# Center for Transportation and the Environment (CTE) Response to the Federal Transit Administration's Request for Information on Transit Bus Automation Research and Demonstrations

## Introduction

The Center for Transportation and the Environment (CTE) appreciates this opportunity to respond and provide input on the Federal Transit Administration's (FTA) Strategic Transit Automation Research (STAR) plan and future programming. CTE is a 501(c)(3) nonprofit, membership-based planning and engineering organization. CTE's mission is to improve the health of the climate and communities by bringing people together to develop and commercialize clean, efficient, and sustainable transportation technologies. CTE collaborates with federal, state, and local governments; fleet operators; and vehicle technology manufacturers to develop, deploy, and plan for these innovative technologies.

CTE considers itself an engineering organization first, and an advocacy organization second. Our staff is experienced in developing, implementing, and administering advanced transportation technology projects with a focus on zero-emission medium- and heavy-duty (MHD) vehicles and fleets. CTE has provided technical assistance and project management services on many zero-emission transit bus development projects made possible through FTA's National Fuel Cell Bus Program (NFCBP), Low or No Emission Vehicle Program (Low-No), Transit Investment in Greenhouse Gas and Energy Reduction Program (TIGGER), Clean Fuels Program, Safety Research and Demonstration Program (SRD), and Integrated Mobility Innovation Program (IMI).

CTE's responses to this RFI are informed by its three decades of experience supporting transit bus advanced technology development, including powertrain, energy storage systems, fueling/charging infrastructure, and vehicle automation. CTE has been supporting the Connecticut Department of Transportation (CTDOT) since March 2020 on an FTA-funded automated transit bus demonstration under the IMI program. The project will involve CTDOT deploying three New Flyer 40-foot battery electric buses (BEB) equipped with automated driving systems (ADS) technology on the CT*fastrak*, a controlled-access busway between New Britain and downtown Hartford, CT. The project will feature demonstration, data collection, and analysis of on-road ADS operations up to 40 mph, precision docking at station platforms, cooperative adaptive cruise control (platooning) operations with multiple buses, and signalized intersection navigation utilizing vehicle-to-infrastructure (V2I) communication capabilities.

Through this work under the FTA IMI program, CTE has seen firsthand many of the challenges associated with planning, developing, and deploying ADS technologies on transit buses. To date, CTE and its project partners have completed or are near completion on contracting, hazards analysis, operational design domain definition (ODD), functional specification definition, research design, ADS design, vehicle design and build, and infrastructure design.

Over the next year, the team expects to complete ADS hardware integration and testing, CTDOT operations and maintenance planning, operator training development and delivery, infrastructure deployment, and demonstration go-live. Data collection will continue for a year after deployment, with results included in a final FTA research report.

CTE has also led industry panels and working groups with transit agencies, manufacturers, testing centers, and other stakeholder organizations on zero-emission bus technologies, some of which have incorporated discussion on transit automation priorities. The most notable of these forums is the FTA Transit Vehicle Innovation Deployment Centers Program's (TVIDC) National Transit Advanced Technology Advisory Panel. Stakeholders on that panel assessed FTA's existing STAR programming, and shared their desire to see greater focus on automation capabilities that improve on-road safety and accessibility, as well as those that support adoption of zero-emission buses. Similarly, CTE has been engaged with national labor groups to identify and prioritize transit automation capabilities that simultaneously provide value to transit agencies and their customers, complement human operators, and have workforce buy-in as the technology advances. These values are fully in alignment with Biden Administration priorities.

Overall, CTE's experience informs a perspective that industry marketing has gotten ahead of technological reality, and that while speculation of long-term outcomes produces engaging discussion, it can also steer limited resources in unproductive directions. To this end, CTE would like to see FTA remain focused on near-term and medium-term objectives for technology development and commercialization, including demonstrations, educating agencies on the state of technologies and their challenges, and workforce development programming.

