Public Transit Increases Exposure to Automated Vehicle Technology

Key Takeaways

1. While fixed-guideway transit systems have been using automated technology for decades, bus systems are just beginning to explore this technology for mainline operations.
2. Because of the increase in capability, accuracy, and affordability of AV technology, there have been limited tests of certain automated features for bus systems similar to those being developed by automakers and tech companies for use in private vehicles.
3. Transit agencies are also engaged with low-speed automated shuttle pilots in the hope that they may eventually fill unique service gaps.
4. Many considerations have been noted regarding the adoption of AV technology by transit. Additional research, along with carefully constructed policy guidance will be required to navigate future AV technology deployments.

Automated Vehicle (AV) advancement is being pursued intensely by the technology and automobile industries. An analysis by the Brookings Institution found that, from 2014 to 2017, over $80 billion were invested in autonomous technology, a level likely to be surpassed by the amount in 2018. [1] AV development is progressing in the public transportation industry through pilot programs, partnerships, private sector involvement, and research by the federal government and the Transit Cooperative Research Program (TCRP). Public transit agencies will face complex challenges in implementing AV technology over the coming decades, though there is hope that the technology will lead to improved operations, more efficient cost structures, and enhanced safety.

This paper seeks to summarize and incorporate findings from several significant research works such as NCHRP's *Impacts of Laws and Regulations on CV and AV Technology Introduction in Transit Operations,* FTA's *Transit Bus Automation Project: Transferability of Automation Technologies,* and U.S. DOT's *Low-Speed Automated Shuttles: State of Practice.* U.S. DOT's *Automated Vehicles 3.0* report is also referenced.

Definitions of AV Technology and Systems

Autonomous vehicle systems are driven by three basic sets of technology: sensors to monitor the environment around the vehicle, software systems that analyze the data collected, and actuators that

[1] https://www.brookings.edu/research/gauging-investment-in-self-driving-cars/

operate the vehicle's systems such as steering or brakes. Below are brief definitions of AV components and applications frequently mentioned in the reports listed above:

Components

Lidar: Lidar examines the greater environment around the vehicle by reflecting laser lights and analyzing the reflection to detect objects and form a representation of the vehicle's surroundings.

Dedicated Short Range Communications (DSRC): A type of wireless communication specifically used by vehicles to link with other vehicles and infrastructure.

Signal Phase and Timing (SPaT): This is information that can be transmitted from the traffic signal controller to AVs, allowing shuttles that do not have the ability to interpret traffic signals a way of navigating intersections.

Applications

Adaptive Cruise Control (ACC): Onboard sensors (typically radar-based) are able to detect approaching vehicles and adjust the cruising speed so a safe distance is maintained.

Driver Fatigue/Inattention Alert: These systems detect if the driver is drowsy and can issue an alert waking and reminding the driver to pull over. Driver fatigue alert systems use a combination of monitoring the driver's eyes/face, monitoring the lane position, and comparing steering patterns to a baseline pattern to tell if the driver is fatigued. Various driver attention systems have existed in rail transit vehicles for many years.

Object Detection and Collision Avoidance (ODCA): These systems help vehicles avoid collisions with pedestrians and other vehicles. Radar or camera sensors detect the presence of pedestrians in the area in front of the vehicle, or other vehicles located in a blind spot. The system can then trigger a warning to the driver and deploy collision avoidance measures if the driver takes no further action. Similar technology exists for when the vehicle is in reverse gear.

Automatic Braking: Automated technology has several applications to braking. Perhaps the most notable are automatic emergency braking (AEB) systems, which can detect an impending obstacle and react before the driver can. There is also dynamic brake support (DBS), which can supplement a driver's manual braking if it is not severe enough.

Lane Keeping Assist: Lane keeping assist monitors the position of a vehicle in relation to the lane markings (through cameras, infrared sensors, or Lidar) and warns the driver if the vehicle is drifting. Lane keeping also allows for automated corrective steering to keep the vehicle within the lane lines.

Parking Assist: Using a combination of the systems and technologies previously listed also enables vehicles to park autonomously. While transit buses are not parallel parking, they are navigating into depots, bus bays and washing bays frequently. This type of technology can also be used for docking at stations or stops.

