Automated Vehicles - Planning for the Future

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About N-CATT

The National Center for Applied Transit Technology (N-CATT) is a technical assistance center funded through a cooperative agreement with the United States Department of Transportation's Federal Transit Administration (FTA). Operated by the Community Transportation Association of America (CTAA), the mission of N-CATT is to provide small-urban, rural and tribal transit agencies with practical, replicable resources that help them apply technological solutions and innovations. Among its activities, N-CATT produces a series of white papers, technical reports such as this document, and other resources, all of which can be accessed on-line at https://n-catt.org.

About this Document

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1 Introduction

This white paper goes beyond current technology for implementing automated vehicles (AVs) at a wide scale across transit agencies. Instead the paper recognizes that the technology is still in development. This paper addresses testing, piloting and planning for a future in which vehicles will drive themselves without a human operator on-board. With so much investment in the US and internationally in AV research and development in both the public and private sectors, a future with AVs will become reality. But because there is time before full automation arrives, we have the luxury of using the time to slowly develop and test these new vehicles as well as to ponder and plan for the related disruptions that they will cause in the mobility ecosystem.

This paper explains where we are today on the road to fully automating transit vehicles, and covers the following:

- Transit AV technology
- The AV market assessment conducted by the US Department of Transportation's (DOT's) Federal Transit Administration (FTA);
- Rural and small urban AV scenarios;
- AVs used in transit service; and
- Actual public transit automated operations and additional information about other work that is being conducted in this area, such as using AVs for non-transit service (e.g., deliver medical supplies or food) and identifying the costs associated with transit automation.

This paper is written for transit agencies in small urban, rural, and tribal communities and their stakeholders, however most of the activity in AV transit pilots (and equivalent pilots that have not involved transit agencies) has occurred in urban and suburban environments within metropolitan areas.

Please be aware that terms used to refer to automated and autonomous vehicles can be confusing. In this paper, we refer to autonomous vehicles as those that are capable of full driving operation without a human driver. These are SAE Level 4 and 5 AVs. See Figure 2 below for an explanation of the SAE levels.

Any mention in this paper of automation that assists a human driver or where a human operator is required is referred to as automated driver assist systems (ADAS). ADAS is a term used by the USDOT.[1]

Automation in public transit started in the US in 1975 when the then Urban Mass Transportation Administration (UMTA) "announced its Downtown People Mover [DPM] Program and sponsored a nationwide competition among the cities, offering them the federal funds needed to design and build"[2] automated guideway transit (AGT), which was fully automated with no driver inside the vehicles operating on a fixed guideway. Four DPM systems resulted many years later: Miami's Metromover opened in 1986; Detroit's People Mover opened in 1987; Jacksonville's Skyway opened in 1989; and Morgantown Personal Rapid Transit opened in 1975. These systems were all based on the extensive research that was conducted by UMTA starting in the late 1960s and the demonstration of four AGT systems "at $1.5 million each at a transportation exposition called TRANSPO '72."[2]

Further, "China launched the world's first self-driving bus in August 2015[3]. [In Europe,] Italian consulting firm, Mobility Thinklab, first tested driverless minibusses in 2013. In November 2015, the Netherlands had a self-driving shuttle bus successfully transport passengers on a public road without human assistance[4] [80]."[5]

Finally, in March 2018, "the town of Neuhausen Rheinfall, Switzerland started operating a Navya autonomous shuttle on their regular service route. Passengers can now take the autonomous shuttle on Route 12 to the Rhine Falls, the largest waterfall (by volume) in Europe, which receives 1.5 million visitors annually. The autonomous shuttle operates well in a busy urban environment mixed into regular traffic (bus, auto, bike and foot alike). For this service to be successful, it required full support from state and local government, the transit operator and technology providers."[6]

2 What Transit Should Consider

According to the FTA, "Transit automation has the potential to provide benefits to both urban and rural areas. Given the lower population density of rural areas, the specific automation technologies and the implementation of those technologies in rural areas may require different approaches from urban technologies. Automation technologies could make certain types of transit service in rural areas more cost-effective. For example, cost effectiveness may be achieved through the use of smaller vehicles more suited to rural areas. Automation may also lead to greater cost-effectiveness through the use of such services as on-demand shared rides with flexible routing. Rural areas may be well-suited to benefit from transit bus automation use cases such as automatic driver assist systems (ADAS), automated ADA paratransit, and mobility-on-demand shared ride services, among others. Overall, transit bus automation will improve geographic and temporal access to transit because of the associated cost savings and the capability to provide new service models, such as late-night and off-peak service."[7]

Given the focus of this white paper on the application of AVs in rural and small urban areas, Table 1 shows the types of questions that should be considered when contemplating using an AV in transit/paratransit service in these areas.

Table 1. Implications for Rural Complete Trip

Trip Stage	Implications
Pre-trip	• If automated reservations, can traveler access reservations? • If payment necessary, can traveler pay if un-banked or no credit card?
Trip origin	• Can AV reach trip origin?
Between trip origin and location where first mobility service accessed	• Can AV reach stop?
Where first mobility service accessed	• Is stop accessible?
Board first mobility service	• If no driver, can traveler board AV?
On-board access	• If payment on-board, can traveler pay with no assistance? • If automated payment, can traveler pay if un-banked or no credit card?
En-route using first mobility service	• If travel disrupted, how can traveler re-book or change itinerary? • If behavior issues on-board, how will it be addressed with no driver?
Before alighting first mobility service	• If no driver, can traveler move within AV to prepare to alight vehicle?
Alighting first mobility service	• If no driver, can traveler alight with no assistance?
Travel between alighting point and transfer point	• Does traveler need directions? • Is the path accessible?
Travel between final mobility service stop and final destination	• Does traveler need directions? • Is the path accessible?

3 From Technology that Requires a Human Driver to Technology Without Human Operation

Figure 1 shows the full range of automation from ADAS, which require human drivers, to AVs that can operate on their own without any human assistance or operation. Any level of vehicle automation works by gathering information from a suite of sensors, which may include:

- Cameras;
- Radar;
- Light detection and ranging (LiDAR)[8];
- Ultrasonic; and/or
- Infrared.

