 below). The operator also wore headphones to discourage participants from prolonged conversation, which could have resulted in a reveal of the disguise.

To further convince participants of the ruse, the disguised operator would exit the shuttle after each trip and leave the immediate area. When the participant came to board the shuttle, it appeared empty and driverless. After the participant boarded the shuttle, the student photographer (the disguised operator) would approach the shuttle, look curious, and then board the shuttle before it automatically started driving away.

During the shuttle ride, the operator remained silent, only speaking when spoken to by another rider or participant. Under normal circumstances, when the operator is not disguised, the operator would have to manually intervene several times throughout the route to maneuver around obstacles, or slowly stop the shuttle to avoid abrupt emergency stops. To avoid this scenario members of the research team were hidden throughout the shuttle route to remove any potential obstacles that might have stopped the shuttle, and directed traffic off the route to avoid any manual intervention which would have revealed the operator disguise. The operator was instructed only to manually intervene in case of emergency, or if a participant pressed the emergency call button located inside

the shuttle. After their ride, participants were asked on a scale of 1-10 how obvious it was that the other rider aboard the shuttle with them was actually the shuttle operator (1 = not obvious at all and 10 = completely obvious). Participants in the operator disguised condition rated the operator's disguise on average as 1.59. This deception was approved by the University of Utah Institutional Review Board (IRB).

Operator Visible Condition

Participants were not explicitly told there would be a shuttle operator on the shuttle for the operator visible condition, but the operator was wearing a uniform to indicate he was the operator. In addition to the uniform, the navigation controller was visible around his neck (see Figure 2). In this condition the operator still was told not to initiate conversation about the shuttle, but could freely answer riders' questions about the operation. Participants in this condition were also asked to rate how obvious it was that the other person on the shuttle was the operator, which was rated an average of 9.69 on the scale of 1-10.

Figure 2. Operator visible in uniform.

Figure 3. Operator in disguise (right).

Procedure

Prior to arrival, participants filled out a demographics form, and a Coronavirus symptom screening survey. Once the participant arrived, a researcher checked the temperature of every participant before beginning the study. No participants reported, or showed signs of coronavirus symptoms according to a symptoms checklist released by the Center for Disease Control (CDC, 2020). The researcher then consented the participant and instructed them to wait at the research station until the shuttle arrived at the stop.

When participants boarded the shuttle, a researcher assigned them a seat and they were reminded to wear a mask, and seatbelt at all times during their ride. Participants were also informed of the emergency call buttons located inside the shuttle, and that their ride was being filmed for research purposes. Prior to boarding, participants were instructed to think about how the shuttle

compares to manually operated shuttles, and how the shuttle might influence their commute if they were to utilize it every day. The shuttle ride was approximately fifteen minutes, going up to a second stop and back down to the stop they boarded. After their ride, participants exited the shuttle and were escorted back to the research station. Participants then took a brief seven item Likert-scale style survey asking general questions about their experience. Lastly, they took part in a structured open ended verbal interview where they could share their thoughts and feelings about their shuttle experience. Finally, participants were debriefed on the purpose of the study, informed of the operator disguised manipulation and compensated for their time.

Measures
Video

A Go-Pro Hero 7 Black portable camera was mounted on a window inside the shuttle to gather continuous, high quality video and audio of the participants. The camera was placed in a visible location where a researcher would turn it on as soon as the participant boarded.

Videos were analyzed using Behavioral Observation Research Interactive Software (BORIS) to identify behaviors such as manual navigation or intervention, and casual/informational waving by the operator (a friendly wave to a pedestrian or waving-on a yielding car). Conversations between the participant and the operator were also coded. These included casual (weather, sports, etc.), informational (Lidar, speed, etc.), and general shuttle conversations (i.e., "Wow this shuttle is neat"). Keyboard letters were assigned to behaviors for researchers to quickly flag behaviors of interest (i.e., c = conversation) while watching the video. Every time the researcher saw a behavior, they would click the key, noting the event with a timestamp in a computer file. Two types of behaviors were coded, state behaviors (behaviors that have a duration) and point behaviors (behaviors that occur at an instance). For state events, researchers would click the associated key for a behavior to start an event and hit the key again when that behavior ended.

Survey

A seven question Likert-scale survey using RedCap (Harris, Taylor, Thielke, Gonzalez, & Conde, 2009) was given to participants verbally and tracked on an i-Pad. In this survey participants rated certain statements on a scale of 1-10, 1 being extremely poor and 10 being the extremely well (Table 1). The questions in this Likert-scale correlate to the questions of the structured interview.

Table 1
Post-rider questionnaire and correlating themes. Survey was given on a 10-point Likert scale with 1 being extremely poor and 10 being extremely well.

Keywords	Questions
Traffic	How well did the shuttle obey traffic laws?
Obstacles	How well did the shuttle avoid and maneuver around obstacles?
Comfort	How successful was the shuttle in making you feel safe and comfortable?
Safety	How well did you feel the environment was being safety monitored?

Welcomed   How welcomed did you feel when boarding the shuttle?

Information How well was crucial information (stop location and times, safety instructions, etc.) communicated to you?

Road Users How well did the shuttle communicate its intentions to other road users (pedestrians, bikes, cars, etc)?

