University of Denver
Autonomous Vehicle Shuttle

Automated Driving Demonstration Grants
March 21, 2019

Transportation SOLUTIONS Foundation

RTD

DENVER THE MILE HIGH CITY

easy mile

1864 UNIVERSITY of DENVER

March 21, 2019

Sarah Tarpgaard
US Department of Transportation (USDOT)
Federal Highway Administration (FHWA)
1200 New Jersey Ave, SE; Mail Drop E62-204
Washington, DC 20590

Subject: Automated Driving System Demonstration Grant

Dear Ms. Tarpgaard,

The Regional Transportation District (RTD) of Denver is excited to submit this application to the US Department of Transportation (USDOT) for the department's Automated Driving System Demonstration Grant Program. With a total project budget of $6,652,961, RTD is requesting $6,331,506 in federal funds to implement a fleet of autonomous transit vehicles at the University of Denver (DU). RTD has committed $25,000 in local match funds (cash) as well as $156,260 in staff time (in-kind) to help support this project. This amount is included in the project team's total local match of $321,455. RTD has assembled a project team with experience in the implementation of similar, smaller-scale autonomous vehicle projects. These stakeholders include the City and County of Denver, the University of Denver, EasyMile, and Transportation Solutions.

As noted, autonomous vehicles are nothing new to RTD. In January 2019, the agency, joined partners (including the City and County of Denver and EasyMile), to implement a bus route served by an autonomous transit vehicle. This service, called the 61AV, was the first autonomous shuttle on a public roadway in the state of Colorado, as well as one of the first public transportation routes operated by an autonomous vehicle in the country. RTD is constantly seeking to improve service through innovative technological advances and the University of Denver AV Shuttle project is being viewed as the next step in understanding how autonomous vehicles can be used in a transit setting.

By reducing the number of human-caused collisions, the DU AV Shuttle will have a direct impact on safety in the service area. In the proposed university environment, the project team will be able to develop a better understanding of how pedestrians, cyclists, automobiles, and autonomous vehicles interact. RTD is committed to sharing data from the demonstration project with USDOT to identify risks, opportunities, and insights relevant to USDOT safety and rulemaking priorities. We also intend to disseminate the processes followed and provide lessons learned from the demonstration project. The information will then be sent to other transit agencies around the country with the goal of reducing barriers to the integration of autonomous vehicles into the nation's public transportation fleets.

We are excited at the prospect of working with USDOT through the Automated Driving System Demonstration Grant Program. Please contact me at bill.vanmeter@rtd-denver.com or 303-299-2448 if you have any questions or need any more information.

Sincerely,

William C. Van Meter
Assistant General Manager, Planning

Summary Table

Project Title	University of Denver Autonomous Vehicle Shuttle
Eligible Entity Applying to Receive Federal Funding	Regional Transportation District (RTD) 1660 Blake Street Denver, CO 80202
Point of Contact	Bill Van Meter, Assistant General Manager, Planning Bill.vanmeter@rtd-denver.com 303-299-2448
Proposed Location for the Demonstration	Denver, Colorado
Proposed Technologies for the Demonstration	Level 4 automated transit vehicle (according to SAE J3016) which has no steering wheel or pedals. The vehicle can carry up to 15 passengers.
Proposed Duration of the Demonstration	2 years
Federal Funding Amount Requested	$6,331,506
Non-Federal Cost Share Amount Proposed	$321,455
Total Project Cost	$6,652,961

Table of Contents

PART I – Project Narrative and Technical Approach

Executive Summary

The Regional Transportation District (RTD) requests an Autonomous Driving System Demonstration Grant of $6,331,506 to support the implementation of the University of Denver (DU) Autonomous Vehicle (AV) Shuttle. The total project budget is $6,652,961 and the project team has secured a total local match of $321,455. DU is a university located in south Denver which has over 12,000 students enrolled. A light rail station served by RTD's E, F, and H lines is located near the northern border of the campus and provides a critical connection to the region for students and faculty. Many studies have been conducted in the past few years by RTD, the City and County of Denver, and DU on how to improve mobility to and from the station and on campus. These studies identified the need for a circulator to provide first and last mile connections between the rail station and DU's campus as well as trips between DU's campus and the surrounding neighborhoods. DU entered into an agreement with Chariot to provide microtransit service on campus and to/from DU Station in the summer of 2018. With the recent shutdown of Chariot services nationwide, DU currently has engaged a contractor to provide shuttle service on campus on an interim basis and is interested in pursuing a longer term AV-based solution. Ridership on the service met targets for the initial stage of service implementation and merits continuation thru the AV demonstration.

Meanwhile, in January 2019, RTD launched a six-month pilot project called the 61AV. The 61AV project implemented the first fully autonomous transit vehicle on a public roadway in the state of Colorado, and one of the first in the country. The 61AV operates revenue service Monday through Friday on a fixed route that connects the 61st/Peña commuter rail station with Panasonic's Denver offices. Through an unprecedented partnership among the public and private sector, the 61AV project allows stakeholders (RTD, Denver, EasyMile, Panasonic, Fullenwider Developers LLC, Transdev) to advance an innovative, first-of-its-kind project.

With the recent departure of Chariot from DU's campus, RTD identified the DU campus area as a prime opportunity to implement the next phase of its autonomous vehicle demonstration program. The 61AV shuttle was purposefully implemented in a low-density area of Denver to help prove the technology. RTD hopes to gather operations data from this pilot to better understand the nuances of operating AVs in a transit application. Because of this ongoing pilot project, RTD is in a unique place where it can apply the data gathered and lessons learned from the 61AV to the planning of the DU AV Shuttle. RTD intends to use the same vehicle from its 61AV project for the DU AV Shuttle: EasyMile's EZ10. This vehicle is a Level 4 automated vehicle (according to SAE J3016) and has no steering wheel or pedals. Partners for the DU AV Shuttle project include RTD, DU, the City and County of Denver, EasyMile, and Transportation Solutions, the transportation management association (TMA) that covers the DU campus area. The DU AV Shuttle is proposed to run primarily on High Street and Illif Avenue and operate revenue service for 12 hours a day at 15 minute frequency. A map of the route can be seen in Figure 1 on Page 10. This service will be free and open to all, providing a significant public benefit through increased mobility in the area.

Once funding is awarded, the project team expects it to take approximately 12 months to complete all required startup tasks, which are listed in more detail in the Technical Approach. In the first year, RTD expects to complete a traffic engineering study, design and implementation of necessary infrastructure improvements (including signal retiming, bus stop installation, facility upgrades, etc), regulatory approvals, staff training, vehicle acquisition, and set-up. Following the start-up phase of the project, RTD will begin a one (1) or two (2) year operation phase; RTD expects to begin operation of the DU AV Shuttle on July 1, 2020. This project is scalable and RTD is flexible on whether operations are funded for one (1) or two (2) years. A Gantt chart of the project schedule and all associated activities can be seen on Page 11. The project will be under continuous evaluation based on the criteria specified in this proposal and a final report will be generated summarizing the shuttle's performance. The project team also intends to create a "how to" guide for starting AV transit service that could be used by other transit agencies around the country and will include lessons learned from the DU AV Shuttle.

Goals

Safety

Through the 61AV, RTD has already implemented an AV project in an environment with some traffic, buildings, and other activity. This was intended to be a proof-of-concept, where the technology itself could be tested with little interference. RTD is now pursuing the next step and implementing the technology in a more active environment that more closely resembles situations that an AV would experience on most US roads. The project area is a university campus, and therefore has many interactions between automobiles, transit vehicles, pedestrians, and bicyclists. Implementing the AV in an environment with such varied activity poses a potential challenge, but it is one that must be solved to advance the integration of AV technology in the US. Though EasyMile completed an initial site assessment to determine the viability of the proposed route, the company will conduct a final site assessment before deployment of the AV vehicle, which is a formal risk assessment to ensure the vehicle can operate safely in the environment. Since its launch in summer 2018, DU's circulator vehicles have been involved in two separate crashes with other vehicles which were caused by human error. There have also been numerous crashes along the proposed route involving vehicles, cyclists, and pedestrians. Between 2014 and 2018, crashes occurred at the following intersections:

- Buchtel Ave & High St- 5 total crashes, 1 serious injury
- High St, north of Evans Ave- 17 total crashes, 1 pedestrian crash
- Evans Ave & High St- 26 total crashes, 1 serious injury
- High St, south of Evans Ave- 4 total crashes
- Iliff Ave, between High St to York St- 15 total crashes, 1 serious injury, 2 bike crashes, 1 pedestrian crash

The specific cause of each of these collisions varies, but human error/negligence is the most common. AV technology provides the opportunity to remove human error from the equation, and thereby improving the safety of public transportation services and other road users. DU also has completed a technical transportation analysis on the campus that measured pedestrian flows. Depending on the intersection, hundreds to thousands of pedestrians will cross paths with the DU AV Shuttle on a daily basis, providing increased safety for those pedestrians and providing policy makers with the ability to better understand how AVs and pedestrians will interact.

