TRANSIT TECHNOLOGY PRIMER

FDOT

FLORIDA DEPARTMENT OF TRANSPORTATION

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Executive Summary

As the pace of technology adoption has increased in recent years, small and medium sized transit agencies have struggled to keep up with large transit agencies, which have the resources and expertise to meet with technology vendors, review products, and participate in organizations to remain abreast of existing and emerging technologies. Large agencies, however, have their own challenges of deciding which emerging technology to pursue, whether to be an early adopter, or on how the new technology will affect service delivery. This Transit Technology Primer and the accompanying Transit Technology Assessment Framework Tool (TTAFT) are intended to be resources for transit agencies in researching traditional and emerging transit technologies. This report is a synthesis of the policy and regulatory framework surrounding transit technology; past and ongoing research, prototype, and pilot efforts; commercially available products; and the experiences of transit agencies.

The report first defined transit technologies as the following categories:

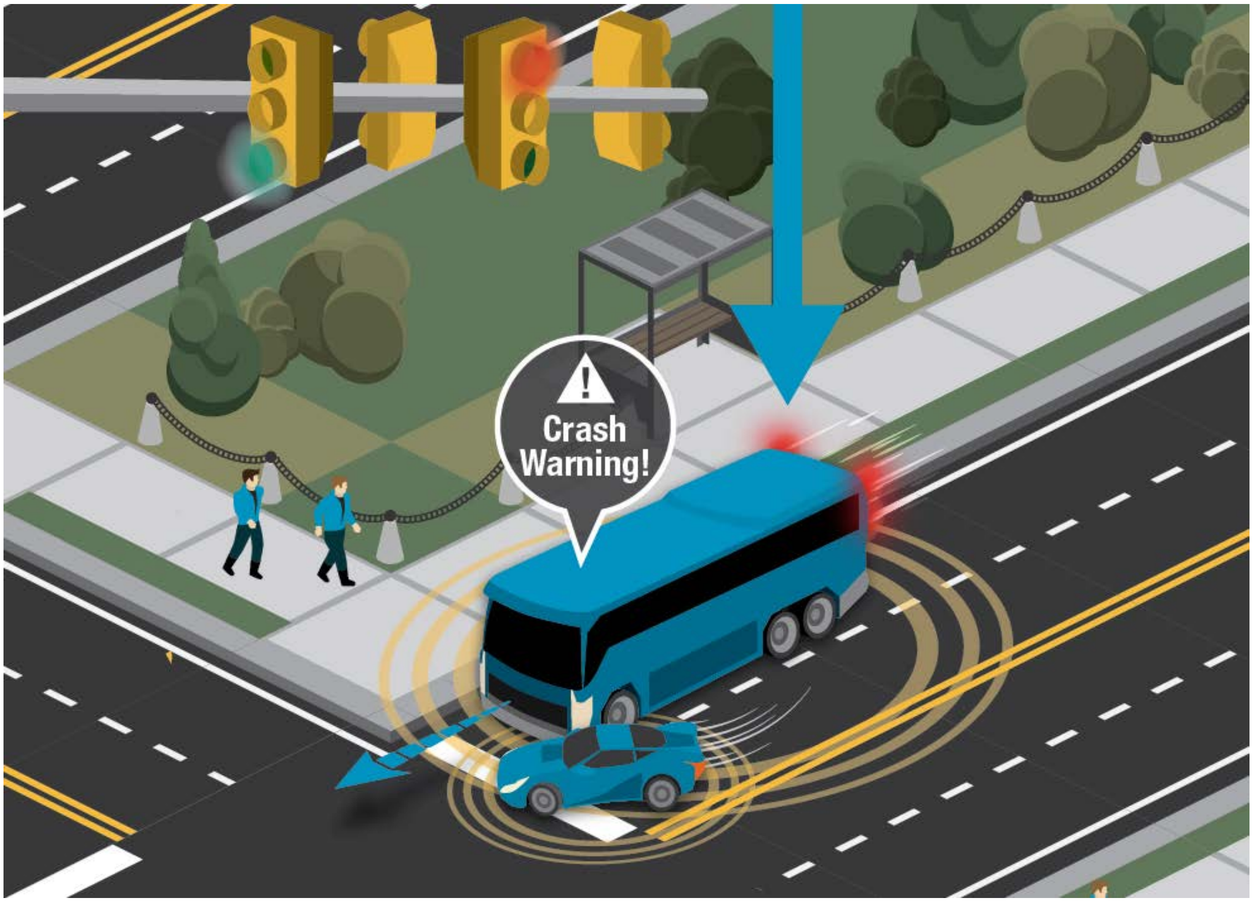
- **Safety** systems designed to reduce collisions with vehicles, cyclists, and pedestrians;
- **Mobility** enhancing technologies that increase access to transit options, and increase trips speed and travel time reliability while completing trips;
- **Accessibility** features and services that make trips easier for the elderly and travelers with disabilities;
- **Environmental** technologies that reduce fuel consumption and emissions;
- **Fare Collection and Processing** systems that enable easier payments across multiple modes;
- **Traveler Information** technologies that provide users with actionable trip planning options prior to and while completing transit trips;
- **Operations** systems that support transit agencies back office planning, operations and maintenance of transit systems and assets; and
- **Emerging Service Models** that may complement traditional transit service in the future.

These categories cover the majority of functions and activities performed by transit agencies in order to effectively and efficiently transport customers to the destinations.

Once the technology categories were defined, a review of the federal and state policy/regulatory environment was conducted. This review summarized both the supporting policies and programs, as well as identified potential barriers to technology adoption. While there is a significant amount of federal and state guidance on more traditional technologies (such as asset management, accessibility, mobility, and fare collection), the policy landscape for emerging technologies is rapidly shifting. Among the key findings is the need to revise the Federal Motor Vehicle Safety Standards to allow for the certification of autonomous vehicle (AV) technology and to address the uncertainty about whether connected vehicle (CV) technology will be mandated by the National Highway Transportation Safety Administration. While the exact timing of AV/CV

EasyMile EZ10 Gen-2 Vehicle

adoption is unknown, there are a number of Federal funding programs for these emerging transit technologies. Furthermore, Florida is seen as a national leader in transportation technology, by passing the nation's first regulation to legalize fully autonomous vehicles without a driver behind the wheel on roadways and supporting many AV/CV pilots. Florida is also one of the few states in the nation that regulates transportation network companies (i.e. Lyft and Uber) at the statewide level.



Tampa CV Application Pilot - Vehicle Turning Right in Front of Transit Vehicle

Since policymakers at the Federal level have struggled to keep pace with emerging technology, states have enacted a patchwork of legislation to help bridge the gap in the meantime. The following considerations are important for the Florida Department of Transportation (FDOT) to evaluate as it seeks to help Florida transit agencies deploy new technologies:

- Revisions to Federal Motor Vehicle Safety Standards is needed to ensure the AV industry grows with consistent safety requirements. In the meantime, exemptions to certain requirements at the state level are recommended to help microtransit vehicles enter pilot or permanent deployments within a given geographic boundary.
- Despite a large body of Federal research and standards on connected vehicle technology, uncertainty remains about the pending vehicle-to-vehicle communications requirement for new vehicles affecting future adoption rates, and the benefits to transit agencies, in jeopardy.

- Transportation technology provides numerous opportunities to meet the needs of elderly and those with disabilities while meeting various provisions of the Americans with Disabilities Act (ADA). Some of these technologies, however, remain in research and development stages, or are not yet cost-effective enough for small to medium transit agency to pursue.
- Both Intelligent Transportation Systems (ITS) and emerging autonomous/connected vehicle applications provide an unprecedented means of real-time monitoring of individual movements. While there are some privacy protections at the Federal level, states should consider passing additional private regulations.
- As emerging transit models enter the market to provide first and last mile service, state regulators should ensure that Transportation Network Companies (TNCs) policy remains flexible enough to account for the needs of local agencies while consistent enough to meet Federal law including ADA.

A literature review was conducted, which focused primarily on prototype and pilot efforts rathe than theoretical research. The United States Department of Transportation (USDOT) has for many years funded prototypes for transportation technology deployments through its ITS Joint Program Office. Subsequently, pilot projects, including the Tampa Connected Vehicle Pilot site, have sought to deploy multiple integrated technologies simultaneously. State and local agencies, with many in Florida, have also conducted research and pilot projects of their own. Jacksonville Transportation Authority (JTA), for example, has been making notable progress into the realm of AV technology. Since JTA's existing Skyway system is due for a complete overhaul, JTA officials decided to research alternatives to replace the monorail vehicles and evaluate future plans for expanding the Skyway system to surface level. JTA, ultimately, decided to invest in an AV system given the technology's capabilities, emerging trends, and overall financial savings of its integration. Unlike other transit modes, the AV system would allow vehicles to operate on the existing Skyway infrastructure and along existing roadways, reducing the need to construct additional infrastructure.

Florida is seen as a national leader in embracing transportation technology testing and deployment. FDOT's Transportation Systems Management and Operations Division administers the Florida Connected Vehicle Initiative. The connected vehicle initiative technologies include:

- **Wireless Communications**
- **Signal Phase and Timing (SPaT)**
- **Roadside Units (RSUs)**
- **On-Board Units**
- **Freight Signal Priority**
- **Transit Signal Priority**
- **Emergency Vehicle Preemption**
- **Vehicle Sensors**
- **Global Positioning System Navigation**

The initiative includes five planning projects, nine design and implementation projects, and one operational project. One of the innovative planning projects is the Central Florida Autonomous

Vehicle Proving Ground[1]. This project seeks to create the nation's premiere hubs for research and development of automated vehicle technology. It consists of multiple existing and planned facilities that will offer simulation at state-of-the-art universities, test tracks offering extreme environmental and controlled scenario testing, and open deployment on select roadways, among other capabilities. The remaining projects under this Division are spread throughout the state and shows FDOT's commitment to be on the cutting edge for transportation technologies.

USDOT, state DOTs, industry groups, and universities also have a number of ongoing programs with results that will shape future transit technology deployments. For example, the Federal Transit Administration's (FTA) Mobility on Demand (MOD) Sandbox program recently funded a set of partnerships between a taxi company, paratransit service, and car sharing company in St. Petersburg, FL to develop a model for on-demand, door-to-door paratransit service. Similarly the ongoing Advanced Transportation and Congestion Management Technology Deployment (ATCMTD) program has funded numerous ITS deployments in Orlando including the PedSafe, GreenWay, SmartCommunity and SunStore. Other states including Colorado (RoadX), Missouri (Road to Tomorrow), and California (Program for Advanced Technology for the Highway) have embarked on research programs of their own. Non-profit organizations and universities have similarly funded transit technology research and pilot projects, with the University of Florida leading one of the seven national University Transportation Centers.

To understand the impact of technology on the industry, outreach was conducted for a number of stakeholder groups: transit agencies within Florida, the ten largest transit providers in North America, and ten cutting-edge transit agencies[2] which provided a cross-section of the different types of transit agencies. The responding agencies summarized their experience with transit technologies with all indicated a desire to pursue new technology over the next five years. The majority of the respondents want to add mobile payments, provide on-board traveler information, and upgrade back end operations. About 30% of the respondents are evaluating autonomous vehicles to deploy in the near future.

A key finding, however, for the reason why stakeholders are not implementing new technology is the lack the adequate funding to purchase the product or not having a dedicated source to cover the recurring costs. Other reasons for not adopting new technology was not having a time sensitive plan or the resources to evaluate new technology. Following the survey, interviews with select stakeholders were conducted to further analyze agency approaches to pursuing transit technology. Vendors were also contacted to collect information about their products and how agencies have benefitted by using them.

This analysis illustrated the many challenges and benefits associated with the technologies and related projects. The challenges are caused by a lack of resources, technological limitations, cost of integration, concerns regarding cyber security and data management, or a lack of communication and data sharing amongst organizations. However, there are many benefits with investing in transit technology, such as increasing safety along roadways, providing greater mobility for disabled individuals across communities, and making transit systems more efficient

[1] http://centralfloridaavpg.com/

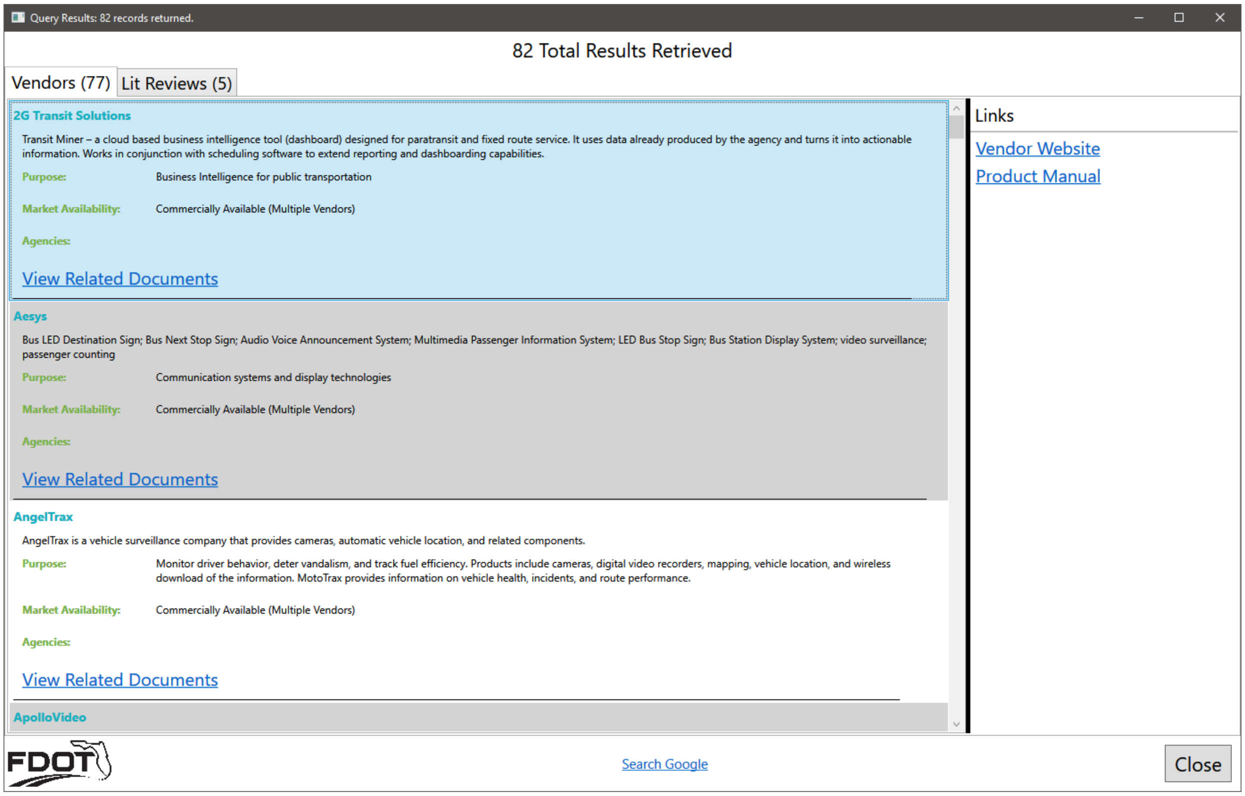
[2] https://smartasset.com/mortgage/best-cities-for-public-transportation;

through coordination and data sharing. There is a value of transit technology and how it can help agencies do more with available resources. To help overcome the challenges and help agencies implement transit technology, assistance is needed to navigating the process, identify funding opportunities, and summarize the benefits of these products for decision-makers. The accompanying TTAFT compiles all the information gathered into one location to provide this assistance. The TTAFT applies a consistent approach to categorizing technologies for review and research by the transit agency. The TTAFT will allow users to perform searches for products, ranging from the prototype stage through commercially available, from multiple vendors that meet the required search criteria.