*Note: Use of the terms "ADS" and "ADAS" (advanced driver assistance systems) in this RFI response correspond to their definitions established in the standard SAE J3016: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles.*

**1. Priority Areas**

- *What topics should be a priority for FTA's transit bus automation research and demonstrations over the next five years? What specific activities or products should be a priority for FTA within these areas?*

FTA should focus its transit bus automation demonstrations on capabilities that advance vehicle engineering and are likeliest to result in commercially viable products in the medium term (5-10 years). Through existing development work in the transit bus industry and observations in the light vehicle and freight automation industries, we can reasonably assume commercial deployment of highly automated transit buses at scale is a decade off, or longer. More focused efforts can advance commercial deployments in settings or use cases that are most technically

feasible in the medium-term, including but not limited to depots, bus rapid transit (BRT) facilities with protected right-of-way (ROW), and ADAS for regular on-road operations.

CTE's position is also informed by its work on the NFCBP, which catalyzed the US zero-emission transit bus market and helped multiple manufacturers begin to electrify their powertrains. Subsequent projects funded under FTA's Clean Fuels and TIGGER programs also advanced early stage development and demonstrations, and allowed the major transit bus original equipment manufacturers (OEM) to prepare for larger commercial deployments funded through the Low-No Program. CTE sees benefit in FTA supporting a similar development pathway for ADS and ADAS, with a decade-long funding commitment to demonstrations that catalyze the industry.

To advance commercial deployments of automation technologies, transit bus OEMs will need to develop and integrate drive-by-wire systems for steering, acceleration, and braking actuation, and progressively improve the efficiency and reliability of these systems. Any FTA-funded demonstration will support these engineering efforts, along with enabling OEMs to begin integrating core ADS components into their vehicle designs. These components include, but are not limited to: lidar, radar, high-definition cameras, computing systems, and new telecommunications equipment. These designs will not remain static, with evolution in those component markets allowing and necessitating changes to improve energy efficiency and performance. The first prototype Proterra fuel cell electric bus funded under the NFCBP represented an impressive engineering achievement, but was nonetheless a far cry from the BEBs it was selling commercially five years later.

FTA has served a critical role in supporting transit bus technology research and development for decades, and should continue to do so. This can also extend to the cutaway market, as it has with FTA's funding of a demonstration under the Accelerating Innovative Mobility (AIM) program. Heavy-duty transit buses and cutaways have not benefitted from significant private investment, unlike light vehicles, trucks, delivery vans, and even smaller low-speed passenger shuttles. Therefore, FTA's demonstration program resources and direction are especially critical for bus and cutaway OEMs to continue modernizing their platforms, for the ultimate benefit of agencies and their riders.

Given the Biden Administration's priorities in supporting the transit industry's transition to zero-emission technologies, FTA should also connect these demonstrations and associated research efforts to its broader efforts to support zero-emission bus (ZEB) and cutaway adoption. CTE sees multiple potential applications in which automation technology can either directly produce or enable increased energy efficiency in MHD transit vehicles. Even allowing for power load requirements from sensors and computing hardware, augmenting human driving to reduce performance variability should substantially increase energy efficiency and therefore vehicle range.

CTE has supported or is currently supporting the planning or deployment of hundreds of ZEBs across more than 100 projects in the United States. These deployments are geographically diverse, and include conditions ranging from high heat in the Southwest to extreme cold in the upper Midwest and New England. They also cover a variety of topographical environments, including some settings where buses need to operate on routes featuring significant grades. Heating or cooling the vehicles draws a substantial power load from buses, as does accelerating up steep terrain. For each of its ZEB deployments, CTE performs energy modeling activities prior to launch, and then tracks energy consumption and battery performance data while vehicles are in service. Even beyond extra power loads required to heat and cool the cabin, and driving across hilly terrain, CTE has observed that ZEBs can experience significant variability in energy consumption from the driver behind the wheel.

This inefficient driving behavior, particularly caused by harsh acceleration and braking, can reduce vehicle range by up to 25 percent. For buses that employ regenerative braking, poor use of the system also minimizes potential gains. Automated acceleration and braking would reduce efficiency losses and produce better ride quality for passengers. Synchronization with traffic signals via V2I communications can further improve ride quality and use of regenerative braking features.