Data for Safety Analysis and Rulemaking

RTD understands that one of the USDOT's main goals of the ADS grant program is to provide the federal government with the data and information needed for safety and rulemaking priorities. Through its 61AV project, RTD has identified specific metrics to characterize the safety risk of ADS integration. These metrics include the number emergency stops (e-stops), the number of operator interventions (when the operator has to manually operate the AV), the reason for those interventions (weather, software errors, other external forces), and the crash rate. In addition to monitoring and reporting technical information related to the AV technology, DU researchers will take the lead to conduct a market research study to assess the public's opinion of the AV and how its use is perceived by the public. Generally speaking, secondary research indicates that the public is currently skeptical of AVs, posing a potential barrier to the widespread adoption of the technology; improving public perception is critical to the continued implementation of AVs. The project team hopes to develop a greater understanding of what makes the public wary of AVs and how that opinion might change after interacting with the technology directly.

Collaboration

RTD has assembled an experienced team of partners to implement the DU AV Shuttle project. These partners include the City and County of Denver, the University of Denver (DU), EasyMile, and Transportation Solutions (the Transportation Management Association in the DU area). If awarded grant funding, this group of stakeholders will meet regularly to ensure the successful implementation of the shuttle. Each organization's general contribution to the project is defined below:

- RTD: project management lead; will manage the implementation and operation of the transit services and will lead the ongoing reporting efforts once the service is in operation.
- Denver: owner of the street right-of-way; will oversee the traffic engineering study and infrastructure design and installation.
- DU: will lead the research component of the project.
- Transportation Solutions: will lead the public outreach and marketing portions of the project.
- EasyMile: AV technical expert; will provide the vehicles for the project and operations technical support.

Through this group of partners, RTD is able to tap into the strengths of each organization to ensure the successful implementation of the project. In addition to these direct stakeholders, RTD will coordinate with the Denver Regional Council of Governments, Colorado Department of Transportation, Colorado State Patrol, and other agencies as needed to ensure the project is implemented safely.

Project Background

In 2006, RTD opened the Southeast Corridor light rail line, which provides rail service to the University of Denver via a station on the campus's northern edge. The light rail station provides a tremendous resource to DU for campus commuting and neighborhood connectivity. RTD, the City and County of Denver, and the University of Denver have carried out a number of studies in recent years that identified opportunities to energize the station, enhance opportunities for the institution and the neighborhood, and overcome a lack of connectivity and transportation options to the station. An *Urban Land Institute Advisory Services Panel* (2016) and the *University of Denver Campus Transportation Master Plan* (2016) both identified the need for a circulator service or shuttle system on campus to provide better car-free mobility to students and faculty wanting to get around campus and to/from the light rail station. The *University/Colorado Multi-Station Study* (2017) and *Next Steps Study* (2017) identified University Station as a potential site for the development of a "mobility hub," where seamless integration of transportation modes provides improved mobility for all. These studies also identified infrastructure projects that would promote active transportation modes and improve connections between the station and the campus, which were funded through a 2017 General Obligation Bond approved by Denver voters. Finally, in 2018, the *Denver Advantage Campus Framework Plan* was adopted by DU, calling for a blurring of boundaries between the campus and the surrounding neighborhoods and adopting the recommendations of the *University/Colorado Multi-Station Study* and the *Next Steps Study.*

Providing mobility for a demographic with low car ownership (students) is a priority for DU, RTD, and Denver and the large population of “early-adopters” makes the campus a good area to implement new technologies. DU has launched several mobility pilots in the past few years including a pilot with Lyft which provided university-subsidized trips around campus and to the light rail station, a dockless bikeshare program, and a campus shuttle service operated by Chariot. Each of these pilots had varying degrees of success, however, the demand for a campus shuttle service was clear. Once Chariot shut down operations in February 2018, DU hired another contractor to fill the void left by Chariot. Ridership on the service is growing as the population becomes more accustomed to the service provided.

Mobility on DU’s campus has been studied in great detail by the projects’ stakeholders. This, along with the large student population (many of whom are car-free and “early adopters” of technology) and the demonstrated demand for a campus shuttle prove that the DU campus, the surrounding neighborhoods, and the general public would benefit significantly from this project.

Project Description

The DU AV Shuttle is proposed to operate a total of 2.2 miles from the University Station, south on High Street, east on Illif Avenue, and north into the campus on an internal road where the vehicle will turn around and follow the same path back to the light rail station. EasyMile has conducted an initial site assessment for this route, however final routing will be subject to the transportation engineering study completed by Denver. A map of the proposed route can be seen in Figure 1 on Page 10. Though exact hours and schedules will be determined during the planning phase of the project, RTD anticipates operating revenue service from 7:00 AM to 7:00 PM seven days a week with 15 minute frequency. This will require a total of four (4) vehicles – 3 operating the route and one spare. RTD intends to operate the service using EasyMile’s EZ10 vehicle. This is the same vehicle that RTD currently uses on its 61AV route. Further explanation on the selection of this vehicle can be found in the Technical Approach below. No fares will be collected on the vehicle and the service will be branded as another RTD bus route and open to the public.