The results of the technology search will allow agencies to compare technology options based on:

- Benefits;
- Costs;
- Time to implement;
- Market availability;
- Prior deployments;
- Data collection requirements; and
- Eligibility for federal funding.

Hundreds of commercially available products, as well as dozens of relevant research, prototype, and pilot studies from past and ongoing research have been compiled. The output provides a summary of technology vendors and research with links to where additional information may be found**.** By using this report and tool, transit agencies will have what they need to make informed decisions about what technology to pursue, how it will impact their system, and how to maximize its benefits.



Contents

Executive Summary i

Introduction 1

- Purpose of Project 1
  - Target Audience 1
  - Goals & Objectives 1
  - Report Organization 2
- Technology Categories 2
  - Safety 2
  - Mobility 3
  - Accessibility 3
  - Environmental 4
  - Operations 4
  - Fare Collection & Processing 5
  - Traveler Information 6
  - Emerging Service Models 7

Policies and Regulations Framework 8

- Autonomous Vehicles 9
  - Federal Regulations 10
  - State Regulations 12
  - Model Federal Guidance 13
- Connected Vehicles 13
  - Federal Regulations 13
  - Model Federal Guidance 14
- Accessibility 15
  - Federal Regulations 15
  - Model Federal Guidance 16
- Asset Management 18
  - Federal Regulations 18
  - State Regulations 19
- Reporting 19
  - Federal Regulations 19
  - State Regulations 20
- Data and Privacy 20
  - Federal Regulations 20
  - State Regulations 21

System Integration 21
Federal Model Guidance 21
Transportation Network Companies 24
Funding 25
Traditional Transit Funding Programs 25
Funding for Emerging Technology 30
Florida Funding Options for Alternative Fuels 31
Summary of Policy and Regulation Findings 32
Literature Review 35
Methodology 35
Scope of Search 35
Types of Sources 35
Overview of Findings 35
Early Stage Research and Prototypes 35
Pilot Projects and Commercially Available Technologies 41
Literature Review Summary 48
Ongoing Research Summary 50
USDOT Research Programs 50
Mobility on Demand (MOD) Sandbox Program 50
Accessible Transportation Technologies Research Initiative 52
USDOT Grant Pilot Programs 55
Connected Vehicle Regional Pilots 55
Smart City Challenge 57
Advanced Transportation & Congestion Management Technology Deployment 59
State DOT Research Programs 63
Florida 63
Research Program Examples from Other State DOTs 68
Industry Group and University Research 69
Bloomberg Philanthropies 69
Universities 71
Looking Ahead to New Ideas 72
Hyperloop 72
Aerial Personal Rapid Transit 73
Autonomous Flying Taxi 74
Summary of Ongoing Research 75

Stakeholder and Vendor Outreach 76

Methodology 76

Stakeholder Selection 76

Vendor Selection 82

Stakeholders 87

Outreach Strategy 87

Questions and Outreach Results - Stakeholders 89

Follow Up Interviews 90

Vendors 93

Outreach Strategy 93

Questions & Outreach Results - Vendors 95

Case Studies 95

Summary of Stakeholder and Vendor Outreach Results 100

Technology Assessment Framework 101

Review of Historical Technology Readiness Assessment Frameworks 102

Overview of a Transit Technology Assessment Framework Tool 104

Technology Categories 105

Type of Technology 106

In- or On-Vehicle 107

Roadside 107

Back-Office / Transportation Management Center 108

Acceptable Technology Readiness Level 108

Research Prototype 109

Pilot-Ready 109

Single Vendor Commercial Availability 110

Widely Commercially Available 110

Required Foundational Elements 110

Communication Systems 111

Infrastructure Systems 111

Staff Resources 111

Fiscal Resources 112

Output of Technology Options 112

Benefits 117

Costs 117

Time-To-Implement 117

Market Availability 118

Prior Deployments 118

Data Collection Requirements 118
Eligibility for Federal Funding 118
Vendor Abstract 118
Technology Assessment Framework Summary 119
Conclusion 121
Appendix A – Stakeholder Responses to Initial Survey A-1
Appendix B – Stakeholder Follow-Up Questions and Full Responses B-1
Appendix C – Vendor Responses C-1
Appendix D – Transit Technology Assessment Framework Tool User Guide D-1

Tables

Table 1: Regulation Key Findings 8
Table 2: Federal and State Responsibilities 10
Table 3: Connected Vehicle Applications 14
Table 4: Funding Options....26
Table 5: Summary Crosswalk to Technology Use Cases....47
Table 6: MOD Sandbox Grantees....51
Table 7: ATTRI Grantees....54
Table 8: ATCMTD 2016 Grantees 60
Table 9: ATCMTD 2017 Grantees 62
Table 10: Operating Budget Tiers....77
Table 11: Florida Transit Agencies 78
Table 12: Top 10 Transit Agencies by Ridership....80
Table 13: Cutting Edge Peer Cities....81
Table 14: Technology Vendors....83
Table 15. Summary of Test Readiness Levels to Assess Technologies 102
Table 16: Sample Technology Literature Review Abstract....113

Figures

Figure 1: TBEST Transit Planning Software 42
Figure 2: EasyMile EZ10 Gen-2 Vehicle 44
Figure 3: Contra Costa Autonomous Shuttle 44
Figure 4: Example using GIS to measure ridership 46
Figure 5: ATTRI Vision 53
Figure 6: New York City Connected Vehicle Pilot Deployment Program 56
Figure 7: Tampa Pilot - Vehicle Turning Right in Front of Transit Vehicle CV Application 56
Figure 8: Smart City Challenge Vision Elements 57
Figure 9: Smart Columbus Operating System 58
Figure 10: Florida Connected Vehicles Initiative Projects 64
Figure 11: Bloomberg Global Atlas of Autonomous Vehicle Projects - 2017 71
Figure 12: Hyperloop One Prototype Vehicle 73
Figure 13: skyTran Prototype Vehicle 74
Figure 14: Transit X Prototype Vehicles 74
Figure 15: UberAir's eVTOL Prototype Vehicle 75
Figure 16: FDOT Email to Transit Agencies 88
Figure 17: Email to Vendors 94
Figure 18. Overview of Transit Technology Assessment Framework Tool 105
Figure 19: Technology Category 106
Figure 20: Type of Technology 107
Figure 21: TTAF Acceptable Technology Readiness Levels 109
Figure 22: TTAFT Required Foundational Elements 111
Figure 23: TTAFT Output of Technology Options 113

INTRODUCTION

Introduction

Purpose of Project

Transportation technologies are changing on a daily basis with new technologies emerging all the time. Technologies once considered state of the art only a few years ago are reaching obsolescence or being surpassed by improve products. At the same time, transit agencies need to adopt established, proven technologies that have a definable benefit to improve the operation, efficiency, and customer experience of the transit system. Agencies should be diligent to make sure that whatever technology they adopt is stable and provides tangible benefits compared to the costs of the technology.

Transit agencies are at the forefront of the emergence of transportation technology. For example, new optical, radar, and Light Detection and Ranging (LiDAR) equipment for the detection of pedestrians and bicyclists has only recently been introduced to the market, but has quickly become a “must have” component for transit agencies. Large transit agencies have the resources and internal staff expertise to meet with technology vendors, review products, and participate in organizations to remain abreast of existing and emerging technologies. They also need assistance in evaluating emerging technology, deciding whether or not to be an ‘early adopter’, and identifying non-traditional funding opportunities Small to medium sized transit agencies, whose need is just as great, may not have the same level of access to resources and are reliant upon published literature and ‘word-of-mouth’ information exchanges. This yields a paradigm where the large agencies predominate as ‘first adopters’ with the other agencies being ‘late adopters’, who may not realized the full benefit of the technology..

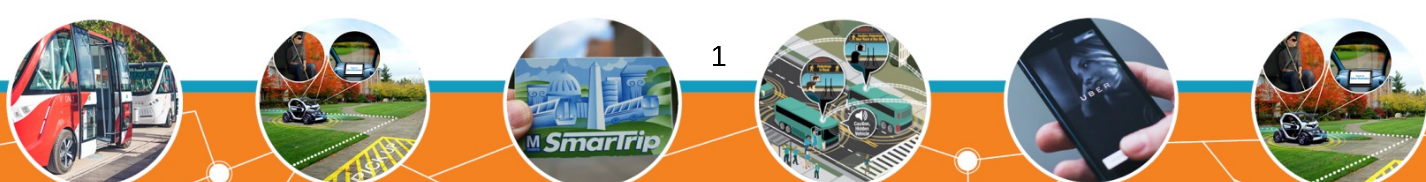
The purpose of this project is to help all agencies improve operations through implementation of appropriate technologies, particularly within the gap between the rest of the industry. By compiling information from literature, conferences, and direct interaction with transit agencies and vendors an interactive Transit Technology Primer (Primer) has been developed. Primer is comprised of a series of technical memorandums that provide background research, stakeholder outreach, and a technology assessment framework, as well as an innovative tool to communicate the information gathered and analyzed during this project.

Target Audience

The target audience are transit agencies located within the State of Florida and other agencies across the country. While the report serves as a clearinghouse on current technologies to help small to medium sized transit agencies learn about what is on the market, large, urban agencies will also benefit through the summary and analysis of emerging transit technologies discussed in this report, such as autonomous vehicles, real-time vehicle diagnostics, and mobility applications. Transit agencies will be able to use this report and the accompanying Transit Technology Assessment Framework Tool (TTAFT) to learn about what is currently on the market, the state of emerging technologies, available vendors, and case studies. All of this information will be helpful as transit agencies prepare capital budgets and technology plans to improve system efficient and customer service.

Goals & Objectives

The goal of the Primer is to help demystify the established, new, and emerging technology available to transit agencies. This is accomplished through summarizing the current transit technology landscape, highlighting new and emerging technology trends, and providing tools for transit agencies to conduct further research. Specific objectives of this Primer are:



- Develop a Transit Technology Primer that can serve as a basis or framework for describing, classifying, and assessing the readiness of a wide variety of transit technologies; and
- Develop general guidance on transit technology assessment and evaluation.

This Primer and TTAFT meets the goal and objectives by providing information on current, new, and emerging transit technology as well as additional information on regulations, funding options, and case studies to help transit agencies make decisions on what products to pursue.

Report Organization

After defining the technologies evaluated for the Primer, the rest of the report consists of the following sections:

- Transit Technology Policy and Regulations – Summarizes the Federal and State Policies and Regulations associated with the use of transit technology. Provides funding strategies for implementing transit technology;
- Literature Review – Provides an overview of transit technology projects at different stages of development, including projects at early research stages, prototypes, and pilot projects;
- Ongoing Research Summary - Overview of the ongoing research activities and technology trials relevant to transit;
- Stakeholder and Vendor Outreach - Summarizes the outreach efforts to transit agencies (stakeholders) and vendors and provides an analysis of their responses; and
- Technology Assessment Framework - Provides an overview of technology assessment methodologies and how they might be utilized for transit technology.

Each section is a separate technical memorandum that may be printed and used independently of the full report.

Technology Categories

The following are the technology categories used in the development of the Primer and TTAFT.

Safety

Safety systems are designed to reduce collisions with vehicles, cyclists, and pedestrians as well as provide personal safety for passengers. To accomplish this, different technologies exist to enhance safety within the transportation system. Traditional safety technology is either an active system with direct monitoring at a central hub or a passive system where the technology surveys the environment and provides notification only if there is a problem. On the emerging technology front, autonomous and connected vehicle technologies have the potential to decrease human error and replace it with different levels of autonomy with built-in safety protocols. Smart transportation infrastructure also provides information to ensure that all users of the system are aware of accidents, incidents, or other disruptions.

Traditional transit safety technology includes monitoring of the system and environment to provide warnings if obstacles are detected. Cameras, vehicle diagnostic systems, and supporting infrastructure provide active monitoring of the system and report information for review and action back to a central hub. Other systems scan the space surrounding the transit vehicles to deliver warnings to the operator or other individuals when the system detects an unsafe action or conditions.

Mobility

Mobility technologies increase access to transit options, increase trip speed, and improve travel time reliability. Mobility is defined as the ease of movement of people and goods within a transportation system. As it relates specifically to transit, mobility corresponds to the level of freedom people have to use the transit system to meet their daily needs. Technology impacts mobility through improving the efficiency and safety of the system.

There are many emerging technologies that have the potential to increase mobility – one example can be seen in USDOT's Integrated Dynamic Transit Operations (IDTO) project[3]. This technology includes several smartphone applications that would increase accessibility of users to transit providers. Applications under IDTO include Connection Protection (T-CONNECT), Dynamic Transit Operations (T-DISP), and Dynamic Ridesharing (D-RIDE) – each application is designed to enhance coordination between riders and transit services to improve accessibility to transit options and service efficiency through the use of cellular technology. These applications increase the accessibility to accurate transit data and ultimately mobility services.

There are also some challenges associated with integrating transit technologies through the use of smartphones. Some people may not be able to afford smartphone data plans to utilize mobility apps, and many rural areas are not located in areas to benefit from transit providers.

Mobility technologies can relay real-time information about the entire system through various sensors in surrounding vehicles and/or infrastructure. Transit providers can use this information to make quick decisions to respond to incidents such as detours, dispatching additional resources, and/or customer notifications in order to improve the travel options and experience for passengers.

Accessibility

Accessibility features and services are those that make trips easier for older adults and travelers with disabilities. Customer-facing technologies are those hardware and software packages that focus on improving the ease of seniors and disabled individuals to interact with and access the system. Traditional technologies that fall into this category include but are not limited to: trip reservation systems, stop announcements, and audible signals. Emerging customer-facing accessibility technologies include the introduction of interactive wayfinding technologies for persons with disabilities and older adults as well as other assistive information devices.

