Strategic Transit Automation Research Plan Roadmap

Introduction

Advancements in technology, such are automated driving systems, are rapidly transforming the transportation system. While automated operations in rail transit are relatively mature, their use in bus transit is still emerging. The Federal Transit Administration's (FTA's) Office of Research, Demonstration and Innovation is currently exploring the use of automation technologies in bus transit operations.

The U.S. transit industry is often conservative in adopting new technologies, services, and business models. While funding and policy constraints may play a role, there is also a reasonable unwillingness to risk public funding or to undertake new operational models without a full understanding of the approach or without federal leadership and guidance.

The Strategic Transit Automation Research (STAR) Plan builds on extensive stakeholder consultation and use case analysis to define a five-year research agenda which will move the transit industry forward. The plan will be completed in Fall 2017, with a number of high-priority activities already underway. "Bus" is defined broadly to consider a range of sizes and passenger capacities, and could include both traditional and novel vehicle designs (e.g. full-size city buses, articulated buses, and small shuttles).

Methodology

The development of the STAR Plan is grounded in thorough literature review and specific subject matter expertise, as well as stakeholder consultation. It also includes a risk and barrier assessment and a benefit-cost analysis for identified transit bus automation use cases (see figure below of use cases).
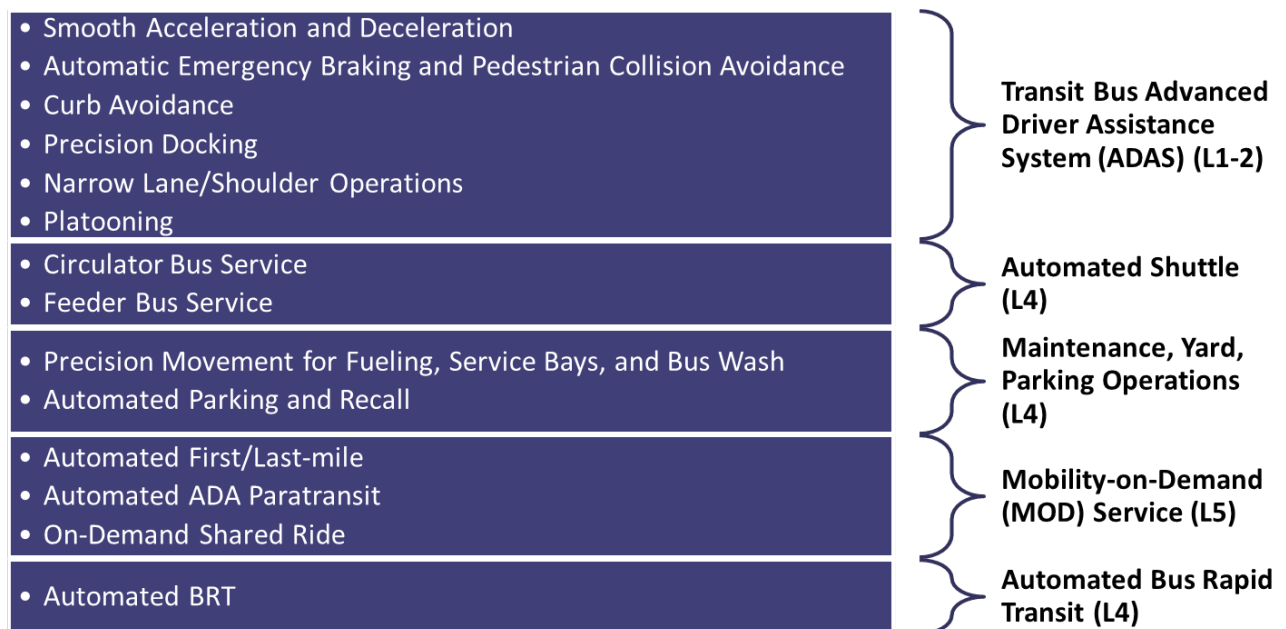