Interview

In order to gather in-depth responses, researchers interviewed the participant in an open-ended, casual fashion which allowed participants to elaborate on their shuttle experience. To target the factors that influence trust, the interview was structured into five sections: General operation, safety and comfort, accessibility, information to riders, and information to other road users. Two additional follow-up questions were also posed to participants which had them elaborate on potential deterrents and solutions. Within those sections, there were smaller probing questions to ensure participants were truly considering all potential variables that shape their shuttle experience or scenarios that were not present at the time of their ride such as weather, number of riders, time of day, etc. Questions and follow-up probes are provided in Table 2.

Table 2

Semi-structured interview questions with correlating themes and additional probing questions

Sections	Questions
General Operation	Compared to a normal manually operated shuttle, that you would ride in the city, tell me what stood out about this shuttle regarding its speed, ability to navigate around obstacles and obey traffic laws?
	Probe: Do you think the shuttle might operate differently at a different time of day or during inclement weather?
Safety and Comfort	What worked for you? What about the shuttle made you feel safe?
	What didn't work for you? What about the shuttle made you feel unsafe?
	Probe: Would your feelings of safety and comfort change if you were riding at max capacity? What about riding alone?
Accessibility	Tell me about any challenges or advantages a disabled individual would face when riding the shuttle.
	Probe: What about someone with a non-physical disability such as a visual or hearing impairment?
Information to Riders	What information did you get from the shuttle's displays, audio, or signs?
	What information did you wish you got from the shuttle's displays, audio and signs?
Information to Road Users	What do you think other pedestrians and drivers thought of the shuttle?
	Did they understand where it was going or what it was going to do?

Interviews were transcribed in real time using Google Voice Talk to Text and were recorded on a voice app on the laptop. Following each interview, a research assistant read through the full

transcription while listening to the interview and corrected any mistakes made by the automated software. The full transcript of these interviews, showing the positive, neutral, and negative coding of the responses, is included Appendix A.

Interviews were analyzed according to the structured sections provided in Table 2. Within those sections, themes to each central question were developed using a thematic analytic technique (Nowell, Norris, White, & Moules, 2017). In the Driving Ability section, four common themes were traced between all the interviews: Shuttle speed, traffic law adherence, ability to navigate obstacles, and the effect of different weather or lighting conditions on the shuttle's ability to drive. A detailed description of the themes as well as examples can be viewed in Table 3. Three themes were identified in responses to the Safety and Comfort interview questions: Social comfort inside the shuttle, availability of emergency features onboard, and how the shuttle's ability to drive affected riders' feelings of safety and comfort (Table 4). Two themes were identified in the Accessibility section: Ease of use to those with physical disabilities; and those with auditory or visual impairments (Table 5.) In the Information to Riders section, three common themes emerged: Audio inside the shuttle, interior displays or signs, and the operator as an information source (Table 6). Lastly, three response themes were identified to the Road Users probe: Audio communication to other road users, visual displays of communication, and perceptions of other road users regarding the intent of shuttle operations (Table 7).

Comments categorized under each theme were coded as being negative, positive, or neutral. Neutral comments were coded to establish a baseline comment value for each participant, but were not used for analysis. Negative comments suggested that the autonomous shuttle was insufficient at operating like a manually operated shuttle, and did not meet expectations. Positive comments suggested that the autonomous shuttle was consistent with, or better than a manually operated shuttle and met, or exceeded expectations. Only comments that were specifically related to operator roles were coded. Other comments such as number of seats inside the shuttle, aesthetics of the shuttle, etc., were not coded since these features are not specific to automated shuttles and cannot be controlled by the operator. A Qualitative Data Analysis software (QDA Miner Lite) was used to code the interviews (Provalis Research, 2004). The program allowed researchers to highlight lines of text from the interviews, assign it a theme, and code the comment as being positive, negative, or neutral. A plain text file which contained the frequency and percentage of each comment type was exported and cleaned for further analysis.

Lastly, to quantify the prevalence of comments in each theme we assigned positive comments a score of +1 and insufficient comments a score of -1. For example, "I could walk faster than the shuttle." would be coded as a -1 for the speed theme. If that same participant made another negative comment for speed their score would be -2. If a participant made a negative comment like, "There were not enough auditory instructions inside the shuttle" coded as -1 and one positive comment such as, "I thought the audio inside the shuttle was very clear" coded as +1, the sum of their scores for that theme would equal 0. This technique allows us to identify clear differences in scores between the two groups and to run statistical analyses on the results.

Table 3

Driving Ability (Interview question number one). Themes, description, and examples.

Theme	Description	Example
Speed	**Participant speaks about the shuttle's speed.**	
Insufficient	Speed being too slow, too fast, or any negative connotation relating to speed. Absolutely insufficient in meeting the needs of the passenger.	"It's just way too slow. I could walk faster."
Sufficient	Positive, or enthusiastic connotation to the speed. Suggests the speed of the shuttle is sufficient for the needs of the passenger. No need for improvement.	"I thought the speed was relaxing. It made me feel safe."
Conditions	**Participants speak about how weather, time of day, or lighting conditions may impact the shuttle's ability to drive, or their willingness to ride.**	
Insufficient	Snow, rain, wind, lighting, etc. restricts the shuttle's ability to drive. Also if any type of weather or time of day would deter someone from riding. Absolutely would deter passengers, or restrict the shuttle from operating.	"Yeah, I don't think it would ride it at night time because I would feel unsafe."
Sufficient	Positive or enthusiastic connotation in regards to how weather, or time of day affects the shuttle. Or any answer suggesting that weather aids, or does not affect the shuttle's ability to drive.	"I think this is a great thing especially if it's raining. If it was really hot or really cold, it would be nice to ride this to class."
Obeying Traffic Laws	**Participants were asked how well the shuttle obeyed traffic laws. Any comments pertaining to stop signs, right of way, speed limit, etc.**	
Negative	Disobeyed traffic laws, did not follow any traffic standards compared to a manually operated bus/shuttle. Negative comments relating to traffic laws.	"Yeah it went way past the stop sign. I wasn't even sure it was going to stop."
Positive	Enthusiastic comments regarding its ability to obey traffic laws. Or any comment suggesting the way it drove was sufficient.	"Yeah, I think it obeyed all traffic laws just fine."
Navigating Obstacles	**Comments pertaining to the shuttle's ability to navigate around obstacles**	
Negative	The shuttle did a poor job of navigating around obstacles. Comments about running into obstacles, fear of running into things, or the shuttle stopped behind an obstacle for a long time. Negative connotation to the comments.	"We were stopped behind a bus for a really long time, and the shuttle did not go around it. If I was in a hurry this would be an issue."
Positive	Enthusiastic comments about how the shuttle navigated around obstacles.	"Yeah it drove right around that bus and pulled right up to the curb!"