The combination of different automated driving assist technologies determines the rating given to a vehicle on a formal 0-5 scale developed by the Society of Automotive Engineers.[2] Level 5 automation, where a vehicle is capable of driving in all conditions without driver intervention, is seen as the ultimate goal.

AV Applicability to Mainline Bus Transit Operations

While automated transit systems have been in operation for more than 40 years, they have almost exclusively been systems running on fixed guideways with dedicated right-of-way. Because of the increase in capability, accuracy, and affordability of AV technology, there have been limited tests of certain automated features for bus systems similar to those being developed by automakers and tech companies for use in private vehicles. Bus Rapid Transit (BRT) systems are likely positioned first for AV technology adoption since they operate in more separate and exclusive lanes.

In FTA's report[3] on automated technologies, 13 automation systems were assessed in their potential transferability to transit vehicles. The report notes that though sensor development is mature and that certain autonomous applications are ready for transfer to transit, others require a significant level of vehicle redesign and modification before adoption.

Current Automated Transit Bus Activities

Lane Transit District (LTD)

LTD in Eugene, OR, in partnership with UC Berkeley, tested automated steering and docking on the EmX BRT line beginning in 2013.[4] [5] Three miles of magnetic markers were laid (costs are around $20,000-30,000 per mile) and one bus was equipped with the necessary technology.

Minnesota Valley Transit Authority (MVTA)

A $4.2 million grant from FTA helped MVTA establish lane-assist technology as part of a bus-on-shoulder BRT system. The system uses GPS to track the position of the bus and sensors to track the lane position. If the bus begins drifting outside its lane, the visual display in front of the driver changes to a red color, eventually resulting in the bus driver's seat vibrating. If no corrective action is taken, a motor on the steering wheel activates and steers the bus to the center of the lane.

Pierce Transit

A $1.66 million FTA Safety Research and Demonstration (SRD) grant was awarded to Pierce Transit in 2017 to research and implement collision warning and automated braking technology in buses. Mobileye Shield+, a collision avoidance system that uses cameras to alert bus drivers of possible obstacles, will be installed on 176 buses. Also, automated braking technology will be installed on up to

[2] https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety
[3] *Transit Bus Automation Project: Transferability of Automation Technologies Final Report*
[4] Jill Huang, "An articulated bus under automated steering control on EmX Route at Eugene, OR" https://www.youtube.com/watch?v=_oKsleOocFM
[5] https://pdfs.semanticscholar.org/4a22/076ff8a6999a6ea5f22fe9acba71302fb5d5.pdf

30 buses.

Mercedes-Benz

A Mercedes-Benz Future Bus, operated with the CityPilot autonomous software, was tested along a 12-mile route in the Netherlands. The buses are equipped with automated lane-keeping, acceleration, braking, precision docking, and door opening. While an operator is positioned in the driver seat, the buses are able to react to traffic lights and other road obstacles autonomously.

Nanyang Technological University, Singapore

Volvo announced in early 2018 that it would provide two of its 7900 electric buses for a pilot program in Singapore.[6] The buses will be equipped with Lidar and GPS technologies and will be tested autonomously on a closed-circuit route. Testing will begin in early 2019.

Object detection and collision avoidance systems are classified as requiring the least amount of modification for transfer to transit. However, automated braking applications, such as automatic emergency braking, would be more difficult. This is due to the existing pneumatic braking systems commonly found in buses that make electronic control challenging. FTA's report goes on to suggest that a new communication system architecture may be required to deliver complex signals to braking systems. Finally, electric hybrid and battery-electric buses (BEBs) are more suitable for automated technologies than traditional buses, due to the existence of certain electronic functions, communications architecture, and sensors.[7] Hybrid buses already use automation software for efficient powertrain management and BEBs use electronically-actuated regenerative braking.

