



To: RTD Board of Directors

Through: Dave Genova, General Manager and CEO

From: Bruce Abel, Director of Special Projects

Date: August 6, 2019

Re: 61AV- Demonstration Project

Please find the attached final report for the 61AV autonomous shuttle vehicle demonstration project which recently concluded. As you are aware, this six month demonstration project launched on January 29, 2019 and concluded on August 2, 2019. The purpose of this final report is to communicate the background and results of the demonstration project as well as to share lessons learned during the planning, implementation and operation of the autonomous shuttle vehicle that was operated in the area of RTD's 61st & Pena rail station. As part of this process I would like to publically thank our partners in this project EasyMile (the autonomous vehicle provider), Transdev (the operator and provider of the on-board Customer Service Ambassador), Panasonic (co-developer of Pena Station Next), LC Fulenwider (co-developer of Pena Station Next) and the City/County of Denver (Public Works and DEN). I would also like to thank the State of Colorado Autonomous Vehicle Task Force (AV Task Force, consisting of representatives of the Colorado Department of Transportation (CDOT), the Colorado State Patrol (CSP) and the Colorado Department of Revenue/Division of Motor Vehicles (CDOR/DMV)) for providing guidance, assistance and oversight throughout the process.

The 61AV demonstration project provided RTD with valuable information about AV shuttle technology and what role it may play in RTD's future service offerings. While a number of technological challenges, especially related to weather events such as snow, heavy rain, steam rising from melting snow, etc., were observed during the demonstration period, staff is impressed by the response of the AV vehicle/technology supplier to address the issues identified during the demonstration. While the current Generation 1 (Gen1) autonomous shuttle vehicle may not provide the type of service reliability needed to operate in a transit service environment, staff was impressed with the response of the vehicle/technology supplier to address these issues in future generations of AV shuttle vehicles now coming to market. The EZ10 Gen 2 vehicle is already on the market and includes a heater to address issues of operator and passenger comfort as observed during the 61AV demo project as well as improved battery life. The EZ10 Gen3 vehicle is just now starting to be deployed and includes improved sensor technology to address snow, rain and steam weather events as observed during the 61AV demo project. The Gen3 vehicle also provides securement

devices for mobility aides and also provides improved battery life to extend vehicle range. It should be of interest to RTD to investigate the degree to which these new technological advances do indeed address the issues identified during the 61AV demo project.

Towards that end RTD has submitted a grant application to the USDOT for funding another AV demo project that has been requested by the University of Denver (DU), and Transportation Solutions TMA to provide a first/last mile connection between DU and the DU light rail station. Other project partners include C/C Denver and EasyMile. RTD is interested in continuing to advance our knowledge of AV capability in a more complex environment such as a university environment with large volumes of pedestrians, bicyclists and vehicles. In addition, this demonstration would include "V-to-I" (vehicle to infrastructure) technology to allow the AV shuttle vehicles to communicate and integrate with the traffic signals along the route. The project would also include a market research component thru DU to conduct pre and post surveys of the campus community, the surrounding neighborhoods and customers. We continue to receive inquiries and requests from other parties that are interested in partnering with RTD for AV demonstration projects.

Att.

61 AV

An Autonomous Shuttle Demonstration Project

Final Report



Regional Transportation District
August 2019

Background:

On January 29, 2019, RTD and its partners launched the 61AV demonstration project, a six-month demonstration of a potential “first and last mile solution” using an autonomous shuttle vehicle. The project connected RTD’s 61st and Pena rail station to the Panasonic building, an emerging apartment complex (Elevate at Pena Station) and the Pena park-n-ride, owned and managed by Denver International Airport (DEN).