Accessible Transportation Technologies Research Initiative (ATTRI) is one program used to increase accessibility throughout transit services[4]. This project seeks to enhance mobility for people with disabilities through the use of emerging technologies. Some of the technologies that

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[3] USDOT, "Integrated Dynamic Transit Operations (IDTO) Concept of Operations," MAY 2012, https://ntl.bts.gov/lib/54000/54000/54067/12-083.pdf

[4] ATTRI, "Accessible Transportation Technologies Research Initiative (ATTRI) User Needs Assessment: Stakeholder Engagement Report," MAY 2016, https://ntl.bts.gov/lib/60000/60100/60128/FHWA-JPO-16-354.pdf

may be used to improve accessibility include wayfinding and navigation applications, V2V/V2I technology, real-time trip planning services, intelligent transportation systems (ITS), assistive technology, one-fare payment applications, automation, robotics, data integration, and enhanced human services transportation. Implementing these technologies can improve quality of life by providing greater accessibility to seniors and people with disabilities.

Environmental

Environmental technologies reduce fuel consumption and emissions. They are designed to improve the operational efficiency of the system to reduce greenhouse and carbon gas emissions. In its basic form, environmental technology options consist of improving overall fuel economy through more efficient engine designs and lighter vehicles, reduced particulate pollution through advancements in catalytic converters, and alternative fuel vehicles. Emerging environmental technologies focus on improvements to the overall transportation network through vehicle-to-infrastructure communications. Specifically, eco-signal preemption/priority applications evaluate traffic and environmental parameters at each intersection in real time and adapt to ensure the traffic network is optimized using available green time to serve the actual traffic demands while minimizing the environmental impact[5].

Traditional environmental technology applications in transit focus primarily on addressing the environmental impacts associated with the transit vehicles. Transit vehicles are more efficient than personal vehicles transporting the same number of people along a corridor. A full bus takes at least forty vehicles off the road and is more fuel efficient than seven personal automobiles. Overall, transit vehicles today are much cleaner and more efficient than previous design iterations. New emission standards and fuel economy requirements for transit vehicles have resulted in a significant reduction in the amount of pollution they produce.

This does not stop the transit industry from exploring and implementing alternative fuels to achieve greater efficiency and reduction in the environmental impact of the transit system. An alternative fuel vehicle is a vehicle that runs on substances other than the conventional petroleum gas and diesel. Examples of alternate fuels include electric, solar, biodiesel, ethanol, propane, compressed air, hydrogen, liquid natural gas, and liquid petroleum[6]. Currently, alternative fuel vehicles are primarily either compressed natural gas or electric. Some agencies, however, have explored using biodiesel to power transit. An example of this is an intercity bus in the United Kingdom that runs on biodiesel generated from the treatment of sewage[7].

Operations

Back-office operations systems support transit agencies in planning, operating, and maintaining their transit systems and assets. Back-end operations hardware and software packages focus on

[5] https://local.iteris.com/cvria/html/applications/app21.html

[6] http://whatis.techtarget.com/definition/Alternative-fuel-vehicles-AFV

[7] http://money.cnn.com/2014/11/24/technology/bus-poo-environment/index.html

providing and analyzing relevant information to transit agencies to help them to do their job more effectively.

For example, Mobile Data Terminals (MDTs) are tablet sized computers placed on transit vehicles to provide the operators information about their transit run and/or trip itinerary. These devices communicate in real-time to a central dispatch where dispatchers may see where the vehicle is, be notified of any deviation to its schedule, and change the route and/or trip itinerary for the operator in response to changing conditions such as detours, trip cancelations, or new trip reservations. It replaces the paper manifests with a dynamic trip itinerary that plans the route of the operator more efficiently. Scheduling software uses information on the system to plan runs based on user-defined operators. This provides for more efficient scheduling of staff than what is allowed through traditional pen and paper approaches.

Another example is maintaining the paratransit customer records and trip itineraries to prepare and submit the proper invoices to service providers and/or seek reimbursement from federal/state grants. In addition, transit agencies are required to maintain a record of customer complaints on the operation of the paratransit system as a means to identify deficiencies and plans for improvement. Invoicing, billing, and reporting software keeps track of the required information and may also create the necessary bills, invoices, and reports at regular intervals for service providers, decision makers, and program auditors.

Better route planning, efficient trip invoices, comprehensive reports, and timely processes are all benefits of implementing these back-end technologies. There are significant costs associated with implementing these programs. They should be implemented as part of an organization technology plan due to their potential to integrate with other parts of transit operations.

Fare Collection & Processing

Fare Collection and Processing refers to systems that enable payments for transportation services. Advancements include payments that are seamless and easy across multiple modes, as well as enhanced access for unbanked households.

Transit fare payment is the compensation provided by the customer in return for use of the service. Fares are either paid on the transit vehicle or at the transit station/stop/terminal prior to boarding the vehicle. They began with a cash lockbox on the transit vehicle where proper payment is visually verified by the transit operator or passes purchased at manned ticket booths where validation is done by separate conductors on the vehicles. The cash-based systems limit fare options to one-way passes with or without transfer tickets, with some systems offering multiple-ride tickets verified by manual hole punches. As technology improves, cash lockboxes are being replaced with smart fare boxes that include automatic bill/coin validators and bus pass readers via magnetic strip, smart chip, and/or radio frequency identification devices (RFID). Depending on the chosen system, the customer may interact with a small Quick Response (QR) Code or Near Field Communication (NFC) device, speeding up the boarding process compared to traditional methods of accepting cash payments.

A major benefit of upgrading fare systems is improved efficiencies and decreased passenger delay at transit stops. The major drawbacks are the back-end support programs that must be added to implement a smart fare system and the challenges associated with encouraging customers to use a new fare type. Traditional fare technologies revolve around upgrades to the farebox and the fare options they provide. Emerging technologies reduce the need for a farebox through the use of mobile smartphone applications and regional interoperability with other transit agencies.

Technology opens the door to new fare types such as unlimited-ride or value-added cards, where customers can choose the amount of fare they want to purchase. Biometric fares may even allow a customer to pay with their face. Fare technologies improve the efficiency of the system by replacing single ticketing booths to multiple ticket vending machines and reduction of passenger delay at transit stops by speeding up the customer interactions with the fareboxes. In addition to quicker and easier transit boarding, emerging processes for fare collection open up the potential for seamless integration of mobility services across multiple modes and providers.

Traveler Information

Traveler Information technologies provide users with actionable trip planning options prior to and while completing transit trips. Traveler Information for transit systems focuses on providing front facing applications and programs to help customers navigate the fixed-route or paratransit system. The goal is to provide reliable and accurate systems that enable customers to plan their trips and know when their bus is coming. Traditional technology employed by transit agencies in this space includes trip planning software, trip reservation programs, and real time location. In addition, it includes automatic stop announcements on the bus. Traveler information is provided through geographic position system (GPS) based technology with the information relayed to supporting applications that distribute it to customers through websites, digital displays at stops/stations and smartphones. Emerging technology integrates the traveler information with the connected vehicle infrastructure to improve the accuracy of the information as it relates to real-time traffic information and broadcasts the information directly to the customers.

For a transit agency to instill customer trust, it must be able to provide accurate and reliable information to their customers on where the bus is and where the bus is going. Traditionally, this was done with the production of print materials (Ride Guides) to provide the bus route information to customers. Due to size limitations, the ride guides usually contain streamlined descriptions of the routes with arrival times at only key bus stops along the route. The first application technology moved this information from the printed ride guides to agency websites which usually suffers from the same size limitations.

Trip planning programs changed all of this by using GPS information contained in scheduling software used by transit agencies. First developed by Google, General Transit Feed Specification (GTFS) provided the standard format to display scheduling and runcutting outputs used by transit operations in a customer-friendly format. Now, customers could plan transit trips from their house to their destination in the same way people would use mapping programs (such as MapQuest) to get over-the-road directions. This eliminated some of the confusion associated with transit, and opened the door for new riders to try the system.

While trip planning software laid the foundation to demystify transit, automatic vehicle location makes the system easier to use. Real-time vehicle location uses either information provided by MDTs or standalone devices to track schedule adherence to show customers where their bus is and when it is expected to arrive at their location. With this technology, customers are no longer bound to the ride guide or even trip planners to prepare their itineraries and are allowed to be more spontaneous in using transit. Real-time bus locations provide more freedom in using transit by allowing customers greater flexibility regarding when they need to leave their location to arrive at their bus stop. It also quickly provides customers information on any delays, detours, or other obstacles affecting the operation of the system. In current applications, real-time bus location is available online, in smartphone applications, and at bus stops on variable message boards.

Emerging Service Models

Emerging Service Models refers to new technologies that are giving rise to service that may complement traditional transit. One technological trend that has been growing in recent years is the rise of shared mobility providers. Shared modes of transportation include rail, bus, bike-sharing, car-sharing, and ridesourcing. Ridesourcing companies, such as Lyft and Uber, offer an efficient way for people to travel when other transportation options may not be feasible. Car-sharing companies, such as car2go and Zipcar, offer an opportunity for people to freely use a rented automobile without the commitment of owning a personal car. Additionally, bike-sharing companies offer an opportunity to resolve first- and last-mile gaps while promoting healthy and sustainable mobility solutions.

Shared mobility services can often be utilized and scheduled through the use of mobile apps, which increases accessibility for a wide range of consumers. While data is limited, shared modes of transportation have the potential to provide multiple benefits, such as reducing overall transportation costs, complementing existing public transit services, and resolving many first- and last-mile gaps, which ultimately increases overall mobility in communities. As the use of shared mobility technology continues to become more integrated in society, continued coordination between public and private agencies appears inevitable. Many organizations are also hoping to improve mobility options for transportation disadvantaged populations, and improving paratransit services through emerging transit service models is a viable option for agencies.

POLICIES AND REGULATIONS

Policies and Regulations Framework

The purpose of this section is to provide an overview of the current regulatory and policy framework as it relates to transit technology.

One challenge in evaluating transit technology regulations within this framework is that policies do not cleanly align around use cases; rather, regulations tend to span multiple use cases. For example, connected vehicle technology may have implications that span across multiple use cases:

- Vehicle-based safety systems;
- Signal technology that enables enhanced mobility and decreased emissions;
- Front-facing traveler information applications; and
- Back office-facing operations support.

For the purposes of this document, policy and regulations are grouped according to the existing structure of Federal and state laws, utilizing the following break-down:

- Autonomous vehicles;
- Connected vehicles;
- Accessibility;
- Asset Management and Reporting;
- Data and Privacy;
- Integration;
- Transportation Network Companies; and
- Funding.

This document presents findings related to each of the above policy categories, with discussion of some or all of the following subtopics: Federal regulations, state regulations, and model guidance. A summary of the findings is provided in **Table 1**.

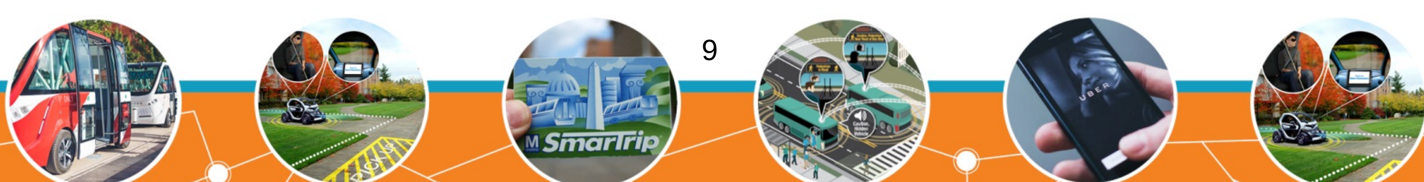
Table 1: Regulation Key Findings

Category	Key Findings
Autonomous Vehicles (Federal Regulations)	Certain Federal Motor Vehicle Safety Standards (FMVSS) requirements as currently written present challenges for the certification of new autonomous vehicles (AVs) and autonomous vehicle systems as they include definitions for vehicle "drivers" among other language. However, vehicle manufacturers are able to seek exemption on a case-by-case basis from NHTSA.
Autonomous Vehicles (State Regulations)	Florida passed the nation's first regulation that legalized fully autonomous vehicles on roadways, and is seen by many in the industry as a leader in AV state policy.
Autonomous Vehicles (Model Federal Guidance)	NHTSA recently released its *Automated Driving Systems 2.0: A Vision for Safety* to encourage new entrants to the AV market, make regulatory processes more nimble, and to clarify USDOT's opinion on the differences in State and Federal jurisdiction for highly autonomous vehicles.

Category	Key Findings
Connected Vehicles (Federal Regulations)	There is uncertainty about whether NHTSA will mandate vehicle-to-vehicle communications, which may impact the connected vehicle user base, and potential effectiveness of vehicle-to-vehicle connected vehicle applications on transit vehicles. Also, the Federal Communications Commission has indicated that they may release the dedicated 100 MHz within the 5.9GHz spectrum currently reserved for transportation for mixed use.
Connected Vehicles (Model Federal Guidance)	USDOT has deployed a number of connected vehicle applications through its prototyping and pilot efforts. These efforts have resulted in a substantial volume of Federal guidance on implementing vehicle-to-infrastructure connected vehicle technology.
Accessibility (Federal Regulations)	Technology is key to meeting requirements for travelers with disabilities under the Americans with Disabilities Act 49 CFR Part 38, Subpart G. Guidance is given in Federal Transit Administration circulars for creating accessible websites, announcing bus stops, scheduling paratransit trips, and tracking complaints.
Accessibility (Federal Guidance)	Technology helps to remove or lessen mobility barriers for those with disabilities. If implemented correctly, it can provide information, travel options, access, and assistance to help those with disabilities meet their transportation needs.
Asset Management (Federal Regulations)	Under the Fixing America's Surface Transportation Act, transit agencies are required to track, report, and maintain their assets. Emerging technology may supplement programs that help agencies write and implement their Transit Asset Management Plans.
Data and Privacy (Federal Regulations)	The E-Government Act of 2002 requires Federal agencies (also applicable to recipients of Federal funds) to conduct a privacy impact before developing or obtaining technology that collects, maintains, or disseminates identifiable information.
Integration (Model Federal Guidance)	USDOT has set forth guidance to ensure that transportation technology projects follow a rigorous systems engineering process and comply with regional data architecture standards.
Transportation Network Companies (State Regulations)	Unlike most states, Florida regulates Transportation Network Companies (TNCs) such as Uber and Lyft at the statewide level. TNCs may play a role in emerging transit service models.
Funding (Emerging Technology)	Beyond traditional transit funding programs, USDOT provides competitive funding for emerging technologies. FDOT has enabling legislation to offer a state grant program, though it is not yet funded. Transportation technologies are allowable cost components of most of the large Federal grant programs including CMAQ, TIGER, and INFRA.

Autonomous Vehicles

There are numerous examples of autonomous vehicles (AVs) operating on public roads from companies covering a range of industries: most automotive manufacturers are testing a range of autonomous vehicle technology to offer as a feature on personal vehicles; transportation network companies such as Uber and Lyft are piloting autonomous rideshare concepts; and technology



companies such as Waymo (Alphabet) and Apple are tapping into their technology product experience to develop autonomous driving solutions.