Low-Speed Automated Shuttles an Additional Application of AV Tech

For fixed-route service, the standard 40-foot transit bus is often the cornerstone of an agency's operations. However, some agencies envision low-speed shuttle AVs as disrupting existing cost structures and enhancing operations. For example, lower-demand routes currently served only by infrequent fixed-route service may be better served with smaller AV shuttles operating more frequent on-demand-based service. AV shuttles might also be used for point-to-point connections, helping riders with First-Mile/Last-Mile (FM/LM) travel, and boosting overall network ridership.

According to U.S. DOT research,[8] there are just over one dozen current domestic AV shuttle pilots in total (either in operation or planning). These pilots utilize electric vehicles with a 10- to 15-person capacity, 10-12 mph cruising speed (top speed is usually 25 mph), and a 30-60-mile range. Testing has been limited to protected environments (e.g. closed courses and campuses) or on limited routes in urban areas. Some

[6] https://www.theengineer.co.uk/volvo-singapore-autonomous/
[7] *Transit Bus Automation Project: Transferability of Automation Technologies Final Report*, Pages 15-16
[8] *Low-Speed Automated Shuttles: State of the Practice Final Report*

current pilots have vehicles receiving traffic signal information (SPaT) through DSRC. Vehicles are also equipped with a range of sensors to address hazards.

AV technology is still in the development and pilot project stage, so the current AV shuttles can require frequent intervention from the on-board attendant and software updates to help monitor the surrounding environment. Many AV shuttle pilots have run into unanticipated costs and delays, notably through unexpected increases in staff time. Transit agencies seeking to pursue AV shuttle pilots should clearly define goals, weigh cost/benefits and be mindful of the existing technological restrictions.

Current AV Shuttle Activities

Keolis

Keolis is currently operating an automated Navya shuttle around downtown Las Vegas, NV, among mixed-flow traffic. The vehicles use DSRC to receive signal information at six of the intersections on the route.

Jacksonville Transportation Authority (JTA)

JTA is planning an automated shuttle network that leverages its existing Skyway infrastructure (referred to as the Ultimate Urban Circulator (U^2C)). In the meantime, the agency is testing automated shuttles in different track locations.

Contra Costa Transportation Authority (CCTA)

CCTA has been testing automated shuttles in closed environments for close to two years now. The agency became the first to test an automated shuttle on California public roads in March 2018.

Livermore Amador Valley Transit Authority (LAVTA)

In June 2018, LAVTA began a 2-3-year testing of automated shuttles around the East Dublin/Pleasanton BART station. The project goal is for the shuttles to be an effective first/last mile option to BART.

Toledo Area Regional Transit Authority (TARTA)

TARTA received a $1.8 million federal grant to launch a three-year automated shuttle pilot, likely to be in downtown Toledo.[1] It will begin in mid-2019.

May Mobility

May Mobility has launched a fleet of Polaris automated shuttles in downtown Detroit, MI as part of a contract with the property management company Bedrock. The shuttles are meant to transport the company's employees to and from offices, parking sites, and company events.[1] May Mobility is also planning on launching shuttle services in Columbus, OH and Grand Rapids, MI.

Broader Considerations for Transit AV Adoption

The following broad issues present potential obstacles to the deployment of AV technology in roadway public transit:

1. Funding: Constrained funding can prevent transit agencies from investing in AVs for pilot projects, even though they can result in valuable lessons on operating practices and AV technology. Ongoing federal and state support is needed to help agencies prepare for AVs through capital acquisition, pilot programs, and workforce training.

2. Vehicle Procurement: Buy America requires that a certain percentage of transit vehicle components be sourced from American manufacturers. However, current AVs rely on foreign components and may not be able to comply (the majority of AV shuttle vehicles have been manufactured in Europe). In the near term, exceptions for whole projects may be needed to enable AV transit systems to begin revenue service quickly. FTA has said it will assess areas of potential regulatory barriers, including those regarding funding eligibility and technology procurement requirements.

3. Deployment: Transit facilities will need to evolve to accommodate new types of AV services. For example, demand-based AV service will require more staging points for vehicles spread throughout the transit service area than current fixed-route service. With a demand-based AV system, the agency will want to keep vehicles on standby near high-demand areas when they are not in use, requiring additional lots or garages throughout the service area. In U.S. DOT's AV 3.0 report, transit agencies are encouraged to implement AV technology to address specific problems rather than as a novelty. Engaging with local governments and communities to develop complete street policies to complement AVs is also recommended.