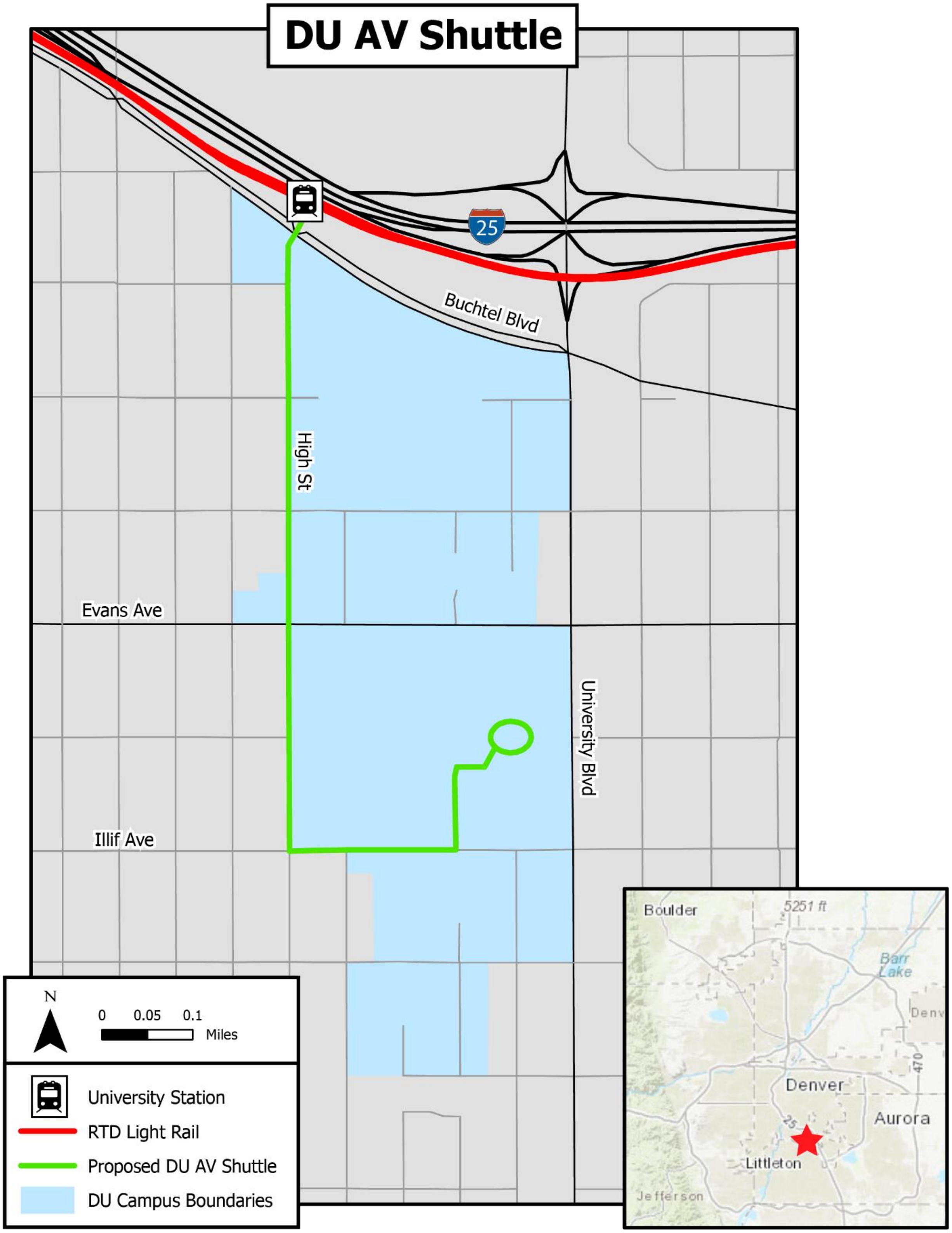
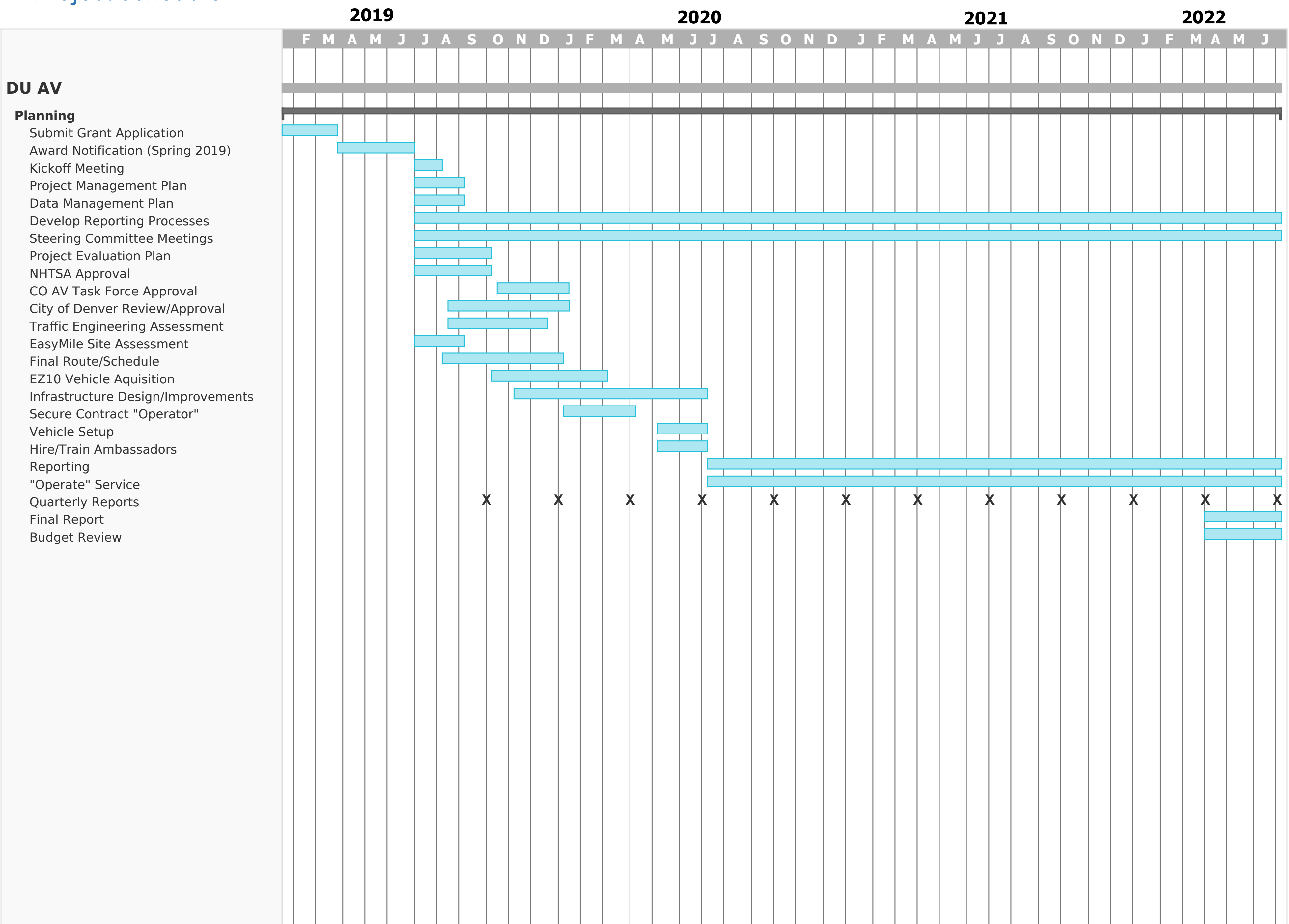


Figure 1: Map of proposed DU AV Shuttle route

Project Schedule



Technical Approach

Building on the approach taken for the successful implementation of RTD's 61AV autonomous vehicle demonstration project, RTD will convene a stakeholder steering committee to oversee and guide the implementation of the DU AV Shuttle. A full description of the members and responsibilities of the steering committee can be found in the Management Approach in Part II.

Based on RTD's experience in implementing the 61AV demonstration project to operate an autonomous vehicle on public roadways in Denver, the steps necessary to operationalize the DU AV Shuttle can be grouped into several very broad categories:

- Regulatory (Federal, State and Local)
- Contractual (external with USDOT and internal between stakeholders and with service provider)
- Operational planning (including traffic analysis and engineering design as needed, development of data capture and reporting processes and development of service delivery processes and procedures)
- Infrastructure improvements
- Operations implementation (including hiring and training of on-board "Customer Service Ambassadors" and implementation of service operations and maintenance processes)
- Marketing and communications (including public outreach and education)
- Market research (to assess consumer perspectives)

Details of the activities to be undertaken in each of these categories are as follows:

Regulatory

Federal Level

The project will be required to get a federal exemption from the National Highway Traffic Safety Administration (NHTSA) to operate an autonomous vehicle on public roads, as no autonomous shuttle complies with the current Federal Motor Vehicle Safety Standards (FMVSS). In October 2018, NHTSA updated their process for granting these approvals and EasyMile was the first to apply and be approved for projects via this new process. EasyMile worked extensively with the federal government during this change process. This is a testament to the level of experience that EasyMile has deploying the autonomous technology around the world, including the 61AV demonstration in Denver. EasyMile is recognized as being a leader in the autonomous shuttle space and they continue to work closely with NHTSA, Federal Transit Administration (FTA), Federal Highway Administration (FHWA), Volpe, and other branches of the federal government as well as with states such as California and Colorado, as driverless regulations are developed and refined.

Lauren Isaac, EasyMile's Director of Business Initiatives, and the co-chair of ITS America's Autonomous Vehicle Taskforce will lead this effort as the updated federal process requires the vehicle importer to submit vehicle and project-specific information. Once the application is submitted, the process is estimated to take 60-90 days. To date, EasyMile has successfully imported all of their vehicles (around 20 vehicles) and received approvals for all of their projects (over 30 project-specific approvals).

Though RTD is familiar with the Buy American Act, the agency is unaware of any domestic supplier of autonomous transit vehicles. It should be noted that RTD will not be purchasing the vehicles used in this demonstration, but rather be leasing them along with other accompanying services from EasyMile. RTD and EasyMile are willing to work with USDOT to address this opportunity within the constraints identified herein. All supporting infrastructure that will be built using federal funding as part of this project will comply with the Buy American Act.

State Level

In order to provide a state regulatory framework and oversight process for autonomous vehicle demonstrations in the State of Colorado, the state created the State AV Task Force that consists of representatives of the Colorado Department of Transportation (CDOT), the Colorado Department of Revenue/Department of Motor Vehicles (CDOR/DMV) and the Colorado State Patrol (CSP). This group is responsible for reviewing and approving any autonomous vehicle pilot project on public roadways in the State of Colorado. This group will review the proposed routing and procedures associated with any such project with an eye towards all safety related aspects of the proposed project, as well as inspect all vehicles to be operated as part of any such demo project.

The RTD/EasyMile team was the first to complete Colorado's new AV regulatory process via the State AV Taskforce as part of the extensive approval process to launch RTD's 61AV demonstration project. We have every reason to believe that the Taskforce will be supportive of this project and we estimate that this approval process will take approximately 30-60 days. The exact timing of this process is dependent on the timing of the NHTSA approval process as AV Taskforce approval cannot be completed until receipt of NHTSA approval, final site analysis and traffic engineering assessments have been completed, and a final route design has been determined, as the AV Taskforce must review the final route.

Local Level

As the owner and operator of the roads over which the DU AV Shuttle will operate, Denver will also be involved in reviewing and approving final details of the proposed DU AV Shuttle project. As members of the project steering committee, Denver and DU will work with the project team to ensure the traffic engineering elements of the DU AV Shuttle project align with Denver's and the University of Denver's broader mobility goals in the project area. As evidenced by the partnership formed to submit this grant application, these parties have already reached conceptual agreement on the proposed project scope. RTD, Denver, and EasyMIle, as well as other stakeholders, all worked together to navigate the local process during the implementation of RTD's 61AV demonstration project. Denver intends to develop guidance for AV deployment in the public right-of-way, and the DU AV Shuttle will be compliant with Denver standards. The proposed project team will work together to ensure that signage, traffic signalization, and pedestrian and bike movements all work together to enhance safety and overall mobility in the project area and to secure final Denver approval of the proposed DU AV Shuttle demonstration project. It is estimated that this approval process may take approximately 90 days but the actual timeline will be affected by the findings of the detailed traffic engineering review and analysis to be discussed later.