The demonstration project was a partnership between RTD, EasyMile (the autonomous vehicle provider), Transdev (the operator and provider of the on-board Customer Service Ambassador), Panasonic (co-developer of Pena Station Next), LC Fulenwider (co-developer of Pena Station Next) and the City/County of Denver (Public Works and DEN). The project was conducted within the regulatory framework developed by the State of Colorado Autonomous Vehicle Task Force (AV Task Force). The AV Task Force was created as a result of legislation passed by the Colorado State Legislature in 2017 and consists of representatives of the Colorado Department of Transportation (CDOT), the Colorado State Patrol (CSP) and the Colorado Department of Revenue/Division of Motor Vehicles (CDOR/DMV). The project came about as a result of conversations that had taken place between the partners since “Autonomous Vehicle Day” in December of 2017. RTD got involved in the planning of the project in May of 2018.

The goals of the project were:

- To safely introduce an autonomous vehicle on a public roadway in Denver;
- Assess the reliability and availability of an AV shuttle vehicle and its suitability for a transit application;
- Provide “first/last mile” service to/from an RTD bus/rail station; and
- Align the interests of multiple stakeholders in order to advance the project.

The Service

After six months of stakeholder steering committee meetings and fairly focused operational planning activities, the demonstration project kicked off on January 29, 2019. The final route was approximately 1 mile in length and consisted of an essentially circular route operating in one direction from RTD’s 61st & Pena station, along Richfield Street, 60th Street, N. Salida Street, through the Panasonic building parking lot, N. Panasonic Way and 61st Street back to Richfield and RTD’s 61st & Pena station. This was the first deployment of an autonomous vehicle operating in mixed traffic on a public roadway in the City/County of Denver and in the State of Colorado. This was also one of the first deployments *nationally* of an autonomous vehicle operating on a public roadway and integrated with a transit agency’s service offering.



Posted speeds along the streets comprising the 61AV route were 25 mph and there were relatively low traffic volumes in the developing area. Needed infrastructure improvements such as ADA accessible stops, curb cuts etc. were provided by LC Fulenwider, as was a Transportation Engineering Plan (TEP) developed as part of Fulenwider's development plan review activities with the City/County of Denver. This plan included the placement of MUTCD compliant "slow moving vehicle" warning signs along the route to advise motorists that slow moving vehicles could be encountered in the area. The signage component of the plan was developed with assistance from RTD, EasyMile and Denver staff and was approved by the City/County of Denver. The 61AV route and signage was also approved by the AV Task Force through a review conducted by CSP and CDOT.

The 61AV service operated on 15 minute frequency, Mondays through Fridays between the hours of 10:00 AM and 6:00 PM. Service was provided along a predetermined route and according to a predetermined schedule designed to integrate with RTD rail service at the 61st & Pena rail station. The 61AV route was treated as any other RTD fixed route service and information was included in RTD's fixed route data base so that it appeared in all RTD data streams for the RTD trip planner, next Ride and real time information streams etc. as we desired to integrate the 61 AV service completely into the RTD service offering and treat it, and monitor it, as any other RTD fixed route service offering.

61AV service was provided using an EasyMile EZ10, Generation 1 ("Gen 1") driverless electric shuttle vehicle with a capacity of 10-12 people. The EZ10 vehicle operates at

level 4 level of autonomy (out of 5 levels) per Society of Automotive Engineers (SAE) guidelines/definitions. The vehicle operates along a pre-mapped network of roads at an operating speed of approximately 10-12mph. The EZ10 vehicle is equipped with a built-in automatic access ramp to provide access for individuals with disabilities, but the Gen 1 vehicle did not include securement devices for individuals using mobility aides. RTD and EasyMile consulted with representatives from the Colorado Cross Disabilities Coalition (CCDC) during the planning of the service to address issues relative to access for individuals with disabilities. While some issues were able to be addressed during the planning of the service, not all issues could be resolved with the EZ10Gen1 vehicle prior to project launch.