Table 4

Safety and Comfort (Interview question number two). Themes, description, and examples.

Theme	Description	Example
Social Comfort	**Aspects of the shuttle that relate to social, or emotional comfort/uncomfort in terms of safety or comfort.**	
Negative	Comments in regards to insufficient safety or comfort about social or emotional aspects.	"I wouldn't ride this at night time because as a woman I would be scared if I was riding with someone suspicious."
Positive	Enthusiastic comments about how social aspects made them feel safe or comfortable.	"I felt really safe having the operator on board with me. His presence felt welcoming"
Emergency Features	**There are a number of safety features onboard in case of emergency. Any comments relating to these are coded here.**	
Negative	Comments about the insufficiency of emergency features. Lack of instruction, security, etc. Negative connotation, would not know what to do in an emergency.	"I saw the emergency buttons but it's unclear who they call, or what to do in the case of an actual emergency. "
Positive	Comments about the emergency features onboard. Made the passenger feel safe and comfortable.	"Yeah I saw all the emergency buttons, and the camera made me feel safe!"
Shuttle Behavior	**Any comments that are made about how the way the shuttle drives makes the rider feel safe or unsafe.**	
Negative	Comments related to the way the shuttle drove made them feel unsafe. Negative phrases. Jerky, stops in the wrong places, etc.	"The fact that it went past the stop sign made me feel like it wasn't safe to ride in."
Positive	Positive comments made about how the way the shuttle drives made the rider feel safer. Smooth, stopped in all the right places, etc.	"It was so smooth, and the fact that I knew the shuttle was going to stop for pedestrians made me feel much safer."

Table 5

Accessibility (Interview question number three). Themes, description, and examples.

Theme	Description	Example
Physical Disability	**Comments about the safety, comfort and security of those in wheelchairs or other physical disabilities that does not include comments about the amount of space inside the shuttle.**	
Negative	Comments that suggest someone with a physical disability could not ride. Or that the accessibility features of the shuttle are unsafe, inconvenient, or harmful to those with physical disabilities.	"I didn't see a wheelchair ramp, I'm not even sure they could ride it."
Positive	Comments that suggest all the accessibility features that are needed for someone with a physical disability are safe, and are usable by the person. Also could be how the shuttle is useful for their commute and can aid in transportation for disabled populations.	"I think this is a great use for them. This is much better than taking your wheelchair up the hill."
Audio/Visual Disability	**These are comments targeted at those with visual or auditory impairments. Any comments about the safety, comfort, or convenience the shuttle has for these people.**	
Negative	Comments that suggest the shuttle does not accommodate those with visual or auditory impairments. Or that the features to aid (or lack of) those with audio/visual impairments are unsafe.	"I didn't hear any audio instructions so if I was blind there is no way I would know when or how to get off."

Positive	Comments that suggest all features of the shuttle accommodate those with visual/auditory impairments. Also could be how the shuttle is useful for their commute and can aid in transportation for those populations.	"Yeah since it announced the stops and showed it on the screen I think if you were blind or deaf you would be able to navigate it."

Table 6

Information to Riders (Interview question number four). Themes, description, and examples.

Theme	Description	Example
Audio	**Comments about the audio inside the shuttle, or noises the shuttle makes on the outside that inform or aid riders**	
Negative	Comments about lack of or too much audio. Or that the audio was not informative, volume was too low/high, language preferences, etc. Any comments that suggest the audio did not aid in the shuttle experience or actively made it worse.	"I didn't hear any audio.. it would have been nice to announce when we were getting to the stop or something."
Positive	Positive comments about how the audio helped inform or aid riders on the shuttle. No improvements needed, good as is.	"Yeah I really liked that it announced what stop we were at before we got there."
Displays	**Comments about the displays and signs inside the shuttle that aid or inform riders**	
Negative	Comments about not being enough, or too many displays inside the shuttle. Confusing, not helpful, etc.	"I just really wish it showed a map of the campus. I don't know where I'm going."
Positive	Comments about how the displays of the shuttle aided in their ride experience, or how the displays are fine as is and do not need to be changed.	"Yeah all the little pictures on the buttons made it very clear what they all do."

Table 7

Information to Road Users (Interview question number five). Themes, description, and examples.