FTA's other research programming should help agencies understand the challenges incumbent in developing and deploying viable transit automation products, and provide them resources to pursue their own pilot projects. FTA should continue to monitor developments in vehicle engineering, as well as ADS activity specifically in the freight and industrial vehicle sectors. It should also explore both cybersecurity and overall liability considerations to assess the potential impediments to contracting and deployment due to those concerns. Finally, FTA should continue to explore benefits from automation, using agencies as case studies to assess route-, depot-, or fleet-level benefits to deploying specific capabilities.

- *For any priority areas identified, are there activities that stakeholders have undertaken? What were the challenges? Are there specific areas where FTA engagement may be needed?*

While CTE cannot speak to the experience of other projects involving automated transit bus, cutaway, or low-speed shuttle technologies, we have learned considerably from our nearly 2.5 years of work with CTDOT and the project team on the CT*fastrak* deployment. Challenges to date have included defining performance requirements, defining testing requirements, and navigating a regulatory hurdle with the Federal Communications Commission (FCC) mandating the abandonment of dedicated short range communications (DSRC) technology. Other challenges will likely emerge over the duration of the project due to its unprecedented and groundbreaking nature.

Unlike the low-speed automated shuttle deployments to date, where agencies have procured a standard product with little-to-no customization, future commercial deployments will require ADS technology to conform to specific agency procurement and operational requirements. Agencies will need to know what to ask of OEMs and ADS developers, and those technology suppliers will need to understand what they can reasonably commit to deliver. This process may require considerable back-and-forth, given there are no accepted industry standards for capabilities, performance assessment, liability, or delineation of responsibilities between the parties.

Agencies are unlikely to modify vehicle procurement specifications in the short-term to accommodate pilot projects, which may have implications for the ADS design. This is especially true for the human-machine interface (HMI) for status, alerts, and controls, which will be subject to existing operator-area design features such as fareboxes and protective screens. CTE has witnessed physical design challenges firsthand with HMI integration on both the CTDOT project and a demonstration of Mobileye Shield+ collision avoidance systems on the Los Angeles County Metropolitan Transportation Authority's (LA Metro) New Flyer buses under FTA's SRD program. The LA Metro project encountered several weeks of delays when the team needed to modify heads-up display placement to comply with driver field of view standards (SAE J1050). CTDOT, New Flyer, and Robotic Research have been working to overcome similar challenges with driver field of view and farebox considerations.

Vehicle OEMs and their ADS developers (if external) will need to determine their own testing requirements independently of agency partners, and some of these may come from upstream in their manufacturing supply chain. For instance, Tier 1 and Tier 2 automotive suppliers may set their own testing benchmarks for ADS operation in revenue service. Some of this will depend on the manner in which liability is shared between manufacturers and suppliers. Development of clear ODD and functional requirements will help manufacturers define their own requirements as they move forward with their initial deployments. FTA can frame these challenges and develop guiding materials for agencies to help them engage potential vendors and develop pilot projects. However, in this early period of rapid evolution, FTA should lean toward producing best practices versus standards-setting on use cases, vehicle designs, and performance metrics. It should also steer agencies toward best practices for testing, namely SAE J3018: *Safety-Relevant Guidance for On-Road Testing of Prototype Automated Driving System (ADS)-Operated Vehicles*.

When the IMI project began in March 2020, the project team expected to use DSRC for signal phase and timing (SPaT) and map message (MAP) communications, yet, the FCC's December 2020 decision to revoke DSRC's authorization after one year required the team to pivot to a cellular vehicle-to-everything (C-V2X) alternative. While no state or federal policy changes have otherwise impacted ADS development, the evolving national policy environment in these early stages of vehicle automation will continue to pose risks for projects of multiyear durations involving vehicles with long asset lifecycles. FTA should continue to monitor impacts from

federal regulatory and legislative activity, and communicate their implications to the transit industry. Additional examples of this include new Infrastructure Investment and Jobs Act (IIJA) provisions that require the National Highway Traffic Safety Administration (NHTSA) to issue a rule by November 2023 that mandates automated emergency braking (AEB) in all new commercial vehicles, and to study driver monitoring systems (DMS) for a potential future mandate.