A Customer Service Ambassador (CSA), provided through a contract with Transdev, was on board the 61AV vehicle at all times to ensure safety and to answer customer questions regarding the vehicle and/or service. The CSA also provided various reports to assist with the monitoring of the service and also took manual control of the EZ10 vehicle when necessary to maneuver the vehicle around unplanned obstructions such as construction vehicles given the nature of the specific route. If conditions resulted in the inability of the EZ10 to operate due to any reason, the CSA replaced the EZ10 vehicle with a RTD provided body-on-chassis (or "cutaway") vehicle so as to always meet the commitment to our customers to provide the service.

The Results

As discussed, one of the main objectives of the pilot was to demonstrate the AV technology in a transit application and assess what AV technology could do and what challenges would exist with utilizing an autonomous vehicle in a transit setting. Towards that end our metrics were focused on service disruptions and operator interventions, safety (e-stops) and related issues. We knew that there would be very limited ridership potential given the very limited employment in the area (about 80-100 folks between Panasonic and EasyMile offices and no residential population until the apartments opened). The apartments (Elevate at Pena Station) recently began moving in tenants. From early February 2019 through July 26, 2019, the 61 AV has generated 597 passenger boardings. We have had very limited ridership from the park-n-ride and most riders have been folks coming to see the AV technology and check out the ride. The other objectives of the 61AV project were to navigate the process to actually implement the project on a public roadway in Colorado (the first project to do so) and to mobilize numerous partners to work together in order to implement the project. The project was successful in meeting these goals.

Regarding transit related metrics and the 61AV project, the following results were generated during the period beginning in early February of 2019 and running through July 26, 2019:

- Service availability (the percent of scheduled 61AV hours that were actually operated by the AV shuttle in AV mode), when measured on a weekly basis, ranged from a low of approximately 45% to a high of 99+%. Over the life of the demonstration project, the 61AV service was provided by the AV vehicle in Autonomous mode 89% of the time when factoring out non- technology related issues;
- The primary technology related issues affecting AV service availability were that the AV sensors read falling snow, heavy rain and/or steam rising from the street due to melting snow as an obstruction causing the vehicle to stop and therefore the AV shuttle was replaced by a standard transit vehicle during these events...these types of weather events resulted in the AV being removed from service on several occasions during the weeks of 2/25/19, 3/4/19; and 3/11/19 (bomb cyclone etc). Heavy winds also caused intermittent service disruptions during the demonstration period;
- Other events that led to the replacement of the AV shuttle with a body-on-chassis transit vehicle were severely cold weather events or very hot weather events. The EZ10 Gen 1 shuttle vehicle that was used had no on-board heater for the operator or passengers (Gen 2 vehicle being now being deployed does have an on-board heater, and Gen 3 vehicle to be deployed in Q4 of this year also adds improved sensors to address weather issues mentioned above as EasyMile works to address some of the results of our demo). As a result, during very cold weather the 61AV either lost AV service intermittently as the operator would pull indoors to warm up else they would replace the AV shuttle vehicle with the transit vehicle in order to stay warm. Similarly, in very hot weather, the air conditioner would be utilized resulting in a power drain on the battery

- resulting in the need to replace the electric AV vehicle with the transit vehicle in order to complete the scheduled service day. In general, the electric AV vehicle was able to perform approximately 6 hours of the regularly scheduled 8 hour service day in very hot weather before the batteries needed to be recharged;
- AV performance was very good when operating in “normal” weather conditions (not very cold and not very hot). Service availability ran in the upper 90%’s in terms of percent of AV service operated in AV mode, generally in the 95+% range. Events that led to very minor amounts of AV service loss included events when the AV continued to operate but in manual override to circumnavigate unplanned/ temporary obstructions impeding the progress of the AV vehicle along the preprogrammed AV route. These interruptions in AV service were generally caused by construction vehicles given that there was lots of construction going on in the area of our demonstration project. These events normally took about 1-2 minutes per event to circumnavigate the unplanned/temporary obstruction. This is exactly what is supposed to happen when the AV sensors identify an obstacle in the preprogrammed route; and
 - There have been no accidents involving the AV vehicle as it has performed “as advertised” from a safety perspective. Very quick to respond to obstacles (faster than a human operator can) and thus very safe. This was especially important in an area that exhibited fairly high levels of unplanned vehicle activity due to construction in the area. Safety is one of the key and major advantages of AV technology.