Within the transit sector, a number of companies such as EasyMile and Navya have AV microshuttle vehicles in circulation today. Additionally, companies such as Daimler and Proterra are developing fully autonomous bus prototypes. These examples typically operate in highly controlled environments and often require a human operator on board as a fallback. Within the microshuttle space, however, transit agencies and municipalities are increasingly exploring permanent deployments in mixed traffic scenarios.

Federal rulemaking authorities have had difficulty establishing the flexible, yet comprehensive, regulatory framework needed to support continued autonomous vehicle development due to the speed of technological advancement within the industry. States, meanwhile, have responded with a patchwork of enabling AV legislation, sometimes in an effort to entice companies to test AVs in their states. Generally speaking, Federal legislation regulates vehicle safety, while states are responsible for registering vehicles and licensing drivers. However, with autonomous vehicles, the lines between licensing "drivers" and vehicle safety systems have become blurred. **Table 2** below[8] elaborates on these roles.

Table 2: Federal and State Responsibilities

Federal Responsibilities	State Responsibilities
• Setting Federal Motor Vehicle Safety; Standards (FVMSSs) for new motor vehicles and motor vehicle equipment • Enforcing compliance with FMVSSs; • Investigating and managing the recall and remedy of noncompliance and safety-related motor vehicle defects nationwide; and, • Communicating with and educating the public about motor vehicle safety issues.	• Licensing human drivers and registering motor vehicles in their jurisdictions; • Enacting and enforcing traffic laws and regulations; • Conducting safety inspections, where States choose to do so; and, • Regulating motor vehicle insurance and liability.

Federal Regulations

FMVSSs define the design and safety requirements for vehicles offered for sale in the United States. In the long term, these standards will require modification to allow for fully autonomous vehicles to meet FMVSS standards. For example, FMVSS currently requires that turn indicators be visible to other drivers; yet there may be more effective ways to indicate to the machine vision of an autonomous vehicle that a vehicle intends to turn. In a scan of the 73 standards specified by FMVSS, the following potential challenges were found:[9]

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[8] https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf

[9] https://ntl.bts.gov/lib/57000/57000/57076/Review_FMVSS_AV_Scan.pdf

- 33 of 73 FMVSSs may present certification challenges for certain types of automated vehicles because they contain references to a driver.
- 32 of 73 FMVS's may present certification challenges for certain types of automated vehicles because they contain performance specifications, test procedures, or equipment requirements that present potential barriers to the certification of one or more AV concepts. These types of conflicts generally fall into the following categories:
  - The vehicle must communicate information to the driver in a specific way;
  - The standard requires that the vehicle provide switches, or other means of operating certain parts of the vehicle, to a human driver;
  - The driver must be able to observe the outside environment with the arrangement of furnished equipment;
  - The driver position or physical state is in a standard definition or required test.
  - Specified control forces for equipment are based on human factors;
  - Characteristic(s) of autonomous vehicle concept violate(s) a safety standard;
  - Other.

The National Highway Transportation Safety Administration (NHTSA) recognizes that further rulemaking will be necessary, but in the meantime has issued policy guidance for autonomous vehicles (see additional discussion on *Automated Driving Systems 2.0: A Vision for Safety* below). One workaround in the meantime is for entities testing AV technology to apply for an exemption from certain FMVSSs. Currently, NHTSA can exempt up to 2,500 vehicles in a 12-month period from FVMSSs. The SELF DRIVE Act (H.R. 3888), passed by the House of Representatives with bipartisan support and awaiting action by the Senate, proposes to lift this exemption for autonomous vehicles to 25,000 vehicles in the first year; 50,000 vehicles in the second year; and 100,000 vehicles in the third and fourth years.[10] Beyond this exemption, SELF-DRIVE will establish the following:

- A timeline for Federal regulatory action, requiring that within 24 months of passage the Secretary of Transportation issue a final rule requiring the submission of safety assessment certifications regarding how safety is being addressed by each entity developing a highly automated vehicle or an automated driving system.
- Preemption of state and local governments from prescribing the design, construction, or performance of autonomous vehicles, automated driving systems, or components of automated driving systems unless such law or regulation is identical to the Federal standard.

If passed, this would represent the first national law that expressly regulates autonomous vehicles.

One key emerging technology of interest for transit agencies is autonomous microshuttle vehicles. With respect to autonomous microshuttles, one interim approach is to classify this vehicle type as a "low-speed vehicle," which would make it exempt from certain Federal standards (similar to the approach taken for golf carts operating below 25 miles per hour). However, as written, these regulations limit gross vehicle weight to 3,000 pounds. By comparison, an autonomous microshuttle typically weighs more than twice this weight. However, transit agencies such as

[10] https://www.insurancejournal.com/magazines/features/2017/10/16/467087.htm

Contra Costa Transportation Authority, the Regional Transportation Commission of Southern Nevada, and others have applied for and received NHTSA exemptions from FMVSSs. Many others, including the Jacksonville Transportation Authority and the Hillsborough Area Regional Transit Authority in Florida, are at varying stages of seeking FVMSS exemptions for planned autonomous microshuttle pilot projects.

State Regulations

Autonomous vehicles are being driven by private industry and are quickly moving into the market. According to the National Council on State Legislatures twenty-one states—Alabama, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Illinois, Louisiana, Michigan, New York, Nevada, North Carolina, North Dakota, Pennsylvania, South Carolina, Tennessee, Texas, Utah, Virginia and Vermont—and Washington D.C. have passed legislation related to autonomous vehicles. Further, “Governors in Arizona, Delaware, Massachusetts, Washington and Wisconsin issued executive orders related to autonomous vehicles.” Much of this legislation involves requirements on the performance expectations and testing needed for an autonomous vehicle manufacturer to operate vehicles on public roads in their respective State. However, some states, such as Michigan, have essentially created an “open door” policy for autonomous vehicle manufacturers, based in part upon the state’s existing relationships with automotive manufacturers and past precedent for on-road testing.

In 2012, Florida passed the HB 1207 Bill which announced its decision to promote the development of AVs on public roadways.[11] This Bill also asked the Department of Highway Safety and Motor Vehicles to create a report recommending how the state should approach AV regulations. Later in 2012, the HB 599 Bill was passed – the AV-related policies of this Bill are identical to the policies stated in HB 1207.

In 2016, the HB 7027 Bill was passed, which removed the requirements that AV operation would be completed for testing purposes and that a human driver needed to be present throughout its operation. Later in 2016, the HB 7061 Bill was passed, which defines autonomous technology and driver-assistive truck platooning technology. It also requires a study on the operation of truck platooning technology and allows for the implementation of a pilot project once the study is complete. The HB 1207 Bill[12] defined ‘autonomous vehicle’ and ‘autonomous technology’ – it encouraged safe development, testing, and operation of AVs on public roads. This Bill authorized people with driver’s licenses to operate AVs and required drivers to have insurance prior to operating an AV.

Florida’s HB 7027 Bill was the nation’s first regulation that legalized fully automated vehicles on roadways without a driver behind the wheel. Since Florida was the first state to pass this legislation, it will become the model as other states begin to regulate AV policy as well. Unlike other states, Florida has consistently competed to become the leader in AV regulation since 2011, predominantly due to the numerous benefits AVs potentially offer.

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[11] http://www.govtech.com/fs/How-States-Are-Legislating-Autonomous-Vehicles-Interactive-Map.html
[12] http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx

California adopted regulations in 2012 which allowed for the testing of AVs on public roads. Companies are required to apply for state permits and put up a $5 million bond in order to test AVs. Approximately 20 companies have been granted these permits. While California has strict laws regarding the operation of AVs, Florida has some of the least restrictive AV regulations compared to the states that have begun regulating AVs. Since Florida laws treat AVs like any other vehicle operating on roads and there are no permits required, the state doesn't have any information regarding how many Floridians own an AV.

Model Federal Guidance

The legislative and policy landscape for autonomous vehicles is changing and potentially changing rapidly. In September of 2017, the NHTSA issued their second version of guidelines related to highly autonomous vehicles titled *Automated Driving Systems: A Vision for Safety 2.0*. This guidance document sets forth NHTSA's interpretation on roles and responsibilities between Federal and State agencies as well as defines terms and conditions associated with performance characteristics of highly-autonomous vehicles including defining the "Operational Design Domain," the "Object and Event Detection" and "Fallback position." Additionally, the guidelines provide 12 safety priority elements and a voluntary self-assessment for manufacturers. In this guidance document, NHTSA suggests Best Practices for States Regulatory Actions as well as a division of responsibilities between the Federal and State governments.

Connected Vehicles

Federal Regulations

The United States Department of Transportation (UDSOT) has been developing connected vehicle concepts, prototypes, and real-world deployments for more than a decade. As it pertains to their program, the term "connected vehicle" refers to a dedicated short-range communications (DSRC), a point-to-point communications protocol that utilizes the 5.9 GHz band reserved for message exchange among vehicles, infrastructure, and other enabled devices. Since the passage of the Transportation Equity Act for the 21st Century, the Federal Communications Commission (FCC) has maintained oversight of the maintenance of this bandwidth for intelligent transportation systems purposes as well as technical rules guiding DSRC operations. As state and local agencies deploy infrastructure and vehicle-based DSRC units, it is important to keep in mind that the FCC must license these units under Part 95 of their rulemaking statute.

Agencies and automakers are now watching USDOT as it considers action to require inclusion of DSRC radios on newly manufactured vehicles. In late 2016 NHTSA released proposed rulemaking to require vehicle-to-vehicle (V2V) communications using DSRC, including the following:

- A definition of the communication technology;
- Connected vehicle message format and communication protocols;
- DSRC spectrum use;
- Connected vehicle message authentication;
- Misbehavior detection and reporting;
- Cybersecurity; and

- Consumer privacy.[13]

It is anticipated that, if enacted, such rulemaking would include comment and phase-in periods, with full implementation of the law in the early 2020s. However, it remains to be seen whether USDOT will pursue enactment of the proposed rulemaking under the new administration.

Connected vehicle technology can be deployed with or without the V2V mandate, and there are numerous potential vehicle-to-infrastructure (V2I) applications for transit vehicles. For example, utilizing DSRC to transmit signal phase and timing data (SPaT) from traffic signal controllers to vehicles can be used to enable transit vehicles to traverse corridors more efficiently or enact signal preemption or priority. However, the absence of V2V requirements may limit the effectiveness of V2V safety applications, unless automotive manufacturers elect to include DSRC radios regardless of the outcome of rulemaking.

Model Federal Guidance

USDOT has produced a substantial volume of guidance on connected vehicle technology based on the applications, prototypes, and pilot project the agency has funded. **Table 3** below shows a list of the connected vehicle applications envisioned by USDOT, with shaded cells to indicate which ones might be best suited for transit applications.

Table 3: Connected Vehicle Applications

V2I Safety	Environment	Mobility
Red Light Violation Warning	**Eco-Approach and Departure at**	**Advanced Traveler Information**
Curve Speed Warning	**Signalized Intersections**	**System**
Stop Sign Gap Assist	Eco-Traffic Signal Timing	**Intelligent Traffic Signal System**
Spot Weather Impact Warning	**Eco-Traffic Signal Priority**	**Signal Priority (Transit, Freight)**
Reduced Speed/Work Zone Warning	Connected Eco-Driving	Mobile Accessible Pedestrian Signal
Railroad Crossing Violation Warning	Wireless Inductive/Resonance Charging	System
Pedestrian in Signalized Crosswalk	Eco-Lanes Management	Emergency Vehicle Preemption
Warning (Transit)	Eco-Speed Harmonization	Dynamic Speed Harmonization
V2V Safety	Eco-Cooperative Adaptive Cruise	Queue Warning
Emergency Electronic Brake Lights	Control	Cooperative Adaptive Cruise Control
Forward Collision Warning	Eco-Traveler Information	Incident Scene Pre-Arrival Staging
Intersection Movement Assist	Eco-Ramp Metering	Guidance for Emergency
Left Turn Assist	Low Emissions Zone Management	Responders
Blind Spot/Lane Change Warning	Alternative Fuel Vehicle Charging /	Incident Scene Work Zone Alerts for
Do Not Pass Warning	Fueling Information	Drivers and Workers
Vehicle Turning Right in Front of Bus	Eco-Smart Parking	Emergency Communications and
Warning (Transit)	**Dynamic Eco-Routing (light vehicle,**	Evacuation
Agency Data	**transit, freight)**	**Connection Protection**
Probe-Based Pavement Maintenance	Eco-Integrated Corridor Decision	**Dynamic Transit Operations**
Probe-Enabled Traffic Monitoring	Support System	**Dynamic Ridesharing**
Vehicle Classification-based Traffic Stu	**Road Weather**	Freight-Specific Dynamic Travel
Connected Vehicle Enabled Turning	Motorist Advisories and Warnings	Planning and Performance
Movement & Intersection Analysis	Enhanced Maintenance Decision Support	Drayage Optimization
Connected Vehicle Enabled	System	**Smart Roadside**
Origin-Destination Studies	Vehicle Data Translator	Wireless Inspection
Work Zone Traveler Information	Weather Responsive Traffic Information	Smart Truck Parking

[13] https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/v2v_pria_12-12-16_clean-2.pdf

USDOT has developed, at a minimum, a Concept of Operations for most of the above applications. Additionally, the following have been prototyped: Pedestrian in Signalized Crosswalk, Forward Collision Warning, Vehicle Turning Right in Front of Bus Warning, Connection Protection, Dynamic Transit Operations, and Dynamic Ridesharing, each of which are well documented by USDOT. Additional available guidance includes the following:

- Vehicle-to-Infrastructure Deployment Guidance Resources;
- Dedicated Short Range Communications Roadside Unit Specifications Document v 4.1;
- Guide to Licensing Dedicated Short Range Communications for Roadside Units;
- Connected Vehicle Pilot Deployment Program; and
- Smart City Challenge.

Accessibility

Federal Regulations

The Americans with Disabilities Act (ADA) became law in 1990. The ADA is a civil rights law that prohibits discrimination against individuals with disabilities in all areas of public life, including jobs, schools, transportation, and all public and private places that are open to the general public.[14] Title 49 Part 37 addresses transportation services for individuals with disabilities. While the purpose of this section is providing disabled individuals with equal access to transportation, there are numerous parts of the law and corresponding circulars focusing on technology and its implementation. The following components of ADA are applicable to transit technology:

- Accessible Websites: Transit agency websites are a primary source of information for customers. Having a fully accessible website is one of the best ways the adequate information requirement found in Section 37.167 (f) can be achieved. While Federal Transit Administration (FTA) does not set the standards for websites, agencies are directed to review Department of Justice Guidance, “Accessibility of State and Local Government Websites to People with Disabilities.”
- Stop and Route Announcements: Transit agencies are required to announce stops at transfer points to other routes, major intersections and destinations, and at sufficient intervals to help travelers with visual impairments or other disabilities to orient themselves, and at any stop requested by riders with a disability. In addition, FTA recommends maintaining a database of stops to announce. This list can be developed in cooperation with groups that represent or work with individuals with visual or cognitive disabilities. If using a stop annunciator system, it must be periodically audited to make sure it is working correctly and announcing the correct stops. If it is not functioning properly, drivers or rail personnel must verbally announce stops. Similar rules apply for announcing when more than one route serves a stop.
- Trip Reservation: Entities that are required to provide complimentary paratransit service are also required to schedule service to any eligible person at any requested time on a particular day in response to a request service made the previous day. The reservations may be taken by agents or technological means, such as real-time scheduling systems, voicemail systems, online, or through smartphone applications.

