Deployment Playbook

Based on the Smart Columbus Demonstration Program

FINAL REPORT | May 19, 2021
# Table of Contents

Chapter 1. Introduction ........................................................................................................... 3  
Chapter 2. User Needs Development .................................................................................... 4  
  2.1. Operational Concept ................................................................................................. 4  
  2.2. Policies and Constraints ............................................................................................ 5  
  2.3. Defining the Purpose .................................................................................................. 5  
  2.4. Stakeholder Input ........................................................................................................ 6  
Chapter 3. Procurement ......................................................................................................... 7  
  3.1. Request for Information .............................................................................................. 7  
  3.2. Request for Proposals ................................................................................................. 7  
    3.2.1. Operational Requirements .................................................................................. 8  
    3.2.2. Vehicle Requirements ......................................................................................... 8  
    3.2.3. Data ..................................................................................................................... 9  
    3.2.4. Testing Requirements ......................................................................................... 10  
    3.2.5. Other Considerations ......................................................................................... 10  
Chapter 4. Safety .................................................................................................................. 11  
  4.1. Safety Management Plan ........................................................................................... 11  
  4.2. Standard Operating Procedures ............................................................................... 11  
  4.3. Testing ....................................................................................................................... 12  
Chapter 5. Interoperability ................................................................................................... 13  
  5.1. AV Deployment .......................................................................................................... 13  
  5.2. Deployment Playbook ................................................................................................. 13  
Appendix A. Lessons Learned from the Linden LEAP ......................................................... 1  
  Executive Summary ........................................................................................................... 1  
  A.1 Introduction ............................................................................................................... 3  
    A.1.1 Overview .............................................................................................................. 3  
    A.1.2 Purpose ............................................................................................................... 5  
    A.1.3 References ........................................................................................................... 6  
  A.2 Confounding Factors .................................................................................................... 7  
    A.2.1 Incident ............................................................................................................... 7  
    A.2.2 COVID-19 .......................................................................................................... 8  
  A.3 Lessons Learned ......................................................................................................... 9  
    A.3.1 Route .................................................................................................................... 9
## Table of Contents

A.3.2 NHTSA Approval................................................................................................................. 10  
A.3.3 Geometry and Cargo Weight .......................................................................................... 12  
A.3.4 Independent Review of Shuttle Safety ............................................................................. 12  
A.3.5 Weather Operations ......................................................................................................... 13  
A.3.6 Vegetation.......................................................................................................................... 13  
A.3.7 Stakeholder Input.............................................................................................................. 13  
A.3.8 Procurement ..................................................................................................................... 15  
A.3.9 Testing.............................................................................................................................. 15  
A.3.10 Data ............................................................................................................................... 16  
A.3.11 DriveOhio and Licensing .............................................................................................. 17  
A.3.12 Operator Hiring............................................................................................................... 18  

### List of Figures

Figure 1: Linden LEAP Passenger Service Route Map ................................................................. 3  
Figure 2: Linden LEAP Food Pantry Service Route Map ............................................................. 4  
Figure 3: Linden LEAP EasyMile EZ10 Shuttles ........................................................................ 5  
Figure 4: Linden LEAP Route in Procurement Document .......................................................... 9  
Figure 5: Closed-Course Route for Testing Purposes as Submitted to NHTSA ......................... 11
Chapter 1. Introduction

The purpose of this document is to lay out the recommended process to deploy automated vehicle projects based on the experience of the City of Columbus through the Linden LEAP Connected, Electric, Autonomous Vehicle (CEAV) project as part of the Smart Columbus program. The document is also built upon the lessons learned from the Linden LEAP deployment, which are included in this document as Appendix A along with the deployment description. This document should be useful to other agencies looking to deploy automated shuttles. It should be recognized that local laws, policies, and stakeholders may dictate alterations in the process as recommended, but the core of the document should be applicable to any deployment.

When deploying self-driving shuttles, there are many challenges. The time for a truly autonomous vehicle is still in the future, as the technology and sensors aren’t ready for every day, every situation Level 5 automation based on the Society of Automotive Engineers (SAE) J3016 standard. Refinement and enhancements need to occur to accommodate a vehicle that performs every driving task, and pilots can assist the development and acceleration of the technological advancements. Therefore, when deploying a shuttle, the stakeholders should:

- **Be realistic about expectations** – Learn about the limitations of the technology and account for situations where it will not perform. For instance, weather will present significant challenges to operation, so if there is a daily route being serviced, other accommodations may need to be made to serve riders who rely on the operation.
- **Be flexible** – There are many variables that go into successful automation, and when encountering a limitation outside of the operational design domain, the project team needs to be flexible and make adjustments for an overall successful deployment.

While fully autonomous vehicles are still in the future, now is the time to start planning for their arrival. Evaluating policies, procedures, and serviceable routes could prepare a city for their arrival, as will deploying pilots for additional lessons learned.
Chapter 2. User Needs Development

For a project to be successful, it must meet the needs of the potential users of the system. If transportation technology is deployed for technology’s sake, the deployment team will only showcase that technology can work, not that it can be used to solve problems or fit within the context of everyday mobility. Therefore, the most important step in a deployment process is defining who will use the system and what the needs of the users are, which will aid in capturing the goals of the program.

2.1. OPERATIONAL CONCEPT

When Columbus first submitted the Smart City Challenge application, the proposed use case in the application was in a fast-growing region with a growing demand for workers. The goal was focused on first-mile/last-mile challenges in connecting a transit center to a shopping and employment center. While it was recognized that these connectivity challenges existed across the city, the City of Columbus attempted to assure basic needs were being met with the project by undertaking a rigorous systems engineering process to define the system to be deployed. During the process, many obstacles presented themselves while developing the documentation, but two critical takeaways were:

- The systems engineering process lends itself to defining what an automated vehicle (AV) should be rather than focusing on solving the transportation problem, and
- Based on the state of the technology, the use case in this region was simply too high a risk due to the high traffic volumes and large intersections to cross with the proposed route.

In response to these challenges, a pivot was made to be more Agile in the approach. One of those changes was to simplify the systems engineering to focus more on defining and designing the operational environment. A traditional Concept of Operations (ConOps) is a very valuable tool, but in this case, tended to define the system to be designed and the project team was not intended to develop an automated vehicle from scratch. It was recognized that the City of Columbus would be procuring a commercially available off-the-shelf vehicle as a result of the program. The goal was to document the important elements of the project approach in a manner consistent with a ConOps, but to avoid needs and descriptions specifically related to the vehicle and to focus on the needs for the deployment and operation. Out of this refinement, an Operational Concept (OpCon) was developed.

An OpCon should be developed as a potential deployment moves from ideation to a project. The OpCon describes the development of the phased approach to the project and provides a quick reference for project stakeholders to ensure a consistent understanding of project attributes. The document is inclusive of user needs, high-level requirements, the goals of the project, performance evaluation, and

---

use cases for deployment, but does not include fully developed operational scenarios. The fully developed operational scenarios would be part of a ConOps but do not entirely apply to this document since the specifics of vehicle operation are outside its scope.