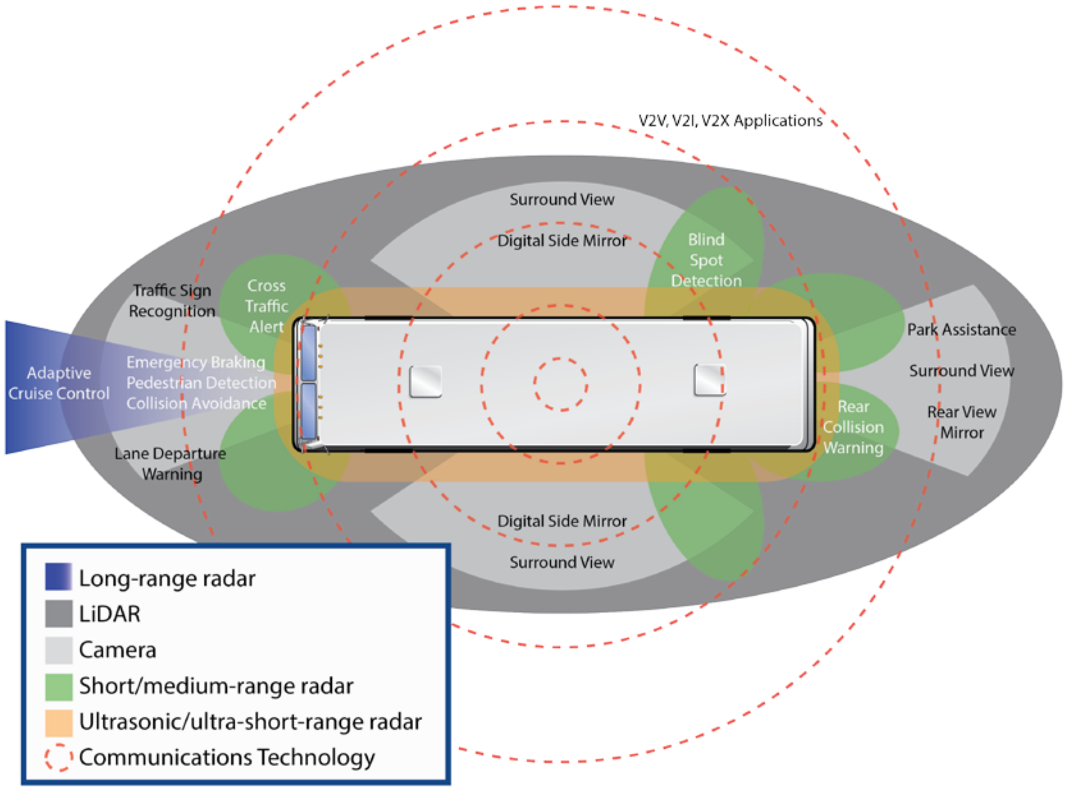

Figure 1. Vehicle Automation Technologies (image Adapted from the Texas Instruments ADAS Solutions Guide)[9]

Positioning systems may include global positioning system (GPS), inertial measurement units, and detailed map data. ADAS and AVs may combine these data with other inputs, including vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) inputs."[10] This means that signals are sent from the automated driving system to electronic components that control vehicle steering, acceleration and braking, to manage the driving task. Also, data exchange and software uploads to the on-board automated driving system are accomplished using Internet communications.

Further, automated vehicles are classified using SAE[11]'s levels of automation, which are shown in **Figure 2**. There are six levels of automation, from none through ADAS and full AVs, with specific definitions: Level 0 represents no automation, "Levels 1 to 3 are such that the driver has primary control over the vehicle and automation is partially used, and Levels 4 and 5 are met when the vehicle can be fully controlled autonomously."[12]

	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Driver's role	Performs all tasks	Controls vehicle	Engages in driving and monitoring the environment	Necessary to take control	May have the option to control	May have the option to control
Automation features	-	Driver assist features	Some automated functions	Some automation functions and monitoring the environment	Vehicle performs all driving functions under certain conditions	Vehicle performs all driving functions under all conditions

Figure 2. AV Automation Levels (adapted from SAE)

Finally, the potential benefits of transit bus automation include the following[13]:

- **Safety and Reduced Liability:** Automation may increase safety by reducing the severity and frequency of collisions, thereby reducing agencies' liability and other collision costs.
- **Operations and Maintenance:** Agencies may realize operations and maintenance savings from changes in workforce needs, decreased vehicle wear, and increased efficiencies (e.g. bus yard operations).
- **Environmental Impact:** Fuel savings from better routing and smoother acceleration and deceleration may reduce a vehicle's environmental impact.
- **Service Availability and Operational Efficiency:** New transit services, such as circulators or late-night service, or operations in low-density areas, may become cost effective, improving transit access.
- **Passenger Experience:** Automation may improve service reliability and delivery, enhancing rider experience.
- **Driver Stress and Workload:** ADAS may reduce driver stress and workload, resulting in safer systems and more satisfied drivers.

4 Market Assessment

In 2019, FTA issued a market assessment of transit bus automation[14] recognizing that there was a great deal of information available describing automation in general, but little information about the actual state of availability, capabilities and limitations of automated transit bus technology. This market assessment was updated in 2020[15]. Key information provided in the report is as follows.

- For the most part, while there has been significant progress, development of automation systems for transit buses has been gradual, and such systems are prototypes and not yet commercially available. Progress on prototype testing has continued, and some new automated transit bus pilot tests have been announced, but there have been no announcements of new products that have been commercialized or that will be commercially available in the near future.

- As of late 2019, no suppliers offer a commercialized product for automating steering or braking in transit buses. However some of the components needed to support those systems exist. Similar systems have been developed and installed in other heavy-duty vehicles (e.g., commercial trucks, motor coaches, and school buses) to enable adaptive cruise control (ACC), automatic emergency braking (AEB), and lane-keeping functions.
- In the face of mounting challenges, some projects have focused on addressing driver warning systems instead of automation systems. In some cases, research projects to develop and test transit bus automation systems have been rescoped to focus on driver assistance systems (e.g., driver warnings), with automated actuation (e.g., of braking systems) postponed until the technology has been further developed, additional resources are available, or bus manufacturers more aggressively engage in the process.
- Small, low-speed automated shuttle vehicles have been employed for early pilot testing and demonstrations. Although numerous demonstrations and pilot projects feature these new types of vehicles, they are not currently produced at scale, and many models do not comply with Federal requirements such as the Federal Motor Vehicle Safety Standards (FMVSS) and the Americans with Disabilities Act (ADA).
- These automated shuttles are limited to carrying relatively few occupants and operating at low speeds (typically between 10 and 15 miles per hour), which may preclude many transit use cases, particularly in small urban, rural, and tribal areas. As a result of these challenges, most automated shuttle customers to date have purchased or leased vehicles for research purposes rather than to operate a service to meet an existing transportation need.
- Participation of bus manufacturers is seen as necessary to develop systems that are safe and scalable. Although retrofit products may be useful for small, agile proof-of-concept testing, transit agencies prefer to work with bus manufacturers for integrated solutions. Factory-installed systems that have been integrated by the bus manufacturer are more attractive due to considerations regarding issues such as those related to procurement, liability, and safety.
- Some transit agencies are looking to collective action as an option to stimulate automated transit bus development. To overcome some of the issues related to low volumes and high customization, some transit agencies have joined efforts through consortia such as ABC, [CALSTART, a national non-profit organization that promotes clean transportation technologies, announced that, as part of its Connected and Automated Transportation Users Forum] CATUF, and FABULOS to jointly specify and procure automated transit buses. Through such cooperative efforts, participating members hope to incentivize industry to develop automated transit bus products that meet their needs.
- Companies are developing capabilities for unstaffed operation, but transit agencies plan to retain an official staff presence on vehicles for the foreseeable future. The broader use of unstaffed operation on public roads in mixed traffic remains a distant capability, and many

transit agencies have expressed the need for an official staff presence on their buses. However, some companies, such as EasyMile, Navya, and Robotics Research, are beginning to experiment with unstaffed vehicles on private sites or other closed test environments.

- Automated transit buses will require new workforce skills and capabilities. Transit agencies are increasingly aware of workforce training needs due to the adoption of other technologies (e.g., new vehicle powertrains and new information systems). Although it may be too soon for most transit agencies to invest in such training, regions with aggressive automated vehicle testing plans, such as Singapore, are already working to address this need.

The FTA market assessment remains an accurate picture with the one exception of the efforts into 2021 and beyond of planned pilot projects that will utilize full-size AV buses.

5 Rural and Small Urban AV Scenarios

Union Internationale des Transports Publics (UITP), as part of their Shared Personalised Automated Connected vEhicles (SPACE) project[16], developed a toolkit that focuses on the opportunity to integrate AVs into public transit service. The toolkit contains three major sections, one of which describes possible scenarios in which AVs will operate. Rural and small urban scenarios are shown in Table 2.