Use Cases	Technology Package
• Smooth Acceleration and Deceleration • Automatic Emergency Braking and Pedestrian Collision Avoidance • Curb Avoidance • Precision Docking • Narrow Lane/Shoulder Operations • Platooning	**Transit Bus Advanced Driver Assistance System (ADAS) (L1-2)**
• Circulator Bus Service • Feeder Bus Service	**Automated Shuttle (L4)**
• Precision Movement for Fueling, Service Bays, and Bus Wash • Automated Parking and Recall	**Maintenance, Yard, Parking Operations (L4)**
• Automated First/Last-mile • Automated ADA Paratransit • On-Demand Shared Ride	**Mobility-on-Demand (MOD) Service (L5)**
• Automated BRT	**Automated Bus Rapid Transit (L4)**

Figure 1: Technology Packages and Use Cases (Levels refer to SAE International J3016)

Plan Approach

The plan leverages the core strengths of academia and the public and private sectors, and is organized around three complementary work areas: **Enabling Research, Integrated Demonstrations**, and **Strategic Partnerships**. Ongoing stakeholder engagement and knowledge transfer activities will ensure that the research meets stakeholder needs, and that the industry can quickly build on results.

Anticipated outcomes of the STAR Plan work areas are outlined below:

STAR Plan Work Area	Anticipated Outcomes
Enabling Research	Accelerate entry of manufacturers, suppliers, and transit providers into automation by building common understanding of foundational issues (human factors, Federal policy, costs and benefits, etc.)
Integrated Demonstrations	Grow industry and expand knowledge base by demonstrating automation technologies in real-world settings
Strategic Partnerships	Improve quality and usefulness of research by other actors and disseminate findings to broad community, expanding participation of providers and suppliers

Overview

The five-year strategic transit automation research (STAR) roadmap describes a set of research projects which complement each other and collectively advance FTA and DOT goals in automation.

Integrated demonstrations are at the core of the plan. While there are many and diverse research questions, they are fundamentally interrelated. A single demonstration can, with planning, address multiple topics. Details of the demonstrations will vary according to the partner(s) and project(s) selected, but they are expected to include assessment of impacts in the following areas:

- transit operations and maintenance;
- fuel and emissions;
- service quality;
- safety;
- passenger experience, comfort, and acceptance;
- accessibility;
- travel options and mode choice;
- fare collection; and
- cost-effectiveness.

The demonstrations are also expected to include testing of system capabilities and limitations, communication and equipment, and cybersecurity. FTA will also monitor research, demonstration, and deployment internationally, and identify opportunities to learn from international peers wherever possible.

Topics for the demonstrations are suggested based on findings from the literature review, stakeholder consultation, and market research. The first demonstration will focus on high-priority advanced driver assistance use cases. The second demonstration will focus on automated shuttles, either in circulator or first/last mile service. Both of these use cases can be demonstrated with technologies and vehicles that

are either market-ready, or that can be adapted to the purpose relatively quickly. Subsequent demonstrations involve technologies that are currently in development and may change as the plan evolves. The third, fourth, and fifth demonstrations will focus on automated maintenance yard applications, automated mobility-on-demand, and automated bus rapid transit, respectively.

The demonstrations are bookended by two types of **enabling research**. The initial set of projects investigate basic questions with regard to technology availability, business case, policy, human factors, and safety, to sharpen the research focus of the demonstrations and help resolve policy and technical issues that affect their viability. As the demonstrations draw to a close, the second set of planned projects will use data and results from the demonstrations as inputs to more in-depth analysis of key topics, such as workforce and service planning.

Finally, **strategic partnerships** will allow FTA to leverage investments by others, in both the private and public sectors, and gain access to datasets and results which would otherwise be unavailable.

The following sections briefly describe planned projects by year and work area, for the five years of the roadmap.

Year One (FY18)

The initial set of projects will lay the groundwork for successful demonstrations, both with regard to establishing feasibility for transit automation use cases and in terms of research design and data collection.

Enabling Research	
Automation Policy Review	This project will review the set of established laws, regulations, and policies that may delay or prevent the demonstration and deployment of bus transit automation systems.
Transit Bus Applications of Light and Commercial Vehicle Automation Technology	This project will explore potential application of automation technologies from the light and commercial vehicle areas to bus transit. It will examine transferability and delineate gaps of automated technology applications from light vehicles and heavy trucks to transit bus operations, as well considering opportunities to bridge those gaps.
Market Analysis for Automated Transit Buses and Supporting Systems	To date, there has been limited availability of automation capabilities in the transit bus market. This project will research the availability and costs of automation-related systems and products, with an emphasis on the US domestic bus market. It will inform the demonstration planning and create a baseline for evaluation.
Transit Automation User Acceptance Study and Human Factors Research	This project will assess both user acceptance of and human factors design considerations for high-priority transit automation use cases involving passengers, bus drivers, and other transit users.
Hazard and Safety Analysis of Automated Transit Bus Applications *(ITS JPO-funded)*	This project proposes to apply hazard analysis techniques to identify high-level hazards associated with automated transit bus applications, such as entering/exiting bus stops and embarking/disembarking passengers, and will provide generic risk mitigation functions that may facilitate the safe deployment of automated transit buses.