To be thorough, some of the requirements must reflect different perspectives that mirror each other. For example, from an operations perspective the vehicle currently needs to have staff on-board who have the ability to take manual control of the vehicle if deemed necessary, since its capabilities are still limited. Similarly, from a safety perspective, operations staff need to be properly trained and capable of taking such manual control. Both requirements focus on the on-board staff but are developed from a different perspective.

2.2. POLICIES AND CONSTRAINTS

There are various evolving policies and procedures that must be considered when deploying automated shuttles in the United States as well as the laws that vary from state to state. On the federal level, these include the Federal Automated Vehicles Policy, currently in version 4.0 and the Federal Motor Vehicle Safety Standards. In Ohio, Executive Order 2018-04K dictates the process and licensing for the state and establishes guidelines for testing AVs. For example, Ohio requires a designated human operator to monitor the vehicle at all times, but this may not be the case in every state.

In general, AV technologies are an emerging field, and in many cases, existing regulations have not kept pace with the growing capabilities of available products, or they have been kept intentionally strict to minimize risk while new advances are tested and added competences are demonstrated.

In cases where the AVs are intended to be operated as a public transit service, this system has to be designed with US laws and regulations on public transit in mind. Mandatory compliance with these rules is generally determined by funding source and operating entity, but even if the vehicle is not technically required to comply, operating in line with industry best practices to the extent possible could be a deployment goal, such providing accessible features like a ramp, tie-downs, and braille.

2.3. DEFINING THE PURPOSE

A successful project has a strong definition of what the purpose is. There are many types of deployments that can occur with automated vehicles, but the industry has moved beyond demonstrating technology to deploying technology. The deployment needs to serve a purpose like being a transit link, delivering goods, or connecting two key points with mobility issues between. The stronger the purpose, the more likely the service will be regularly used and deemed a success by public users; the service should not be seen just as an attraction with limited utility or use.

It is also important to determine the purpose prior to determining the route or the purpose will be built around what the route serves. Some evolution to the purpose can occur as the project is further defined and deployed, but the core at which it should operate should be the basis for all decisions made during the project development lifecycle.
2.4. STAKEHOLDER INPUT

Convening a group of interested stakeholders that could benefit or be impacted by the deployment is critical for success. These stakeholders can not only aid in the development of a route or the goals that the deployment should achieve, but they can also assist in overcoming planning and deployment barriers. For instance, a representative from the state department of transportation and/or the bureau of motor vehicle licensing may be able to identify state laws and policies for deployment as well as help navigate the licensing and registration process.

Suggested stakeholders could comprise of the following list, but local context should be added as applicable:

- State transportation department
- Local transit authority
- Municipality / City departments
  - Transportation
  - Recreation & Parks
  - Neighborhoods
- University or College
- Tourism / Visitors Bureau
- Businesses
- Non-profit organizations
- Developers

While ultimately the list of stakeholders could vary based on the purpose of the route and the location of the deployment, engaging with the stakeholders will help in having a more successful deployment with more community buy-in. Creating common goals or criteria that can be scored if evaluating multiple routes will align all stakeholders on the purpose and importance of the project’s outcome. The stakeholders can provide input into the criteria and what is most important to each of their agencies. This also serves as a benchmark to compare the criteria with the vision and mission. The criteria that Smart Columbus used can be found in Appendix A, but some criteria for consideration are as follows:

- Transit connectivity – at least one station of the route connects to transit
- Access to services – the route connects to needed services such as grocery stores
- Ladders of opportunity – the route can aid in connecting residents to jobs or opportunity centers
- Transit duplicity – deduct points if the route duplicates an existing transit route
- Vehicle storage and charging – there is storage and charging for the vehicle less than 0.5 mile (ideally 0.25) away from the route.
Chapter 3. Procurement

A well-written and thorough procurement document will assure the agency will get the service desired. Breaking the procurement into phases, while it adds time to the overall schedule, enables an opportunity to engage with industry to determine where the technology has progressed and get feedback on potential routes or services the project is intended to provide.

3.1. REQUEST FOR INFORMATION

Releasing a Request for Information (RFI) allows an agency to collect information desired from prospective bidders without the guarantee of a selection. This opportunity exceeds traditional research because it fosters an environment for vendors to share capabilities of the technology and near-term roadmap improvements. To arm the entity writing a Request for Proposals (RFP) with the most current information about potential deployers, releasing an RFI will help make their understanding stronger.

Further, the opportunity to solicit feedback on potential routes and characteristics can help avoid significant changes to the project after the vendor is selected. To collect adequate responses, an inventory of the potential routes and characteristics should be provided. This inventory should include, at a minimum: speed limits, traffic control, adjacent parking, roadway directions, typical roadway widths, traffic calming measures, and daily traffic volumes. If possible, recording a video of the route will also assist in viewing current conditions. Another consideration is the sidewalk network and the location of the stations, as it is preferred to deploy an accessible ramp onto a landing pad or sidewalk rather than the roadway surface.

3.2. REQUEST FOR PROPOSALS

Beyond providing a selected route map and route characteristics for proposers to bid on, the RFP should include a robust list of functional requirements for the service being procured. The City of Columbus chose to procure a turn-key solution, so the proposer had to offer an entire package that included the vehicles, the operators, the insurance, and the storage. While this may not meet the needs of all entities procuring automated vehicles, the turn-key approach moves the liability for the operation to the vendor and not on the entity procuring. Some agencies may opt to procure the vehicles and operate them independently since that solution meets their needs. This section details some important high-level considerations for procurement. The RFP used by the City of Columbus is accessible on the Smart Columbus website² for use in developing an RFP suited to the procurement agency’s needs.

3.2.1. Operational Requirements

This section should clearly identify the hours of operation and the headway between stops at the stations. The requirements could specify the number of vehicles or leave that up to the proposer to determine based on the requirements. Accessibility of the vehicle, such as a deployable ramp (either manual or automated), wheelchair tiedowns, audible announcements, display screens, and braille buttons should be addressed here. The type of expected weather operations should be identified and any allowable suspensions from service, such as special events that affect the route or the type of weather emergency declaration (e.g. Level 1 Snow Emergency) that ceases operations.

If a storage area is not being provided, the requirements around the storage and maintenance area should be included here. Ideally, the location of storage should be within less than one-half mile of the route, but less than one-quarter mile is preferred if the vehicle is electric powered. Charging considerations should also be addressed, particularly if electric vehicle supply equipment needs to be installed to recharge the vehicle.

Finally, all requirements regarding the operators and training need to be clearly identified. Based on local laws, policies, or preferences, the requirement for on-board or remote supervision must be clear. While the proposer will handle the actual training and training plan, any additional training such as an ambassador program to support the conveyance of information to passengers as well as certifications like first aid should be included.