A complete compilation of project metrics is included as Attachment A

Project cost

- Out of pocket cost/budget for the six (6) month 61AV demonstration project is approximately \$170,000. All staff time from all project partners (RTD, City/county of Denver, DEN, EasyMile, Transdev, Panasonic, and Fulenwider) was provided as in-kind contribution from the partners with no charge to the project; and
- Out of pocket cost to RTD will be approximately \$16,000. This money supports regulatory signage/installation and a portion of the ongoing O&M cost. Other project costs are being borne by EasyMile (provision of AV vehicle), Transdev (reduced O&M cost for on-board customer service ambassador), Fulenwider (infrastructure improvements such as ADA compliant AV stop pads etc.), Denver (regulatory signage poles) and Panasonic/EasyMile (a portion of ongoing O&M costs).

Lessons Learned

LL1- Stakeholder alignment is key

It is important to identify and involve all of the potential stakeholders from the beginning/very early on in the process. Provide a detailed introduction as to how AV

shuttle technology works and the process by which AV technology is deployed. Have meaningful conversations about what each partner is attempting to accomplish and what potential drawbacks might be and reach agreement on project goals. Discuss roles and responsibilities for project planning and implementation.

LL2- Processes take time

The process behind the implementation of the 61AV demonstration service can generally be broken down into roughly 5 broad/general categories or steps:

Regulatory-

- National Highway Traffic Safety Administration (NHTSA)- Due to the fact that AV shuttle vehicles do not currently meet Federal Motor Vehicle Safety Standards (FMVSS) (no steering wheel, no brakes, etc.), vehicles must be approved by the National Highway Traffic Safety Administration (NHTSA) in order to be able to operate in the U.S.. EasyMile, the AV shuttle provider, took the lead on this process.
- State of Colorado- AV Task Force (CDOT, DOR/DMV,CSP)- in order for any AV demonstration/pilot program to take place on public roadways in the State of Colorado, it is necessary to receive approval from the State AV Task Force. The AV Task Force consists of representatives from the Colorado Department of Transportation (CDOT), the Colorado Department of Revenue/Division of Motor Vehicles (DOR/DMV) and the Colorado State Patrol (CSP). EasyMile took the lead role in working with the State's AV Task Force with RTD subsequently joining EasyMile in the process of working with the AV Task Force to secure project approval
- Local jurisdiction (City/County of Denver)- While the State of Colorado, through the AV Task Force, provides the overarching authority and guidance for AV deployments on public roadways in Colorado, local jurisdictions may request signage etc in order to operate AV's on streets owned and/or managed by the local jurisdiction. LC Fulenwider took the lead on this process through the City's development review process and the Transportation Engineering Plan required by CCD. This process was supported by staff from RTD, EasyMile (and EasyMile's site assessment report) and CCD Traffic Engineering as well as by CDOT staff. The outcome was a signage plan advising area motorists of the possibility of encountering slow moving vehicles along the AV route.
- Denver International Airport- DEN also had a regulatory process in place to guide potential deployments of AV technology on DEN property. RTD took lead in securing DEN "Rule 41" approval with assistance from DEN staff.

Contractual-

- RTD/Transdev- level 4 autonomous vehicles still require that a person be onboard the vehicle at all times that the vehicle is in operation. This contract was negotiated and entered into by representatives of RTD and Transdev. RTD chose

- to contract with Transdev through an existing fixed route service contract that existed between RTD and Transdev.
- Vehicle procurement- the decision to buy or lease the AV vehicle must be made by any AV service provider. The procurement process must then be implemented. In the case of the 61AV, EasyMile provided the vehicle lease at extremely reduced (no) cost.
 - Funding- amount of financial contribution and flow of funds must be determined and agreed upon by all parties involved.