Table 2. AV Scenarios in Rural and Small Urban Areas

Scenario---→	**Area based service and feeder to public transport station**	**Premium shared point-to-point service**	**Shared point-to-point service**	**Local bus service**	**School bus**	**Premium - Robo-taxis**	**Car-sharing**
Environment	Small, isolated city Rural (low density)	Urban (high density) Suburban Small, isolated city Rural (low density)	Urban (high density) Suburban Small, isolated city Rural (low density)	Small, isolated city	Small, isolated city Rural (low density)	Urban (high density) Suburban Small, isolated city Rural (low density)	Suburban Small, isolated city Rural (low density)
Operational Needs				Ticketing, app, dispatching, control room, maintenance			
Public Transport Integration	Fully integrated in public transport offer: ticket, fare, app, dispatching, control room	Fully integrated in public transport offer: ticket, app, dispatching, control room, higher fare	Fully integrated in public transport offer: ticket, fare, app, dispatching, control room			Fully integrated in public transport offer: access, app, dispatching, control room	Fully integrated in public transport offer: access, app, dispatching, control room

Scenario---→	**Area based service and feeder to public transport station**	**Premium shared point-to-point service**	**Shared point-to-point service**	**Local bus service**	**School bus**	**Premium - Robo-taxis**	**Car-sharing**
Vehicle Needs	Mixed traffic, low-floor, ramp, space for stroller/luggage/ wheelchair	Mixed traffic, comfortable vehicles, no standing, accompanying person onboard, low-floor, ramp, space for stroller/luggage/ wheelchair, special equipment according to target user	Accompanying person onboard, low-floor, ramp, space for stroller/ luggage/ wheelchair	Mixed traffic, low-floor, ramp, space for stroller/ luggage/ wheelchair	No integration unless part of contract	Vehicle designed for high comfort, equipped with premium facilities like WiFi. Geofenced covering a defined area	High comfort, SEA level 4 if limited to a certain area, outside the vehicle would need to drive manually or would need SEA level 5 automation
Target User	Users in areas not covered by public transport core network	Business customers, children	All users	All inhabitants	Pupils, students	Family, private groups, business customers	Family, private group, business customers

Scenario---→	**Area based service and feeder to public transport station**	**Premium shared point-to-point service**	**Shared point-to-point service**	**Local bus service**	**School bus**	**Premium - Robo-taxis**	**Car-sharing**
Description	This shared service would be a proximity and area-based service with dynamic routing and on demand stops. It would also act as feeder to high capacity public transport.	This would be a premium shared, on-demand, point-to-point service with dynamic routing. The vehicles would be operated during extended hours.	This would be a shared, on-demand, point-to-point service with dynamic routing when or where demand is low. The service would have extended operational times.	This is a local bus service which would replace local public transport in small cities. This would be an on-demand shared fleet based service with dynamic routing and operational 24 hours a day.	This point-to-point service would follow a fixed route on a fixed schedule to bring children to school.	This point-to-point, on demand, premium service would be available for private use and sequential sharing.	This service would work as an on-demand, sequentially shared private service with dynamic routing. It will be possible to reserve the vehicle for a certain period of time during its extended operational hours.

6 AVs Used in Transit Service

There are many transit automation pilot projects being conducted in the US and abroad, but the number of projects being conducted in rural and small urban areas is limited. Table 3 summarizes the AV projects taking place in rural and small urban areas in the US. A larger list of many of the US current, completed and planned projects is shown in Appendix A.

Table 3. US Rural and Small Urban Transit Automation Projects

US State/ Country	Transit Agency / Lead	Description	Funding Program	Status
AL	New Flyer and Robotic Research LLC	Developing a 40' automated transit bus, with initial development and testing in Gaithersburg, MD, followed by additional testing and demonstration in Anniston, AL.	N/A	Planned[17]
CA	San Francisco County Transportation Authority (SFCTA) and San Francisco Municipal Transportation Agency (SFMTA)	Testing automated shuttles to provide first-last mile circulation on Treasure and Yerba Buena Islands.	USDOT ATCMTD[18]	Planned[19]
CA	Yolo County Transit District (YCTD)	Demonstrating an EasyMile EZ10 automated shuttle.	N/A	Completed[18]
IA	University of Iowa	Testing automated vehicles in a loop from Iowa City through rural areas and small towns, providing an example for how ADS can connect rural populations (focus on connecting rural transportation-challenged populations such as older adults).	USDOT ADS	Planned[18]
MI	Michigan Department of Transportation (MDOT) and PlanetM	The Huron (HTC) is a rural shuttle that connects the Sharon Apartments, Harbor Villa Apartments, and Port Austin Motel to a manufacturing plant in Pigeon, MI. It is currently operated by a local demand responsive service provider.	N/A	Planned[20] [18]
ND	Capital Area Transit	Demonstrating an EasyMile EZ10 automated shuttle.	N/A	Completed[18]

US State/ Country	Transit Agency / Lead	Description	Funding Program	Status
OH	Western Reserve Transit Authority	Western Reserve Transit Authority will partner with the Santa Clara Valley Transportation Authority to deploy automated electric vehicles designed for accessibility in Mahoning Valley, Ohio and Santa Clara Valley, California to augment fixed-route bus and paratransit services. The two locations will test the ability of the AVs to provide more efficient and cost-effective service under different climates and operating conditions.	AIM - $2,331,000	In Progress/ Grant awarded on August 27, 2020[21]
SC	County of Greenville	Testing of automated shuttles (modified Cushman Shuttle 6 and Local Motors Olli models).	USDOT ATCMTD	In Progress[18]
SD	West River Transit Authority d/b/a Prairie Hills Transit	Prairie Hills Transit (PHT), which serves 15 rural communities in western South Dakota, will receive funding to automate its paratransit dispatch system using AI technology. The system will collect real-time field data to replace most radio communication, allowing PHT to manage more rides with the same number of dispatchers and decrease costs.	Acceleratin g Innovative Mobility (AIM) - $308,912	In Progress/ Grant awarded on August 27, 2020[20]
UT	Utah Transit Authority (UTA) - Utah Department of Transportation (UDOT) is the lead	Testing an EasyMile EZ10 automated shuttle in different communities in Utah.	N/A	In Progress[18]

7 Actual Public Transit Automated Operations and Additional Information

While most automated transit vehicles are being operated in pilot programs, there are four projects that are putting automated vehicles in actual public transit service:

- Jacksonville Transportation Authority (JTA) Ultimate Urban Circulator (U^2C) Program - Autonomous Avenue Project
- FABULOS Project, including the Gjesdal, Norway pilot
- Hamburg Electric Autonomous Transportation (HEAT) Project
- Connecticut DOT (CTDOT) Automated Bus project

Further, AVs are being used to deliver medical supplies and food during the Coronavirus pandemic. This use of AVs is described in Section 6.5.

7.1 JTA U²C Program

The Jacksonville Transportation Authority (JTA) is an independent agency of the State of Florida governed by a seven-member board of directors. JTA plans, designs and builds roads and bridges, but it also operates Jacksonville's public bus service, downtown automated Skyway and paratransit service. JTA has made a significant investment in automated transit (and now has an Automation Division) through its "Ultimate Urban Circulator Program (U^2C), a first-of-its kind program to transform downtown Jacksonville through modernization and expansion of its downtown circulator (Automated Skyway Express) to accommodate Autonomous Vehicles (AV) and to extend service to nearby neighborhoods. The U^2C autonomous transportation network will utilize and leverage multiple existing federal investments, including the elevated Skyway Automated People Mover (APM) infrastructure and street-level roads through the urban core. The existing Skyway is a 2.5-mile system, with 8 stations, an Operations and Maintenance (O&M) Center and crosses the St. Johns River on the Acosta Bridge. The envisioned system will convert the existing system and expand to approximately 10 miles by combining the at-grade and elevated infrastructure. This will also include the deployment of autonomous vehicles with modern stations and provide more frequent service with improved access for all customers."