Theme	Description	Example
Shuttle Audio	**This is specifically comments that relate to how the shuttle communicates to road users by audio.**	
Negative	Comments about how the exterior shuttle audio does a poor job at communicating to road users. Or, audio is not loud or frequent enough	"I don't think it makes any sound or anything, it's really quiet actually it could easily sneak up on someone."
Positive	Comments about how the shuttle uses audio to communicate to road users.	"Yeah I noticed it dings whenever it crosses a crosswalk"
Shuttle Visual	**This is specifically comments that relate to how the shuttle communicates to road users by visual displays or visual cues from the operator.**	
Negative	Lack of visual displays that make it hard for the shuttle to communicate with road users. Any negative comments about how the shuttle does a poor job of communicating to road users using displays or signs.	"As a pedestrian I don't think I'd know what it was. It needs to say like an Automated shuttle on it or something. There's just no way to know"
Positive	Comments about how the shuttle used displays to communicate to road users	"Yeah I saw it had little turn signals on it which was really necessary"
Shuttle Behavior	**How the shuttles behavior gave insight to other road users of what it was going to do.**	
Negative	Comments that suggest the way the shuttle drives is confusing to other road users.	"As a car I wouldn't know what this thing was if I was stuck behind it."
Positive	Enthusiastic comments that suggest other road users understand what the shuttle is going to do and what it is.	"Yeah we saw a biker and he seemed to know what this thing was, he seemed comfortable."

Results

Several statistical tests were used in the analyses that follow: Mean (*M*), Standard Deviation (*SD*), T- Test, and the Kruskal Wallis Test. Mean values in this study are observations averaged. For state video observations the mean represents duration in seconds; for point video observations, the mean is number of observations; mean values in the survey data show average score on the 10-point Likert Scale; and mean scores for the interviews exemplify the ratio of positive to negative comments. For example, if a participant made one positive comment and one negative comment the scored sum of those two comments would cancel out to zero. If a participant made 2 negative comments to 4 positive comments, their summed score would be +2, and so on.

The Kruskal Wallis test is an alternative option to a one-way ANOVA designed to handle non-parametric data (Kruskal & Wallis, 1952). This test analyzes the between-group difference using Chi Squared (χ2), degree of freedom (df), and *p* values. Chi Sq. characterizes the sum of deviations between two conditions. Thus, as the Chi Sq. value increases, the p value decreases. The significance of results in this study are based off of the threshold of *p* < 0.05, consistent with common statistical practices. *Df* values are the number of observations within the statistical test that have the freedom to vary which is dependent on sample size, and parameters measured. A higher *df* signifies more observations, or parameters measured for the given sample size which yields more power to find significant *p* values.

The Kruskal Wallis test was used to evaluate differences between the two conditions, but for the interview responses analysis we used a T-test to analyze if that difference was significant in a positive or negative direction relative to zero. The T-test provides *t*, *df*, and *p* values. The *t* value is the difference of the groups means combined relative to 0. If the *t* statistic is negative that would mean all participants regardless of condition, responded negatively to the question theme; and positive *t* value means all participants responded positively to the given theme.

Video

Video results were analyzed to ensure the efficacy of the primary operator visible/disguised manipulation. State events and point events were analyzed separately for the video data. Descriptive statistics for the state events can be viewed in Table 8, and Table 9 for point events

Table 8
Results on state observations from video data in seconds.

	Visible	Disguised	Kruskal-Wallis Test		
Observation	**M (SD)**	**M (SD)**	**Chi Sq.**	**df**	**p**
Casual Conversation	118 (118)	182 (168)	3.16	1	0.08
General Conversation	97.6 (112)	123 (103)	2.47	1	0.12
Informational Conversation	397 (224)	0.18 (1.12)	67.03	1	< 0.001**
Manual Navigation	9.44 (24)	0.00 (0.00)	7.05	1	0.008**
Overall	604 (254)	263 (220)	28.55	1	< 0.001**

Note. ** = *p* < .01

A one-way Kruskal Wallis test was conducted on the dependent variables between the operator visible and disguised groups. Results showed that there was a statistically significant difference in informational conversations between the participant and the operator ($M = 118$, $SD = 118$; $M = 182$, $SD = 168$), and manual navigation issued by the operator ($M = 9.44$, $SD = 24$; $M = 0$, $SD = 0$), see Table 8. More specifically, those in the operator visible condition experienced more informational conversations as well as manual navigation compared to those in the operator disguised condition. Additionally, the operator visible condition had more state observations overall ($M = 604$, $SD = 254$; $M = 263$, $SD = 220$) which indicates that the operator had more of an active role in the visible condition than in the disguised condition.

A Kruskal Wallis test showed that there was a statistically significant difference between all the dependent measures: manual intervention ($M = 3.47$, $SD = 2.46$; $M = 1.86$, $SD = 0.67$), casual waves ($M = 0.64$, $SD = 0.85$; $M = 0.11$, $SD = 0.39$), and informational waves ($M = 0.23$, $SD = 0.48$; $M = 0$, $SD = 0$), see Table 9. Those in the operator visible condition rated higher on all statistically significant point events seen below. The operator visible condition also had more overall point observations recorded overall ($M = 4.38$, $SD = 2.93$; $M = 1.97$, $SD = 0.60$). The purpose of these video analyses was to confirm that operator behavior differed in the visible and disguised conditions in a manner that would be expected due to the manipulation. These statistically significant findings provide support for the integrity of the manipulation.

Table 9
Point event observations from video data.