Integrated Demonstrations	
Test Facility Requirements for Automated Transit Vehicles	This project will identify technology areas and develop requirements for an outdoor/indoor testing facility in order to test automated transit vehicle technologies based on use cases identified in the five-year STAR Plan.
Evaluation Guidance for Integrated Demonstrations	This project is designed to ensure that the integrated demonstrations provide meaningful results and lessons learned that can be applied by other transit agencies and stakeholders. FTA will develop a document to assist its partners in developing a robust, rigorous evaluation component to planned demonstration projects. The will include guidance on evaluation methods, performance measures, and reporting.
Transit Automation Consortium Solicitation	This project will use findings from previous tasks to solicit one or more consortia of public sector, private sector, and academic partners to conduct major integrated demonstrations in future years. The consortium may also conduct enabling research projects in later years (FY21 and 22), which build on and analyze data from the demonstrations.
Integrated Demonstration 1: Automated ADAS for Transit Buses	This project will demonstrate market-ready advanced driver assistance technologies (SAE L1-2) to support partial transit automation in revenue service.

Year Two (FY19)

During the second year, some initial projects will conclude. Based on preliminary results, planning and execution for the demonstrations will become the focus.

Enabling Research	
Transit Automation User Acceptance Study and Human Factors Research	*Continuing Project*
Hazard and Safety Analysis of Automated Transit Bus Applications *(ITS JPO-funded)*	*Continuing Project*
Automated Transit Labor Impacts Assessment	This project will produce a qualitative analysis of the labor-related considerations with bus transit automation, including potential workforce changes, perspectives of organized labor, legislative and regulatory provisions, and other societal factors. The research will include both driving and non-driving tasks of bus operators, as well as related operations and maintenance personnel. (A follow-on project will address these questions from a more quantitative perspective, using findings from the integrated demonstrations.)
Automation Policy Implementation	This project will implement recommendations from the Automation Policy Review and develop input to Congress on recommended changes for consideration in developing the next surface transportation bill.
Business Case for Transit Automation	Budget-constrained transit agencies will need information on the business case for transit automation investments, i.e., the extent to which they generate cost savings, ridership gains, or other benefits that justify their costs. This project will build on existing research to produce business case information for market-ready automation investments and provide tools that agencies can use to assess their own business case.

Integrated Demonstrations	
Integrated Demonstration 1: Automated ADAS for Transit Buses	*Continuing Project*
Integrated Demonstration 2: Automated Shuttles	This is an integrated demonstration project focusing on low-speed shuttle buses with L4 automation. Use cases include circulator service and first- and last-mile access to transit networks.

Year Three (FY20)

During the third year, Demonstrations 1 and 2 will conclude and Demonstration 3 will begin. Results from previous years will be used in an analysis of the accessibility implications of automation.

Enabling Research	
Automation Policy Implementation	*Continuing Project*
Accessibility Analysis	Existing accessibility standards assume the presence of a human operator to deploy ramps, assist with securement of mobility devices, give wayfinding information, etc. While existing and near-market technologies address some of these needs, preliminary research has identified some gaps as well. This project will refine needs for accessibility research as part of the integrated demonstrations.

Integrated Demonstrations	
Integrated Demonstration 1: Automated ADAS for Transit Buses	*Continuing Project*
Integrated Demonstration 2: Automated Shuttles	*Continuing Project*
Integrated Demonstration 3: Automation for Maintenance and Yard Operations	This is an integrated demonstration project focusing on L4 automation in transit maintenance yard settings. Specific use cases may include precision movement for fueling, maintenance, and bus wash, and automated remote parking and recall.