There will be "an approximately 10-mile system that will be developed in the following phases:

- "Bay Street Innovation Corridor (Phase 1) – This project is the Transit component of a wider, multi-partner effort to transform Bay Street in downtown Jacksonville. Partially funded by a USDOT BUILD grant of $12.5M, the Bay Street Innovation Corridor will create approximately 3 miles of at-grade AV-shuttle service along Bay Street from the Skyway Central Station to the Sports and Entertainment Districts near TIAA Bank Field, home of the Jacksonville Jaguars. It is anticipated that this section will include a new operations and maintenance center at the Jefferson lot near Jefferson Station.
- "Autonomous Avenue (Phase 2) – Conversion of an approximately ¼ mile section of existing elevated guideway between the new Jacksonville Regional Transportation Center (JRTC) terminal and Jefferson station. This will be developed as a proof of concept to better define the scope of work needed to convert the elevated track to accommodate the autonomous vehicle system.
- "Skyway Conversion and Brooklyn Station Expansion (Phase 3) – Replace the aging vehicles with rubber-tired shuttles and convert the 2.5-mile elevated infrastructure by removing the existing monorail guideway and creating a smooth running-surface as well as system and station upgrades. The proposed conversion of the existing Skyway to accommodate autonomous vehicles includes an extension of the existing elevated guideway to the ground level to the Brooklyn neighborhood adjacent to the current Skyway Operations and Maintenance Center.
- "Neighborhood Extensions (Phase 4) – Expansion of AV shuttle service to four additional corridors: West (Riverside and Brooklyn neighborhood), North (Springfield neighborhood and regional hospitals), South (San Marco and Baptist Medical Complex), and Southeast

(The District master plan and future commuter rail connection in San Marco). Preliminary evaluations considered a mix of concepts including elevated and at-grade segments with transitions.

"The initial phases will include the development and/or expansion of the supervisory system and route technology necessary to support an autonomous vehicle network as well as deployment of vehicles and station modifications or new at grade stops. All Program components will also include both physical and cybersecurity best practices."[22]

JTA held an Industry Forum in February 18-20, 2020 which resulted in numerous presentations and discussions between attendees and the U^2C Development Team. Presentations and other material available at this Forum can be found at https://u2c.jtafla.com/industry-forum/.

In terms of the automated vehicles that will be used for the U^2C, JTA has identified 20 key features and capabilities called the "Golden 20."[13] The development of these requirements was two-fold: (1) there are no existing "standard" transit AV requirements, and (2) JTA has specific requirements due to the environment in Jacksonville where these vehicles will operate. The requirements are as follows:

1. Full ADA Compliance
2. Buy America/Buy American Compliance
3. Cybersecurity
4. Remote Route Programming with Low Latency
5. National Highway Traffic Safety Administration (NHTSA) Approval to operate on Public Road
6. Vehicle to Infrastructure and V2X Capabilities (DSRC & 5G)
7. Traverse Slope of ± 12 Degrees w/ Full Passenger load (Sustained Acceleration/Deceleration)
8. Operate bi-directionally up to 35 MPH
9. ≥12 hours of battery life
10. Operate at speeds of 15 MPH within ± 1 foot of Stationary Object and Operate at speeds of 15 MPH within ± 3 feet of Moving Object
11. May Operate during Inclement Weather (Rain, Fog, Wind, and Extreme Heat)
12. Internal Cab – Environment control with Rapid Cool capability & Sustained temperature with Full Passenger Load
13. Ability to be towed; Push/Pull and Steer AV Manually or towed via another AV
14. Crash Worthy up to 35 MPH
15. Ability for Fast Charge/Opportunity Charging
16. Ability to regulate passenger capacity
17. System for recording/storing video for at least 30 days (Black Box)
18. Emergency button to contact Authority/Agency control center
19. Remote command & control operations of vehicles with low latency
20. Complete Vehicle Monitoring system, including health monitoring

The COVID-19 pandemic has somewhat delayed the JTA U2C project, so as of October 2020, an update on the project's progress is not available.

7.2 Future Autonomous Bus Urban Level Operation Systems (FABULOS) Project

"The FABULOS project was initiated [in 2018] to speed up the introduction of new types of automated transport solutions entering the European market. Project work 'focuses on how cities can use automated buses in a systematic way. The project is applying a systematic approach—the all-inclusive solution is not merely about the vehicle, but also on the fleet management capabilities, control room functions and integration in existing Public Transport.'"[23]

Five European cities are taking part in the FABULOS project. Pilot automated buses were operated as part of the existing public transport systems in Gjesdal, Norway; Helsinki, Finland; and Tallinn, Estonia in 2020. Pilots will also be launched in Lamia, Greece and Helmond, Netherlands in Fall 2020[24]. **The Gjesdal pilot shows an AV operation in a somewhat rural and small urban area. A video showing this operation in public transit service can be viewed from https://fabulos.eu/gjesdal-pilot/. There will be an additional pilot in this location in Fall/Winter 2020.**

Figure 3 shows where the FABULOS project fits into the timeline of other European automated transit projects.

The FABULOS project is using a unique approach to procuring, testing and piloting automated vehicles in transit service. During the pilots, "the functionality, interoperability and security of the autonomous fleets will be evaluated. 'All the pilots will take place in urban settings, but each pilot location has its own special challenges. In Gjesdal, there is a 12% incline due to the mountainous terrain, whereas in Lamia high temperatures must be successfully managed. In the Netherlands the large number of cyclists must be taken into consideration and in Helsinki the route passes the second busiest train station in the country. In Tallinn, the connection to the airport will be improved, leading to challenges with factors such as existing bus traffic.'

"In all pilot sites, 'the shuttle services will be tested to ensure the functionality of remote operability from the control room. Furthermore, the buses must be able to autonomously overtake obstacles such as parked cars. The shuttles are expected to be driverless, and a safety person will only be allowed on board if local regulations require this.'"[32]