	Visible	Disguised	Kruskal Wallis Test		
Observation	**M (SD)**	**M (SD)**	**Chi Sq.**	**df**	**p**
Manual Intervention	3.47 (2.46)	1.86 (0.67)	15.42	1	< .001**
Casual Wave	0.64 (0.85)	0.11 (0.39)	12.22	1	< .001**
Informational Wave	0.23 (0.48)	0.00 (0.00)	8.82	1	0.003**
Overall	4.38 (2.93)	1.97 (0.60)	26.71	1	<0.001**

Note. .* = $p < .05$, ** = $p < .01$

Survey

A Kruskal Wallis test was conducted to analyze the variance in responses between the visible and disguised condition on the Likert-Scale. Respondents rated all questions at near ceiling levels. Only responses on a single question (Road Users), fell below a 9 out of 10. Post hoc tests revealed that those in the operator visible condition rated the shuttle as more capable at obeying traffic laws ($M = 9.81$, $SD = 0.53$; $M = 9.46$, $SD = 0.97$), felt more welcome upon boarding the shuttle ($M = 9.83$, $SD = 0.66$; $M = 9.31$, $SD = 1.15$), and felt that crucial information was communicated to them more effectively compared to those in the operator disguised condition ($M = 9.10$, $SD = 1.57$; $M = 8.35$, $SD = 2.15$), see Table 10. We can conclude that the operator in the visible condition was more active in fulfilling operator roles such as gestures to other road users, and issuing manual intervention compared to the disguised operator.

In addition to the seven survey questions, participants were asked to rate how obvious it was that the student photographer on the shuttle was actually the shuttle operator. Those in the operator disguised condition reported that it was not obvious at all ($M = 1.59$, $SD = 1.85$, $\chi(1)= 63.93$, $p < .001$) compared to those in the operator visible condition who reported it was extremely obvious ($M = 9.69$, $SD = 1.36$) which confirms that the manipulation of the operator disguise was successful between the conditions.

Table 10

Results for ten-point Likert-Scale survey responses. Higher values indicate better performance.

	Visible	Disguised	Kruskal Wallis Test		
Keyword	*M (SD)*	*M (SD)*	**Chi Sq.**	*df*	*p*
Traffic	9.81 (0.53)	9.46 (0.97)	4.32	1	0.04*
Obstacle	9.23 (1.17)	9.31 (1.30)	0.45	1	0.50
Comfort	9.65 (0.76)	9.52 (0.80)	0.83	1	0.36
Safety	9.69 (0.75)	9.48 (0.97)	1.13	1	0.29
Welcomed	9.83 (0.66)	9.31 (1.15)	9.07	1	0.003**
Information	9.10 (1.57)	8.35 (2.15)	4.25	1	0.04*
Road Users	8.42 (1.83)	8.19 (2.03)	0.23	1	0.63

Note. See Table 1 for keyword descriptions. * = p < .05, ** = p < .01

Interview

A Kruskal Wallis test was conducted to examine the effect of the operator visible/disguised condition on the participant's shuttle experience categorized by positive (+1) and negative comments (-1) that correspond to each theme in the verbal interview. Scores in each theme were summed and analyzed using a Kruskal Wallis test. Additionally, a one sample T-test was performed on all interviews combined for each theme to evaluate the riders' overall general experience with the shuttle despite condition.

Driving Ability

In the aggregate, there were no statistically significant differences seen between groups for themes speed, traffic laws, navigating obstacles, and conditions. However, the T-test revealed that all participants despite condition made a statistically significant number of negative comments about the shuttle's speed, $t(95) = -6.77$, $p = <0.001$. Participants in general made a significant number of positive comments that show the shuttle does a sufficient job at obeying traffic laws, $t(95) = 2.84$, $p = <0.005$, navigating obstacles, $t(95) = 3.24$, $p = <0.002$, and operating under diverse conditions, $t(95) = 1.95$, $p = <0.05$. See Table 11 for detailed statistics.

Table 11

One way Kruskal-Wallis Test and T-test results for negative and positive statements for the Driving Ability theme identified from participant interviews. Values indicate the summed scores between the conditions. Positive scores indicate increased positive statements, and negative scores indicate increased negative statements.

	Visible	Disguised	Kruskal Wallis Test			T-test		
Theme	**M (SD)**	**M (SD)**	**Chi Sq.**	**df**	**p**	**t**	**df**	**p**
Speed	-0.83 (1.29)	-0.92 (1.25)	0.58	1	0.45	-6.77	95	< 0.001**
Traffic Laws	0.38 (0.70)	0.15 (1.05)	1.69	1	0.19	2.84	95	0.005**
Obstacles	0.23 (0.93)	0.35 (0.84)	0.25	1	0.62	3.24	95	0.002**
Conditions	0.21 (1.35)	0.31 (1.27)	0.00	1	0.95	1.95	95	0.05*

Note. * = *p* <.05, ** = *p* < .01

Safety and Comfort

The Kruskal-Wallis test found that those in the operator visible condition felt more comfortable with the social atmosphere of the shuttle than those in the operator disguised condition who reported that the social atmosphere inside the shuttle was insufficient ($M = 0.21$, $SD = 0.68$; $M = -.13$, $SD = 0.73$). Additionally, the T-test showed that all participants felt that the emergency features inside the shuttle. $t(95) = 2.18$, $p = 0.032$, and the way the shuttle drove and behaved made them feel safer and more comfortable. $t(95) = 4.43$, $p = <0.001$. See Table 12 for detailed statistics.

Table 12

One way Kruskal-Wallis Test and T-test results for negative and positive statements for the Safety and Comfort theme identified from participant interviews. Values indicate the summed scores between the conditions. Positive scores indicate increased positive statements, and negative scores indicate increased negative statements.