3.2.2. Vehicle Requirements

The Federal Motor Vehicle Safety Standards (FMVSS) govern vehicle components, such as steering wheels, pedals, and mirrors, and some automated vehicles do not include these features due to the lack of a full-time driver. When these features do not exist, the importer of the vehicle must obtain an exemption from the National Highway Traffic Safety Administration (NHTSA). Domestic manufacturers are currently not able to exclude FMVSS features unless grandfathered in, and the one known domestic shuttle manufacturer has an agreement with NHTSA to follow the importing procedures. This process involves submitting the vehicles and route to the Box 7 Imports Team within NHTSA. The proposer should demonstrate the ability to secure this exemption in a timely fashion, so the deployment is not impacted. A list of the expected capabilities of automation should also be included based on the route that the vehicle will cover. For instance, the RFP could include that the vehicle shall be able to enter a stop-controlled traffic circle if one is on the route, as it was in Columbus. These capabilities will be part of the test plan that must be passed prior to operation.

Other vehicle features, such as connectivity to the infrastructure should be identified. If the vehicle will traverse a signalized intersection, it may need to communicate with the traffic signal to receive the Signal Phase and Timing (SPaT) message. The equipment in the traffic signal cabinet could also be installed by the procurement entity or a stakeholder. Different vendors may have different approaches to accommodating communications with traffic signals, and the agency should be aware of any infrastructure impacts that may result.
If there is a desire to wrap and brand the vehicle, this should be identified so the proposer is prepared to include this in the price and account for the wrapping in the schedule. Some proposers may not want to grant full control over the wrap design so this must be expressly stated to avoid conflict later.

Other considerations for agencies within the vehicle requirements are:

- **Operating speeds** – It may be helpful to provide speed limits of route roadways or the desired operating speed of the vehicle.
- **Climate control** – Depending on the climate of the deployment, heating and cooling may be required for the comfort of passengers. Any climate accommodations will likely impact the range of the vehicles, so this needs to be considered as well.
- **Powertrain** – If the agency prefers or requires a specific type of powertrain for the vehicle (e.g. electric powered), it should be identified. This may have other impacts such as providing electric vehicle charging at the storage location.
- **Passenger capacity** – The agency may want to identify the number of seated passengers and overall capacity that the vehicle should accommodate. This could also affect the number of vehicles that the respondent provides.

### 3.2.3. Data

Performance measurement of the demonstration not only tells the story of success, it could also be used as justification for future demonstrations or deployments. Therefore, collecting necessary data is very important. A thorough evaluation or performance measurement plan should be developed by the agency prior to the procurement so the needs and impacts of the evaluation can be identified. A helpful guide from the Federal Transit Administration can be found here: [https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/146801/considerations-evaluating-automated-transit-bus-programs-fta-repor-no0149.pdf](https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/146801/considerations-evaluating-automated-transit-bus-programs-fta-repor-no0149.pdf)

While data sharing can be a sensitive topic, identifying the data needed in the RFP, the format, and how it is to be transmitted will provide any potential responders with a clear starting point. Some agencies find monthly reports developed in a spreadsheet and emailed acceptable, where others want to collect the real-time status information of the vehicle every two seconds from an Application Programming Interface (API). Consideration to storage requirements will be important to determine the level of data to be provided.

A thorough list of data to be provided should be included in the RFP, while asking the vendor to comment in its response if any data cannot be provided. It is better to ask and decide to remove certain data based on the response to the RFP than not to ask for it, as it will be much more difficult to get the data once the procurement is closed and the contract is signed. Further, if on-board surveys are part of the performance measurement, this should be identified as well as any staffing impacts that could occur as a result.
3.2.4. Testing Requirements

While a test plan may not be developed at the time of the procurement, the types of tests expected to be demonstrated should be included as well as the requirement that the proposer participate in the testing. The City of Columbus participated in a Factory Acceptance Test to act as a factory audit and witness the testing of the vehicles before shipment to a deployment site, but this is not necessary for every agency to do. Preliminary acceptance testing and final acceptance testing should be performed, and the preliminary phase may be done on a closed course.

Ultimately, the testing should have the vehicle demonstrate the following:

- Everyday operations on the route, demonstrating lane adherence, turning, stopping and starting, and safe reactions to situations the vehicle happens to encounter
- Service of the passenger stops (including pulling over, opening and closing doors, use of the ramp, and merging back onto the route)
- Operations in changing roadway/weather conditions (if present)
- Operations in peak and off-peak traffic

3.2.5. Other Considerations

The RFP should also include any other recommendations, expected support on deliverables, and preferences. It is recommended that the agency include the Operational Concept as an appendix, as it will provide additional insight for the proposers.

The agency may choose to identify any route accommodations that have been installed already or accommodations it is willing to provide following a final route assessment by the vendor, such as paving, repairing potholes, repainting or installing new pavement markings, adding signage for awareness or localization, and other changes to landscaping or shrub/tree maintenance.

As it relates to safety and the common understanding of safety, development of Standard Operating Procedures (SOPs) with the agency should be included. The SOPs lay out the roles, responsibilities, and tasks of all stakeholders and operators for a variety of situations, including if there is an incident. Including the SOPs in the RFP helps make everyone aware of the expectations.

If the route intends to link to transit, it is recommended that the integration of transit agency information onto any on-board information systems be included. This information could help the travelers make connections to other transit they seek and integrate the AVs as a more seamless part of their travel experience.

Finally, a recommendation to apply for a closed-course testing route for quicker NHTSA exemption approval to import the vehicle while the full route is reviewed for exemption should be included, if necessary. The closed course presents minimal risk and may be reviewed quickly by NHTSA. While that is being done, the full operational route submission can be prepared and the vehicles can be imported while the full route is under review, provided the closed course route has received the exemption. This closed course submission should be coordinated with the vendor and NHTSA in advance to assure that NHTSA agrees with the plan.
Chapter 4. Safety

Safety must be the cornerstone to any automated vehicle deployment. While recognizing that the manufacturers make safety a priority, public agencies also carry the public trust of safety and must ensure that appropriate measures are taken with safety in mind. While the training of the operators and the procurement of vehicles that default to no action over unsafe action keeps safety at the forefront, the additional steps within this section will define what safety is and provide for project milestones where the safety is checked before deployment.

4.1. SAFETY MANAGEMENT PLAN

In the interest of adhering to the systems engineering process and thoroughly vetting any safety concerns with a project, it is recommended to develop a safety management plan. This document should follow the principles of assigning an Automotive Safety Integrity Level (ASIL) to the identified safety scenarios for the project in adherence with the International Organization for Standardization (ISO) standard 26262.

This plan identifies the major safety issues associated with each project and lays out a preliminary plan to promote the safety of participants, motorists, other road users such as pedestrians, bicyclists, and transit riders, and any resident that may interact or engage with the deployment. The plan accomplishes these goals by describing the underlying needs of the demonstration with respect to participant and traveler safety. It also documents the impacts of various scenarios at the program and project levels. For example, communication failures, unintended or malicious attacks, severe crashes, and adverse weather conditions may be situations identified within the plan. It assesses each risk and documents the guidance on the inclusion of a safety-critical system that is capable of either eliminating these risks based on the vehicle’s function, reducing the risks by modifying the design to lower the probability of the occurrence of the hazard, or – at a minimum – mitigating the impact of the hazard if it does occur.