Contractual

The contractual element of this project is essentially a series of technical business-to-business transactions to clarify roles, responsibilities, and funding flows between various participants in the DU AV Shuttle demonstration project. It is currently anticipated that contracts will need to be developed and executed to address the following:

- USDOT/RTD- the contract authorizing, defining, and funding the grant to implement the DU AV Shuttle demonstration project;

- RTD/Service provider- RTD currently has contracts in place with both Transdev LLC and First Transit Corp. to provide contracted fixed route service for RTD customers. Both of these firms have experience providing autonomous vehicle services and both of these firm's contracts with RTD provide the capacity to amend the existing contracts to include provision of additional services. It is anticipated that RTD will enter into negotiations with these firms and amend one of the contracts to include the provision of "Customer Service Ambassadors" and maintainers to provide the DU AV Shuttle service and the provision of appropriate insurance(s) for the service;
- EasyMile – it is currently anticipated that the DU AV Shuttle service will be provided utilizing an EasyMile EZ10, Gen2 driverless electric shuttle vehicle. It will be necessary to execute the appropriate lease/contract with EasyMile to provide the autonomous shuttle vehicles to be used to provide the DU AV Shuttle service. It is currently anticipated that the vehicles will be obtained through a lease to be executed between the selected service provider and EasyMile in order to facilitate a more "turn-key" approach to service delivery during the demonstration project, however the final decision may utilize a different means to obtain the vehicles; and
- If necessary, contracts or Memorandums of Understanding (MOU's) between stakeholders to clarify funding responsibilities and invoicing processes.

Operational Planning

There are a series of technical activities that must be undertaken to ensure that all necessary actions are designed and developed to provide the delivery of safe, reliable, customer focused AV shuttle service. Among these activities are:

The Selection of the AV Shuttle Vehicle

The DU AV Shuttle service will be provided using an EasyMile EZ10, Gen2 driverless electric shuttle. This vehicle will accommodate up to 15 people on board (10 seated and 5 standing), including passengers with reduced mobility (the vehicle has a passenger-activated lift that can be deployed to allow passengers with mobility devices to use the shuttle). The vehicle operates at Level 4 automation (according to SAE J3016) and has no steering wheel or pedals. The EZ10 can navigate autonomously and travel at speeds of up to 15 mph. Over 100 EZ10 autonomous vehicles have been deployed to date and have travelled over 200,000 miles in these deployments. To date, these vehicles have no accidents reported in operations, in either autonomous mode or during manual operation by a trained agent.

EasyMile made the strategic decision to work with an OEM for the design and production of their vehicles. Ligier is a French OEM and the largest European manufacturer of special lightweight vehicles. EasyMile's EZ10 is manufactured by Ligier on a dedicated assembly line in its Vichy's factory. In 2018, Ligier produced over 15,000 electric vehicles. To date, Ligier has manufactured 100 EZ10 vehicles and can assemble up to 3 per week. Ligier, a renowned automotive manufacturer and leader in specialized vehicles, complies with all European standards and has unparallelled know-how when it comes to setting up production lines for new vehicles. Ligier established a dedicated EZ10 production line that follows automotive industry best practices. As a result, EasyMile is benefiting from Ligier's expertise in assembling vehicles and in managing the supply chain with respect to the spare and replacement parts required for maintenance and operations. EasyMile can therefore rely on economies of scale for standard parts, in addition to an excellent delivery quality.

Working in close collaboration with Bosch and Continental, two established sensor and automotive industry equipment suppliers, EasyMile is testing and integrating the latest components available on the market to stay ahead of the market and the competition. Similarly, EasyMile has established strategic partnerships with leaders in their respective fields, including, for example, Continental, Bosch, Lacroix, Nokia, Ericsson and Panasonic. These partnerships have enabled EasyMile to develop and deploy innovative solutions based on market needs.

Similar to complex transportation systems like commercial aircrafts, EasyMile has equipped the EZ10 shuttle with multiple layers of redundancy in order to maximize the safety of the passengers, other road users and the vehicle itself.

- Redundant coverage by sensors
- Independent obstacle detection function
- Fail-safe and redundant braking system
- Redundant industry-grade emergency buttons

All of these aspects have enabled EasyMile to obtain approval by authorities all around the world to drive on complex, public roads.

Braking safely is crucial. This is especially important in a campus environment such as DU. The EZ10 is equipped with several independent braking systems.

- During normal operations the autonomous system can change its speed to smoothly decelerate, using the regenerative braking system. For harder deceleration, the system, can also use the electrical calipers.
- In case of an Emergency Stops (e-stops) the autonomous system uses all the previous braking systems but also the hydraulic braking.
- In case of complete power loss, or when the vehicle is turned off, fail-safe brake is automatically activated.

This architecture mitigates the risk of failure in two braking systems and even a failure in the battery system that would lead to complete loss of electric power.

In case of an emergency situation, passengers on the EZ10 shuttle can trigger an Emergency Stop using one of the three E-Stop buttons strategically located inside the vehicle. Those buttons are continuously monitored by the PLC in such a way that if an error is detected, an E-Stop is automatically triggered by the vehicle. This monitoring can prevent a short-circuit, for instance. A Customer Service Ambassador (CSA) will also be on-board the vehicle at all times to answer customer questions and ensure the vehicle is operating safely

Since its inception, EasyMile has been working closely with the global leaders in transportation operations, receiving day-to-day feedback to improve the passenger experience. The EZ10 fully meets the quality and safety criteria for people transportation. The vehicle's subway-like sliding doors, anti-slip flooring, and hand grips are all sourced via leading suppliers within the public transportation industry.

Additionally, the vehicles are equipped with fire extinguishers, emergency hammers and can be fitted with seat belts upon request. Passengers can contact the supervision center by pressing the emergency button at any time during their journey.

EasyMile uses a variety of methods to ensure a high level accuracy for passenger counting.

- EasyMile uses passenger counters based on calibrated weights (this data is updated every half second)
- EasyMile uses the internal video cameras passenger counters
- EasyMile can also use the industry leading IRMA MATRIX, an Automatic Passenger Counting (APC) sensor with high resolution

The EZ10 is equipped with passenger rail and transit standard automatic doors, with a key locking system and an internal and external emergency unlocking system. The sensitive edges reopen the doors if an obstacle is detected to avoid any pinching. Door opening and closing is controlled via the green button inside and outside the vehicle or it can be programmed based on location or timing. This button is also touch-sensitive and incorporates braille for people with impaired vision. Accessibility for all is a priority for the acceptance of new, innovative transportation systems shared by the public. A simple touch on the blue button will automatically deploy an access ramp to help passengers entering or exiting the shuttle. Buttons are located on the inside and outside of the vehicles.

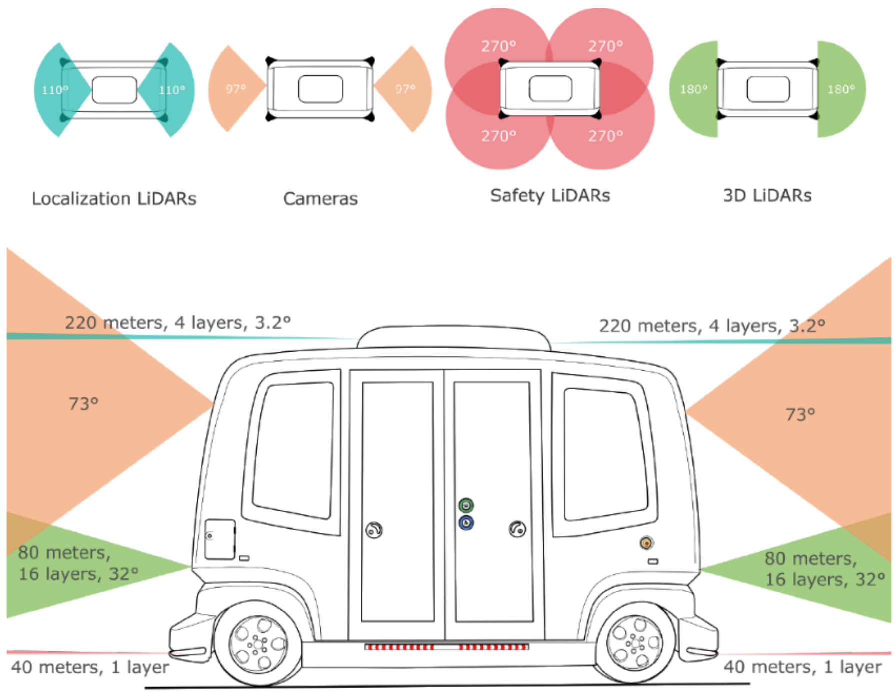
The EZ10 shuttle vehicle is equipped with both air conditioning and heating systems to offer passengers optimal comfort in all operating conditions. Air conditioning and heating may be adjusted using a touch screen inside the vehicle. The vehicle’s interior has been designed by a professional team of designers from the automotive industry. The anti-slip floor, mat plastics, wooden chairs and hand grips from the transportation industry illustrate the extremely high level of quality. The EZ10 can also be equipped with wheelchair anchors points. The 6 seats and 2 stand-up seats made of wood configuration accommodates 8 seated passengers and 4 standing passengers. A 2-bench and 2 stand-up seats configuration accommodates 10 seated passengers and 5 standing passengers. The EZ10 has 8 USB chargers throughout the interior of the shuttle offering passengers the possibility to recharge their equipment.