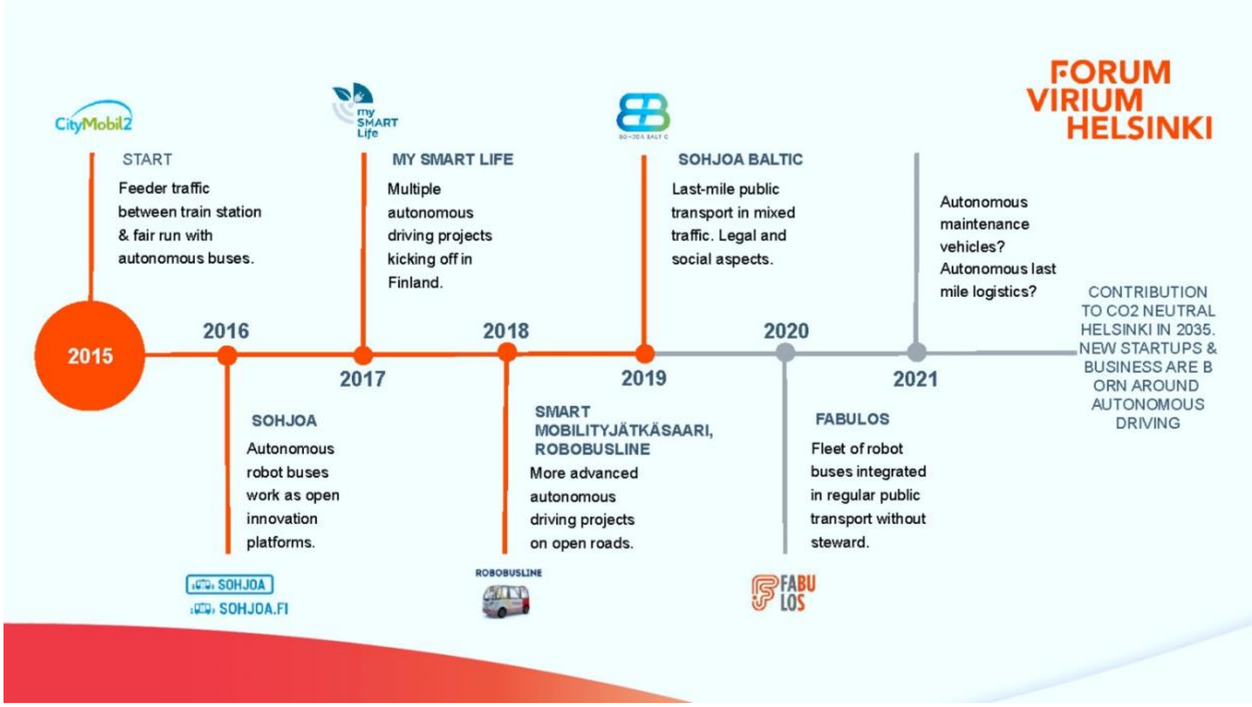

Figure 3. Timeline of Selected Automated Transit Projects in Europe [101]

The primary purpose of the FABULOS project is to challenge the market to provide the following[25]:

- An off-the-shelf service (one-stop shop)
- That can operate fleets of autonomous shuttles in mixed traffic
- Without a steward on-board
- Remotely operated from a control room
- Driving regular speeds
- Part of public transport systems
- Test sites adding value, cities determine the ambition level
- A scalable solution, proof-of-concept in several cities

The lessons learned to date include the following[24]:

- Fleets were monitored from control rooms, and some sites could give commands to the AVs
- Steering could be conducted via 3G and 4G communication but not in mixed traffic
- Actual remote driving was not done in mixed traffic – more research and development is required
- Incorporating 5G communication tests was delayed because of the Coronavirus
- In terms of infrastructure, smart traffic lights, and open and real-time data greatly facilitated operations

- More lessons learned will be provided at the conclusion of the Fall/Winter 2020 pilots in Gjesdal, Norway; Helmond, Netherlands; and Lamia, Greece. These pilots will include user acceptance surveys.

As of October 2020, the pilots in Norway and Greece are still being conducted - they were delayed due to the pandemic. At the conclusion of the pilots, it is expected that more lessons learned will include how people used the pilot systems, changes in travel behavior due to the pilot systems and how people outside of the AVs reacted to these vehicles operating in the four pilot locations.

7.3 Hamburg Electric Autonomous Transportation (HEAT)

HEAT is an integral part of Hamburg, Germany's vision for urban mobility (see Figure 5). The HEAT project started in 2018 with research and development, continued in 2019 with testing on a fixed route in the HafenCity area and is expected to conduct autonomous driving with up to 50 kilometers (km) per hour in 2021.

Key objectives of the HEAT project are meant to answer the following questions:[26]

- Safety and technology: Can driverless vehicles (minibuses) be used for regular operations in public transport? Is the needed technology available?
    - With a permitted maximum speed of 50 km/h (according to vehicle approval)
    - In regular road traffic
    - Without steward (technical personnel)
- Customer acceptance: How do our customers react on the new technology? How does the vehicle interact with other traffic participants?
- New business models: How do profitable and sustainable business models for AV look like? How can these models be integrated with the current public transport systems?

The three key characteristics of HEAT are: (1) Specific technology on-board the vehicle; (2) Decentral infrastructure: sensors and digital communication systems on the road (including high precision maps); and (3) Permanent supervising control center at HOCHBAHN, which is the public transport operator in Hamburg. The vehicle and operations are being developed using a user-centric research.

The HEAT vehicles (shown in Figure 4) have the following characteristics:

- 8 sitting passengers plus wheelchair (or 2 additional seats)
- 10 m turning radius
- 2.88 t total weight
- 4 t gross load weight
- Equipped with 5 radar and 8 lidar

HEAT will operate on a 1.84 km route, with five stops, six traffic lights and nine intersections.

Figure 4. HEAT Vehicle

7.4 Connecticut Department of Transportation (CTDOT) Automated Bus Project[27]

The Connecticut Department of Transportation (CTDOT) is planning to introduce the first automated heavy-duty buses in revenue service in North America, with the project set to go live sometime in 2023. The project includes the deployment of three battery-electric 40-foot New Flyer Xcelsior CHARGE™ vehicles.

"The project will focus specifically [on] cooperative adaptive cruise control (commonly referred to as 'platooning') to improve operational flexibility, precision docking at BRT station platforms, and safety and energy efficiency gains while the ADS is active."[28]

The automated buses, capable of up to SAE Level 4 automation (SAE J3016) with a safety driver behind the wheel, will operate on the CTfastrak bus rapid transit (BRT) guideway, a 9.4-mile fully separated guideway with BRT stations and 18-inch boarding platforms that connects downtown Hartford and downtown New Britain. One guideway feature is a five-mile multi-use trail, 10-feet wide and separated with a fence, for pedestrians and cyclists to access stations and use for recreational purposes.

Because of the way the infrastructure is set in place on CTfastrak, it is an opportune place to test several technologies including automated buses. Because CTDOT manages the guideway, the signalization, and the buses themselves, it makes the CTfastrak a safe environment to introduce and test this type of equipment.

The pilot program consists of several partners, including CTDOT, New Flyer, and Robotic Research Inc., which is supplying, configuring, and supporting the automated driving systems that will be integrated into the New Flyer buses. Another team member is the Center for Transportation and Environment (CTE), which is acting as the project manager and technical consultant for the program, as well as the University of Connecticut and the Capital Region Council of Governments.