Separately and with support from FTA under the TVIDC program, CTE brought together more than a dozen transit agency general managers, leading transit bus manufacturers, all three federal bus testing centers, and public transit advocacy groups to form an advisory panel on transit bus technology research priorities in 2019. Among other topics, FTA charged this panel with exploring industry priorities for FTA research on transit bus automation. Both transit agencies and OEMs expressed wanting to see FTA focus resources on ADAS that improves on-road safety, yard capabilities for automated battery electric bus charging and parking, and more research into liability implications of vehicle automation.

The panelists generally expressed interest in seeing more FTA activities around automation. However, some had also lost enthusiasm either due to underwhelming experiences with low-speed automated shuttle pilots, or their engagement with the subject had illustrated the long timeline before they could see commercially-scalable technology on public roads. These sentiments track with what CTE has heard from engagement with other stakeholders.

Agency personnel are still early in their engagement with automation capabilities and potential benefits, and their hypothetical interest often tracks ahead of their understanding of the state of the technology. This is an area FTA engagement can help the industry move forward in a smart and productive manner. Because the technology is evolving rapidly, an annual or biannual “state of the technology” report would provide value to the industry, as would surveys of agencies gauging their interests in various ADAS and ADS capabilities.

**2. Enabling Research**

- *What specific research questions should be addressed by FTA-supported foundational research within the next five years? Possible topic areas for research include, but are not limited to, cybersecurity, equity, standards, and workforce training.*

FTA should focus its research efforts on topics that will address the greatest barriers to ADS adoption and operation. These hurdles include procurement, liability, workforce issues, and requirements definition. Automated transit bus deployments will require customization, and agencies are not sufficiently familiar with the technology to effectively define ADS performance requirements and contractual terms. Measuring ADS technology performance is more complicated than prior adopted innovations (e.g. ITS, electrification), and requires new skillsets not currently present among agency staffs. We can expect agencies will remain dependent on

consultants for the foreseeable future, who are themselves at an early stage of understanding automation technologies.

However, any attempt at procurement standardization at this stage would be misguided with the technology at its very early levels of development. CTE led an industry working group on behalf of the American Public Transportation Association (APTA) to develop procurement guidelines for BEBs and their charging infrastructure, only after many demonstrations and multiple vendors were selling commercial products. Premature work on standardization may be overly prescriptive and stifle industry development, especially with respect to ADS functional design. The same applies to any attempt at a large joint procurement among multiple agencies, as we might see with maturing commercial technologies that simply need manufacturing scale to reach cost efficiencies. Each agency's ODD, vehicle specifications, and other operational requirements are too varied and will require too much mapping, software customization, and testing to reach any efficiencies of scale for the foreseeable future. "Robotaxi" developers have already learned this expensive lesson the hard way.

That said, FTA may play a productive role in further research on enabling technologies, including sensors and drive-by-wire components, and what agency maintenance personnel need to learn about maintaining these systems. As we have seen with key zero-emission technologies such as batteries and fuel cells, automation-enabling components are rapidly evolving and their asset lifecycles are much shorter than the 12 years required by FTA for transit buses. FTA should evaluate the capital planning and maintenance implications of these components, as well as how agencies can ensure suppliers maintain functional interoperability and compatibility as they replace obsolete components.

Similarly, vehicle operators and maintenance staff will require additional training to support automation technologies. CTE does not see a realistic scenario in which human operators are entirely removed from the driving task for the foreseeable future. FTA should continue to operate with this baseline assumption. Though some long-range industry visioning discusses scenarios in which operators are retrained as on-board concierges to solely assist passengers, this is highly unlikely for at least another decade, and likely longer. Therefore, operators will need to be trained on use of HMIs, as well as other standard and emergency ADS operations topics. FTA can support the industry by exploring strategies for operator training curriculum development.