Project Pre-Planning

- Finalization of AV route and schedule- actually part of an iterative process as it is a component of the regulatory process by which the AV Task force approved the project including final approval of the route by the CSP and AV Task Force. Includes the Site Assessment Report (SAR) conducted by EasyMile, traffic analysis conducted by RTD staff and local jurisdiction traffic engineering staff and, in the case of 61AV project, the TEP prepared by Fulenwider as part of the CCD development review process for Pena Station Next.

Project Implementation

- infrastructure improvements – construction of ADA compliant AV stops, installation of project required signage and vehicle storage and charging facilities. In the case of the 61 AV project, Fulenwider provided construction of ADA compliant stops and curb cuts etc. RTD produced and installed project signage and Panasonic/Easymile provided for vehicle storage and charging facilities.
- First Responder Training- training was conducted by both the project team as well as by CSP personnel for Denver Police and Denver Fire Department personnel to ensure that first responders were familiar with the AV shuttle vehicle should they need to respond to an emergency situation;
- Operator (CSA) training including:
 - AV technical vehicle training
 - Pre-trip
 - Autonomous mode
 - Manual mode
 - Environmental hazards
 - Post-trip including data collection
 - Route training
 - Customer service
 - AV test trip
 - Service training
 - Route, schedule and time points
 - Hand held radio procedures
 - Communications with RTD Dispatch

- Check-in and check-out procedures
- Adverse weather conditions
- ADA passengers
- ADA vehicle pre/post-trip procedures
- ADA vehicle operations
- ADA securement procedures
- Training records
- Facility procedures
- Reporting procedures/metrics

Marketing and communications activities (see Lessons Learned #3 below)

LL3 Proactive marketing and communications are vital

A dedicated marketing and communications steering committee with representation from all project stakeholders was created to help identify key ideas and messages, key dates for project marketing and communications activities and other marketing and communications needs for the 61AV demo project. Meetings need to start early enough in the project to ensure that all stakeholders are aware of project goals and objectives and AV technology. Communications between the committee and the stakeholder steering committee/project team is vital to ensure that all project activities are aligned. Activities undertaken as part of the 61AV demonstration project included:

Marketing and Communications

- Public information-route/schedule into trip planner, real-time info, etc
- Public information- website, FAQ's etc
- Public information- media advisories, public relations, etc
- Public/internal communications- info to TIC
- Internal communications- information flows in Operations and other parts of RTD organization (dispatch etc)
- Project launch
 - location and time/date
 - invitations
 - speakers
 - facilities (room, chairs, tables, AV, etc.)

LL4 Budget for all necessary project elements

As projects of this complexity and magnitude evolve, numerous activities are often overlooked at the outset of the project. It is necessary to identify all project costs and sources of revenue at the outset of the project.

Conclusions and Potential Next Steps

This 61AV project provided RTD with valuable information about AV shuttle technology and what role it may play in RTD's future service offerings. While a number of AV service disruptions were observed during the demonstration period due to technological challenges, especially related to weather events such as snow, heavy rain, steam generated by melting snow, etc., staff is impressed by the response of the AV vehicle/technology supplier to address issues identified during the demonstration. While the current Generation 1 (Gen1) vehicle may not provide the type of reliability needed to operate in a transit service environment, staff was impressed with the response of the vehicle/technology supplier to address these issues in future generations of AV shuttle vehicles now coming to market. The EZ10 Gen 2 vehicle is already on the market and includes a heater to address issues of operator and passenger comfort as observed during the 61AV demo project as well as improved battery life. The EZ10 Gen3 vehicle is just now starting to be deployed and includes improved sensor technology to address snow, rain and steam weather events as observed during the 61AV demo project as well as securement devices for mobility aides. The EZ10Gen3 vehicle also provides improved battery life to extend vehicle range. It should be of interest to RTD to investigate the degree to which these new technological advances do indeed address the issues identified during the 61AV demo project.

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Att. Project metrics