The risks and mitigations should be developed amongst the project team and key stakeholders. There is a preference to include technical experts in automation, operation, and vehicles, but other individuals that are closely associated with the project and the local environment would provide value as well. Once the mitigations are identified, a tracking process should be developed to confirm that the mitigations have been implemented.

4.2. STANDARD OPERATING PROCEDURES

In an effort to align multiple stakeholders and employees associated with the deployment, Standard Operating Procedures (SOPs) should be developed. SOPs describe the processes for operational situations the AV service is likely to encounter during normal operations and in non-normal situations. SOPs are step-by-step instructions agreed upon by a stakeholder team to help all stakeholders complete routine, and at times complex, operations in a consistent and agreed-upon manner. The intent of SOPs are to ensure that all affected parties are aware of their roles, obligations, and responsibilities, and that
tasks are completed efficiently and safely, while reducing the risk of miscommunication and failure to comply with all applicable laws, regulations, and agreements.

The purpose of the document is to ensure the safe and efficient operation of the automated vehicles. It helps project stakeholders by giving them appropriate procedures so they can make every effort to ensure the safety of passengers, staff, and other members of the public throughout the duration of this project.

4.3. TESTING

As identified earlier in this document, the RFP should identify the types of tests the vendor should expect to perform to validate the system and operation of the vehicle. To properly validate, a test plan should be developed for all entities involved to follow. The purpose of the test plan is to document the strategic plan for testing and the criteria for acceptance of the system before the AV service is deployed.

The test plan is prepared for the verification of project elements in order to commission the system for operation. Verification evaluates the functional deployment against its intended function and implementation of the system requirements. A fully developed test plan accomplishes this by establishing a set of test cases intended to evaluate the degree to which each amenity and its functions conform to the requirements set forth in the procurement documentation. The test plan will also develop test scenarios to verify the status of technical progress on the project, substantiate the achievement of technical performance, and certify operational readiness to move forward with validation.

The test plan will establish a common framework for testing. This includes describing various testing methods and setting expectations of which method(s) should be used and when. Each case will thoroughly describe the number of people needed, the materials needed, the test procedure, the expected results, and the pass criteria. For instance, if the test is that the vehicle should stop and go with traffic, another vehicle operated by a tester would need to drive in front of the automated vehicle that is likely overseen by an on-board operator, and the lead vehicle would simulate stop-and-go traffic. The expected result is that the automated vehicle would stop when the lead vehicle does and then begin moving when the other vehicle clears the safety detection zone. This test plan will ensure that the goals, objectives, and specifications that were developed and agreed upon throughout the project are all being tested and verified.
Chapter 5. Interoperability

This section details the interoperability of the deployment and the playbook to other AV deployments across the country. A program goal of Smart Columbus is to detail how projects could be transferred and scaled in other environments so others can build upon the work completed in Columbus.

5.1. AV DEPLOYMENT

The City of Columbus deployments do not have a significant number of interoperable characteristics to be used outside of the neighborhoods in which they were deployed. The routes are specific to characteristics of the roadway network and the station locations serve the local population. However, documents developed by the City of Columbus, such as the OpCon and the RFP, do have utility with other agencies and can be modified to local laws, policies, and route characteristics.

As for the vehicles themselves, the City of Columbus oversaw deployments involving May Mobility Polaris Gem e6 vehicles and EasyMile EZ10 Gen3 shuttles. Both of these were electric vehicles. Specific processes of lessons learned from these two vehicle types are directly applicable to other deployments, and largely should apply to other shuttle-type vehicles. Automated personal vehicles or larger transit vehicles may come with their own sets of challenges but should be able to largely follow the process contained in this document.

5.2. DEPLOYMENT PLAYBOOK

The interoperable aspect of both deployments conducted was the process that was developed and refined. This document outlines that process so that other agencies can replicate and make decisions based on the local environment, laws, and preferences. Coordination needs to be across multiple agencies and stakeholders, and that needs to occur at various times throughout the deployment. While laws may vary by jurisdiction, the process of researching and developing them will always apply.

Every project needs to follow a project development process to deal with changing conditions and situations. The process contained in this Deployment Playbook is thorough and encompasses most, if not all, key considerations throughout the lifecycle of the project. Continual refinement is expected, and the City of Columbus looks to engage with others that use and adapt the process.
Appendix A. Lessons Learned from the Linden LEAP

EXECUTIVE SUMMARY

Building upon lessons learned for the first self-driving shuttle deployment in Ohio, this document culminates additional lessons accumulated during the second deployment. While not all lessons will apply to another agency looking to deploy a shuttle, many will be of interest. The project team can relay lessons obtained through experiencing a safety incident and a global pandemic, shifting from passenger service to a goods delivery concept. The lessons learned by the project team were:

- **Route** – Being flexible in the route design to meet project needs, such as service time or headway as well as accommodating roadway constraints, is important when finalizing the route and operation schedule.

- **NHTSA Approval** – It is highly recommended to include a testing route submission prior to the full route submission as it aids in retaining the overall deployment schedule, and to perform a review of the surrounding environment and businesses to identify and mitigate potential vulnerable populations.

- **Geometry and Cargo Weight** – While most of our route inventory consisted of posted speeds, traffic control, and adjacent features, evaluating grade differentials for driveways and street crossings based on manufacturer specifications will reduce the risk of changes as deployment nears.

- **Independent Review of Shuttle Safety** – Having a thorough Safety Management Plan is in the best interest of all parties so the team can be prepared for anything. While incidents are not anticipated, this plan can clearly define and communicate any actions or steps required prior to placing the vehicles back into operation.

- **Weather Operations** – The vehicles did not perform as expected during precipitation events. This highlights that improvements to technology still need to be made before full-time use in the real-world. Any near-term deployment scenario should account for weather downtime and ways to address ridership during those events.

- **Vegetation** – Brush alongside the roadway poses as much influence on automation as overhead limbs and needs to be monitored and maintained regularly for successful operation in automated mode.

- **Stakeholder Input** – A fully developed list of criteria that the service aims to address will align partners in determining the ideal route for deployment and should be developed early in the project development timeline.

- **Procurement** – To assure that the system desired is procured, a thorough procurement process and document is needed that outlines each requirement a vendor should meet.

- **Testing** – Testing is critical to validate the system delivered is the same as procured. A thorough test plan communicates the expectations of the testing and aligns the tests with the requirements.
• **Data** – With well-defined procurement requirements related to data, it is possible to request the data needed to evaluate the success of the project and work with the vendor for its use.

• **DriveOhio and Licensing** – Be prepared for scammers to contact the registrant seeking additional fees, claiming to be affiliated with the Public Utilities Commission of Ohio (PUCO) or similar. Also, working closely with the BMV prior to procurement can alleviate delays prior to launch related to registering the vehicle and paying any related fees that could be associated with electric vehicles.