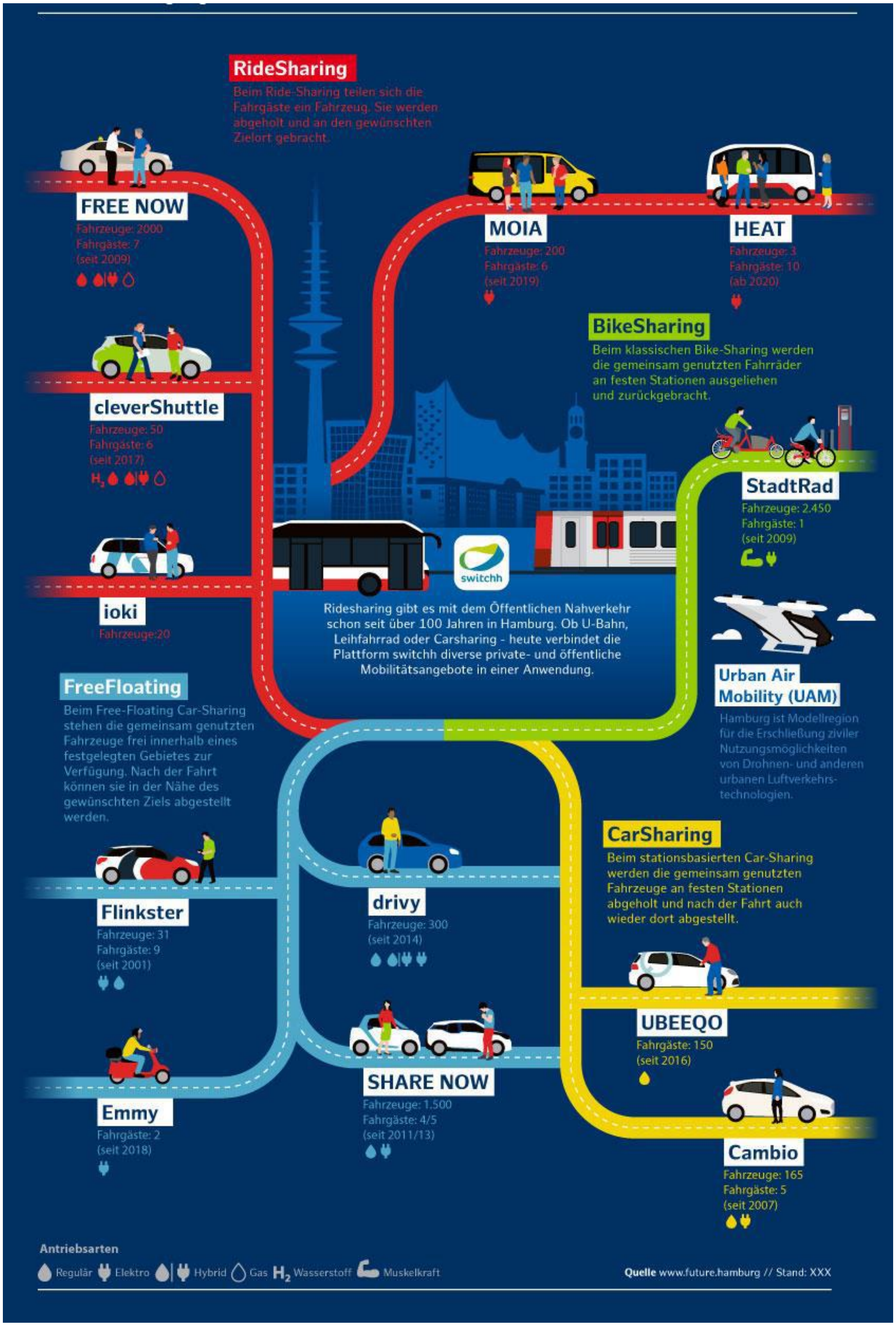

Figure 5. Enabling and Orchestrating Urban Mobility in Hamburg, Germany[25]

7.5 AVs for Medical Supplies and Food Delivery

There are numerous examples of AVs being used for delivery services instead of carrying passengers. Some of these AVs were designed as delivery vehicles, while some were transitioned from passenger transportation after the initial shutdowns of AV operations due to COVID-19. Both delivery-designed and passenger-designed AVs employed for deliveries include the following services[29]:

- JTA, AV fleet shuttle provider Beep and autonomous driving system provider NAVYA have been transporting Covid-19 test samples without drivers in the vehicles from drive-thru test centres to the Mayo Clinic.
- Beep partnered with the Park Pizza & Brewing Company to deliver donated lunches via its AV shuttle to healthcare workers at the Orlando VA Medical Center.
- Nuro delivery pod vehicles are transporting supplies such as food, personal protective equipment (PPE) and linens around two Covid-19 treatment centres in California.
- Beep is testing autonomous grocery delivery in Arizona and Texas, and post-Coronavirus, they expect to deliver pizzas for Domino's via AVs.
- Former robotaxi service Pony.ai has switched to contactless delivery in California. Pony.ai vehicles are delivering meals to an emergency shelter at the Islander living complex in Fremont, California.

7.6 Additional Information

One aspect of automated transit that is not well understood is the cost associated with AVs and their operation. One of the few pieces of literature describes an in-depth cost analysis[30]. "Using a comprehensive analysis of the respective cost structures, this research shows that public transportation (in its current form) will only remain economically competitive where demand can be bundled to larger units. In particular, this applies to dense urban areas, where public transportation can be offered at lower prices than autonomous taxis (even if pooled) and private cars. Wherever substantial bundling is not possible, shared and pooled vehicles serve travel demand more efficiently. Yet, in contrast to current wisdom, shared fleets may not be the most efficient alternative. Higher costs and more effort for vehicle cleaning could change the equation. Moreover, the results suggest that a substantial share of vehicles may remain in private possession and use due to their low variable costs. Even more than today, high fixed costs of private vehicles will continue to be accepted, given the various benefits of a private mobility robot."[28]

In Section 4 of this paper, FTA's Market Assessment was summarized as it was applicable to the scope of this paper. However, there are several other documents from the STAR program that are relevant as well. They are as follows and can all be found in https://www.transit.dot.gov/research-innovation/transit-automation-research-resources :

- Strategic Transit Automation Research Plan
- Transit Bus Automation Overview Factsheet

- Transit Bus Automation Project: Transferability of Automation Technologies Final Report
- Challenges of Transferring Automation Technologies from Light-Duty Vehicles and Commercial Trucks to Transit Buses Factsheet
- Transit Bus Automation Risks, Barriers, & Mitigations Factsheet
- Determining Requirements for Automated Transit Bus Test Facilities: Considerations for Practitioners
- Determining Requirements for Automated Transit Bus Test Facilities: Considerations for Practitioners Factsheet
- Transit Automation Case Study: Jacksonville Transportation Authority
- Transit Automation Case Study: Pierce Transit
- Transit Automation Case Study: Valley Metro
- Considerations for Evaluating Automated Transit Bus Programs
- Transit Bus Automation: State and Local Policy Scan

8 Conclusion and Next Steps

The many environments in which AV testing and pilots are taking place makes clear that this is a technology that is not yet ready for general transit use and certainly not for widescale operation without backup driver-operators. The value of knowing about AV transit activities that are discussed in this paper is to understand what has been accomplished to date and to consider what is necessary for AVs to be deployed in transit service. Further, this background can facilitate engaging with FTA and state DOT staff about their work in preparation for broad adoption.

Also, this paper aims to provide a state of the practice as it stands in late 2020 relative to full availability and adoption of AVs throughout our transportation system. We encourage readers to research the pilots we have referenced, as well as the information and lessons learned. In addition to the technical results of each pilot, we recommend supplementing this with the following items that FTA has noted in FTA's Transit Bus Automation: State and Local Policy Scan (written by Stephanie Fischer, Cristopher Calley, Joshua Cregger, Elizabeth Machek, Sean Peirce and Heather Richardson, April 2020, https://www.transit.dot.gov/sites/fta.dot.gov/files/2020-05/FTA-Report-No.-0162.pdf):

- Existing State and local legislation and regulations regarding automated vehicles are diverse but generally do not explicitly consider transit applications. The extent to which legislation facilitates or impedes the deployment of automated vehicles varies widely by state, and it is likely that approaches will continue to evolve over the coming years.
- Transit agencies vary in their plans and priorities regarding automation, which influences their overall approach to potential policy barriers.

- Many challenges faced by States and local agencies (e.g., transit agencies) when deploying advanced technologies are "soft barriers"—institutional, structural, attitudinal, or political—rather than legal or regulatory. These barriers include:
    - Workforce, training, and labor
    - Market readiness and product availability
    - Business case
    - Risk aversion
    - Limited resources
    - Data access, management, storage, and sharing
    - Fare payment

FTA has outlined several key activities focused on the aforementioned challenges. Table 4 shows the alignment between planned FTA research and each identified issue.