	Visible	Disguised	Kruskal Wallis Test			T-test		
Theme	**M (SD)**	**M (SD)**	**Chi Sq.**	**df**	**p**	**t**	**df**	**p**
Social Atmosphere	0.21(0.68)	-0.13 (0.73)	6.49	1	0.01*	0.56	95	0.57
Emergency Features	0.06 (0.95)	0.33 (0.81)	1.55	1	0.21	2.18	95	0.032*
Shuttle Behavior	0.438 (0.94)	0.35 (0.81)	0.00	1	0.08	4.43	95	< 0.001**

Note. * = *p* <.05, ** = *p* < .01

Accessibility

Table 13 shows the analysis of comments in the accessibility theme which revealed that all riders believed the shuttle was well equipped to serve physically disabled populations, $t(95) = 2.67$, $p = 0.009$,

but those in the operator visible condition had significantly more positive comments than those in the disguised condition (*M* = 0.83, *SD* = 2.17; *M* = 0.19, *SD* = 1.51).

Table 13

One way Kruskal-Wallis Test and T-test results for negative and positive statements for the Accessibility theme identified from participant interviews. Values indicate the summed scores between the conditions. Positive scores indicate increased positive statements, and negative scores indicate increased negative statements.

	Visible	Disguised	Kruskal Wallis Test			T-test		
Theme	*M (SD)*	*M (SD)*	**Chi Sq.**	*df*	*p*	*t*	*df*	*p*
Physical Disability	0.83 (2.17)	0.19 (1.51)	3.85	1	0.05*	2.67	95	0.009**
Audio/Visual Disability	0.10 (1.04)	-0.13 (0.79)	0.59	1	0.44	-0.20	95	0.91

Note. * = *p* <.05, ** = *p* < .01

Information to Riders

   Statistical tests were not significant for this theme based on the threshold of < 0.05 for *p* values, but can be viewed in Table 14.

Table 14

One way Kruskal-Wallis Test and T-test results for negative and positive statements for the Information to Riders theme identified from participant interviews. Values indicate the summed scores between the conditions. Positive scores indicate increased positive statements, and negative scores indicate increased negative statements.

	Visible	Disguised	Kruskal Wallis Test			T-test		
Theme	*M (SD)*	*M (SD)*	**Chi Sq.**	*df*	*p*	*t*	*df*	*p*
Audio	-0.10 (1.23)	-0.04 (1.18)	< 0.001	1	0.11	0.61	95	0.55
Displays	-0.13 (1.51)	0.25 (1.10)	1.33	1	0.25	0.46	95	0.64

Note. * = *p* <.05

Road Users

   Our analysis of the comments in the Road Users theme found that participants in the operator visible condition thought that the way the shuttle behaved, or drove was insufficient at communicating to other road users compared to those in the disguised condition, who believed the shuttle was sufficient in its' behavior toward other road users (*M* = -0.03, *SD* = 0.88; *M* = 0.06, *SD* = 0.61). The T-test showed that all the riders, despite condition, thought that the shuttle was insufficient at communicating to road users via exterior displays like turn signals, signs, etc., *t*(95) = -2.20, *p* = 0.03. See Table 15.

Table 15

One way Kruskal-Wallis Test and T-test results for negative and positive statements for the Road Users theme identified from participant interviews. Values indicate the summed scores between the conditions. Positive scores indicate increased positive statements, and negative scores indicate increased negative statements.

	Visible	Disguised	Kruskal Wallis Test			T-test		
Theme	*M (SD)*	*M (SD)*	**Chi Sq.** *df*		*p*	*t*	*df*	*p*
Shuttle Audio	0.00 (0.46)	-0.04 (0.41)	0.33	1	0.57	-0.47	95	0.64
Shuttle Displays	-0.17 (0.83)	-0.13 (0.39)	0.01	1	0.91	-2.20	95	0.03*
Shuttle Behavior	-0.03 (0.88)	0.06 (0.61)	6.68	1	0.009**	-1.71	95	0.09

Note. * = *p <.05, ** = p < .01*

Discussion

This study was designed to evaluate how the presence of a shuttle operator influences the development of rider trust in a low-speed automated shuttle. Automated shuttles currently require a backup operator to step in and take over control if needed. Operators in automated shuttles fill many of the same roles as operators in traditional, manually driven shuttles. In order for riders to utilize automated shuttles they will need to trust the automation. This study explored several factors associated with trust development in an operator visible and operator disguised condition. Riders experienced either of the conditions then completed a brief survey and an open-ended interview regarding their experience. Interview responses were first coded to identify common response themes. Responses in each theme were then characterized as either suggesting that the shuttle provided *sufficient* (positive) or *insufficient* (negative) support for each theme. Finally, comments were quantified and analyzed to determine overall response patterns across the operator visible and operator disguised conditions. This experimental design allowed us to address our two primary research questions.

Q1: How do factors associated with the development of rider trust differ when a shuttle operator is visible versus disguised?

After participants completed all survey and interview questions, they were asked to rate how aware they were that the gentleman standing by the door was the operator. Answers to this question were provided on a 10-point Likert scale. Not surprisingly, almost all participants in the operator visible condition answered with a 10 (*M* = 9.69), indicating that they were completely aware. However, the mean response score in the operator disguised condition was just 1.59. This indicated that our participants were, for the most part, completely fooled by the manipulation. In light of this, participant responses to the survey and open-ended questions were all the more interesting.