• **Operator Hiring** – While not all agencies may have the opportunity to hire local to the deployment, doing so can provide new and advanced jobs for the community. Also, this can provide additional comfort level with the passengers.
A.1 INTRODUCTION

A.1.1 Overview
As part of the Smart Columbus program, the Connected, Electric, Autonomous Vehicles (CEAV) project sought to demonstrate automated vehicle technology that could serve a purpose in the community. The Linden LEAP served a first-mile/last-mile connection in the Linden neighborhood of Columbus seven days a week from 6am to 8pm. The intent of the deployment was to demonstrate automated vehicle (AV) technology in a real-world application, further refine procurement methods, document the steps for deployment to aid others in the future, and educate residents and visitors about the technology. The route, shown in Figure 1, had four stations (1) St. Stephen’s Community House, (2) Douglas Community Recreation Center, (3) Rosewind Estates, and (4) Linden Transit Center. The route selected was identified through stakeholder input as a solution to a transit gap for visitors and patrons of St. Stephen’s Community House, as there is no direct transit access to the site.

Figure 1: Linden LEAP Passenger Service Route Map
Source: City of Columbus

The passenger service launched on February 5, 2020 and operated until February 20, 2020 when an emergency stop resulted in a passenger slipping from her seat. Passenger service was suspended and the shuttles continued to operate to go through testing and training runs with project staff only. On April 4, 2020, all operations ceased due to the pandemic. In addition, the COVID-19 pandemic that
affected the United States in early 2020 had far reaching impacts to various industries including transportation and mobility. Guidelines that stressed the importance of social distancing and increasing the necessary sanitizing procedures have greatly limited the ability to accommodate passengers in the EasyMile EZ10 shuttles procured for the CEAV project.

As a result, the City of Columbus issued Appendix A – Alternate Use Case to the CEAV Operational Concept on May 19, 2020. This addendum evaluated and outlined utilizing the shuttles for food pantry box delivery into the Rosewind community in light of the restrictions and impacts that the pandemic had on passenger service. In early November 2020, the City of Columbus made the determination not to return to passenger service due to the ongoing impacts of the pandemic and the success of the food pantry service in the community. The food pantry route is shown in Figure 2.

![Figure 2: Linden LEAP Food Pantry Service Route Map](image)

*Source: City of Columbus*
A.1.2 Purpose

The purpose of this document is to detail the many lessons learned through the second automated vehicle (AV) shuttle deployment in Ohio, the Linden LEAP. The AV shuttles were deployed through the Smart Columbus CEAV project and the project was envisioned to encompass all types of self-driving vehicles. The lessons learned apply to most types of vehicle applications. This document summarizes the lessons learned throughout the deployment process for organizations that are considering future AV deployments.

This document also builds on the first AV shuttle deployment, the Smart Circuit. The lessons learned from that deployment can be found on the Smart Columbus website\(^3\). These insights were used for the second deployment and enabled the project team to be cognizant of potential issues.

![Linden LEAP EasyMile EZ10 Shuttles](https://d3hzplomz6qe4.cloudfront.net/2019-07/Smart%20Columbus%20Autonomous%20Vehicle%20Lessons%20Learned_0.pdf)

Figure 3: Linden LEAP EasyMile EZ10 Shuttles

*Source: City of Columbus*

---

\(^3\) [https://d3hzplomz6qe4.cloudfront.net/2019-07/Smart%20Columbus%20Autonomous%20Vehicle%20Lessons%20Learned_0.pdf](https://d3hzplomz6qe4.cloudfront.net/2019-07/Smart%20Columbus%20Autonomous%20Vehicle%20Lessons%20Learned_0.pdf)
### A.1.3 References

<table>
<thead>
<tr>
<th>Document Name</th>
<th>Date</th>
<th>Link</th>
</tr>
</thead>
</table>
A.2 CONFOUNDING FACTORS

A.2.1 Incident

On February 20, 2020 one of the Linden LEAP shuttles was traveling at 7.1 miles per hour and came to a sudden stop. As a result, one of the two passengers slipped from her seat to the floor and sought medical attention. The City of Columbus temporarily suspended operation of both Linden LEAP shuttles, pending further review. On February 24, EasyMile arrived on-location to initiate its review. On February 25, the National Highway Traffic Safety Administration (NHTSA) suspended all U.S.-based operations of EasyMile pending a safety evaluation. Upon review, EasyMile determined that a slight deviation in the steering of the shuttle, similar to the steering wheel slipping in a car, caused the sudden stop on February 20.

Sudden stops in autonomous vehicles can be caused by a multitude of factors, including some that are not apparent to the human eye. These can include objects, such as insects or exhaust from another vehicle being picked up by the shuttle’s sensors. Stops can also be caused when operating conditions conflict with safety chain requirements, a set of rules that need to be met in order to safely operate the shuttle. In the case of the incident on Feb. 20, the steering deviation didn’t fit within the established safety chain rules. The shuttles are programmed to stop when there is a discrepancy between the defined rules and current conditions. Factors including weight distribution and road conditions can also affect the vehicle’s ability to meet the safety chain requirements and, therefore, stop.

As a result of these findings, EasyMile adjusted its safety chain to modify the rules, within established safety limits to reduce sudden stops. Columbus-based operators also received additional training to proactively identify external factors that could cause a sudden stop and how to prevent them. While these modifications will reduce the frequency of sudden braking, they will not entirely prevent them, especially if the vehicle detects an obstacle in its path.

EasyMile worked closely with NHTSA to complete its safety evaluation. With input from the City of Columbus and the 10 other U.S. stakeholders operating EasyMile shuttles, EasyMile developed a Passenger Safety Enhancement plan. The plan details changes that need to be made before all U.S. shuttles could return to passenger service. These changes included:

- Audio alert reminding passengers the vehicle can make sudden stops
- Additional signage
- Additional operator training on safety
- Alternative manual remote for the operator
- Operator performance measuring, and
- Seat belts installed on all vehicles
A.2.2 COVID-19

The COVID-19 pandemic that began to affect the United States in early 2020 had far reaching impacts to various industries including transportation and mobility. As mentioned above, on March 18, 2020, City of Columbus Mayor Andrew Ginther declared a State of Emergency for the city that encouraged all employees to work from home, if able. On March 22, 2020, State of Ohio Governor Mike DeWine issued an Emergency Declaration that enabled the Department of Health to issue guidelines for private businesses regarding appropriate work and travel restrictions. As a result of these declarations, citizens of Columbus and the state of Ohio at-large were instructed to remain at home, only making necessary trips for specific reasons, such as food or essential travel. The Central Ohio Transit Authority (COTA) also requested that all trips on its buses be limited to essential travel and reduced the routes, frequencies, and operating hours.

Additional guidelines that stressed the importance of “social distancing”, defined as maintaining six feet of separation from another person, and increasing the necessary sanitizing procedures greatly limited the ability to accommodate passengers in the EasyMile EZ10 shuttles procured for the CEAV project. While the shuttles paused passenger service following the February 20, 2020 emergency stop that resulted in a passenger slipping from her seat, the shuttles continued to operate, completing testing and training runs with project staff only, until April 4, 2020, when all operations ceased due to the pandemic.