[14] http://adata.org/learn-about-ada

- Complaint Process: Private or public entities providing paratransit service are also required to have a complaint process. Each complaint is required to be kept on file for one year and a record of complaints, which may be in summary form, is to be kept for five years.

These requirements are intended to give flexibility in what solutions transit agencies pursue provided the delivery of the transportation services meets the standards set forth by law and corresponding circular.[15]

Model Federal Guidance

Elderly individuals and those with disabilities have significant needs and barriers to mobility. It is important for any transportation system to both take into consideration and involve those with disabilities to ensure they are provided with equal access to transportation as required with the ADA. The areas of concern for those with disabilities are information, travel options, travel assistance, and access to transportation facilities. USDOT recently released the ATTRI User Needs Assessment, which provided additional guidance on how transportation technology can serve travelers with disabilities. Highlights of this document are discussed below.[16]

- Information: Providing accurate and up to date information is a critical component for improving mobility for those with disabilities. This means making sure websites, smartphone applications, trip planners, etc. contain the correct information and is compatible with accessibility devices such as screen readers. Section 508 of the Rehabilitation Act of 1973, as amended (29 U.S.C. 794d) requires that individuals with disabilities, who are members of the public seeking information or services from a Federal agency, have access to and use of information and data that is comparable to that provided to the public who are not individuals with disabilities, unless an undue burden would be imposed on the agency.[17] (US Access Board). The U.S. Access Board, Easter Seals, and WebAim all provide guidance and training on how to make information accessible to those with disabilities.

- Options: Those with disabilities need travel options before and during their travel. Many needs and barriers are directly associated with the lack of or the perceived lack of travel options. Having options improve the quality of life for elderly and those with disabilities especially for those in rural areas and those who desire to remain in their community, instead of having to move to more accessible areas. Transit agencies can improve travel options by implementing One Call/One Click centers. According to the National Center for Mobility Management, "One-call or one-click services enable customers to make one phone call or search one website to receive information about all transportation services available in the community. As one-call or one-click services become more advanced, they allow customers to schedule, receive confirmation of, and pay for rides. Transportation providers can interact with the database supporting a one-call or one-click service to schedule customer trips, communicate with customers, and even receive

[15] https://www.transit.dot.gov/regulations-and-guidance/fta-circulars/americans-disabilities-act-guidance-pdf
[16] https://ntl.bts.gov/lib/60000/60100/60128/FHWA-JPO-16-354.pdf
[17] https://www.access-board.gov/guidelines-and-standards/communications-and-it/about-the-section-508-standards

payment for trips."[18] The Community Transportation Association of America created a toolkit to help transit agencies and municipalities to set up One Call/One Click Centers.

Another emerging trend in providing options to those with disabilities is partnering with taxis, Uber, Lyft, or other transportation network companies (TNCs) to provide first mile/last mile connectivity between the trip origin and the destination. These arrangements allow for travelers to plan every aspect of their trip via mobile devices and/or see what travel options are available during a time when the transit agency is not providing full service. The FTA Mobility on Demand Sandbox[19] program provides both examples of how other agencies provided travel options to those with disabilities and can be a funding source for agencies wishing to establish their own programs. Additional discussion of TNC policy and regulation in Florida is found in the "Transportation Network Companies" section of this document.

- Assistance: More travel assistance could be given to those with disabilities during their trips. Many times this assistance is provided through travel training programs where members of the agency staff or partnering accessibility agencies travel with the individual with disabilities to help them to navigate the transit network. Technology could improve the experience through the use of wayfinding devices to help individuals locate bus stops and accurate automatic stop annunciators on the vehicles. Emerging technology, such as Apple's Ibeacon[20] service, allow agencies to place Radio Frequency Identification Devices (RFID) on bus stop poles to help those with visual disabilities locate the stops. It does not need to be as high tech as this, provided transit agencies use current GPS and asset management programs to identify the locations of all bus stops and amenities. This information along with the latitude and longitude coordinates is then provided to those with disabilities to help them find their bus stops. Similarly, GPS based stop annunciators take the responsibility of announcing stops out of the hands of the operator and gives it to onboard systems. This provides the announcement of stops in a consistent manner in compliance with ADA regulations. The aforementioned U.S. Access Board provides the guidance on providing assistance to those with disabilities.

- Access: Access to transit facilities could be improved through technology solutions. For many of those with disabilities, however, the current methods of improving physical configurations and layouts of facilities are largely sufficient in meeting their needs. Curb cuts, raised strips, and connected pathways are examples of approaches used to meet the access needs of persons with disabilities. This does not mean that assistive technologies could not be used to improve transportation access. For example, white canes with sensors to detect hazards, tactile navigation systems, proximity-based public announcements, or autonomous vehicle systems are all options that could improve access to the transportation system.

It is also important to take into consideration the needs of those with disabilities when designing the ITS architecture for a transit system. Not only does it make the system easier

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[18] http://nationalcenterformobilitymanagement.org/onecall-oneclick/

[19] https://www.transit.dot.gov/research-innovation/mobility-demand-mod-sandbox-program.html

[20] https://developer.apple.com/ibeacon/

for those with disabilities to navigate, in many instances the technology meets requirements under the ADA. Additional discussion of ITS model guidance is found in the System Integration section of this document.

Asset Management

Federal Regulations

As part of the Fixing America's Surface Transportation (FAST) Act, the FTA requires all receipts of Section 5301, 5310, and 5311 funds to develop and submit a Transit Asset Management (TAM) plan. The TAM requirement was developed in response to the backlog of transit infrastructure needed replacement or rehabilitation. The TAM is a business model that uses the condition of assets to guide the prioritization of funding in order to keep transit networks in a state of good repair.[21] The benefits of developing a TAM are to:

- Improve transparency and accountability;
- Make informed decisions to optimize capital investment;
- Have more data for maintenance decisions; and
- Improve overall transit safety.

The TAM feeds into and guides transportation investment documents such as local transit development plans, long range transportation plans, and transportation improvement programs. Transit agencies in receipt of Federal funds are divided into two tiers. Tier I are those agencies that operate a rail system or any system with over 100 vehicles. Tier II properties are recipients of Section 5311 funds, American Indian Tribes, or those that operate less than 100 vehicles. Both tiers are required to have the following elements:

- Inventory of Capital Assets;
- Condition Assessment;
- Decision Support Tools; and
- Investment Prioritization

Tier I properties are also required to include:

- TAM and State of Good Repair Policy;
- Implementation Strategy;
- List of Key Annual Activities;
- Identification of Resources; and
- Evaluation Plan.

Technology exists to meet these requirements by serving as a clearing house by maintaining the asset inventory, documenting maintenance activities, and reporting the condition of the asset. Transit asset management programs are offered by a variety of vendors. These programs utilize a comprehensive inventory database that provides information on the asset life cycle and its condition, asset location, available funding, and other information. The databases could then be

[21] https://www.transit.dot.gov/TAM

exported and used to create prioritized capital improvement plan to meet the requirements of the TAM program.

State Regulations

FDOT will sponsor a group TAM plan for recipients of Section 5311 and 5310 funds. In addition, FDOT requires an accounting of the age and condition for all assets purchased with Federal and state funds. This requirement is also found in other states, such as Alabama,[22] Georgia,[23] and Washington.[24]

Reporting

Federal Regulations

Congress requires agencies to report to the National Transit Database (NTD) if they receive or benefit from Section 5307 and Section 5311 funds.[25] FTA uses this information to annually submit reports to Congress that summarize transit service and safety. In addition, this information is used to determine the apportionment of funds to transit agencies. Depending on the size and type of the agency, agencies are required to report a variety of data ranging from financial information to performance measures to the NTD. Transit technology, such as automatic passenger counters (APCs), smart fare boxes, scheduling software, and automatic vehicle locators are helpful for collecting and preparing the data (ridership, fare box recovery, system miles, miles between breakdowns, etc.) for submission. The only specific requirement for technology as it relates to reporting data to the NTD is associated with the use of APC. The use of APCs must be approved by FTA with a corresponding benchmarking and maintenance plan. These plans must include the following elements:

- Validation of the APC for unlinked passenger trips and passenger mile trips against a manual sample;
- A description of the APCs system;
- A description of the agency's sampling procedures;
- A list of trips that were flagged and rejected from the sample with explanations for each;
- The percentage of trips that do not have valid APC data over the course of the year for any reason;
- Descriptions of the differences (if any) between the set of distances between stops used to calculate passenger miles traveled and the APC data; and
- A less than 5% difference between manual counted data and APC data.

While not currently addressed in the NTD Reporting Manual, autonomous vehicles, microtransit, the use of transportation networking companies (Lyft, Uber, etc.) could be separate reporting categories in future reports submitted by transit agencies to the NTD.

[22] https://www.dot.state.al.us/tpmpweb/mp/transit.html
[23] http://www.dot.ga.gov/InvestSmart/Transit/Documents/StateManagementPlan/StateManagementPlan.pdf
[24] http://www.wsdot.wa.gov/Transit/Grants/Plan.htm
[25] https://www.transit.dot.gov/ntd





State Regulations

Similar to the Federal requirements, agencies receiving state funds are required to report their performance measures to the applicable agency. These measures are used to evaluate the success of the program in the State's Department of Transportation Annual Report to the Executive or Legislative Body and used to determine state appropriations to transit agencies/programs. Technology plays an important role in gathering and preparing the data for submission. Requirements for specific pieces of technology are not identified at this time.

Data and Privacy

Federal Regulations

Both traditional ITS and emerging autonomous and connected vehicle applications provide an unprecedented means of real-time monitoring of individual and vehicular movements. In addition, the technologies are capable of recording and maintaining historical travel pattern data: where a person travels, when they travel, and how often. This data could be aggregated and correlated with other personal information (including such items as gender, race, religion, political affiliation, place of birth and residence and employment, law enforcement history, credit history, income, and so forth) about the individual throughout his or her lifetime.[26] The access to this level of data on individuals either through smart card usage or registering with a paratransit provider, transit agencies should be aware of Federal privacy laws. TCRP Legal Research Digest 25 deals with the privacy issues associated with the use of smart cards. While this report is oriented towards smart cards and farebox technology, there are takeaways in this report that apply to all technology where personal information is obtained.

At the Federal level, the issue with privacy originates with the Fourth Amendment which protects against unreasonable searches and seizures. Privacy, while not included in the U.S. Constitution, is covered under the Fourth Amendment through court cases that establish a reasonable expectation of privacy afforded to all U.S. citizens, residents, and visitors. Statutes that address privacy include:

- The Privacy Act of 1974, which protects individual privacy with respect to Federal agency operations and practices by regulating the government's collection, use, and dissemination of personal information;
- The Computer Matching and Privacy Protection Act of 1988, which amended the Privacy Act by designating the manner in which Federal agencies could engage in computer matching and by providing certain protections for those applying for and receiving Federal benefits;
- The Health Insurance Portability and Accountability Act of 1996, which provides privacy protection for electronically transmitted health information; and
- The E-Government Act of 2002, which requires Federal agencies to conduct privacy impact assessments before developing or procuring information technology that collects, maintains, or disseminates personally identifiable information.[27]

The key takeaway is for transit agencies to develop a privacy policy before establishing a smart card, customer registration, or similar program where customer data is collected. The policy

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[26] https://www.nap.edu/download/23104#
[27] https://www.nap.edu/download/23104#

should establish what data is collected, how it will be used, prohibit the selling of data to third party vendors, and provide an opportunity to opt out. The policy should be applied to all programs where customer data is collected. It's important to note aggregate data such as using mobile fare information to track boarding and alighting at bus stops is very useful in evaluating route performance to make informed planning decisions. It is the use and dissemination of individual data that runs against privacy laws and may require additional actions or permissions before it can be used.

State Regulations

Some states do establish their own privacy regulations with Texas being the only state with regulations governing the use of smart cards. While the Texas law pertaining to smart cards is focused on the use of health information, it does provide lessons on how to handle private information obtained by transit agencies. The Texas law limits who has access to the information, what can be gathered, and how the information is stored and communicated to other agencies. Other states have legislation concerning public records requests. Some data, such as personal information on elected or appointed officials, is exempt from disclosure. The State of Washington has a provision exempting certain records held by transportation entities. With respect to personally identifying information contained on stored value smart cards and magnetic strip cards, the exemption from disclosure has three exceptions:[28]

- Disclosure to an entity responsible for paying for the transit pass;
- Disclosure to news media when reporting on public transportation or public safety; and
- Disclosure to governmental agencies or groups concerned with public transportation or public safety.

Exemptions from disclosure also exist for individually identifiable records collected for vanpool, carpool, or other ridesharing programs and paratransit. Florida does establish a right to privacy in the Florida Constitution.[29] Florida also passed the Florida Information Protection Right of 2014.[30] This law created Section 501.171, Florida Statutes, which requires any government to take reasonable measures to protect and secure data in electronic form containing personal information. Government entities are required to report to the State any breaches where 500 or more individuals in the state are affected. It also requires individuals to be notified of any breach within 30 of identifying the breach. It is important for transit agencies to check to see if there are any regulations in their state concerning privacy and access to public records.

System Integration

Federal Model Guidance

The wide range of technology that exists or is emerging in the marketplace has the potential to greatly improve system efficiency and the quality of the service provided. The challenge, however,

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[28] https://www.nap.edu/download/23104#

[29] http://www.leg.state.fl.us/statutes/index.cfm?submenu=3

[30] http://www.leg.state.fl.us/statutes/index.cfm?App_mode=Display_Statute&Search_String&URL=0500-0599/0501/Sections/0501.171.html

facing transit agencies is the proper implementation and integration of the technology into the delivery of transit service. Many transit agencies have not integrated their deployed technologies to any significant degree. Rather, these agencies deploy technologies separately and are implemented in a standalone fashion, ignoring the synergistic benefits.[31]

The key obstacle to the successful implementation of transit technology is integration of the technology systems and subsystems at the project level, within the transit agency, and in the region. To accomplish this, the USDOT developed the National Intelligent Transportation System Architecture to facilitate the integration of services between and among transportation stakeholders and protocols (TCRP, 13). All ITS projects receiving Federal funding are required to perform a systems engineering analysis, develop a project-level ITS architecture, and incorporate the regional ITS architecture.

System engineering analysis shall include, at a minimum:

- Identification of portions of the regional ITS architecture being implemented (or if a regional ITS architecture does not exist, the applicable portions of the National ITS Architecture);
- Identification of participating agencies' roles and responsibilities;
- Requirements definitions;
- Analysis of alternative system configurations and technology options to meet requirements;
- Analysis of financing and procurement options;
- Identification of applicable ITS standards and testing procedures; and
- Procedures and resources necessary for operations and management of the system.