4. Workforce: The Federal Transit Act requires transit agencies to protect certain worker rights in exchange for receiving federal funding.[9] Agencies must continue existing collective bargaining agreements and the rights, privileges, and benefits offered by those agreements; assure priority of reemployment for displaced employees; and ensure paid training and/or retraining programs. If transit agencies seek to utilize AV technology to reduce labor expenditures, these regulations will need to be monitored.

5. Access: Transit agencies must conform to both the Americans with Disabilities Act (ADA) and other regulations on the social justice impact of transit changes. ADA specifies many design guidelines for transportation vehicles with regard to wheelchair access, circulation clearance, interior handrails, priority seating, and audiovisual announcements. Automated vehicles deployed by transit agencies will likely need to comply with these regulations to ensure the equity of service that transit has provided for years. Current AV shuttles are not fully accessible for people with disabilities, though they typically are equipped with boarding ramps for wheelchairs.

6. Security: Connected vehicle networks are potentially vulnerable to cybersecurity threats and hacking. Auto ISAC, a group of auto manufacturers, has developed best practices for AV cybersecurity, endorsed by NHTSA. AVs may also collect much more data about customers and their surroundings than traditional vehicles. The use of sensors to detect objects and the environment around the vehicle produces a wealth of data. Smartphone access to AV networks and payment via smartphone may allow transit agencies to have access to much more private data than is currently available through transit agency smartcards. This reinforces the need for

[9] 49 U.S.C. 5333(b), also known as Section 13(c) of the Federal Transit Act

transit agencies to understand the importance of their data, which is one of APTA's current priorities.[10] Steps will need to be taken to ensure that collection of this data does not violate the overlapping series of privacy laws that exist in the US.

7. Safety: Finally, new tests for AV sensor and system performance will need to be established to certify that AV systems are safe for transit agency use. Standards developed by NHTSA, SAE, ASCE, APTA, and others can provide a starting point for developing new tests of AV systems, though new standards and coordination efforts will be required. The FTA's Public Transportation Safety Program exists to provide a framework and rules for assessing the safety of an agency's public transportation operations, which will evolve with AVs. FTA has said it will provide transit agencies with technical assistance in developing a Safety Management System approach that ensures the safe testing of AVs.[11] For analyzing the safety of AV roadway transit service, focus should be placed on the safety of the whole operating system during the entire AV life cycle. This will be complex, as application of AV technology to transit will likely be a progressive adoption of different levels of automation. That is, some aspects of transit vehicle operation will be manual while others will be automated. Bringing in knowledge, experience, and methods from the automotive safety practice into the transit industry is recommended.

Private Sector Involvement in AV Mobility

Current AV system developers are split between traditional manufacturers of vehicle systems (such as OEMs and OEM suppliers) and newer entrants and startups. U.S. DOT reports[12] that the vehicle production market for AV transit shuttles consists mostly of startups that have limited experience producing at a mass scale. The development of this market will be important to monitor, as well as the products manufactured by the OEMs. As the line between transit and automated vehicle production begins to blur, public transit agencies may procure more from traditional automakers in the future.

These major automakers are investing aggressively in AV technology, acquiring or partnering with mobility and technology firms to sharpen their competitive edge. Many of these automakers have stated that the initial step for AV deployment is through managed mobility services. General Motors has announced that it will make an autonomous ridesharing service available for several big cities in 2019 (through their AV division Cruise Automation). Ford has similar goals (with a 2021 mobility service launch date), bolstering themselves through the acquisition of the microtransit company Chariot (now defunct) and the real-time scheduling software Transloc. Daimler has announced that it will launch an automated shuttle service in Silicon Valley in late 2019, with Bosch providing the autonomous hardware.[13]

[10] See current TCRP work in development (http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4466) as well as upcoming APTA publications
[11] U.S. DOT AV 3.0
[12] *Low-Speed Automated Shuttles: State of the Practice Final Report*
[13] https://www.wardsauto.com/technology/daimler-bosch-launch-driverless-shuttles-silicon-valley