Following expiration of the stay at home orders on May 19, 2020, many of the COTA buses operated at reduced capacity due to spacing requirements and remote work options for workers. Masks were also mandatory to ride public transportation. Overall, the COTA ridership at both the Linden Transit Center and system-wide has dropped significantly compared to the beginning of the pandemic, resulting in about half as many trips completed comparing data January-July 2019 to January-July 2020.

With the expectation that social distancing requirements would be in place for the foreseeable future, the City of Columbus consulted with its stakeholders to determine how a shuttle could otherwise be used to serve the immediate needs of the community consistent with the purpose set forth in the original Operational Concept. It was recognized that localized goals for the passenger service of the shuttle included connecting the community to food and support services. When the pandemic-related directives went into effect within the City, the on-site food pantry at St. Stephen’s Community House shifted from a choice food pantry, where patrons would choose food from shelves to take home, to a pre-packaged system. St. Stephen’s also saw a significant increase in demand during this time. Therefore, the Linden LEAP transformed its mission to a food pantry box delivery service that picked up the boxes from St. Stephen’s and traveled to Rosewind where the community could pick up the boxes.

It was important to be flexible with the use case but still meet some of the goals and community needs of the project. Had the project team not acted to explore other use cases and define one that could be deployed, the operation of the shuttles likely would not have returned given the social distancing requirements, capacity restrictions, and fluctuations in the severity of the spread of the virus. By using the food pantry delivery service, the shuttles were able to serve many households throughout the pandemic to reduce food anxiety and insecurity.
A.3 LESSONS LEARNED

A.3.1 Route

Before narrowing down to the final route that was procured, the City of Columbus evaluated 14 potential routes for the demonstration. The initial work was completed from an office using aerial and street-level imagery. From there, it’s important to drive routes that are considered with a traditional vehicle to fully understand roadway constraints, environmental factors, and traffic. This will help eliminate potential routes from consideration where significant challenges exist, such as a very busy grocery store parking lot with many pedestrians and shopping carts that would affect the reliability of the operation.

The final deployment route for passenger service (Figure 1) differed slightly from the route that was in the procurement documents (Figure 4).

![Linden LEAP Route in Procurement Document](image)

**Figure 4: Linden LEAP Route in Procurement Document**

*Source: City of Columbus*

It was a collaborative process with EasyMile to refine the route for maximum safety and minimal intervention required. Following selection as the vendor, EasyMile performed a site evaluation that identified any concerns or impacts to automation and provided the result to the project team so modifications could be implemented. For instance, the differential between the operating speed of the shuttle and the roadway traffic on 17th Avenue was significant, so the route was modified to minimize the distance the shuttle operated on 17th Avenue, using 18th Avenue instead. 11th Avenue, close to
Linden Transit Center, was narrower than most of the other streets. When there was high enough daily traffic volume on 11th Avenue, the automation on the road would degrade due to the operator having to take over control and allow other vehicles to pass in the opposite direction.

The project team also considered providing a link to the CMAX stations at 17th Avenue and Brooks Avenue, shown in blue on the map figure above. This extension would have required the vehicle to travel for a greater distance on 17th Avenue as designed and added service time to completing a full loop. Ultimately the project team abandoned it.

**LESSON LEARNED:** Being flexible in the route design to meet project needs, such as service time or headway as well as accommodating roadway constraints, is important when finalizing the route and operation schedule.

### A.3.2 NHTSA Approval

To receive permission to import vehicles to the US and operate vehicles without standard controls like a steering wheel and pedals, the importer needs to submit the vehicles and route to the National Highway Traffic Safety Administration (NHTSA) for approval. This gives NHTSA the opportunity to review the route and provide input. Incorporating NHTSA’s feedback on the route was an intensive process but necessary to ensure safety. Two key pieces of feedback were the proximity to elementary schools and daycare and traveling down the center of the roadway on narrow streets with adjacent parking.

To satisfy the concern around the proximity to school children, an inventory of any facility in the area that may have had school-aged children and the protections in place was completed. Most of the facilities were daycares, which have strong security procedures and contain children to the facilities very well. However, the original route proposal did go onsite at the Rosewind Community Center and the Douglas Recreation Center, so the route was modified to stay on public streets and away from the daycare and playground, respectively. Harambee Christian School was already in the process, through an Eagle Scout project, of installing a net to keep balls from leaving the playground and entering the roadway, and this was complete by the project launch. These mitigations and the inventory completed satisfied NHTSA’s request regarding child facilities. As a result of the inventory, NHTSA required EasyMile to suspend operations during the morning arrival and afternoon release at the schools.

On narrower streets, such as 15th Avenue and 18th Avenue, NHTSA expressed concern to EasyMile about programing the path of the vehicle down the center of the street. These streets are narrow with parked vehicles on both sides. To help alleviate the concern, parking counts were conducted throughout the day to show that parked vehicles on both sides of the street were a consistent experience. NHTSA didn’t want the vehicle driving down the center of the road when there were no parked vehicles, but it was showed with data that the cars are typically parked there.

Finally, the City had to make a commitment to install signage along the route. There was a need to inform other drivers of the presence of a self-driving vehicle to increase awareness of the situation. The vehicles themselves also have stickers on the rear indicating that they drive slowly and may stop suddenly.
The complexity of the route can increase the review time at NHTSA and can also take longer to set up through the deployment process. The schedule was developed with some cushion, but the exemption process exceeded the time allotted and pushed on the rest of the schedule, reducing the time the project team had to complete the remaining tasks leading up to launch. Also, there is risk in not having the route approved. When cities develop routes, there isn’t a step that allows for federal review of the routes, and it ultimately falls on the selected vendor to secure the exemption. This could induce political risk in advertising a route that never comes to fruition.

While the NHTSA review of the proposed route was in process, the project team decided to submit a closed-course route approval for testing and training to be able to import the vehicles. Without the exemption approval, EasyMile was unable to import the vehicles to Columbus. And since storage fees at the ports are significant, EasyMile wouldn’t ship the vehicles until the exemption was in-hand. Therefore, the submission of a closed course route, which required minimal NHTSA review, allowed activities that lead up to launch to commence. The vehicles were shipped and imported so the deployment team could schedule and have the wraps installed, begin operator training, perform preliminary acceptance testing, and take professional pictures. During this time, the final route approval was received, but the process recovered several weeks by adding the test route.

**Figure 5: Closed-Course Route for Testing Purposes as Submitted to NHTSA**
*Source: City of Columbus*

**LESSON LEARNED:** It is highly recommended to include a testing route submission prior to the full route submission as it aids in retaining the overall deployment schedule, and to perform a review of the surrounding environment and businesses to identify and mitigate potential vulnerable populations.
A.3.3 Geometry and Cargo Weight

An unexpected challenge faced during route setup was roadway geometry. Columbus was among the first to take delivery of the new Gen3 vehicles, and the sensor configuration and locations changed from previous models. The original route proposal was to use the western driveway at St. Stephen’s, but during route setup it was determined that the vehicle saw the grade differential between the street and the driveway as an obstacle and would e-stop. Therefore, the route had to be modified to use the middle driveway, which has a lesser differential, and submit the change to NHTSA for approval before operations could begin.