The EZ10 shuttle vehicle is equipped with a 29” internal information screen in the vehicle to provide information including audible and visual alerts to passengers about their journey, including progress, next station, arrival time, etc. The screen can also be used to broadcast media, advertisements, explanatory videos and other media as per our customer needs, synchronizing with the vehicle localization to enhance passengers’ experience.

EasyMile AV Technology

The EZ 10 shuttle vehicle is equipped with the latest EasyMile autonomous technology in order to ensure safe operation of the DU AV Shuttle. The EasyMile vehicles are equipped with the technology needed for the vehicle to know where it is located, where it is going and how to get there, and what the environmental conditions are and how to adapt behavior.

The EZ10 is preprogrammed by EasyMile engineers or certified partners to run on predefined routes or network of routes, under certain circumstances. To do so, all EasyMile's vehicles, including the EZ10 are Level 4 according to the SAE definition of Driving Automation Systems for On-Road Motor Vehicles - J3016_201806. A Level 4 system is an Automated Driving System (ADS) that can itself perform all driving tasks and monitor the driving environment – essentially, do all the driving – in certain circumstances.



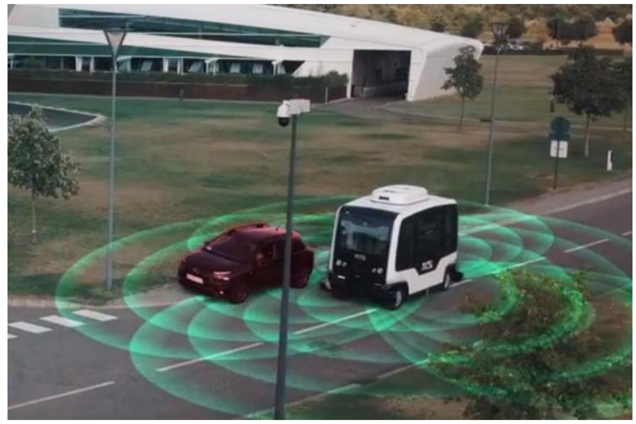
The EasyMile software has been designed to know the vehicle's exact position with centimeter-level precision, at all times. The software can obtain this level of precision through lasers scanning the environment, cameras, differential GPS, visual location, estimation using an Inertial Measurement Unit (IMU) and odometry estimation. Each of the technologies are described in more detail below.

Environmental Laser Scanning - LIDARs

The EZ10 is equipped with several different LIDARs to ensure redundancy in information collection. The first is LMS, also called Safety LIDARs. There is one at each corner of the vehicle (four total) strategically positioned 12 inches above the ground. They have a range of 130 feet and 270 degrees of horizontal scanning. They are single layer LIDAR and used for obstacle detection by high-level software and the Safety Chain as well as for navigation.

There is currently no certified LIDAR on the market, which is why EasyMile has chosen to include redundant sensor coverage sourced from different suppliers. This architecture mitigates any risk of failure of a single sensor. The four LIDARs, each scanning 270°, located at each corner of the vehicle, offer a 360° redundant perception of the environment. Any obstacle within 130 ft of the EZ10 will be detected by at least 2 to 3 LIDARs.

The next sensor type of sensor are LDRMS, also called Localization LIDARs. There are two of these sensors strategically positioned on the roof of the EZ10 to detect fixed elements in the environment (buildings, statues, tree trunks, signs, streetlights, etc.) without being disturbed by moving elements in the environment that are usually smaller and that will not be in the sensor's field of view (pedestrians, cars, bicycles, etc.). The sensor has four (4) layers, a range of 720 feet, 110 degrees of horizontal scanning, 3.2 degree vertical opening, and is used for navigation by the high-level software.



The final sensor type is VLP16, also called 3D LIDARs. There are two of these LIDARs on the EZ10 - one at the front and one at the rear of the vehicle. The LIDAR has 16 layers, a range of 260 feet, 180 degrees of horizontal scanning, 32 degree vertical opening, and is used for navigation and obstacle detection by the high-level software.

Cameras

The EZ10 is equipped with indoor and outdoor cameras. EasyMile completes the development and validation of the use of these cameras for navigation and environmental detection.

Differential GPS

The EZ10 is equipped with a global navigation satellite system (GNSS) antenna from the Canadian manufacturer Novatel. This antenna allows the EZ10 to find its way through space thanks to the constellations of GPS, Glonass and Galileo satellites. EasyMile also uses the services of a GNSS - Real Time Kinematic correction provider referred to as “SmartNet” to refine the vehicle's position, with centimeter accuracy. GNSS corrections are received via the 3/4G network, and are determined using a set of SmartNet reference bases. They do not require the installation of an additional reference base dedicated to this project, which are often problematic and vulnerable to cyber attacks.

Inertial Measurement Unit (IMU)

The EZ10 is equipped with an inertial unit capable of integrating the vehicle's movements (acceleration and angular velocity) to estimate its orientation (roll, pitch and heading angles), linear velocity and position.

Odometric Estimation

The EZ10 has sensors on the wheels to measure the vehicle's movement. Odometry is based on the measurement of wheel movements to reconstruct the overall movement of the vehicle. Starting from a known initial position and integrating the measured displacements, the current position of the vehicle can be calculated at any time.

Software Architecture

The processing power needed to run an autonomous vehicle is huge. There is no certified processing unit with enough computing power to enable obstacle detection functions. The EasyMile approach is based on adding an independent safety layer: the Safety Chain**.** This architecture mitigates the risk of processing unit failure (due to hardware or operating system fault). By design, the EZ10 is composed of two main levels:

- An industrial-grade computer with a tailor-made version of Linux enabling better control of processing and cyber-security than commercial OS (Operating Systems). Complex filtering algorithms are embedded on this computer to monitor obstacles around the shuttle, calculate collision probabilities and adapt its behavior accordingly.
- A Safety Chain based on a certified PLC (Programmable Logic Controller) is independent from the main computer. It uses very simple algorithms and can perform emergency stops should the main computer fail to anticipate the potential collision.

The PLC used in the Safety Chain is SIL3 certified (according to IEC 61508 Functional Safety standard) and PLe certified (according to ISO 13849 "Safety of machinery - Safety-related parts of control systems" standard). The PLC performs the following tasks with a high safety level inherent to its certification:

- Continuous monitoring of critical components (such as steering and traction controllers, braking systems, LIDAR sensors, emergency buttons, main computer, etc.)
- Triggering of an emergency stop, in case of Safety Chain, emergency button activation or detected failure of monitored components. This will enable to ensure that vehicle and its passengers are safe.
- Safe Door and Automatic Ramp management (opening and closing) - one of the most critical function in transportation systems because of potential injuries, failures, and unavailability.
- The PLC outputs are always considered with the highest level of priority over the other robotics, electronic or computer systems. In case the PLC encounters a failure, its certification level ensures that it will reach its fail-safe state. In this state, our fail-safe brake will be automatically activated to enable vehicle to stop.

EasyMile has developed its own Fleet Management system called EZ Fleet which is able to handle a fleet of any type of autonomous vehicles based on real field data from the ongoing projects around the world. The EZ Fleet is the electronic brain of the whole system. It is designed to be flexible and modular, so as to enable different operating scenarios and to adapt to the various needs of our customers.

To travel autonomously, the AV shuttle vehicle runs along a pre-programmed route designed by a deployment Engineer through a known environment. Thanks to localization techniques, the vehicle knows its position on the route and moves from one station to another following its trajectory.
During deployment, the engineer makes an acquisition by driving in manual mode with the vehicle (trajectory, environment, GPS position, etc.). This acquisition is then cleaned, the trajectories reworked to be comfortable for passengers, and serves as a reference map for the vehicle during operations. This map contains the programmed speed for each road section, the activation of the indicators or bell if necessary, the presence of red lights, traffic signs (Stop, Yield, etc), stations, etc.