Project level ITS architecture shall include:

- A description of the scope of the ITS project;
- An operational concept that identifies the roles and responsibilities of participating agencies and stakeholders in the operation and implementation of the ITS project;
- Functional requirements of the ITS project;
- Interface requirements and information exchanges between the ITS project and other planned and existing systems and subsystems; and
- Identification of applicable ITS standards.

The regional ITS architecture shall include, at a minimum, the following:[32]

- A description of the region;
- Identification of participating agencies and other stakeholders;

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[31] http://www.trb.org/Publications/Blurbs/156794.aspx

[32] https://ops.fhwa.dot.gov/its_arch_imp/policy_2.htm

- An operational concept that identifies the roles and responsibilities of participating agencies and stakeholders in the operation and implementation of the systems included in the regional ITS architecture;
- Any agreements (existing or new) required for operations, including at a minimum those affecting integration of ITS projects; interoperability of different ITS technologies, utilization of ITS-related standards, and the operation of the projects identified in the regional ITS architecture;
- System functional requirements;
- Interface requirements and information exchanges with planned and existing systems and subsystems (for example, subsystems and architecture flows as defined in the National ITS Architecture);
- Identification of ITS standards supporting regional and national interoperability; and
- The sequence of projects required for implementation of the regional ITS architecture.

Transit technology integration ensures transit and technology functions are “speaking the same language” to work toward the goal of providing efficient and effective transportation to a community. Examples of potential integration include ensuring route data produced by scheduling software is readable and usable by other programs such as trip planners, geographic information system, automatic vehicle locators, or using automatic passenger counter information to guide the route planning process to adjust resources to meet increasing or decreasing demand levels. The exchange of information across platforms allows for the technology to be used at its greatest potential and lets the agency experience the maximum benefits.

In order to fully implement transit technology, fundamental prerequisites conditions and capabilities should exist in order to carry out the best practices identified by the transit industry. The prerequisites are:

- Leadership that understands and supports technology;
- A vision for how the technology will permeate and benefit the agency. The vision should be linked to a phased, realistic plan that is developed on input from a wide variety of stakeholders;
- An organizational culture that supports technology and accepts change;
- A supportive community that values transit and supports investments in the system; and
- Resources or the ability to accomplish the plan (Transit Cooperative Research Program, 3-4).

In addition, transit agencies should emphasize quality and sustainability when planning for technology and pursuing specific investments. “It is better to provide smaller, fully realized, and lasting improvements than to invest in ambitious systems that cannot be fully integrated within the transit agency or properly maintained over the long term.”[33] It is also helpful to partner with other transit agencies to pool expertise and resources when implementing a technology plan.

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[33] http://www.trb.org/Publications/Blurbs/156794.aspx

Transportation Network Companies

A number of new transit service models have emerged in recent years. In one such model, TNCs offer the potential to interface with traditional fixed route transit to provide first and last mile connections. Unlike most states, where rideshare companies are regulated at the local level, Florida has streamlined TNC requirements under CS/HB 221, also known as the "Uber / Lyft Bill." The bill, which was signed into law in 2017, replaced existing laws throughout the state that required background checks and insurance requirements from ridesharing services – the bill now requires background checks to be done by each company.[34] Under this bill, ridesharing companies will not need to comply with requirements that taxi companies are subjected to, such as vehicle inspections, safety checks, or license verifications.

The bill prevents local governments from imposing regulations on ridesharing companies. Additionally, since taxi cab companies are often regulated by local governments, it has been suggested that taxi drivers may become disadvantaged. Some Florida representatives are also concerned with the implementation of the new bill; in some cities, regions where ridesharing drivers tend to circulate (such as airports) are becoming more congested, the new bill prevents local governments from regulating any issues caused by ridesharing companies.[35] Officials are beginning to consider potential bills to mitigate these inevitable issues. The "Uber / Lyft Bill" requires ridesharing drivers to carry insurance that goes beyond the state's minimum requirements; it requires ridesharing companies to perform background checks on their drivers, and it also requires the companies to adopt zero-tolerance policies on drug and alcohol use.

In Florida, all drivers are required to carry insurance that covers a minimum of $10,000 in personal injury protection (PIP) and also covers $10,000 in property damage liability (PDL). The Bill includes additional requirements from ridesharing drivers under two categories: 1.) when logged on but not providing a ride, and 2.) when providing a ride.

When a ridesharing driver is logged onto their system and not actively carrying a passenger, they are subject to the following requirements:[36]

- A minimum primary automobile liability coverage of $50,000 for death and bodily injury per person.
- A minimum primary automobile liability coverage of $100,000 for death and bodily injury per incident.
- PDL coverage of at least $25,000 per incident.
- PIP and uninsured/underinsured motorist (UIM) coverage as required by the law.

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[34] http://www.wjhg.com/content/news/Florida-Governor-Rick-Scott-signs-UberLyft-bill-into-law-421806483.html

[35] http://www.palmbeachpost.com/news/state--regional-govt--politics/florida-senate-poised-sign-off-uber-lyft-plan/8te2oY9Ep1HTYeYV7rw95M/

[36] http://www.powelllawfirm.com/blog/new-florida-law-enhances-insurance-requirements-for-uber-and-lyft-drivers/

When a ridesharing driver is actively carrying a passenger, they are subject to the following requirements:

- A minimum primary automobile liability coverage of at least $1 million for death, bodily injury and property damage.
- PIP and UIM coverage as required by the law.

These requirements may be met by the ridesharing company or the driver. The Bill also requires the ridesharing company to have coverage in case the driver's coverage is not sufficient. These requirements are not applicable when the drivers are not connected to the company's system. Additionally, ridesharing companies are required to perform background checks before hiring new drivers, and every three years after their hiring date.

Funding

There are a number of funding programs that can be used to fund transit technology projects, including traditional transit funding programs and new programs that target emerging technologies such as autonomous and connected vehicles, traveler information systems, and integrated fare payment. The following sections describe the available programs in additional detail.

Traditional Transit Funding Programs

Table 4 below provides a summary of the Federal competitive and formula funds transit agencies are able to apply and use to fund transit technology projects.

Table 4: Funding Options

Grant Name	Description	Type	Match Requirements	Eligible Projects
Bus & Bus Facility - Section 5339	Provides funding through an allocation process to states and transit agencies to replace, rehabilitate, and purchase buses and related equipment and to construct bus-related facilities. The competitive allocation provides funding for major improvements to bus transit systems that would not be achievable through formula allocations.	Competitive & Formula	80/20	Alternative fuels; signal priority; facility upgrades that include technology infrastructure
Mobility of Seniors & Individuals w/ Disabilities - Section 5310	Formula funding to states for the purpose of assisting private nonprofit groups in meeting transportation needs of the elderly and persons with disabilities.	Formula	80/20 - Capital 100 - Technical Assistance 50/50 - Operating	Transit related information technology; wayfinding; mobility management; ride sharing applications
CMAQ	CMAQ provides funding to areas in nonattainment or maintenance for ozone, carbon monoxide, and/or particulate matter. States that have no nonattainment or maintenance areas still receive a minimum apportionment of CMAQ funding for either air quality projects or other elements of flexible spending. Funds may be used for any transit capital expenditures otherwise eligible for FTA funding as long as they have an air quality benefit.	Formula		Any transit capital project provided it has an air quality component

Grant Name	Description	Type	Match Requirements	Eligible Projects
Surface Transportation Block Grant	Provides funding that may be used by states and localities for a wide range of projects to preserve and improve the conditions and performance of surface transportation, including highway, transit, intercity bus, bicycle and pedestrian projects.	Formula		Any transit project that improves its performance
Rural Areas - Section 5311	Provides capital, planning, and operating assistance to states to support public transportation in rural areas with populations less than 50,000, where many residents often rely on public transit to reach their destinations	Formula	80/20 - Capital 50/50 - Operating	Operational support for computer hardware & software; Introduction of new technology; Technology to support JARC service
Low - No Emission Vehicle Program - Section 5339	Provides funding through a competitive process to states and transit agencies to purchase or lease low or no emission transit buses and related equipment, or to lease, construct, or rehabilitate facilities to support low or no emission transit buses. The program provides funding to support the wider deployment of advanced propulsion technologies within the nation's transit fleet.	Competitive	85/15 - Vehicles 90/10 - Facilities	Alternative fuel vehicles and the technology to support it.

Grant Name	Description	Type	Match Requirements	Eligible Projects
Planning Funds - Section 5303, 5304, or 5305	Provides funding and procedural requirements for multimodal transportation planning in metropolitan areas and states. Planning needs to be cooperative, continuous, and comprehensive, resulting in long-range plans and short-range programs reflecting transportation investment priorities.	Formula	80/20	Could be used to develop a technology strategic plan
Mobility on Demand - Section 5312	Funds projects that promote innovative business models to deliver high quality, seamless and equitable mobility options for all travelers.	Competitive	80/20	Integrate mobility tools, like applications, to make the transit system more efficient and accessible
Public transportation Innovation - Section 5312	Provides funding to develop innovative products and services assisting transit agencies in better meeting the needs of their customers	Competitive		Research, development, demonstration & development, and evaluation of technology of national significance to public transportation
Urban Area Allocation - Section 5307	Provides funding to public transit systems in Urbanized Areas (UZA) for public transportation capital, planning, job access and reverse commute projects, as well as operating expenses in certain circumstances.	Formula	80/20 - Capital 50/50 - Operating	Planning - Technology Strategic Plan Capital - Purchase of New Technology; Introduction of new technology; Passenger Information Displays; Mobility Management
Safety Research and Demonstration Program	Funds cooperative agreements to demonstrate and evaluate innovative technologies and safer designs to improve public transportation safety	Competitive	80/20	Collision avoidance and mitigation; transit worker safety protection

Grant Name	Description	Type	Match Requirements	Eligible Projects
Service Development Grant	Service Development Projects specifically include projects involving the use of new technologies; services, routes, or vehicle frequencies; the purchase of special transportation services; and other such techniques for increasing service to the riding public. Projects involving the application of new technologies or methods for improving operations, maintenance, and marketing in public transit systems are also eligible for Service Development Program funding	Competitive	50/50	Technology designed to improve the service and delivery of the system; technology designed to increase transit ridership
Block Grant	State operating assistance provided to transit agencies	Formula	50/50	Technology contract maintenance
Capital Investment Grants – Section 5309	Discretionary grant program to provide funding for fixed guideway investment such as new and expanded rapid rail, commuter rail, light rail, streetcars, bus rapid transit, and ferries.	Competitive	60/40 (maximum total Federal contribution of 80%)	New Starts (fixed guideway projects seeking $100M+); Small Starts (fixed guideway, extensions, or bus rapid transit projects seeking less than $100M and with a total cost less than $300M); Core Capacity (substantial corridor investments in existing fixed guideway systems to increase capacity); Programs of Interrelated Projects

Funding for Emerging Technology

Advanced Transportation & Congestion Management Technology Deployment Program

The Advanced Transportation and Congestion Management Technology Deployment (ATCMTD) program provides grants to state and local entities to fund transportation technology projects, including the following:[37]

- Advanced traveler information systems;
- Advanced transportation management technologies;
- Infrastructure maintenance, monitoring, and condition assessment;
- Advanced public transportation systems;
- transportation system performance data collection, analysis, and dissemination systems;
- Advanced safety systems, including vehicle-to-vehicle and vehicle-to-infrastructure communications;
- Technologies associated with autonomous vehicles, and other collision avoidance technologies, including systems using cellular technology;
- Integration of intelligent transportation systems with the Smart Grid and other energy distribution and charging systems;
- Electronic pricing and payment systems; or
- Advanced mobility and access technologies, such as dynamic ridesharing and information systems to support human services for elderly and disabled individuals.

This program provides $60M in funding annually, typically in $6M - $12M increments, and requires a minimum of 50% non-Federal cost share. Thus far the program has proved highly competitive, with eight of 81 applications funded in 2016 and 10 of 68 applications funded in 2017. To date, one project in Florida has been funded: FDOT was awarded $11.9M in 2017 to fund the Connecting the East Orlando Communities project, which will advance numerous ITS technologies–including PedSafe, an innovative pedestrian and bicycle collision avoidance system, GreenWay, which uses advanced traffic signal technology, SmartCommunity, for trip planning apps, and SunStore, which integrates FDOT data.

Infrastructure for Rebuilding America

There are many Federal grant programs that are eager to fund innovative transportation projects; one of these programs is the Infrastructure for Rebuilding America (INFRA) grant program. INFRA is searching to fund transportation projects that are focused on enhancing safety through innovation. Examples of potential projects to be funded may include the following characteristics:[38]

Connected vehicle technology, such as V2V or V2I systems;

- Dynamic signaling systems;

[37] https://www.fhwa.dot.gov/fastact/factsheets/advtranscongmgmtfs.cfm

[38] http://statescoop.com/how-cities-can-secure-funding-for-connected-transportation-initiatives

- Signage and other roadway design to facilitate autonomous and connected vehicle technologies;
- Applications that record vehicle data in relation to safety issues, such as near-miss accidents;
- Applications that incorporate signal prioritization and conflict detection; and
- Technologies that provide cybersecurity for transportation systems.

Proposals which demonstrate how transportation investments will enhance the safety of their communities have the best chance of being supported.

Florida Smart City Grant Program

In 2017, Florida passed enabling legislation for the Florida Smart City Grant Program to fund emerging technologies that address the following focus areas: autonomous vehicles; connected vehicles; sensor-based infrastructure; collecting and using data; electric vehicles, including charging stations; and developing strategic models and partnerships. Beyond encouraging incorporating emerging technology into day-to-day operations, this program also indents to increase the state's competitiveness in securing competitive grants from USDOT, the United States Department of Energy, and other Federal agencies. However, the grant program has not yet been funded.

Bloomberg Philanthropies Mayors Challenge

Beyond potential Federal and state resources, competitive grant programs from the non-profit sector such as the Bloomberg Philanthropies Mayors Challenge provide a funding opportunity to encourage cities to consider innovate solutions, including transit technology. The 2017 round of the program will award 35 cities $100,000 each. Champion cities are then invited to come together for an intensive workshop, refine their ideas, and submit a more detailed application. A final grand prize of $5M and four prizes of $1M are then awarded. Past recipients have included a range of city sizes, from Santa Monica, CA (population of 92K) to São Paulo (population of 12M). Future rounds of this grant program present a good opportunity for Florida cities to pursue.

Florida Funding Options for Alternative Fuels

Florida[39] provides different rebate programs and requirements for transit agencies who are interested in pursuing alternative fuel vehicles.