The vehicles also encountered a situation where the sensors would observe differentials in pavement grades as obstacles based on the cargo loading in the vehicle. It appeared to be a factor both in the weight and distribution, and the vehicle would e-stop for these obstacles. It took some route tweaking to have the vehicle traverse these areas in a manner that would not cause an issue during operation.

LESSON LEARNED: While most of our route inventory consisted of posted speeds, traffic control, and adjacent features, evaluating grade differentials for driveways and street crossings based on manufacturer specifications will reduce the risk of changes as deployment nears.

A.3.4 Independent Review of Shuttle Safety

Per the Safety Management Plan⁴, the City of Columbus convened an independent incident review panel consisting of operational, technical and project management experts to review the incident and provide feedback. Based on the feedback, the following adjustments are made to the standard operating procedures, operator training, test plan and safety management plan:

- Install additional signs for riders to be aware of the potential for sudden stops
- Install signage that describes the passenger rights and rules
- Operators will limit the moving of the vehicle following an incident unless instructed to do so by supervisor or law enforcement
- If the vehicle needs to be moved following an incident, it will operate only in manual mode
- Operators will communicate information and next steps with passengers during an incident
- Additional simulated incident training for operators
- Additional validation vehicle testing
- Equip shuttle with regulation orange triangle signage to be placed on road to caution drivers about stopped vehicle ahead

LESSON LEARNED: Having a thorough Safety Management Plan is in the best interest of all parties so the team can be prepared for anything. While incidents are not anticipated, this plan can clearly define and communicate any actions or steps required prior to placing the vehicles back into operation.

A.3.5  Weather Operations

When the project team was developing the procurement for the shuttle service, it was anticipated that some weather was not favorable for the operation of self-driving vehicles due to the sensitivity and current technology limitations of the sensors. These limitations are intentionally designed into the software with safety in mind, which aligned with the project team’s stance of safety first. However, when completing testing on the brand new Gen3 EasyMile EZ10 vehicles, it became clear that the vehicles were much more sensitive to weather than expected. Previous generations of the shuttles have received many software updates to address navigating during light snow and rain events. The new shuttles, while safe to operate, contained a much more complex suite of sensors that was to gradually receive software improvements to enable broader weather operational deployment.

While operating in light rain, mild fog, and light snow events that were not deemed a Level 1 Snow Emergency by Franklin County seemed reasonable, the reality is that most precipitation hindered the operation of the vehicles. While not ideal for reliability and trust of the public given the planned use as a transit link, the issue was lessened when the shuttles were used for food pantry delivery. Any other entity looking to deploy these vehicles should account for some service disruption in the near term until the technology can identify what is weather and what is an object, safely and reliably navigating the planned route.

LESSON LEARNED: The vehicles did not perform as expected during precipitation events. This highlights that improvements to technology still need to be made before full-time use in the real-world. Any near-term deployment scenario should account for weather downtime and ways to address ridership during those events.

A.3.6  Vegetation

While setting up the route and tweaking the speeds of the vehicles, tree limbs and brush were encountered that needed to be trimmed. The Recreation and Parks Department was a partner from the start of this project and was very responsive in responding to requests to allow the shuttle to operate as well as possible. Overhanging tree branches were expected, but the growth along the roadway and fence line of adjacent properties was found to be more troublesome, and the vehicle would slow in the spots that it encountered this perceived obstacle. To quote the Assistant Director of Recreation and Parks, “I guess one thing we’ve learned from this pilot is that forestry is a vital department to keep autonomous shuttles operable. It’s good to be needed.”

LESSON LEARNED: Brush alongside the roadway poses as much influence on automation as overhead limbs and needs to be monitored and maintained regularly for successful operation in automated mode.

A.3.7  Stakeholder Input

As far back as February 2017, the City of Columbus began soliciting input from the community for the Smart Columbus projects. To further support this effort, a group of stakeholders was convened to help identify a route that would serve a community need. This group consisted of Department of Recreation
and Parks, Department of Neighborhoods, CelebrateOne – an agency representing pregnant women, COTA, and the City of Columbus.

This process allowed for consensus with partners on how the City could solve a need within the community. The table below includes ranking criteria that was developed with project stakeholders and utilized to provide final scoring of the routes to select the preferred choice. The stakeholders provided input into the criteria, what was most important to each of their agencies, alignment with the Smart City Challenge grant, and the Smart Columbus vision and mission. Each stakeholder had a criterion associated with it. For instance, it wasn’t ideal to duplicate an existing COTA service but rather to supplement it, so one criterion reflects that.

<table>
<thead>
<tr>
<th><strong>Criterion</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Mobility Hub&lt;sup&gt;5&lt;/sup&gt;</td>
<td>The route provides a connection to a proposed Smart Mobility Hub as part of the Smart Columbus initiative.</td>
</tr>
<tr>
<td>Food and Service Access</td>
<td>The route connects to food and services needed within a community. The list includes: grocery store, bank, pharmacy, and food bank/pantry</td>
</tr>
<tr>
<td>Ladders of Opportunity</td>
<td>The route connects residents with job or opportunity centers for enhanced placement access. The list includes an Opportunity Center and Ohio Means Jobs.</td>
</tr>
<tr>
<td>COTA</td>
<td>The route connects to a COTA stop and acts as a FMLM connection to expand the reach of a traveler</td>
</tr>
<tr>
<td>Alignment Considerations</td>
<td>The route serves more as a missing link than a duplicate of an existing COTA route.</td>
</tr>
<tr>
<td>Safety and Accessibility</td>
<td>The route has lighting and sidewalks in the vicinity of anticipated stops.</td>
</tr>
<tr>
<td>Prenatal Support</td>
<td>The route connects pregnant women with services that can aid in a healthy pregnancy.</td>
</tr>
<tr>
<td>Neighborhood</td>
<td>The route connects to an opportunity neighborhood for increased mobility.</td>
</tr>
<tr>
<td>Storage</td>
<td>The route provides a nearby facility for storage and charging of vehicles.</td>
</tr>
<tr>
<td>Route navigation</td>
<td>The technology at the time of deployment will allow the route to be traveled.</td>
</tr>
<tr>
<td>Recs and Parks</td>
<td>The route connects to a City recreation center or park.</td>
</tr>
</tbody>
</table>

<sup>5</sup> https://smart.columbus.gov/projects/smart-mobility-hubs
LESSON LEARNED: A fully developed list of criteria that the service aims to address will align partners in determining the ideal route for deployment and should be developed early in the project development timeline.

### A.3.8 Procurement

The Linden LEAP was the second self-driving shuttle deployment in Ohio, and the City participated in the first one in partnership with DriveOhio and The Columbus Partnership. There were many lessons learned from that deployment, particularly around procuring the vehicles. Before putting out the request to deploy this route, the City developed a Request for Information (RFI) that encompassed vendors’ current technology capabilities and solicited input on four route alternatives that scored the highest in the stakeholder criteria identified in Section 3.7. The RFI also informed the scoring for the route navigation criterion as that was scored on technology obstacles and not stakeholder input.