The high-level software collects, fuses and interprets data from the above-mentioned sensors.
In particular, a technique called S.L.A.M (Simultaneous Localization And Mapping) laser, consists in measuring the distance from surrounding objects and thus makes it possible to create a mapping of its environment. This system requires sufficient "hang points" for the laser detectors that are used to locate the vehicle in its environment. The environment around the roads planned for the EZ10 in the provision of the DU AV Shuttle service for RTD is very rich in "hang points" for LIDAR localization. The fusion of data from the various sensors ensures redundancy and robustness in the vehicle's localization, with the weak points of one system being compensated by the strong points of the others. The presence of trees

on the route, or indoor traffic are excellent examples of situations where GNSS coverage will be very low or non-existent. The system is then able to detect that the uncertainty related to GNSS information is too high (0 or very few satellites detected when the vehicles normally detect between 10 and 15) and to reject the information from this sensor. The fusion of data from the other sensors is good enough, so the vehicle will continue to run without any problems.

Several types of intersections can be programmed along the EZ10 route, where the vehicle slows down or stops depending on the situation, in order to scan the environment and decide to continue. In all circumstances, the obstacle detection functions described above remain valid. At a Stop or Yield intersection, EZ10s are able to scan the environment and take the decision to cross the intersection when the area is free. Like Yield intersections, EZ10s are to scan a pedestrian crossing and make sure there is no pedestrian crossing or about to crossing before going through. This is extremely important in environments such as the University of Denver campus with high pedestrian volumes.

Vehicle to infrastructure (V2I) communication is a key component of EasyMile's technology. The EZ10 can communicate with traffic signals via a communication network (DSRC, ITS-G5, 3G, 4G, or 5G networks) and with other infrastructure (e.g., railroad crossings), as needed. The ultimate goal is to leverage these technologies in order to introduce more complex traffic situations without human intervention. The EZ10s can read SPaT messages broadcasted by traffic light controllers to determine the Phase and Time of the light, and take the decision to cross or stop at the intersection. To do so, the EZ10 can be equipped with an OBU (On Board Unit) that can communicate using short range communication technology with traffic light controllers equipped with RSUs (RoadSide Units). EasyMile already has an extremely good relationship with V2I equipment suppliers, and can incorporate their technology.

To maximize safety, the obstacle detection features are divided into two independent subsystems: anti-collision software and a safety system. These modules are based on various sensors and LIDAR systems to detect obstacles on the road and safely control braking or stopping. The redundant layers of sensors and control units therefore guarantee maximum safety if a component fails. The braking capacity and speed of the vehicle are taken into account to evaluate whether the observed object risks causing a collision. This module uses complex filter algorithms.

This software module is based on the different LIDARs on the vehicle to slow, brake and stop the vehicle when an obstacle is perceived on the path, before calculating a circumvolution strategy. The braking capacity and speed of the EZ10 are taken into account to determine whether the perceived object is likely to cause a collision.

When an obstacle is detected in the detection area covered by the vehicle, the vehicle reacts according to the position and distance of the obstacle:

- If it is located in front of the vehicle, on its trajectory, the vehicle slows down. The distance from which the vehicle begins to slow down depends on its speed. The closer the EZ10 gets to the obstacle, the slower it slows down, until it stops completely if necessary.
- If it is located on one side of the vehicle, the EZ10 also slows down, but reaction distances are reduced.
- If it is located at the rear of the vehicle, the EZ10 does not take it into account.

The stopping time of the vehicle, following the detection of an obstacle, depends on its speed. The higher the speed, the more the vehicle anticipates its stop and begins to slow down early.

Sometimes when in operation, the predefined route (trajectory) can be blocked by a parked car, construction, fallen tree etc. Within a preprogrammed area, defined during the Setup by the deployment engineer based on the Site Assessment Report, the EZ10 is able to accurately assess this hazard, and if it is safe to do so, perform an overtake of this hazard. Following the successful overtake of the hazard, the EZ10 is able to resume normal operations.

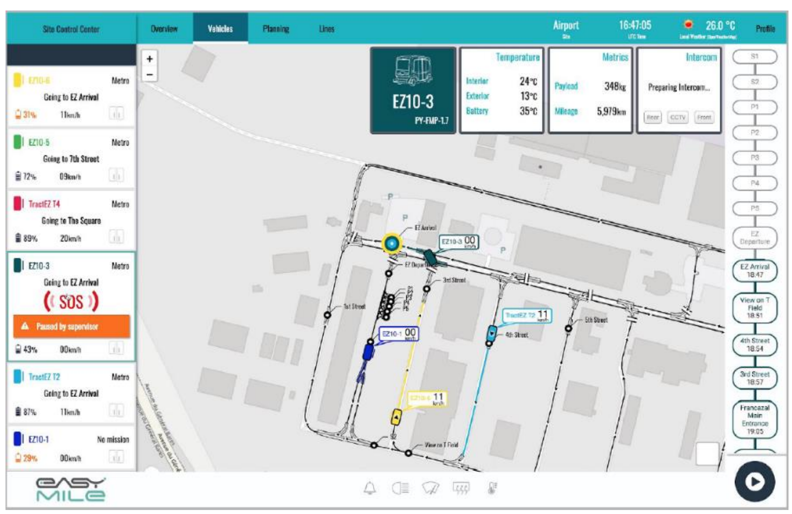
In the event that an obstacle is suddenly detected in the vehicle's safety zone in front of it or its side while running, the Safety Chain triggers an emergency stop. This happens, for example, if a pedestrian suddenly crosses in front of the vehicle or a car rapidly leaves a parking spot just in front of the EZ10. During an emergency stop, the vehicle is programmed to strongly decelerate in order to stop the vehicle quickly, but with minimal risk of the passengers falling.

EZ Fleet Modules

On the EZ Fleet interface, the supervisor will be able to see all vehicles on the sites, their position, assigned routes and destinations, as well as several vehicle parameters such as the inside temperature, the batteries state of charge, the weight etc. The EZ Fleet enable every interactions between the vehicle in operations and the Control Center.

Dynamically assign missions, adjust headway, send a vehicle to the charging point, switch between fixed route and on-demand, EZ Fleet optimize the organization of the autonomous vehicle fleet. Traffic jams on some streets, ongoing construction work blocking a road, those elements can be received and integrated into the EZ Fleet to minimize the impact on service quality.

An example of this in use would be, if an emergency stop be triggered, the supervisor can directly get in touch with the passengers accessing the CCTV camera and speakers to provide guidance. Both the front and back cameras are accessible from the interface to assess the vehicle environment. The passenger screen can also be used to push messages from the control center, for instance to provide geolocalized information, emergency procedures, next stops and ETA etc.



The EZ Fleet provides insightful and meaningful data to improve the overall operations. This module gathers information from the vehicle, site and operations and creates automatic daily, weekly or monthly operating reports. Reports can be fully customized based on customer needs. RTD and EasyMile will collaborate to gather data and develop final reports as addressed elsewhere in this proposal.

EasyMile will provide a web-based app that the Customer Service Ambassadors are required to use in order to operate and manage their vehicles. This highly-secure and flexible app provides real-time information regarding the vehicles' position, status, routing assignment, etc. and it enables the ability to manage on-demand requests and remotely stop or re-arm the vehicle. It can also provide diagnostics in case of vehicle errors and will connect to the EasyMile HelpDesk, if needed.

EasyMile can provide operational information regarding the vehicle's status via different API options. The Position API allows third parties to access the vehicles' positions on a site at all times. This can provide valuable data location information via an organization's website, trip planning app, or other integrated information source. RTD IT staff and EasyMile staff worked together to implement this functionality in RTD's 61AV demonstration project in order to provide real time information to RTD customers through RTD's NextRide program. It is anticipated that this functionality will be incorporated into the proposed DU AV Shuttle service.

More complex than the Position API, the Monitoring API allows our partners to collect operational data to monitor operations as well as develop their knowledge about autonomous vehicle operations. The Monitoring API provides access to various data including current position, speed, battery level, external/internal temperatures, and number of passengers. It is anticipated that this functionality will be incorporated into the DU AV Shuttle service as proposed.