Trust development was operationalized by a set of survey questions and responses to open-ended questions that probed key aspects of the rider experience related to the automation. Results from the 10-point survey suggested that participants generally felt more welcomed on the shuttle when the operator

was clearly identifiable. Additionally, participants felt that the shuttle did a better job of obeying traffic laws with the operator visible. Other questions resulted in non-significant differences between the operator visible and disguised conditions.

Open-ended interviews of riders suggest that they generated more positive comments when the operator was visible on the topic of Social Comfort. They were also more likely to generate positive comments on the potential role of the shuttle in aiding passengers with physical disabilities and were more likely to comment on the positive role of shuttle operator. When asked what they thought other pedestrians and drivers thought of the shuttle, they were less likely to generate positive comments related to the shuttles ability to communicate with other road users. In summary, comments seemed to suggest that riders viewed the operator as a positive authority that was there to help out and had a more difficult time understanding how the shuttle would communicate to other road users if the operator were not present.

Overall, the results are perhaps most striking in their similarities. While several differences were found in survey themes between the operator visible and disguised groups, it is perhaps most interesting to note the lack of finding. That is, our survey data suggest that the automation was, in many respects, very effective at meeting the needs of riders. However, results also point to areas that could be improved. Specifically, results suggest that riders may benefit from additional acknowledgement by the automation as they board the shuttle. This could be as simple as an automated welcome message that is cued by passengers entering the shuttle in a directed fashion. Additionally, more information about the operations of the shuttle could be provided to allow riders to seek out answers to their service-related questions. The shuttle was equipped with an informational display but it was sometimes not operational. Finally, more needs to be done to ensure that the shuttle is capable of handling all of the potential traffic situations that arise on the route. It was sometimes the case that the shuttle required manual intervention to go around vehicles or obstacles that were blocking the path. In the operator disguised condition we instructed the operator to not intervene unless absolutely necessary. This may have led to an increased number of shuttle path conflicts that were only slowly resolved by the automation. We expect these types of conflicts to become increasingly rare as the automation improves.

Q2: How did riders feel that shuttle automation fulfills traditional operator roles?

Participant comments were coded to indicate sufficiency (positive) or insufficiency (negative) of the automation solution. A composite average score of positive or negative comments was generated to determine the overall sentiment of rider response to each topic area and theme. A completely neutral response by riders would return scores that did not differ from zero, scores above zero indicated a positive response bias while scores below zero indicated a negative response bias. Many rider responses were not different from zero, which suggests that rider responses to those items were not sufficiently polarized to cause a mean difference in response bias (i.e., that riders felt that the automation adequately fulfilled most operator roles). However, there were some notable exceptions.

Riders generated more positive comments on themes related to the shuttles ability to obey traffic laws, maneuver around obstacles, and provide utility in a variety of weather conditions. Participants were, however, much more negative and outspoken regarding shuttle speed. On average, participants nearly made 1 more negative comment regarding shuttle speed than positive comment (-.83 [visible] and -.92 [disguised]). The polarity of findings suggests that the slow operational speeds likely traded off with positive thoughts about other aspects of the shuttles general driving ability. This was further supported by

the more positive comments related to Shuttle Behavior, and Emergency Features. Riders were also positively biased in the shuttle's potential utility for riders with physical disabilities, though some riders commented on the need for operator assistance with wheel-chair latching or door operations.

The general prevalence of negative rider comments was also somewhat elevated on the topic of Road Users. Here comments were organized into several themes that indicated insufficient automation performance on issues related to the shuttle communicating via external displays or markers with other road users. The need for automated vehicles to better communicate with road users has been identified as an important gap that is beginning to receive research attention (e.g., Domeyer, Lee, & Toyoda, 2020; Habibovic et al., 2019), participants in this study seemed to agree.

Taken together, results suggest that a positive response bias was observed in 6/15 themes and a negative response bias existed in just 2/15 themes, while 7/15 themes showed no detectable response bias. Thus, riders were generally quite positive overall about the way in which the automated shuttle fulfilled the traditional operator roles with some notable exceptions.

Solutions and Future Directions

This study generated several actionable rider insights to improve trust in autonomous shuttle technology. Action items can be organized using an operator task framework which highlights operator roles and responsibilities as well as methods for filling those roles (See Figure 4 below). Operator roles can be filled by automation, removed through shuttle service constraints, or minimized through education to change rider expectations. Notably, many of the suggestions generated through the lens of this framework have already been identified as target areas for development and deployment. However, we feel that this approach helps to define a development roadmap to maximize the efficacy of future research and deployment efforts.