The combination of previous deployment experience, the stakeholder input, and the RFI enabled the City to develop a strong procurement document with a route that would meet the abilities of available technology. One vendor provided feedback that the City of Columbus Request for Proposals (RFP) was the most well-written to which it had responded. The RFP outlined all of the requirements that a successful vendor would need to meet. The significant effort placed into defining the requirements that the self-driving shuttle should meet was the culmination of the team’s work on an Operational Concept, previous experience, RFI responses, and stakeholder input. The operational requirements such as the route, hours, and days for the service, accessibility guidelines such as a deployable ramp, and the data needed for performance evaluation were all defined. Focusing on these requirements enabled a deployment that met the City and community needs. The City of Columbus has posted its RFP on the Smart Columbus website for others to utilize in procurement development.

LESSON LEARNED: To assure that the system desired is procured, a thorough procurement process and document is needed that outlines each requirement a vendor should meet.

### A.3.9 Testing

A project outcome, as it related to the Smart City Challenge Cooperative Agreement, was to develop a thorough test plan that could be used as a basis to test similar technology and potentially set the standard for testing. The tests were developed to ensure the project team’s expectations, the stakeholder expectations, and the public’s expectations were met while working within the confines of the vendor’s testing. The intent was not to create tests down to the sensor and system level, but more on the operational level so it met the project goals. Since few published standards existed, the project team

---

wanted to document how self-driving vehicles could be tested with a variety of vulnerable road users. Finally, the usage of a closed course prior to the open-road testing afforded the project team the opportunity to ensure that the vehicles safely operate before they interacted with the public.

To simulate Vulnerable Road Users and other obstacles, the project team acted as pedestrians and used scooters, bicycles, cones (roughly the height of small children), and a rolling basketball. These tested lateral and longitudinal interactions. Other vehicles were also used to test interactions in addition to testing the capabilities of the accessibility features like the ramp. And finally, how the sensors detected other objects and the route was monitored.

Testing was completed in three phases: Factory Acceptance Testing, Preliminary Acceptance Testing, and Final Acceptance Testing. The intent of the factory testing was to serve as a factory audit and ensure that there are procedures and protocols in place that support the vision of safety. The preliminary acceptance tests were set up to give the project team the assurance that vehicles can operate as expected prior to moving the testing into the public streets and in mixed traffic. Final acceptance testing was developed to showcase the vehicle can operate on the actual route as identified in the RFP and that it performs the functions of an automated vehicle.

In sum, the testing included 52 unique tests of the vehicles and vendor and resulted in 115 tests completed over the three phases. This is due to the fact that some tests are duplicative over phases, such as showing how the vehicle departs from the station or deploys the accessible ramp, as it was key to validate the performance between the closed course and the actual route. The factory tests may not be required for each agency to witness but requesting documentation of similar tests may be in the best interest of the public. There were some tests that were not completed, such as crossing a traffic signal, but should be completed if a traffic signal is part of the traversable route.

LESSON LEARNED: Testing is critical to validate the system delivered is the same as procured. A thorough test plan communicates the expectations of the testing and aligns the tests with the requirements.

A.3.10 Data

A lesson learned from the Smart Circuit, Ohio’s first self-driving vehicle deployment, was that procurement documents and contracts could be significantly improved around data requirements. Building upon the previous deployment, the project team sought to fully define the data sets, method of transmission, and frequency of the data to ensure the performance measurement goals for the project were met. The table below indicates the data fields requested, and it was specified that the data was to be transmitted via API to the Operating System for storage and evaluation by the project team and the public. All data were set to be open by default, aligning with the overall data goal of the program.

| Vehicle route and schedule (GTFS) | Wheelchair ramp deployments |
### LESSON LEARNED:
With well-defined procurement requirements related to data, it is possible to request the data needed to evaluate the success of the project and work with the vendor for its use.

#### A.3.11 DriveOhio and Licensing

As was the experience with the first shuttle deployment, licensing was a challenge. While there were lessons learned from the other deployment, being that the vehicle was different, particularly with a higher passenger capacity, presented a new set of challenges. First, the vehicles needed to be registered through the Public Utility Commission of Ohio (PUCO), which superseded needing a permit to operate from the City of Columbus. A USDOT Number assigned by the Federal Motor Carrier Safety Administration is needed as part of the PUCO licensure process, and the data entered to obtain this number is made public due to the nature of the request. As with the first deployment, the vendor was contacted by a scammer asking for additional money shortly after the application was approved. The scammer requests further fees and requirements, such as $100 fee per operator. Thanks to previous experience with this registration, the project team preemptively informed EasyMile so it could ignore this request.

Titling the vehicle took more than one month to address through the Bureau of Motor Vehicles. Since the vehicles were new and there was no proof of sale in the United States, several alternative methods needed to be evaluated. Further, sales tax needed to be paid on the vehicles even though they were already owned by EasyMile. This instituted an unexpected delay and ultimately was resolved the morning of the launch, with temporary tags being issued to the shuttles before permanent tags could be issued a month later. It was beneficial having close coordination with the BMV so that when arriving on-site at a public BMV office, the vendor and project team could work with an employee of the BMV who had been briefed on the process to address the licensing in a timely manner.
Ohio also implemented a $200 registration fee for electric vehicles after procurement but before registering the vehicles. A contract modification needed to be executed to account for the registration fees and the aforementioned sales tax, as both were not included in the proposal costs. While not every state has the same fees or registration categories, early coordination and research into the subject can make the process smoother.

**LESSON LEARNED:** Be prepared for scammers to contact the registrant seeking additional fees. Also, working closely with the BMV prior to procurement can alleviate delays prior to launch related to registering the vehicle and paying any related fees that could be associated with electric vehicles.

### A.3.12 Operator Hiring

The City of Columbus wanted the Linden LEAP to be part of the fabric of the community. Initially, the project team explored the use of a represented workforce to operate the shuttles and expressed this preference in the procurement documents. No vendor responded with represented labor in its proposal, so the team relayed a preference to EasyMile to hire local to the community.

EasyMile shared this value and focused on hiring local. EmpowerBus was hired as a local, woman-owned operator to handle the operations of the shuttle and advertised for the operator jobs in the Linden neighborhood. At launch, six of the nine hired operators either currently lived in Linden or were from Linden. This was a success because it enabled the project to provide technology jobs in the community and the community could take a sense of pride and ownership in the operation of the shuttles. While the pandemic affected passenger operations and EmpowerBus ceased operations, EasyMile was able to hire some of the operators back when the food pantry service started.

The project team felt that it was important to have a focus on workforce development for the operators. With technology disrupting transportation, providing jobs and training for the community to be on the cutting edge can provide new opportunities and allow the community to flourish. This built upon other outreach and engagement with the community to build ownership and success for the deployment.

**LESSON LEARNED:** While not all agencies may have the opportunity to hire local to the deployment, doing so can provide new and advanced jobs for the community.