Cybersecurity

Because safety comes also with security, cybersecurity is a main focus throughout the entire product life. As safety aims at protecting the system from accidental failures in order to avoid hazards, cybersecurity focuses on protecting the system from intentional attacks. Safety and security share a common objective of reducing risk. A strong cybersecurity culture is one of EasyMile's fundamental management principles so each individual has the proper attitude, approach and commitment at all levels in the organization

In order to protect the safety of the passengers and of anyone around EasyMile vehicles, and to protect EasyMile and clients from financial or reputational damage, one needs not only to ensure that EasyMile's software stack is behaving correctly in normal circumstances but also that all systems are protected from malicious attacks or unauthorized access which would affect their ability to behave safely. Protecting systems means not only to ensure that vehicles and fleet management solution are generally safe from cyber attacks, but also to prevent any breach upstream by securing as much as possible access to any of the systems. That's why in order to keep EZ10 hardware and the software running on the vehicle itself, and in the Cloud during normal operations safe, a wider perimeter than just the vehicle need to be protected, which goes all the way product lifecycle.

The EasyMile Cybersecurity approach includes the vehicle itself, the vehicle's OS, vehicle-to-Cloud communications, Cloud infrastructure, information systems, employees' physical assets and security audits and penetration tests. International standards for autonomous vehicle security are not yet available, as this domain is relatively new. Therefore, EasyMile strongly inspired its best practices of Standard SAE J3061 which defines the cybersecurity for conventional vehicles. These best practices cover organizational and technical aspects of vehicle cybersecurity, including governance, risk management, security by design, threat detection and incident response and recovering. EasyMile also works with government agencies, cybersecurity experts and security research communities to maintain and advance our cybersecurity capabilities. They aim to implement the ISO 21434, Road Vehicles — Cybersecurity Engineering, which publication is scheduled for end 2019.

Site Assessment Report

Before the autonomous shuttle vehicles arrive on-site, one of EasyMile's experienced deployment engineers will identify and document all potential risks and mitigation strategies along the proposed route. Based on these findings, the EasyMile team will develop a Site Assessment Report, which summarizes EasyMile's requirements and recommendations for the site/route, and gives the scope and conditions of the AV operations on this specific site/route. A preliminary site assessment report has been conducted in order to prepare this grant application, however it is appropriate to conduct a more detailed site assessment as part of the project activities.

The team will review the findings with the RTD, Denver, and the steering committee, assess the feasibility of the proposed routes, and ensure that all of these observations and recommendations are appropriately addressed prior to finalizing the vehicles' route and operating profile. This site assessment will provide baseline data and will be an input into a broader traffic engineering assessment of the proposed route and operating profile to be discussed further below.

Traffic Engineering Review and Analysis

A traffic engineering consultant will be engaged to review and analyze the existing street network, existing traffic signage, traffic signalization, traffic counts and movements, pedestrian counts and movements, bicycle counts and movements, and the proposed AV shuttle route and to undertake updated data capture and analysis as may be required. The objective of this analysis is to determine what, if any, infrastructure improvements may be needed to safely and effectively implement the proposed DU AV Shuttle. Possible infrastructure improvements might include things such as AV stop improvements to ensure ADA accessibility to the DU AV Shuttle service, traffic warning signage that warns drivers of slow moving vehicles along the route, curb line adjustments, changes to traffic signalization and/or other traffic signage (stop signs, etc), and roadway striping. The study will also evaluate impacts to on-street parking, the interface between pedestrians at designated crosswalks, "social path" crossing without signal control, and opportunities for vehicle to infrastructure communications actions. This analysis, and any resultant infrastructure improvements will be an input to approval by both the State AV Taskforce and Denver as well as to RTD's safety assessment as part of RTD's SMS approach to service delivery. While a sufficient amount of work has been done prior to the submission of this proposal to ensure the viability of the route as proposed and described earlier in the document, this traffic engineering review will assess the route in greater detail to validate all aspects of the project to ensure the safe implementation of the DU AV Shuttle. The outcomes of this task will include the identification and design of all infrastructure improvements necessary to ensure the safe and effective implementation of the project. The findings of this review and assessment will provide the guidance to undertake any infrastructure improvements for this project. The time needed for this review and analysis as well as the time needed to implement any appropriate infrastructure improvements identified will have a major impact on the timeline of this project. Based on initial review, we have projected 90-120 days for the review/analysis and design of improvements, and approximately 7-8 months for implementation of infrastructure improvements (to be discussed further below). Both RTD and Denver have on-call traffic engineering consultants, and the project group would plan on engaging one of these on-call consultants to perform the engineering review.

AV Shuttle Schedule Development

Another element of the operational planning phase of the project will be the development of the final operating schedule for the DU AV Shuttle. While sufficient preplanning work has been done to determine that the service can provide 15 minute service frequency using three (3) AV shuttle vehicles (with a fourth as a backup), it will be necessary to determine exact running times and time points at the various stops along the route to ensure that the AV shuttle service integrates appropriately with RTD's light rail service at the nearby University Light Rail Station.

AV Shuttle Vehicle Delivery

EasyMile has developed an expertise in managing the global shipping and delivery of the EZ10s and will arrange for the shipment of the vehicles from Francazal (EasyMile's test and quality assurance site) to the operating and maintenance facility for the DU AV Shuttle project. EasyMile will coordinate with RTD to be sure that appropriate personnel and equipment are available on-site to ensure that vehicles are safely and efficiently unloaded from the container(s).The EasyMile team will ensure that a staff person is on-site to unload the vehicles and validate the vehicle and all associated technology have shipped safely and is assembled appropriately. The EasyMile staff person(s) will ensure the latest software updates have been installed and confirm the vehicle is ready for operations.

Operational Policies and Procedures

Building on the work done for RTD's 61AV demonstration project, RTD and EasyMile will work with the selected "operator" to refine operating policies and procedures to guide the provision of service during the DU AV Shuttle project. Areas to be addressed include:

- Processes at the beginning and end of each service day
- Communications processes
- Emergency procedures
- Safety and security policies and procedures
- Accident and incident procedures
- General AV operating procedures
- Operating procedures for inclement weather
- Responding to AV service interruptions
- AV Maintenance procedures
- Customer service policies and procedures
- ADA policies and procedures
- AV service replacement procedures (if AV is unable to perform due to environmental/safety/ADA-related reasons)

Training Program Development

The objective of the training program for this project is to transfer the knowledge and skills needed to conduct the 'day to day' operations of the AV shuttle and the knowledge and skills needed to deploy and maintain the AV shuttle vehicle. As was done for the deployment of RTD's 61AV demonstration project, RTD and EasyMile will work with the selected service provider to ensure that all persons involved with the project develop the necessary knowledge and skill set to ensure the safe and efficient provision of the DU AV Shuttle service. A full description of RTD's training approach can be found within the Staffing Approach section in Part II.

AV Service Replacement Procedures

RTD will deploy an ADA equipped body-on-chassis vehicle to serve as a back-up vehicle should it be necessary to provide service with a non-AV vehicle for any reason. Existing procedures for the 61AV shuttle project will be modified appropriately to ensure that all parties are familiar with the process for determining when such a replacement will take place and how to go about introducing the replacement service.

Data Capture and Reporting Processes and Procedures

Building on the work begun during the implementation of RTD's 61AV demonstration project, EasyMile and RTD will continue to develop and refine the capture and reporting of data relevant to the DU AV Shuttle project. A full description of RTD's data capture and reporting processes and procedures can be found in the Draft Data Management in Part III.

Infrastructure Improvements

The activities included in this phase of the project consist of the implementation of desired infrastructure improvements identified during the site assessment and detailed traffic engineering review and analysis mentioned above. Currently identified infrastructure improvements include AV stop improvements to meet ADA bus stop accessibility guidelines, reconfiguration of the traffic signalization at the corner of High St and Evans Ave as well as possible implementation of vehicle to infrastructure communications capability at this intersection, the potential installation of traffic warning signs to advise motorists, bicyclists, and pedestrians of slow moving vehicles in the service area, and possible adjustments to existing pedestrian crossing facilities. Additional improvements may be identified during the final AV site assessment and detailed traffic engineering review and analysis mentioned above. The timeline for this phase of the project is expected to be a minimum of 90 days and will be adjusted based on the outcome of the assessment, reviews, and analysis. The timeline for traffic engineering infrastructure improvements will impact, and essentially determine, the overall timeline for the project.

In addition to traffic engineering infrastructure improvements, it will be necessary to construct a storage facility for the AV shuttle vehicle to keep the AV vehicles in good condition and minimize curative maintenance tasks. It is planned to construct a simple facility (Tuff Shed or minimal "Butler building") that will provide overnight storage and charging of the vehicles, provide space for minimal storage of operating supplies, and an area for Customer Service Agents (CSA's) to check in and out at the beginning and end of each service day. This facility will be located either on the DU campus near the route or on RTD property near University Station. The traffic engineering assessment will analyze the impacts of these locations and make a final recommendation as to the location of the facility. Requirements for such a facility include being located within 400 feet of the route, having electricity and charging equipment, WiFi connection, a closed shed or garage, 215 square feet per vehicle for storage with a minimum height and width of 10 feet and a load capacity of 2 tons. The facility will be equipped with an

EV charging station - “Home Wallbox”, with Type 1 (SAE J1772) or Type 2 (IEC) connector. The charger will be capable of charging with at least 32A. Should the installation of a Home Wallbox not be possible, the EZ10 will be charged using a domestic plug, and a Portable EV Charger, with Type 1 (SAE J1772) or Type 2 (IEC) connectors.