Assigning liability will also remain problematic for the foreseeable future, and will depend both on the automation capabilities integrated into transit bus operations, and where they are deployed (i.e., ODD). Cybersecurity risks in transit operations and maintenance will grow with the integration of automation technologies, and FTA can provide valuable guidance for addressing these risks. FTA can also leverage the Low or No Emission Vehicle Component Assessment Program (LowNo-CAP) bus testing centers, which have developed facilities and testing capabilities specifically for transit bus automation and cybersecurity.

Equity is a persistent and increasingly important consideration, and FTA should assess where these questions are likely to manifest over the next decade as transit agencies engage with early transit automation technology integration and deployment. CTE expects to see accessibility as an early benefit of automation technology, specifically enabled by enhanced precision docking capabilities at BRT stations with platform boarding (i.e. eliminating non-ADA-compliant platform gaps).

Additional research into specific commercial applications with the nearest term potential would provide value as well, including but not limited to automated BRT operations, ADAS, and yard automation. Finally, FTA should research ways in which automation can support adoption of zero-emission vehicles through increased energy efficiency in vehicle operation and more efficient charging equipment procurement and utilization.

**3. Integrated Demonstrations**

- *Are these demonstration areas still needed? What additional or alternative demonstration areas are a priority?*

Some of FTA's previously-defined automation demonstrations are viable and still needed, while others offer less potential value given the agency's limited resources. The greatest needs are on vehicle platforms that have traditionally depended on FTA support for vehicle and infrastructure technology development, specifically transit buses. The ongoing CT*fastrak* project was a sound selection for the country's first automated BRT demonstration, given its controlled-access busway. Other transit agencies across the US benefit from access to similar dedicated facilities, and offer attractive proving grounds for further FTA-funded demonstration projects. Beyond these few busways, BRT routes with dedicated or partially-dedicated ROW (but no controlled access) should be the next FTA focus for on-road ADS demonstrations.

For other on-road operations, FTA should prioritize ADAS. These capabilities promise the nearest-term commercial viability for transit buses and cutaways because developers can more easily develop them for operation in many service areas with little or no customization. As with ADS, ADAS requires drive-by-wire component integration and some combination of lidar, radar, and camera units. Therefore, these demonstrations will similarly advance OEM general vehicle engineering objectives and better familiarize the industry with maintenance best practices for these components.

Finally, FTA should prioritize off-road applications such as depot operations, including automated bus parking and pullout, BEB charging, and yard hostling. These settings offer lower-risk environments and scenarios where automation can provide significant value with less technology development. Agencies may see operational cost savings from reduced need for manual movement of vehicles around the depot and BEB charging, and capital savings from

reduced real estate requirements due to more efficient parking arrangements. Agencies transitioning their fleets to BEBs may also need fewer chargers due to automated charging cycles and operational efficiencies. They could achieve this either through increased use of overhead conductive or inductive (wireless) pad charging, or the industry's longer-term development of automated plug-in dispensing mechanisms.

FTA's other planned demonstrations are no longer needed. Low-speed shuttles and light vehicles have received significant private sector investment, and have yet to demonstrate utility in transit applications for a variety of reasons. Low speed automated shuttles have neither progressed towards Federal Motor Vehicle Safety Standards (FMVSS) compliance or exemptions, nor FTA's Altoona testing for safety and durability. Light vehicles serving in a transit capacity for mobility-on-demand (MOD) are simply far more expensive and challenging to scale in the low-density urbanized and rural environments where they may offer long-term value. While political considerations may necessitate continued FTA investment in these platforms, they do not offer the transit industry the potential return on investment as funding automation development for MHD vehicles serving fixed routes.

- *What are the biggest successes or challenges to deploying ADAS or ADS technologies for transit?*

The biggest challenge to developing ADAS and ADS technologies has been lack of financial resources for development and integration on transit bus and cutaway platforms. Transit bus manufacturers have limited financial and engineering resources, and developing integrated automation capabilities is a costly endeavor. As of July 2022, New Flyer is the only North American transit bus manufacturer with a prototype ADS bus, and GILLIG is set to join it later this year. Both are working with Robotic Research as their ADS supplier and integrator. While multiple cutaway OEMs have signed development agreements with ADS suppliers, to CTE's knowledge, GreenPower is the only one to develop a demonstration vehicle thus far, with the ADS integration support of Perrone Robotics.