Natural Gas Vehicle (NGV) and Propane Vehicle Rebates

The Florida Department of Agriculture and Consumer Services offers a rebate for up to 50% of the incremental cost to purchase or lease a new original equipment manufacturer NGV or propane vehicle, or convert a vehicle to run on natural gas or propane, up to $25,000 per vehicle and $250,000 per applicant per fiscal year. To qualify, the dedicated or bi-fuel vehicle must be part of a public or private fleet and must be placed into service on or after July 1, 2013. Of the funds

[39] https://www.afdc.energy.gov/laws/all?state=FL

available for these rebates, 40% is reserved for government applicants; the remaining funds are allocated to commercial applicants. Funding is not available for the 2017-2018 fiscal year

Electric Vehicle Supply Equipment (EVSE) Rebate - Sarasota County

ChargeUP! Sarasota County offers rebates to businesses, non-profits, and local governments within Sarasota County for the installation of qualified Level 2 or DC fast charging EVSE. Businesses are eligible for a rebate of 25% of the cost of EVSE purchase and installation, up to $2,000, and non-profits or government organizations are eligible for a rebate of 50% of the cost of EVSE purchase and installation, up to $4,000. Qualified EVSE must be level 2 or DC fast charging stations, publicly available for at least 8 hours a day, and located in targeted locations that do not currently have EVSE. Additional restrictions apply, and program participants must apply for the rebate before EVSE installation.

Fuel-Efficient Vehicle Acquisition and Alternative Fuel Use Requirements

When procuring new vehicles under a state purchasing plan, all Florida state agencies, state universities, community colleges, and local government fleets must select the vehicles with the greatest fuel efficiency available for a given use class, when fuel economy data is available. Exceptions may be made for emergency responder vehicles if these entities provide documentation. In addition, all state agencies must use ethanol and biodiesel blended fuels when available. State agencies administering central fueling operations for state-owned vehicles must purchase ethanol and biodiesel fuels to use in their vehicle fleet as much as possible.

Summary of Policy and Regulation Findings

Transit technology is at a point of rapid change as technologies take hold, including autonomous and connected vehicles and innovative ways for users to find and complete travel options across multiple modes. Against this backdrop, new service models that incorporate nontraditional transportation stakeholders are also emerging. These technologies will likely coexist with more traditional back office applications that help agencies ensure smooth system planning and operations activities for some time. One of the challenges that state and local transportation agencies will face is devising policy and regulations that are comprehensive, yet flexible enough to cover a range of technologies and use cases.

Policymakers at the Federal level have struggled to keep pace with emerging technology, while states have enacted a patchwork of legislation to bridge the gap in the meantime. The following five key considerations will be crucial for the Florida Department of Transportation to consider as it seeks to assist Florida transit agencies deploying new technologies in their systems:

- Revisions to Federal Motor Vehicle Safety Standards will be required to ensure the nascent AV industry grows with consistent safety requirements. In the meantime, exemptions to certain requirements should ensure that microtransit vehicles may enter pilot or permanent deployments within a given geographic boundary.
- Despite a large body of Federal research and standards on connected vehicle technology, uncertainty about the pending vehicle-to-vehicle communications requirement on new vehicles leaves future adoption rates, and the corresponding benefits to transit agencies, in jeopardy.

- Transportation technology provides a number of opportunities to meet the needs of travelers with disabilities while meeting various provisions of the ADA. However, some of these technologies remain in research and development stages, or are not yet cost-effective at the scale that a small to medium transit agency would require.
- Both traditional ITS and emerging autonomous and connected vehicle applications provide an unprecedented means of real-time monitoring of individual and vehicular movements. While there are some privacy protections at the Federal level, states may be pressured to pass additional private regulations in response to citizen concerns, and should be proactive about these conversations.
- The State of Florida is in the unique position of regulating Transportation Network Companies (TNCs) at the statewide level. As emerging transit models enter the market that integrate these companies to provide first and last mile service, state regulators should ensure that TNC policy remains flexible enough to account for the needs of local agencies while consistent enough to meet Federal law including ADA.

LITERATURE REVIEW

Literature Review

The Literature Review serves as an overview of transit technology projects at different stages of development, including projects at early research stages, prototypes, and pilot projects. Within these stages are USDOT, state, university, transit agency, and other examples of transit projects which have been influential for developing transit technologies. These summaries provide an insight to emerging transit trends and also provide examples of transit agencies that have been involved in the advancement of those technology projects.

Methodology

Scope of Search

Research for this section was completed through the development of literature review abstracts which provide summaries of various transit technologies, reports, projects, and transit agencies. Each abstract contains characteristics regarding the project, such as an overview of the technology, benefits, challenges, types of technology used, and deployment. The sources selected for the abstracts were chosen based on the relevance of a particular agency or project in the field of transit technology development, and it was also influenced by the technology categories identified at the beginning of this report. Given the rapidly changing nature of technology, prototype and pilot research efforts are emphasized in order to provide transit agencies with state-of-the-art knowledge. These abstracts pinpoint the most notable transit technology projects throughout small and midsized transit agencies that exist today.

Types of Sources

Research was conducted through online sources derived from a range of transportation, technological, and research entities. These organizations include (but have not been limited to): USDOT, FTA, AV companies, transit agencies across the United States, Transit Cooperative Research Program (TCRP), universities, and other published reports.

Overview of Findings

The Transit Technology Primer tool that accompanies this report includes dozens of abstracts that highlight relevant literature. The remainder of this document provides an overview that summarizes the literature review.

Early Stage Research and Prototypes

Early stage research refers to initial investments to spur innovation. This research may or may not lead to prototypes that model and test new technology. The USDOT has a comprehensive connected vehicle program that has developed a Concept of Operations for several applications, many of which have been prototyped at a limited scale.

A research prototype is a model of a technology released to test an idea and learn from after iterative improvements. A prototype may have a promising solution to a problem, but may have bugs or defects to be worked out as well. A prototype may be tested in limited situations, but have minimal ability to scale or function in a real-world environment at this time.

USDOT/State DOTs

The USDOT is in the early stages of developing a variety of transportation programs under the Connected Vehicles (CV) Pilot Deployment Program, which supports the integration of innovative transit technologies for long-term planning horizons. A few of the most notable programs include:

- Applications for the Environment: Real-Time Information Synthesis (AERIS);

- Integrated Dynamic Transit Operations (IDTO);
- Multi-Modal Intelligent Traffic Signal System (MMITSS);
- V2V and V2I Technology;
- Enabling Advanced Traveler Information Systems (EnableATIS); and
- Vehicle Assist and Automation (VAA).

Applications for the Environment: Real-Time Information Synthesis (AERIS)

The AERIS program consists of five Operational Scenarios: Eco-Signal Operations, Eco-Lanes, Low-Emissions Zones, Eco-Traveler Information, and Eco-Integrated Corridor Management. Each of these Operational Scenarios consists of different applications and regulatory tools that are designed to promote environmentally-friendly roadway practices by dictating the most efficient way for traffic to flow. The existing traffic signal systems have many limitations, such as:

- Existing sensors are location specific;
- Existing systems do not collect data that consider the environmental effects of emissions;
- Existing systems do not grant priority to transit, freight, or emergency vehicles; and
- Existing systems do not provide information to drivers about eco-driving.

The AERIS program applications may mitigate these issues and provide a platform for agencies to collect and analyze connected vehicle data. These technologies have the potential to reduce fuel consumption, reduce carbon emissions, and enhance safety on roadways, ultimately promoting eco-friendly transit practices and efficiency.[40]

Integrated Dynamic Transit Operations (IDTO)

The IDTO program consists of three applications to improve mobility and transit operations: Connection Protection (T-CONNECT), Dynamic Transit Operations (T-DISP), and Dynamic Ridesharing (D-RIDE). T-CONNECT is designed to improve transit transfers, which will help create a more reliable system and increase transit efficiency. T-DISP is an application designed to provide transportation information to riders so that they are more informed of the transit options available to them. Finally, D-RIDE has the capacity to arrange carpool trips between riders and drivers, which ultimately promotes ridesharing and may serve as a complementary service to transit systems. The IDTO program has been deployed as a prototype in Columbus, Ohio and Central Florida.

Some of the challenges associated with deploying these technologies may include:

- Changes in existing mobility procedures;
- Coordination between agencies;
- A greater demand and reliance for accurate, real-time data;
- Challenges with additional training for existing drivers;
- Creating incentives to encourage the use of these applications;
- Barriers for providing these services in rural communities; and

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[40] USDOT, “Applications for the Environment: Real-Time Information Synthesis (AERIS), Eco-Signal Operations: Operational Concept,” October 2013

- Challenges associated with formulating complex algorithms to ensure that these applications are providing a more efficient means of traveling.

Once these applications are ready for deployment, they have the potential to improve transit efficiency, improve accuracy of transmitted data, improve traveler information, and provide additional transportation options to communities.[41]

Multi-Modal Intelligent Traffic Signal System (MMITSS)

The MMITSS technology is designed to be used in a connected vehicle environment for a variety of transportation modes, such as automobiles, transit, pedestrians, freight, and emergency vehicles. The purpose of MMITSS technology is to create a traffic control system that will improve the efficiency for all transit modes and users within a particular environment through applications. Three applications included under this system are the Intelligent Traffic Signal System (I-SIG), Transit Signal Priority (TSP), and Mobile Accessible Pedestrian Signal System (PED-SIG). I-SIG provides signal priority for vehicles and pedestrians; TSP provides signal priority to transit vehicles; and PED-SIG provides cues to visually impaired pedestrians at crosswalks. Once MMITSS is deployed, there may be challenges associated with additional training requirements for employees, and also when defining how system maintenance may affect safety within an MMITSS location. The goal of MMITSS is to provide a system of traffic signal control that will improve mobility and quality of service for all users within a particular environment. Once a connected vehicle environment is established, these applications can be used to increase efficiency for priority vehicles, and also enhance safety for all users.[42]

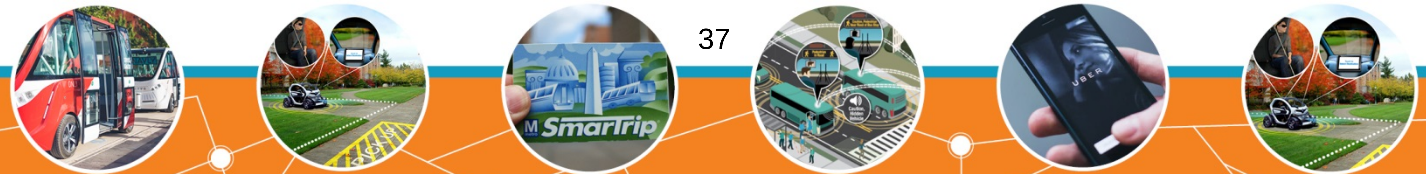
Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) Technology

The USDOT has supported the early development stages of V2I and V2V technologies to increase safety and reduce fatalities on roadways. Some of the emerging V2I applications include:

- Red-Light Violation Warning (RLVW) is an application designed to warn drivers if they may violate an upcoming red light based on speeds and proximity to the intersection.
- Stop Sign Gap Assist (SSGA) is an application designed to warn stopped drivers at an intersection of oncoming traffic.
- Curve Speed Warning (CSW) is an application designed to warn drivers if their vehicle speed is too high in relation to an upcoming curve.
- Stop Sign Violation Warning (SSVW) is an application designed to warn drivers if they may violate an upcoming stop sign based on speeds and proximity to the stop sign.
- Railroad Crossing Violation Warning (RCVW) is an application designed to warn drivers if they need to stop for an upcoming rail crossing.
- Spot Weather Information Warning (SWIW) is an application designed to warn drivers about certain weather conditions that may impact driving.
- Oversize Vehicle Warning (OVW) is an application designed to warn drivers of oversized vehicles regarding restricted clearances that are approaching (e.g. tunnels, bridges).

[41] USDOT, "Integrated Dynamic Transit Operations (IDTO) Concept of Operations," May 2012

[42] University of Arizona, "MMITSS Final ConOps," December 2012, http://www.cts.virginia.edu/wp-content/uploads/2014/05/Task2.3._CONOPS_6_Final_Revised.pdf



- Reduced Speed Zone Warning (RSZW) is an application designed to warn drivers of upcoming reduced-speed zones.[43]

V2I technologies are intended to be used in a fully-functional connected vehicle environment, which currently does not exist. V2I capabilities, however, have the potential to collect and share real-time data to create an overall safer roadway environment. Additionally, some emerging V2V technologies that are being tested include:

- The Emergency Stop Lamp Warning is an application designed to warn nearby vehicles of an impending emergency braking event and possible hazard.
- The Forward Collision Warning is an application designed to warn the driver of an impending rear-end collision with the vehicle ahead in the same lane.
- The Intersection Movement Assist is an application designed to warn the driver if an intersection is unsafe to enter due to a possible collision.
- The Blind Spot and Lane Change Warning is an application that tells the driver if a vehicle is in their blind spot and warns them if it is unsafe to change lanes.
- The Do Not Pass Warning is an application that warns the driver if they cannot pass a vehicle safely.
- The Control Loss Warning is an application that enables a vehicle with Dedicated Short Range Communications (DSRC) technology to broadcast a vehicle control loss to surrounding vehicles. Other vehicles will warn their drivers if the warning is relevant.[44]

V2V technologies are being analyzed to evaluate their safety, practicality, compliance, driver acceptance standards, and effectiveness. V2V and V2I technologies are moving forward through additional research as they strive to enhance safety on roadways and reduce fatalities.