Alternative EV charging products may be provided, if validated. EasyMile is currently testing a wireless charging solution. It is envisioned that wireless charging will be the first step to an automated charging solution where no human intervention will be needed to drive the vehicle to the charging station and plug it. This is designed so the vehicle can be programmed to reach the closest available charging station when reaching a certain level of battery. This will be managed directly through the Fleet Management System called EZ Fleet. This fleet system can also assign a specific charging station to a specific vehicle whenever needed.

Operations Implementation

AV Vehicle Setup and Reference Map Creation

Once the AV vehicles are on site, a trained EasyMile deployment engineer will manually drive the EZ10 on the agreed-upon routes with the purpose of “pre-learning” its possible routes and operating environment. The vehicle creates a “reference map” that represents all the routes and the site environment. Every intersection and station is defined in this map, speed limitations and the use of bell/indicators are programmed so the EZ10 knows exactly what to do and where. This process enables the AV vehicle to know its exact position by comparing its perceived environment to the “reference map.” Once the map and trajectories have been validated with one EZ10, the deployment engineer is able to transfer the information to the rest of the fleet and test with all the vehicles.

Setup Acceptance Certification

Once the vehicle and site are set up and ready for operations, EasyMile will review everything with the RTD and the rest of the project team to ensure that it is to their satisfaction. At that point, EasyMile will ask the RTD to sign a “Setup Acceptance Certificate” confirming that all aspects of the vehicles and operations are set up according to the initial EasyMile Site Assessment Report as well as the findings of the subsequent traffic engineering review and analysis.

Recruitment and Training

It is anticipated that the current service plan will require a minimum of twelve (12) Customer Service Ambassadors to operate. In order to provide flexibility of scheduling for CSA’s, it is expected that approximately 18 CSA’s would be hired and trained. Based on experience from the 61AV demonstration project, it is anticipated that the CSA’s would be recruited/selected from among the existing workforce of fixed route operators at the existing RTD contractor selected to provide the DU AV Shuttle service. Training requirements would therefore be focused on the AV technology and the particular service plan for the DU AV Shuttle, as the CSA’s would have already received training in the operation and “culture” of providing transit service to the public. Accordingly, it is expected that training would take approximately 24 hours per CSA. The timing for training activities would take place during the month leading up to service implementation.

Marketing and Communication

Automated vehicles are new concept for most Denver residents. Fears about safety and how to navigate around a driverless vehicle requires an effective public education effort that offers information for people about the technology, how to use it, and provides guidance on how to share the road with automated vehicles. The campus setting for vehicle operations is challenging from the perspective that there is a large volume of pedestrians, especially between classes. Teaching students, faculty, staff, and nearby residents will be a project priority.

Transportation Solutions Foundation (TSF), the designated Transportation Management Association for southeast Denver will lead the public education, marketing, and community relations segment of the pilot project. TSF has been working in the area for 22 years and has strong standing relationships with employers, resident groups, and all parts of the campus community.

TSF, in coordination with the project team will develop a marketing plan for the project. The plan will include the development of a brand identity, messaging, and tactics for both informing people about the pilot and motivating people to use the service, especially when accessing RTD's light rail station. All university students, staff, and faculty are provided an RTD CollegePass which allows for unlimited usage of RTD's transit services.

The marketing plan will address:

- Digital Marketing
    - Sponsored Facebook Ads
    - Snapchat filters for:
        - SIMS to use at tabling events
        - Riders to use while using the AV shuttle
    - Email communications. TSF maintained an email list of over 6,000 residents, students, employees and others from the area.
    - Partnerships, such as Way to Go Program to share posts, etc.
    - Information on the DU, TSF and City and County of Denver websites
- Field Marketing
    - Tabling in centralized areas
    - Perimeter targeting (nearby restaurants, grocery stores, student center)
    - Grassroots
        - Door hangers at nearby multi-family and senior housing
        - Community events
        - Flyers to individuals within 0.25 miles of the service route
- Other
    - News Releases – It is important to provide news organizations with a news release or media advisory to alert them to any timely event or information relevant to the pilot.
    - Earned media:
        - Local newspapers
        - Radio
        - TV News channels
        - Blogs (i.e., StreetsBlog)
    - Mailers
- Incentives (note that federal funding will not be used for any prizes or incentives; these will be funded directly by TSF using private funds). Three types of incentives include:
    - Try incentives – to ride for the first time (i.e., merchant tie-ins)
    - Maintenance incentives – rewards, recognition, frequent users prize drawings
    - Transit passes – many people who live and work in the area have not used transit, providing passes to individuals who do not have a College Pass and challenging them to

take the AV shuttle to the RTD LRT station and go downtown or to the airport would be a good way to engage the public.

Research

The University of Denver will lead the research component of the project. The University has the capacity to develop and conduct market research to assess the perspectives and reactions of people impacted by the provision of the DU AV Shuttle service. DU intends to research four specific areas of study. This includes a market research study assessing the human impact of the DU AV Shuttle, the change in student travel patterns and behavior with the implementation of an autonomous vehicle, AV technology's role in improving safety, and the development of a prototype cyberinfrastructure to improve safety analysis of emerging technologies.

The Consumer Insights and Business Innovation Center (CiBiC) housed in the Daniels College of Business provides valuable information on technology adoption and potential for economic viability. This laboratory provides supervision to graduate-led research teams who explore questions related to human behavior and its impact on market offerings. This research group is prepared to provide longitudinal consumer and market insights into the demonstration by conducting personal interviews and online surveys, followed by focus group sessions to provide consumer and market insights. These will focus on willingness to use and attitude toward AV shuttle services, seeking to understand any barriers and challenges to use.

Additional existing research initiatives among Geography faculty focus on college student travel patterns and behavior, and how they change as a result of exposure to new modes of transportation. Dr. Andrew Goetz of the University of Denver is working with researchers at the University of Illinois at Urbana-Champaign and Macalester College in Minneapolis to investigate this topic. The researchers will collect extensive data about student travel, including mode choice, geographic patterns of travel, travel distance, trip purpose, and other factors to establish profiles of student travel behavior. These data will be augmented by intensive survey data to gain a deeper understanding of why students make their travel choices, what factors are most important to them, and how their travel experiences have changed as a result of their college environment. The introduction of the AV demonstration pilot will be an important element of this research project. Graduate students and undergraduate courses will be involved in conducting this research.

Expertise in electrical engineering and computer science coupled with geospatial studies provide a unique opportunity to contribute to technical advancements in collaboration with the AV vendor research team. This includes communication and data management for holistic traffic management to improve safety. The growing use of vehicular wireless communications, including mobile WiMAX and 5.9 GHz dedicated short range communication (DSRC), enables autonomous vehicles to communicate with other vehicles as well as with the traffic management authority in real-time. Such real-time information sharing enables increased situational awareness to act upon the dynamics of traffic condition. AVs can gain a good understanding of present traffic conditions, identify the fastest path to get to their destinations, and become aware of potential hazards. The proposed research builds upon the emerging vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication capabilities and introduces a traffic management framework through a holistic traffic signal control. In this project, we propose a hierarchical operation framework for optimizing traffic signal settings based on a multi-agent system (MAS), which is scalable, efficient and implementable for applications in a large-scale transportation system. MAS, an integration of cognitive agents, provides a reliable solution to the real-time intelligent control of complex transportation systems. The proposed MAS operation is divided into two stages. Traffic signal setting at inter-area intersections, and AV decision making. AVs solve a local problem with moderate computational complexity for real-time application. This decentralized optimization mechanism strikes a balance between optimality and timeliness by making coordinated distributed decisions.

Finally, DU proposes the development of a prototype cyberinfrastructure (CI) to address the needs of managing, visualizing and analyzing data for community users. The CI will capture both static (e.g., roads, community boundaries) and dynamic (e.g., GPS tracking information of vehicles, weather, and traffic signals) data. Key techniques and methods to build the CI encompass cloud computing, high performance computing, Artificial intelligence (AI), Augmented Reality (AR) and data fusion. DU will perform safety analysis because safety is the highest priority to be considered for all transportation operations. The proposed CI can manage V2I data and other contextualized data in a coherent way, provide interactive visualization capabilities to enhance the interoperability among the physical transportation system for both planners and riders, and further support intelligent safety analysis using V2I data.