A secondary challenge is industry misconceptions around vehicle automation's commercial pathway and readiness. Some of this has been fueled by aggressive marketing from OEMs, technology developers, and consultants, confusing the SAE's classification system through excessive claims of delivering Level 4 or 5 technology. As a result, CTE continues to encounter transit agency representatives across the country who believe commercial-off-the-shelf (COTS) ADS products are just around the corner for MHD transit vehicles. While utilization of the SAE taxonomy remains an industry best practice, FTA should note that confusion around the "levels" classification system will persist for the foreseeable future.

FTA should also note that a standard demonstration of advanced vehicle technologies can take anywhere from four to six years from the time of funding opportunity announcement to project close-out. Technology components, industry conditions, manufacturer priorities, and the policy

environment can change markedly over that period. CTE has been incredibly fortunate to work with partners in CTDOT, New Flyer, and Robotic Research that have long-range vision and strong commitments to develop and deploy state-of-the-art ADS technology. CTE has a long history of demonstrating other advanced vehicle technologies, and has managed projects where that was not the case. Project partners lose interest altogether due to internal sponsorship turnover or other industry developments, and projects suffer major or even crippling setbacks. This is a risk FTA has witnessed on other demonstration programs in the past, and should be prepared to endure as it continues to fund automation demonstrations.

**4. Strategic Partnerships**

*What ADAS/ADS technologies proven in other transportation applications would be useful and applicable to transit use cases?*

FTA's prior research report "Transferability of Automation Technologies," effectively highlighted the maturity of key technology components and features in the light vehicle and MHD trucking markets, and the near-term feasibility of their adoption in the transit bus market. Due to the similar challenges of integrating electric powertrain components and maneuvering large MHD vehicles, the trucking sector offers the closest parallel to transit.

While commercial deployments are limited to date, demonstrations of automation and teleoperation of trucks and other heavy-duty machinery have illustrated strong commercial potential in off-road settings. Forklifts, yard tractors, and other industrial equipment operating in highly controlled environments have seen growing interest from investor-backed technology startups due to their relative ease versus on-road use cases. With workforce challenges affecting most commercial transportation segments, limiting the need for personnel to move vehicles around a yard safely, or centralizing those movements in a teleoperations center (i.e. remote control of vehicles), offers significant potential benefits. The transit industry can learn from these activities in the commercial freight and logistics industry.

Separately, a team from the John A. Volpe National Transportation Systems Center is currently working with the CTDOT project team on human factors research, specifically the effectiveness of different training methodologies for operators as they prepare for ADS deployment. Findings from this research are expected to benefit both the transit and MHD trucking industries, as both employ trained and commercially-licensed drivers.

**5. Stakeholder Engagement and Knowledge Transfer**

- *Are FTA's methods of stakeholder engagement sufficient? What other methods should FTA consider?*

FTA has provided effective engagement to date in promoting its transit bus automation activities. More frequent webinars, specifically when research reports are completed and published, would be valuable. FTA's web resources on transit automation are easy to access and navigate.

**6. Workforce**

- *What activities have agencies undertaken to understand and prepare for the impacts of automation on their workforce? Please be specific and include examples where possible.*

The CT*fastrak* demonstration project has included engagement across multiple departments within CTDOT and its transit operator brand, CT*transit*. This level of engagement has been necessary to ensure systems design accounts for all operational requirements, including rules of road, station approach and docking behavior, platooning behaviors, signal infrastructure upgrades, bus operator preparedness, and maintenance practices. CTDOT has also met with local union representatives to receive buy-in on key engagement strategies for bus operators and vet planned roles and responsibilities while serving as safety operators on the ADS-equipped buses.