The imminent launch of AV fleet services from these private providers is of interest to the transit industry as either potential competition or a potential complement to traditional service. For example, Waymo (subsidiary of Alphabet) aims to formally launch its automated ride-hailing service in late 2018 in Phoenix, AZ. Waymo uses Chrysler Pacifica minivans and intends to acquire a fleet of electric Jaguar I-pace models in the future.[14] In July of 2018, Waymo and Phoenix's Valley Metro announced an unprecedented partnership to use autonomous Waymo vehicles to connect travelers to the agency's light rail system, addressing FM/LM travel.[15] Finally, transportation network companies (TNCs) are in an interesting position with regard to AV technology as self-proclaimed technology companies with proprietary mobile, on-demand ride-hailing platforms. They have initiated several partnerships to position themselves as the managers of AV fleets and have been experimenting with testing AVs themselves (for example, Uber with Volvo XC90s and Lyft with nuTonomy). Public transit agencies across the country have a wide variety of partnerships with existing TNCs, which could open the door for future coordination with AV pilots.

Conclusion and Other Research Activities

While automated vehicle development is proceeding at a rapid pace in the tech and auto sectors, public transportation agencies are just beginning to explore this technology for mainline operations. As the industry does this, there are a variety of issues that will present themselves along the way. U.S. DOT cautions agencies to establish realistic expectations when implementing pilots and demonstrations.[16] It is important that the entire transit industry engage with stakeholders and experts from other industries to discuss how to implement automated vehicle technology and conclude what adjustments need to be made to enable deployment. Applying this technology to transit vehicles should bring significant safety benefits, including fewer and less severe collisions, as well as a better driving experience for agency drivers. APTA research has already shown that public transportation helps make communities safer.[17] With increased automation in public transit, there is belief that the general public will see not only increased safety benefits, but also greater connectivity and efficiency of travel.

APTA notes that additional AV research is already underway with TCRP J-11/Task 34, *Automation's Effect on the Transit Labor Force*. Among other objectives, this research aims to identify positions susceptible to replacement (and growth) because of automated technologies and steps that public transit agencies can take to prepare their workforce for increased automated technology.

U.S. DOT, in coordination with the Department of Labor, the Department of Commerce and the Department of Health and Human Services, was provided up to $1.5 million in the 2018 Consolidated

[14] https://www.bloomberg.com/news/articles/2018-03-27/waymo-and-jaguar-team-up-with-20-000-car-self-driving-fleet
[15] https://www.azcentral.com/story/news/local/phoenix/2018/07/31/valley-metro-experiment-waymo-autonomous-vehicles/853719002/
[16] U.S. DOT AV 3.0
[17] https://www.apta.com/resources/hottopics/Documents/APTA%20VZN%20Transit%20Safety%20Brief%208.2018.pdf

Appropriations Act to study the impact of Advanced Driver Assist Systems and Highly Automated Vehicle technologies on the workforce.

FTA has a five-year Strategic Transit Automation Research (STAR) Plan that will continue to expose the opportunities and risks of transit automation. This research focuses on achieving safe and effective transit automation deployments, demonstrations of the technology in real-world settings, and transferring knowledge throughout the industry. As part of this, FTA is offering up to $500,000 total for Transit Bus Automation Strategic Partnerships. More information can be found at: https://www.cutr.usf.edu/fta-strategic-partnerships/.

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The American Public Transportation Association (APTA)

The American Public Transportation Association is a nonprofit international association of 1,500 public and private sector organizations that represents a $71 billion industry that directly employs 430,000 people and supports millions of private sector jobs. APTA members are engaged in the areas of bus, paratransit, light rail, commuter rail, subways, waterborne services, and intercity and high-speed passenger rail. This includes transit systems; planning, design, construction, and finance firms; product and service providers; academic institutions; transit associations and state departments of transportation. APTA is the only association in North America that represents all modes of public transportation. APTA members serve the public interest by providing safe, efficient and economical transit services and products.

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APTA Vision Statement

APTA is the leading force in advancing public transportation.