Year Four (FY21)

In year four, Demonstration 3 will conclude and Demonstrations 4 and 5 will begin. Research and demonstration results will be used to inform stakeholders of best practices and strategies for investing in and deploying automated transit technologies.

Enabling Research	
Automated Transit Labor Impacts Evaluation	This project will build on the earlier analysis of labor issues by incorporating labor-related findings from the integrated demonstrations, such as measured changes in staffing levels, job responsibilities, labor hours, and training needs. This may allow a more quantitative approach to estimating automation's impacts on transit employment levels, workforce needs, and wages.
Finance Options for Automated Transit Investments	This project will assist transit agencies in their planning through the development of (non-binding) guidance on Federal funding programs that may be relevant to transit automation investments. This review may also include interviews with stakeholders and a recap of the literature on innovative finance for transit investments, with a focus on automation.
Stakeholder Guidance Updates	A series of policy and guidance documents (e.g., circulars, best practices) will be prepared, building on earlier work and relevant findings from the integrated demonstrations. Topics may include safety and security; accessibility; procurement; funding eligibility; and operations.
Standards Assessment and Coordination	Technical standards for automated vehicles are an emerging area. Without standards, transit agencies may face difficulties in ensuring interoperability or in developing procurement specifications. This project will conduct an assessment of current and developing technical standards in this area and include coordination with key standards bodies, such as SAE and APTA.

Integrated Demonstrations	
Integrated Demonstration 3: Automation for Maintenance and Yard Operations	*Continuing Project*
Integrated Demonstrations 4a, 4b, 4c: Automation for Mobility on Demand	This is a set of integrated demonstration projects focusing on fully automated (L5) provision of a range of mobility-on-demand services. Demonstration 4a will cover Automated ADA Paratransit. Demonstration 4b will be Automated First/Last Mile Service, which involves linking users with existing fixed-route transit. Demonstration 4c will be the On-Demand Shared Ride concept of point-to-point service.
Integrated Demonstration 5: Automated Bus Rapid Transit	This is an integrated demonstration project on automated (L4) operation of Bus Rapid Transit (BRT) service. BRT is a form of bus transit that includes a range of enhancements to improve service efficiency, such as dedicated lanes, signal priority, and expedited fare collection.

Year Five (FY22)

In the fifth year, the final demonstrations will conclude, and additional research will use demonstration results to inform further analysis, and, ultimately, policy change and guidance to the transit industry.

Enabling Research	
Automated Transit Labor Impacts Evaluation	*Continuing Project*
Security & Customer Acceptance Implications of Automated Transit Buses	This project addresses the potential customer acceptance issues associated with fully driverless operation due to perceived security issues or distrust of technology, including acceptance of shared rides without a driver present. It will build on human factors research and user data from earlier projects and demonstrations.
Transition Costs & Planning for Automated Transit Bus Deployment	Transit agencies moving to automation would likely face costs and operational complexities from a transition period during which they would be operating a mix of automated and non-automated vehicles. This research project will produce a practical reference guide for agencies covering key transition areas, such as vehicle maintenance; human factors, labor, and training issues; customer communication; maintaining consistency in the passenger experience; and transit service planning.
Impact on Service Patterns & Users	This project is designed to study the potential impacts of automation-related changes to transit service patterns, such as an increase in point-to-point service using smaller vehicles. The research will primarily rely on qualitative methods, including a mix of interviews, surveys, and focus groups, to understand passenger attitudes, values, and expectations regarding potential changes. It may also include a quantitative modeling component to assess impacts. The final report can be used as a form of market research for transit agencies as they plan future services.
Stakeholder Guidance Updates	*Continuing Project*

Integrated Demonstrations	
Integrated Demonstrations 4a, 4b, 4c: Automation for Mobility on Demand	*Continuing Project*
Integrated Demonstration 5: Automated Bus Rapid Transit	*Continuing Project*

Cross-Cutting Activities

Throughout the five-year period, three types of cross-cutting activities are envisioned: strategic partnerships, stakeholder engagement and knowledge transfer, and complementary research. Brief descriptions are given in the tables which follow.

Strategic Partnerships	
Valley Metro Automation Pilot	FTA has contributed funds to evaluate and share lessons learned from Valley Metro (Phoenix, AZ)'s shared AV pilot.
Additional Partnerships as Identified	Strategic partnerships will be scoped opportunistically, to allow FTA to supplement work by others. FTA grantees working with the private sector are likely partners.