Table 4. Current and Planned FTA Activities to Address State and Local Concerns

State and Local Concerns	STAR Plan Activities
Workforce, Training, and Labor	• Automated Transit Labor Impacts Assessment • Automated Transit Labor Impacts Evaluation
Market Readiness and Product Availability	• Market Analysis for Automated Transit Buses and Supporting Systems • Integrated Demonstration 1: Automated ADAS for Transit Buses • Integrated Demonstration 2: Automated Shuttles • Integrated Demonstration 3: Automation for Maintenance and Yard Operations • Integrated Demonstrations 4a, 4b, 4C: Automation for Mobility on Demand • Integrated Demonstration 5: Automated Bus Rapid Transit • Accessibility Analysis
Business Case *Funding Availability*	• Business Case for Transit Automation • Finance Options for Automated Transit Investments • Transition Costs & Planning for Automated Transit Bus Deployment
Risk Aversion *Political Support* *Institutional Inertia* *Dense Urban Navigation*	• Transit Automation User Acceptance Study and Human Factors Research • Integrated Demonstration 1: Automated ADAS for Transit Buses • Integrated Demonstration 2: Automated Shuttles • Business Case for Transit Automation • Standards Assessment and Coordination • Security & Customer Acceptance Implications of Automated Transit Buses
Data Access, Management, and Storage	*Addressed through coordination with USDOT's Intelligent Transportation Systems Joint Program Office*
Fare Payment	Integrated Demonstrations *Addressed through other FTA initiatives (Integrated Mobility Innovation and Accelerating Innovative Mobility)*
Federal Legislation	• Automation Policy Implementation • Stakeholder Guidance Updates

Appendix A. US Urban Transit Automation Projects

US State/ Country	Transit Agency / Lead	Description	Funding Program	Status
AZ	Valley Metro	Tested Waymo vehicles with Valley Metro employees initially. Currently providing service to users of the RideChoice program via Waymo vehicles.	USDOT MOD[31]	In Progress[16]
AZ	Peoria (suburb of Phoenix)	Free shuttle will run a one-mile route in the city's entertainment district, operating from noon to 6 p.m. daily for a two-month pilot. The 10-person shuttles are manufactured by NAVYA and the project will be managed by Beep, an autonomous vehicle technology provider in Florida	N/A	In Progress[32]
CA	Access Services	Testing automated vehicles to provide shuttle service between a light rail station and Veterans Administration (VA) hospital.	USDOT STAR[33] (Strategic Partner)	Planned[34,35]
CA	Contra Costa Transportation Authority (CCTA)	Testing automated vehicles through three real-world demonstration projects.	USDOT ADS[36]	Planned[18]
CA	Central Contra Costa Transit Authority (CCCTA) and Contra Costa Transportation Authority (CCTA)	Testing two EasyMile EZ10 shuttles at GoMentum Station and Bishop Ranch business park.	N/A	Completed[18]
CA	Livermore Amador Valley Transit Authority (LAVTA)	Demonstrating an EasyMile EZ10 automated shuttle.	N/A	Completed[18,37]
CA	Foothill Transit	Participating as a member of the AECOM Automated Bus Consortium project. This project covers a long distance express bus service between the Montclair Transit Center and downtown Los Angeles with a mid point stop at the Pomona Fairplex Park and Ride. It primarily utilizes the HOV/HOT lanes along I 10.	N/A	Planned[18,38]
CA	Long Beach Transit (LBT)	Participating as a member of the AECOM Automated Bus Consortium project. This project covers Route 45/46 which is a local bus route running between Cal State University Long Beach and the Transit Gallery. The route primarily runs along Anaheim Blvd and Pacific Coast Highway with a deviation towards downtown Long Beach.	N/A	Planned[18,36]

US State/ Country	Transit Agency / Lead	Description	Funding Program	Status
CA	Los Angeles County Metropolitan Transportation Authority (LA Metro)	Participating as a member of the AECOM Automated Bus Consortium project. This project covers the Orange Line BRT (Route 901), which operates within an exclusive right-of-way (ROW) between Chatsworth and the North Hollywood Metro Station, where it connects with the Metro Red Line for rail service into downtown LA.	N/A	Planned[18,36]
CA	City of Fremont and Pony.ai	On-demand, autonomous last-mile service to provide rides for a group of City employees. Participating employees will be transported from Fremont's Amtrak/ACE Station to City Hall and City of Fremont Development Services Center via Pony.ai's autonomous vehicles, which have a safety operator present in each vehicle to ensure safe and smooth navigation of complex road scenarios.	N/A	In Progress[39]
CO	Denver Regional Transportation District (RTD)	Testing an EasyMile EZ10 automated shuttle to connect the 61st Avenue and Peña Boulevard commuter rail station to nearby areas. On January 29, 2019, RTD and its partners launched this 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).	N/A	Completed[18,40]
CT	CTDOT	Participating as a member of the AECOM Automated Bus Consortium project. This project will test automated, electric buses on its CTfastrack bus rapid transit corridor (Route 101) which connects transit centers in Hartford and New Britain along a 9 mile bus only roadway for a majority of the route. The peak headway is 7 minutes. One of the project goals is to improve safety for riders with disabilities. Precision, automated docking and platooning will eliminate driver errors that result in wide platform gaps and other unsafe situations and also will reduce delays.	$2 million from USDOT IMI[41]	Grant awarded on March 16, 2020[42]

US State/ Country	Transit Agency / Lead	Description	Funding Program	Status
FL	Gainesville Regional Transit System	The shuttle, which has six seats and standing room for six more passengers, will operate from 8 a.m. to noon and 3 p.m. to 7 p.m on a daily route between the Downtown Parking Garage on Southwest Second Street and the Innovation Hub	$2.5 million grant from Florida DOT	In Progress[43]
FL	Jacksonville Transportation Authority (JTA)	Testing 15 automated vehicles and other ITS systems along Bay Street in Jacksonville.	USDOT BUILD[44]	Planned[18]
FL	JTA	Testing multiple automated shuttle models (EasyMile EZ10, Navya Autonom Shuttle, and one other model) on a 1/3-mile track as part of a project to replace the existing Skyway monorail.	N/A	In Progress[18,45]
FL	Pinellas Suncoast Transit Authority (PSTA)	Participating as a member of the AECOM Automated Bus Consortium project. PSTA wants to automate their Depot services only at 3201 Scherer Drive. The automated buses could deliver parked buses to the operator at the dispatch area and then could leave the bus there for autonomous parking to reduce operator walking time.	N/A	Planned[18,36]
GA	Metropolitan Atlanta Rapid Transit Authority (MARTA)	Participating as a member of the AECOM Automated Bus Consortium project. This project covers Route 102 which is east-west to connect the red/gold rail line to the blue/green rail lines via primarily North Ave. and Ponce De Leon Ave.	N/A	Planned[18,36]
IL	Quad Cities MetroLINK	Participating as a member of the AECOM Automated Bus Consortium project. MetroLINK will automate their Operations and Maintenance Center (OMC). Automated buses will not operate along specific routes, but instead be automated while at the OMC.	N/A	Planned[18,36]
IN	Bloomington Transit	Demonstrating an EasyMile EZ10 automated shuttle.	N/A	Completed[18]