For instance, CTDOT made two key decisions in the project's design phase to ensure operators are attentive at all times when the ADS in engaged. First, it will limit shifts to two hours, reducing the risks of complacency and fatigue. While ADS developers in the light vehicle and trucking markets have experimented with longer shifts for their safety drivers, the transit industry does not have sufficient data to assess impacts of attentiveness and responsiveness over time in bus operations. Two-hour shifts are not a realistic long-term option for commercial deployment, but reflect a safety-first approach until the industry can determine viability of longer durations.

Second, the project team decided to install a DMS that will alert operators when it senses they are not sufficiently attentive. DMS technologies have proven to be effective components of ADAS solutions in the light vehicle market. CTDOT has also communicated to operator supervisors at CT*transit* and labor representatives that the DMS will not be used in operator performance evaluations, and is solely intended to ensure alertness while performing their role as safety operator with the ADS active.

- *What types of new skills, training, and resources may be required for transit workforce development and transition?*

Integration of transit bus automation into fleets will impact nearly every corner of agency planning and operations, much as the industry has already seen with integration of zero-emission propulsion technologies. Bus operators will need training on new HMIs and situational training, depending on system design. Maintenance personnel will also need training on routine maintenance of sensors (e.g. cleaning dust buildup on lidar units) and basic diagnostics. Technology suppliers will likely manage more advanced diagnostics and troubleshooting. Over time, agencies may develop more in-house capabilities for regular maintenance, but most will likely outsource work to suppliers or third-party fleet operators.

Agency planning staff will need to understand how infrastructure design features can support or hinder automation. This may have implications for capital programs, and will certainly require increased coordination with infrastructure owners (e.g. local departments of transportation). Until ADS technology in the transit market reaches a level of sophistication sufficient to navigate signalized intersections as well as humans can, V2X capabilities and associated signal upgrades may be necessary. Facilities managers will also need to accommodate automated vehicles in their depots, updating safety protocols and other standard operating procedures accordingly. These changes should incorporate thinking around more efficient space utilization from tighter parking arrangements, and implications for BEB charging. As agencies prepare to engage with transit automation, they will need resources to help them identify these impacts to their organization.

The biggest challenge from an agency management perspective will be scoping and procurement, including evaluating technology vendors and their solutions, establishing performance requirements, and assigning liability. Agencies should not expect to see COTS ADS software for the foreseeable future, and they need to be prepared to work with vendors on functional design and operational requirements. Resources that help them assess what automation use cases are both feasible and valuable will also help them determine where in their operations they should pursue pilot projects. Feasibility will change as the technologies evolve, and FTA should therefore continue to track and communicate developments closely. ADAS may reach the market as a standard COTS product, and several developers are targeting mid-decade for their commercially-available solutions.

- *What specific areas of workforce related research should FTA consider?*

FTA should primarily focus workforce development research efforts on bus operators, specifically agency training and outreach necessary to ensure operators are prepared and bought into solutions their leadership pursues. CTE and others have already engaged with labor groups at the federal and regional level to ensure technology development is collaborative and incorporating their stakeholder buy-in. Labor groups and their constituent members will remain

key partners for agencies and manufacturers as the technology develops, and the industry can accelerate deployment by focusing on automation capabilities that complement, not replace, existing personnel. FTA should research the full spectrum of driving tasks and other roles performed by bus and cutaway operators, and assess attitudes toward implementing automation in those areas.

- *What types of resources could FTA provide to help agencies and their workers adopt transit bus automation?*

FTA can provide the greatest value in helping agencies plan for deployments, including vendor/product scoping and evaluation, procurement guidelines, technical performance requirements definition, labor relations expectations-setting and management, and deployment evaluation. FTA should continue tracking and communicating industry developments in periodic reports and webinars.

Realistically, FTA's ability to equip transit agencies with the skills they need to actually operate automated transit buses will be limited. However, CTE's work with CTDOT and other technology partners on the CT*fastrak* deployment has proven instructive on the need to develop training methodologies and performance management systems (e.g. DMS) that are both effective and acceptable to key labor stakeholders. FTA can learn from these efforts and communicate findings across other groups of industry stakeholders, pulling in resources from other USDOT agencies (e.g. FHWA, ITS-JPO) as necessary.