FTA will conduct stakeholder engagement and knowledge transfer activities to disseminate transit automation information and research results to both internal and external stakeholders. Example activities are included below.

Stakeholder Engagement, Knowledge Transfer, and Technical Assistance	
Public Webinar: STAR Plan	In Fall 2017, FTA will convene stakeholders to learn about the five-year automation research plan, and to discuss the state of the practice.
Conference Talks and Panels	FTA staff will discuss transit automation and the STAR Plan at venues, such as APTA events, ITS America events, TRB, and the Automated Vehicle Symposium.
Outreach Materials	Materials suitable for transit stakeholder and public distribution to include: Fact Sheets, Infographics, Briefing Deck, Website, etc.
Technical Assistance	This project is designed to assist local DOTs, transit agencies, and MPOs with practical guidance on demonstration projects, field operational tests, and small-scale deployments. It is intended to include aspects of test design, evaluation, data collection, and reporting. This technical assistance will build on the research projects described above as well findings from the integrated demonstrations. Through this project, FTA will coordinate with potential deployers to provide them with information and guidance that will help improve the outcomes from these deployments. Topics could include state of the practice fundamentals, assistance with pilot design and evaluation, and clarification of Federal policy, rules, and regulation.

Automation has broad implications across the transportation system, and there are critical research questions which cannot be answered by FTA alone. Complementary research, sponsored by FTA programs and other agencies, will support deployment of bus transit automation.
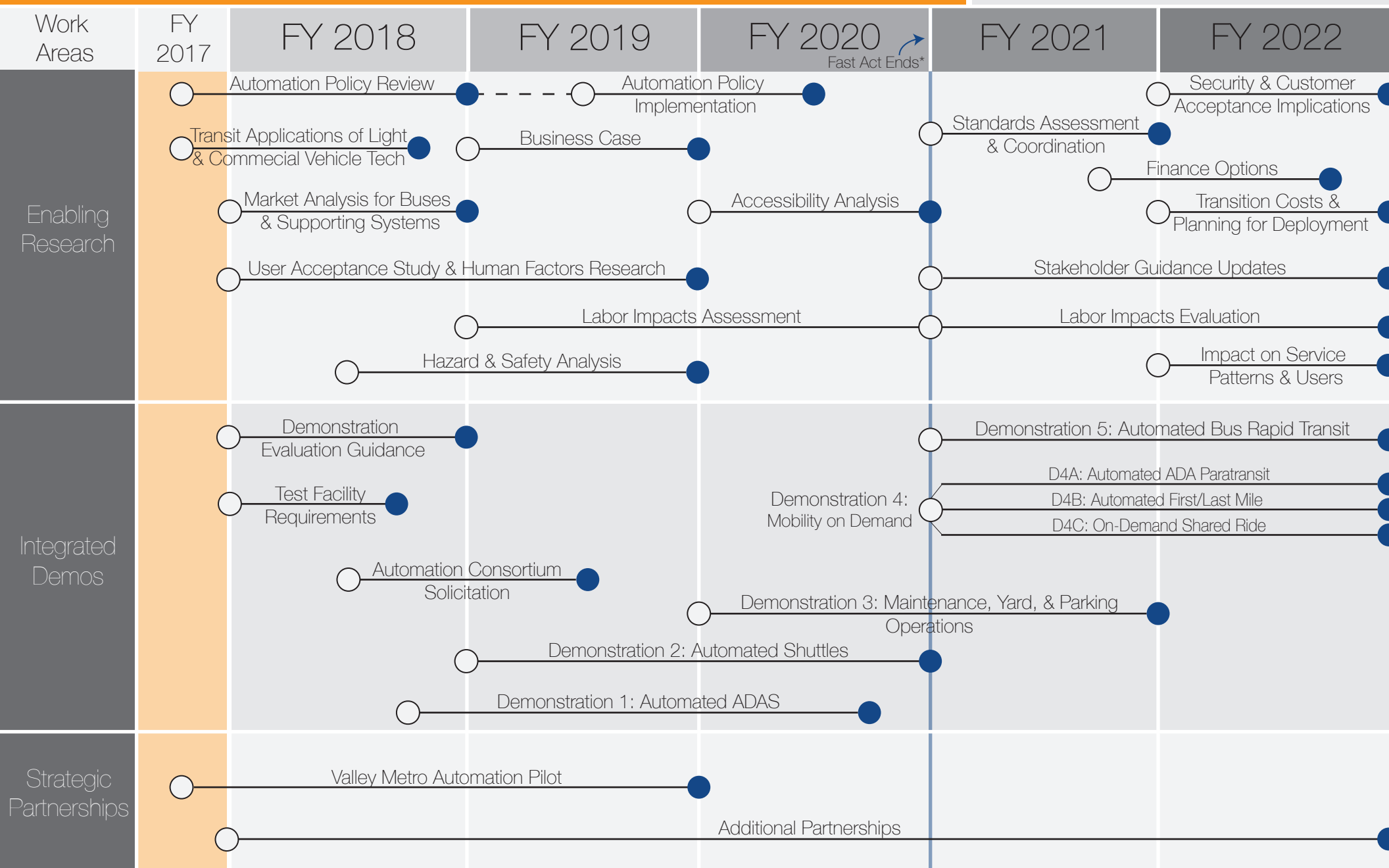
Coordination with Other Research Activities	
FHWA: Congestion Impacts	This project will model the potential impacts of automation on traffic flow and congestion in urban and suburban transit environments, likely using microsimulation tools.
ITS JPO: Data Governance	This project will analyze the legal framework related to data collection in automated transit vehicles, including questions of data ownership and gaps in existing regulations.
ITS JPO or NHTSA: Cybersecurity	This project will develop guidelines for transit agencies and vehicle manufacturers to help prevent un-secure pathways into automated vehicles and other cybersecurity threats. The project will build on NHTSA's "Cybersecurity Best Practices for Modern Vehicles" and other existing resources.
FTA: Multi-modal and Multi-provider Payment Integration Systems Research	Through an existing project to perform cross-cutting research, systems analysis, and stakeholder involvement on the challenges associated with advancing the Nation toward integrated multi-modal and multi-provider payment systems, complementary research on completely automated fare payment could be conducted.
FTA: Mobility-on-Demand (MOD) Program	The MOD Program supports transit agencies and communities as they integrate new mobility tools like smart phone apps, bike- and car-sharing, and ride hailing, micro transit, and innovative paratransit services. Shared mobility research conducted through the MOD Program will inform development of shared automation fleet concepts and demonstration.
ATTRI: Accessibility Technology	The Accessible Transportation Technology Research Initiative (ATTRI) is a multi-agency research program on advanced technologies. ATTRI's portfolio includes robotics and automation and future research could address automation accessibility needs identified by FTA.