US State/ Country	Transit Agency / Lead	Description	Funding Program	Status
MI	Grand Rapids (Grand Rapids Autonomous Vehicle Initiative. The pilot program is a partnership with nine Michigan companies, including May Mobility, Consumers Energy, Faurecia, Gentex, Rockford Construction, Seamless, Steelcase and Start Garden.)	The four-car transportation system is supposed to be the most complex autonomous vehicle route in the world with more than 20 stops. The 3.2-mile route has stops near more than 10 parking lots, as well as the David D. Hunting YMCA, Kendall College of Art & Design, Grand Rapids Children's Museum, Van Andel Arena and Bridge Street Market. It follows an existing transit route. The cars operate Tuesday through Friday from 7 a.m. to 7 p.m., and have a top speed of 25 miles per hour.	$650,000	In Progress (July 2019 – January 2021)[46]
MI	City of Detroit	Developing a replicable safety evaluation process and deploying vehicles on test tracks and on streets in Detroit to evaluate their safety. The project will also work with older adults and persons with disabilities to better understand their mobility challenges.	USDOT ADS	Planned[18]
MI	Michigan Department of Transportation (MDOT) and PlanetM	Participating as a member of the AECOM Automated Bus Consortium project. This project covers CATA Route 32 which services Michigan State University with a park and ride lot to the south and connects with central campus and a stop at MSU's Clinical Center.	N/A	Planned[18,36]
MI	Michigan Department of Transportation (MDOT) and PlanetM	Another project covers CATA Route 38 which services Michigan State University connecting the campus to the Amtrak Station and the Spartan Village which has planned development for additional student housing.	N/A	Planned[18,36]
MN	Minnesota Valley Transit Authority (MVTA)	Equipping buses in MVTA's express bus fleets with GPS-based technology to improve safety and bus service within narrow shoulder lanes along highly congested corridors (a non-automated system).	USDOT SRER[47]	Completed[18]

US State/ Country	Transit Agency / Lead	Description	Funding Program	Status
MN	Minnesota Department of Transportation (MnDOT) and Rochester Public Transit	Participating as a member of the AECOM Automated Bus Consortium project. This project covers Route 18D in Rochester, MN which connects the IBM Campus/ Office Park with Downtown Rochester 4.5 miles away. The route utilizes both local roads and the Hwy 52 general purpose lanes in mixed flow condition.	N/A	Planned[18,36]
NY	Port Authority of New York and New Jersey	Testing lateral lane-keeping and bus platooning to improve operations and reduce headways between buses as they traverse Exclusive Bus Lane (XBL) between the Lincoln Tunnel and New Jersey Turnpike.	USDOT STAR (Strategic Partner)	Planned[18]
NV	Regional Transportation Commission of Southern Nevada (RTCSN)	Testing an automated circulator shuttle in the Las Vegas Medical District.	USDOT BUILD	Planned[18]
NV	Regional Transportation Commission of Southern Nevada (RTCSN)	Demonstrating a Navya Autonom automated shuttle in Las Vegas near the Downtown Container Park.	N/A	Completed[18]
NV	Regional Transportation Commission of Washoe County (RTC)	Testing a Proterra bus equipped with sensors as part of a larger project with Proterra and University of Nevada, Reno to develop an automated bus prototype.	N/A	In Progress[18]
OH	Western Reserve Transit Authority (WRTA) - Eastgate Regional Council of Governments is the lead	Testing automated shuttles in a dedicated shuttle lane as part of the SMART^2 Network in Youngstown, Ohio.	USDOT BUILD	Planned[18]
OH	Central Ohio Transit Authority (COTA) - City of Columbus is the lead	Testing of automated shuttles began in February 2020.	USDOT SCC[48]	Planned[18]
OH	Central Ohio Transit Authority (COTA) - City of Columbus is the lead	Testing May Mobility shuttles on Scioto Mile.	N/A	Completed[18]

US State/ Country	Transit Agency / Lead	Description	Funding Program	Status
OH	EmpowerBus is the operator	The autonomous Linden Empowers All People (LEAP) is serving a roughly 3-mile route through the Linden neighborhood. The primary goal of the pilot is to pilot self-driving technology in a neighborhood setting. The secondary goal of the project is to provide and first-mile, last-mile solution to connect residents to community resources.	USDOT SCC	In Progress[30]
OR	Lane Transit District (LTD)	Testing lateral lane-keeping and precision docking on LTD's Emerald Express Bus Rapid Transit.	USDOT VAA[49]	Completed[18]
RI	Rhode Island Public Transit Authority (RIPTA) - Rhode Island Department of Transportation (RIDOT) is the lead	Testing May Mobility shuttles in downtown Providence from May 15, 2019 to May 2020, 7 days a week. Service Every 10 - 15 minutes from 6:30 a.m. – 6:30 p.m. The fleet of electric vehicles offers rides along a 5.3-mile route in the Woonasquatucket River Corridor of Providence, with 12 stops between Providence Station and Olneyville Square.	$500,000 grant awarded by RI Attorney General's Office as part of settlement with Volkswagen and Federal Highway Administration (FHWA) research funds	In Progress[18,50]
TX	Dallas Area Rapid Transit (DART)	Participating as a member of the AECOM Automated Bus Consortium project. The proposed project will be for Route 524 which connects the Love Field Airport terminal with the Inwood light rail station 2 miles away and transports both air travelers and workers.	N/A	Planned[18,36]
TX	Metropolitan Transit Authority of Harris County (Houston METRO or METRO)	The Metropolitan Transit Authority of Harris County (Houston Metro) will receive funding for an automated electric shuttle bus that will serve Texas Southern University, the University of Houston and Houston's Third Ward community. The shuttle will connect to Metro buses and light rail and be studied for potential use in urban, suburban, and rural environments.	AIM - $1,473,435	In Progress/ Grant awarded on August 27, 2020[20]

US State/ Country	Transit Agency / Lead	Description	Funding Program	Status
TX	Metropolitan Transit Authority of Harris County (METRO)	Participating as a member of the AECOM Automated Bus Consortium project. This project covers Route 160: Memorial City Express Description. This Express service connects Memorial City Shopping Center/ Medical Center and Downtown Houston with an intermediate stop at the Northwest Transit Center.	N/A	Planned[18,36]
TX	City of Arlington	Will integrate autonomous vehicles into its existing on-demand system operated with the Via car-sharing service. The service will include a wheelchair accessible vehicle and allow University of Texas at Arlington students to ride fare free.	$1,698,558 from USDOT IMI	Grant awarded on March 16, 2020[40]
TX	Corpus Christi Regional Transportation Authority (CCRTA)	The first autonomous shuttle service in this area is one of the first in the U.S. to operate on a complex route, exposed to vehicular and pedestrian foot-traffic. The EZ 10 generation III shuttle, manufactured by driverless technology company EasyMile, is the first to be operated in North America and is a zero-carbon-emissions vehicle. It can hold up to twelve riders and has a built-in access ramp for riders with disabilities. Testing EasyMile EZ10 shuttle at Texas A&M University-Corpus Christi began in January 2020. CCRTA partnered with MV Transportation to manage operations.	N/A	In Progress[18,51,52,53]
VA	Virginia Department of Rail and Public Transportation (DRPT) and Hampton Roads Transit (HRT)	Participating as a member of the AECOM Automated Bus Consortium project. This project will cover Route 960, a long distance express bus service between Norfolk and Virginia Beach utilizing the HOV/HOT lanes along I 264.	N/A	Planned[18,36]
WA	Pierce Transit	Testing DCS Technologies' Pedestrian Avoidance Safety System (PASS) automated emergency braking in up to 30 buses.	USDOT SRD[54]	In Progress[18]
WA	King County Metro, Kitsap Transit, Community Transit, Pierce Transit, Intercity Transit, C-Tran, Ben Franklin Transit, Spokane Transit Authority	Testing of driver assistance systems—Mobileye Shield+ (a non-automated collision avoidance system)—on 38 buses from several transit agencies.	N/A	Completed[18]

Endnotes

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1 The term “automated” is used more broadly than “autonomous.” According to the US Department of Transportation, “Automated vehicles are those in which at least some aspect of a safety-critical control function (e.g., steering, throttle, or braking) occurs without direct driver input. Automated vehicles may be autonomous (i.e., use only vehicle sensors) or may be connected (i.e., use communications systems such as connected vehicle technology, in which cars and roadside infrastructure communicate wirelessly). Connectivity is an important input to realizing the full potential benefits and broad-scale implementation of automated vehicles.” https://www.its.dot.gov/automated_vehicle/

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