Figure 4
Framework for solutions to fill operator roles and an application example for the operator role of General Operation. This framework can be utilized for all of the operator roles shown, but the application for each will differ.
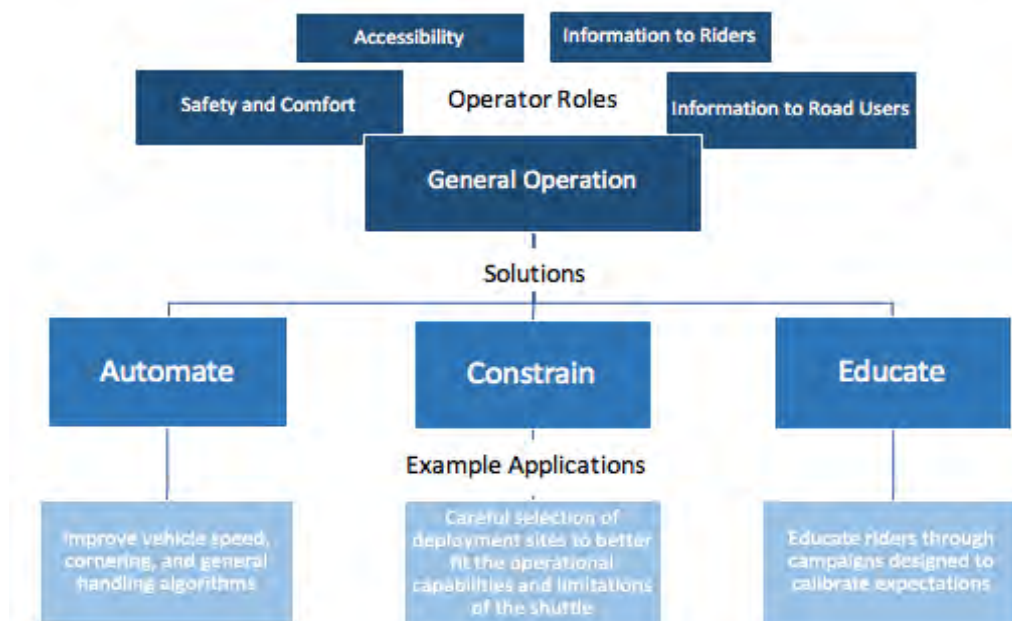
Automation: The current technological solution to automation may need to be further extended to meet rider service expectations. Rider trust could be improved by the following automation developments:

- Improve vehicle speed, cornering, and general handling algorithms
- Better inform riders of steps taken by automation to ensure their safety and security (e.g., automated rider greetings, more visible safety countermeasures, etc.)
- Automate wheelchair latching systems, door open/close functionality, wheelchair ramp extensions, and other technology improvements to meet the needs of disable riders
- Further clarify and improve rider communication regarding service and operation
- Enhance external communication capabilities with other road users

Constraints: Vehicle automation is a nascent technology that cannot currently replace all operator roles. Further technological development will allow automation to gradually fill additional operator roles but a complete replacement of all operator capabilities may never be possible. In order to maximize utilization and foster rider trust, shuttles will need to operate in a constrained environment which changes rider expectations. This recommendation fits the criteria for SAE level 4 automation (SAE, 2019), We recommend several operational constraints to ensure trust development:

- Careful selection of deployment sites to better fit the operational capabilities and limitations of the shuttle
- Operate only in well-lit environments where others are clearly visible and immediately available for assistance or safety aid
- Clarify and constrain service roles for disabled and elderly riders.
- Simplify ride routes to minimize information requirements to riders
- Reduce or eliminate pedestrian or vehicle conflict zones

Education: A final way to increase utilization and foster trust development is through a change in rider expectations through education. Automation has the capability to greatly improve safety and mobility for many riders. However, automated vehicles may not often perform in the ways that riders expect. Prior research has shown that simply experiencing automation will begin reshaping rider expectations (Soe & Müür, 2020). However, more active solutions to aid the transition of rider expectations for an automated future could include:

- Educate riders through campaigns designed to calibrate expectations
- Better inform riders of measures taken to ensure personal safety while aboard the shuttle
- Ensure disabled and elderly riders are informed of what to expect, which may be very different from a manually operated shuttle
- Training programs and aids to help riders better utilize automated service information
- Public outreach to other road users to help them better understand the capabilities and limitations of the automation

Limitations

Current technology does not allow for truly autonomous shuttle operations. In order to probe rider trust development in an autonomous shuttle we disguised the shuttle operator as a fellow rider. Responses to this experimental manipulation indicated that we were highly successful in hiding the true nature of our operator. However, in order to perform this manipulation several additional and potentially unnatural alterations were made to the rider experience that may have influenced trust development. For example, participants were escorted up to the shuttle by a researcher who opened and closed the doors and operation was confined to a highly controlled environment that greatly reduced the potential for automation failures that may have required the shuttle operator to intervene. Future research could revisit the potential impact of each of these factors on the rider trust development.

This research was carried out on a University campus during the Covid-19 global pandemic. There were very few people on campus and almost no traffic on the road. This highly constrained environment provided few opportunities for our participants to witness the shuttle interact with other vehicles and pedestrians. As a result, participants may have experienced shuttle operations in the best possible conditions which could help to explain their overall positive attitudes toward the capabilities of the automation. We identify operational constraints as one possible method for improving rider trust, future research could assess rider trust development in a wider variety of conditions that further challenge the automation.

Summary and Conclusion

Vehicle automation is rapidly developing and will, at some point, no longer require operators to oversee the automation. In order to maximize utilization, it is critical that users trust the automation to meet their performance expectations. This research evaluated rider trust development with an automated shuttle in an experimental condition where the operator was either clearly visible to participants or disguised as a fellow rider. This design was motivated by our desire to address two outstanding questions: *Q1: How do factors associated with the development of rider trust differ when a shuttle operator is visible versus disguised? Q2: How did riders feel that shuttle automation fulfills traditional operator roles?* To address these questions, participants were recruited to take a 25-minute ride in the shuttle and then to provide feedback on their experience through survey responses and an open-ended interview. Questions were structured to target a rider trust framework built from results obtained by Carriero, Crabtree, Cooper & Leonard (2020) which specifies five operator task categories that are changed with automation. Results indicate that several trust development factors were potentially deficient in the operator disguised condition but that reliable and actionable results can be obtained in either condition. Based on these findings, we extend the rider trust development framework to include a scaffolding of procedures to generate actionable steps to improve rider trust. These findings can be used by research or government institutions to improve the utilization of automated transportation systems.

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