Five-year Research Roadmap

The five-year research roadmap provides a graphical representation of the enabling research, integrated demonstrations, and strategic partnerships described in the STAR Plan.

Strategic Transit Automation Research Roadmap

Work Areas	FY 2017	FY 2018	FY 2019	FY 2020 *Fast Act Ends*	FY 2021	FY 2022

Enabling Research

- Automation Policy Review
- Automation Policy Implementation
- Security & Customer Acceptance Implications
- Transit Applications of Light & Commecial Vehicle Tech
- Business Case
- Standards Assessment & Coordination
- Finance Options
- Market Analysis for Buses & Supporting Systems
- Accessibility Analysis
- Transition Costs & Planning for Deployment
- User Acceptance Study & Human Factors Research
- Stakeholder Guidance Updates
- Labor Impacts Assessment
- Labor Impacts Evaluation
- Hazard & Safety Analysis
- Impact on Service Patterns & Users

Integrated Demos

- Demonstration Evaluation Guidance
- Demonstration 5: Automated Bus Rapid Transit
- Test Facility Requirements
- D4A: Automated ADA Paratransit
- Demonstration 4: Mobility on Demand
- D4B: Automated First/Last Mile
- D4C: On-Demand Shared Ride
- Automation Consortium Solicitation
- Demonstration 3: Maintenance, Yard, & Parking Operations
- Demonstration 2: Automated Shuttles
- Demonstration 1: Automated ADAS

Strategic Partnerships

- Valley Metro Automation Pilot
- Additional Partnerships

Knowledge Transfer, Stakeholder Engagement, & Technical Assistance