Enabling Advanced Traveler Information Systems (EnableATIS)

Enabling Advanced Traveler Information Systems (EnableATIS) is the traveler information component of the USDOT Dynamic Mobility Applications (DMA) Program. EnableATIS is a developing framework that is envisioned to support a traveler information environment by recording user decisions and trip data to improve transportation system management. This application is designed to support the exchange of real-time data through connected vehicles, public and private systems, and social platforms. Since there is an increasing amount of mobile source data from mobile devices, there is an opportunity to utilize an individual's data to enhance traveler information systems – an individual could contribute information to a data framework through social media platforms and other applications to share traveler information and enhance mobility. Some challenges to implementing a system like EnableATIS may include limited resources to create and maintain the technology, barriers to implementation in rural areas, and also challenges associated with data sharing between agencies. However, the EnableATIS technology may provide multiple benefits and is envisioned to improve mobility and safety,

[43] Battelle Memorial Institute for USDOT, "Accelerated Vehicle-to-Infrastructure (V2I) Safety Applications: Concept of Operations Document," May 2012

[44] USDOT, "USDOT Connected Vehicle Research Program: Vehicle-to-Vehicle Safety Application Research Plan," October 2011

promote data sharing between agencies, enhance planning and research, and promote partnerships to enhance traveler information systems.[45]

Vehicle Assist and Automation

The FTA and the Intelligent Transportation Systems Joint Program Office (ITS JPO) have funded Vehicle Assist and Automation (VAA) technology that can enhance transit safety. The California Department of Transportation (Caltrans) initiated a project using VAA technology to test guidance and precision docking along their Bus Rapid Transit system. This project was for the "Pilot Program to Demonstrate the Benefits of Vehicle Assist and Automation Applications for Full-Size Public Transit Buses" and additional funds were provided by Caltrans. Through a multistate partnership, the VAA project began testing mid-2013 in Oregon along the Lane Transit District's (LTD) Emerald Express (EmX) Bus Rapid Transit system which spanned over 1.5 miles of test segment and 3 stations. The system uses magnetic sensors and lane guidance technology between stations; the two sensing technologies include magnetic markers as a primary system, and differential GPS with inertial navigation sensors as the secondary system. The VAA system provided better alignment of the bus along roadway, and it also allowed the bus to dock closer to station platforms. There were a few issues observed throughout the project process: in one instance, the bus hit a bump along the roadway which caused the bus to propel onto oncoming traffic; the bus driver took control of the steering wheel and there were no damages or injuries reported as a result. Despite this setback, the system was well received by the community and bus drivers. The VAA system provided better alignment of the bus while in motion, and the technology was able to dock the bus closer to station platforms, ultimately increasing safety for passengers and reducing stress for bus drivers.[46]

Universities

Many universities are partnering with transit agencies to research and deploy projects that use emerging technological trends. As one example, the Transportation Research and Education Center (TREC) at Portland State University partnered with the Tri-County Metropolitan Transportation District of Oregon (TriMet) to develop and test a Transportation Demand Management system that uses social media platforms and ITS technology in order to respond to large-scale emergency situations. This project is being funded by FTA through the Innovative Safety, Resiliency, and All-Hazards Emergency Response and Recovery Research Demonstrations (SRER) program. The Transportation Demand Management system will allow transportation agencies to respond to emergency situations and provide services to communities more efficiently. This system could be used to help TriMet and other transit agencies in the area effectively deploy transportation services during emergency situations – these services could be deployed before a hazardous event occurs (i.e. evacuations), and/or after the event occurs to transport people to necessary resources. The objective of this project is to develop a reliable system that will assist in maintaining the region's mobility throughout the response and recovery period of an event, such as connecting people to their job sites, food sources, and other necessary

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[45] USDOT, "Vision and Operational Concept for Enabling Advanced Traveler Information Services," May 2012

[46] Rob Gregg and Brian Pessaro, "Vehicle Assist and Automation (VAA) Demonstration Evaluation Report (FTA Report No. 0093)," January 2016, https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/FTA_Report_No._0093.pdf

facilities when mobility is limited. Once this system is developed and deployed, it could help alleviate many transportation barriers that occur after large-scale emergency situations.[47]

Universities across the U.S. have studied the integration of AV technologies in small-scale contexts – one recent project is the SmartShuttle Program at Ohio State University in Columbus, Ohio. The goal of the SmartShuttle program is to develop a fleet of AVs that can be used as a mode of transportation throughout the Easton Town Center, a large outdoor shopping center in the city. The university received $200,000 from the National Science Foundation (NSF) as part of the Smart City Columbus initiative and through the Early-Concept Grants for Exploratory Research (EAGER) program. This prototype serves as an opportunity for researchers to collect data regarding the benefits and challenges of AV technology within the shopping center, and it will help the city implement larger-scale projects in the future. The fleet will help transport pedestrians and seniors throughout the shopping center and it has the potential to resolve first- and last-mile issues in the area.[48]

Transit Agencies

The Greater Cleveland Regional Transit Authority (RTA) in Cleveland, Ohio is working with the Battelle Memorial Institute to test connected vehicle technologies to reduce pedestrian and vehicle collisions. The technology they are developing is called the Enhanced Transit Safety Retrofit Package (E-TRP) which uses V2I and V2V connected vehicle technology to prevent accidents caused at crosswalks and intersections between buses and pedestrians. The CV technology is being tested on 91 RTA buses and 5-10 intersections. The V2I technology prevents collisions with pedestrians who are in or near intersections and crosswalks, while the V2V technology alerts the bus drivers when vehicles are anticipated to turn in front of it. The system will also improve the accuracy of bus location, storage capabilities, and it will allow remote system management. The ultimate objective is to determine if DSRC can be combined with on-board safety technologies to alert drivers of real-time potential safety hazards. During testing, there were several discrepancies between the connected technologies; there was a high rate of false alerts for the Pedestrian in Signalized Crosswalk Warning (PCW) and the Vehicle Turning Right in Front of Bus Warning (VTRW) due to system limitations within the GPS and pedestrian detector technologies. Essentially, the system had difficulty distinguishing between pedestrians and slow-moving vehicles, which caused a high rate of false alerts. Although testing in Cleveland began in 2017, the system was originally deployed in 2013 at the University of Michigan where the system was found to be an effective way of providing alerts to bus drivers to improve safety along roadways.[49] [50]

The Los Angeles County Metropolitan Transportation Authority (LACMTA) received funding from the FTA to install and test a Platform Track Intrusion Detection System (PTIDS) at select rail stations throughout the county to increase safety along rail lines. In 2015, LACMTA announced

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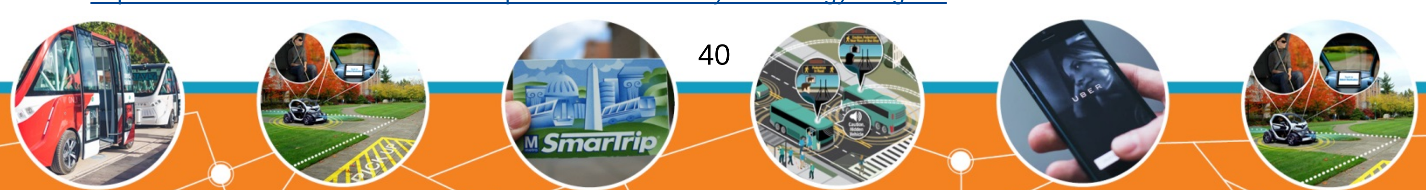
[47] FTA, "Innovative Safety, Resiliency, and All-Hazards Emergency Response and Recovery Demonstration Project Selections," March 2016, https://www.transit.dot.gov/funding/grants/innovative-safety-resiliency-and-all-hazards-emergency-response-and-recovery

[48] Ohio State University, "SmartShuttle Program Receives NSF Funding," August 17, 2016, https://ece.osu.edu/news/2016/08/smartshuttle-program-receives-nsf-funding

[49] The City of Columbus, "Beyond Traffic: The Smart City Challenge," May 2016, https://www.columbus.gov/WorkArea/DownloadAsset.aspx?id=2147487896

[50] RTA, "RTA to develop new vehicle safety technology with FTA grant," October 2016, http://www.riderta.com/news/rta-develop-new-vehicle-safety-technology-fta-grant



plans to test the PTIDS technology at select stations (Gold, Red, and Blue rail lines). This system provides a way to monitor rail station platforms and initiate alerts through radar technology which will reduce injuries and fatalities along railway tracks. PTIDS functions by detecting an object within the track's right-of-way and alerting the track operators so they can decide how to mitigate the issue. [51] The radar sensors are placed in modules which are 2.5 meters long, and the modules can reach up to 160 meters in total length when combined in order to span the length of the station platform. This technology requires little maintenance to operate and is not compromised by rain, fog, debris, or other minor inhibitors, which showcases the system's low false alarm rate and efficiency of use.[52]

Pilot Projects and Commercially Available Technologies

A technology is pilot-ready when a research prototype has been sufficiently developed into a potentially viable product. Several autonomous shuttles are being piloted across the U.S. Commercially available technologies are those that are widely accessible to transit agencies. Some widely used technologies are highlighted in this report, with a larger universe of technologies discussed in the *Stakeholder and Vendor Engagement Section.*

USDOT/State DOTs

TBEST Transit Planning Software

FDOT's Transit Office is at the forefront of transit planning software tools. Transit Boardings Estimation and Simulation Tool (TBEST) is a multi-faceted GIS-based modeling, planning, and analysis tool that is required to be used by Florida transit agencies. It integrates socio-economic, land use, and transit network data for scenario-based ridership analysis. TBEST provides supporting functions for strategic transit development plans, service planning, FTA Title VI, mobility planning, comprehensive operational analysis, General Transit Feed Specification (GTFS) compatibility, grant applications, and performance reporting[53] (**Figure 1**).

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[51] FTA, "Notice of a Buy America Waiver for Proposed Innovative Electronic Platform Track Intrusion System," December 2015, https://www.transit.dot.gov/regulations-guidance/notices/2015-31153

[52] Honeywell, Rail Track Safety, https://cip.honeywell.com/sol/Pages/RailTrack.aspx

[53] https://tbest.org/

Figure 1: TBEST Transit Planning Software

ATSIM Transit Stop Inventory

Automated Transit Stop Inventory Model (ATSIM) is a web-based system for transit agencies in Florida to manage transit stop facilities[54]. It allows for collection, analysis, updating, and management of standard transit stop inventories. It avoids time-consuming manual data entry and duplication of records. Using a tablet device, the system has the capability to store multiple pictures in the database and allows collection of over 100 standard attributes, user-defined fields, and GPS coordinates. Supported by FDOT, the key components of ATSIM include data collection, work orders, data management, and mapping.

Quality/Level of Service Software

FDOT supports Quality/Level of Service materials and tools to evaluate multimodal transportation service. Quality of Service is a traveler-based perception of how well a transportation service or facility operates. Level of Service is a quantitative measure of transportation in the roadway environment. Transit is one of four key modes specified and emphasizes frequency of transit service. LOS Software is available for download on FDOT's website for use by Florida agencies[55].

Scheduling

One practice for many transit providers in Florida is the use of scheduling software for their agency. The National Center for Transit Research (NCTR) conducted a study to analyze the types of scheduling software packages that transit agencies in Florida use in order to understand the benefits of using software as opposed to manual processes. Most transit agencies in Florida use GIRO HASTUS or Trapeze software, such as the Jacksonville Transportation Authority (JTA) in Jacksonville and Hartline in Tampa, respectively. The only agency in Florida that uses a different

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[54] http://www.ftis.org/atsim.html

[55] http://www.fdot.gov/planning/systems/programs/sm/los/los_sw2M2.shtm

software system is the Gainesville Regional Transit System (RTS) who uses Fleet-Net software. Scheduling software saves time spent on the scheduling process, and it's easier than conducting the process manually. The software also provides increased flexibility, reduces cost, is easier to manage, and reduces the need for additional drivers and vehicles. Although the greatest barrier to implementing scheduling software for transit agencies is the cost of the software and hardware, larger transit agencies in Florida have found that the software improves the scheduling process and allows for greater functionality and control over their scheduling services.[56]

Transit Agencies

Autonomous Shuttles

There are many companies that have been developing and deploying autonomous technologies on a global scale, such as 2getthere, EasyMile, Daimler, and Navya. These autonomous technologies have the potential to improve safety, reduce the overall cost of transit implementation, decrease congestion, and be more eco-friendly than the majority of vehicles commonly used today. Additionally, they have the ability to complement existing transit systems to resolve first- and last-mile barriers. Many of these AV vehicles are being deployed in urban centers, transportation hubs, healthcare hubs, retirement communities, convention centers, recreation spaces, theme parks, universities, business parks, and industrial areas.[57]

Las Vegas was the first city in the U.S. to test a fully-autonomous shuttle within real-time traffic in November 2017. The shuttle is called the AAA Free Self-Driving shuttle and was created by Navya, an autonomous vehicle manufacturer. The shuttle operates on a 0.6-mile loop around downtown Las Vegas and stops at three locations. The shuttle operates from 11 am to 7 pm, six days per week, and offers free rides to people within the Innovation District. This project received a lot of attention when a semi-truck collided with the shuttle on its first day of service, which sparked numerous debates regarding AV safety and liability. After the incident, the police confirmed that the human driver was the one at fault, but many people within the community feel reluctant to trust AV technology. The Navya shuttle will continue to be tested and improved through the collection of data and feedback from the community; Las Vegas hopes to deploy additional AV shuttles on a larger scale by expanding the existing system.[58]

As transit agencies in Florida are beginning to understand the value of investing in emerging transit technologies, many have begun to support testing of prototypes to incorporate new technology into their existing infrastructure. One agency that has been making notable progress into the realm of AV technology is the JTA. Since JTA's existing Skyway system (an automated people mover) was due for a complete overhaul of its vehicles, JTA decided to research

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[56] Mark Mistretta, "Fixed Route Transit Scheduling in Florida: The State of the Industry," March 2005, https://www.nctr.usf.edu/pdf/527-01-3.pdf

[57] EasyMile, http://easymile.com/

[58] Nick Statt, "A self-driving shuttle in Las Vegas got into an accident on its first day of service," November 8, 2017, https://www.theverge.com/2017/11/8/16626224/las-vegas-self-driving-shuttle-crash-accident-first-day

alternatives to replacing the monorail vehicles that would also promote future plans for expanding the Skyway system to surface level. Ultimately, JTA determined that investing in an AV system was a viable option given the technology's capabilities, emerging trends, and overall financial savings of its integration. Unlike other transit systems, the AV technology would allow vehicles to operate on the existing Skyway infrastructure and along existing roadways, reducing the need to invest in additional infrastructure. JTA is currently operating an AV test track, with the goal of evaluating the performance of six to eight vendors. The test track will provide a means to introduce AVs to the public[59] (**Figure 2**).

Figure 2: EasyMile EZ10 Gen-2 Vehicle

There are a variety of transit agencies that are partnering with technology providers to enhance mobility and safety in their communities. In one example, the Contra Costa Transportation Authority (CCTA) in San Ramon, California initiated a project to deploy AV shuttles to be used within a local business park (Bishop Ranch). CCTA partnered with EasyMile (**Figure 3**) and Sunset Development Company to deploy two EasyMile Shuttles as part of the second phase of CCTA's AV project. These shuttles are initially being tested in an empty parking lot within the business park, and they will eventually be moved to an adjacent occupied lot for additional testing. The goal is to deploy the shuttles throughout the business park so that people can use the shuttles as a mobility option without needing to cross public roadways. As an incentive to gather data about this service, 30,000 employees who work within the Bishop Ranch center will have the opportunity to ride in the shuttles if they agree to provide feedback about their experience. The final phase of this project will be to test the AV shuttles on public roadways; this project offers an opportunity to resolve first- and last-mile mobility barriers throughout the city.[60]

Figure 3: Contra Costa Autonomous

Automatic Vehicle Location and Automatic Passenger Counters

In response to increasing congestion and demand for services, agencies are also investing more in Automatic Vehicle Location (AVL) technology and APCs in order to improve their services. AVL technology allows increased monitoring and control over transit vehicles, while APC technology

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[59] Jacksonville Transportation Authority, "About the U2C Project," http://www.u2cjax.com/about/

[60] McCauley Ryan, "Driverless Shuttle Program Kicks Off in California to Tackle First Mile/Last Mile Mobility Obstacle," March 6, 2017, http://www.govtech.com/fs/driverless-shuttle-program-kicks-off-in-california-to-tackle-first-milelast-mile-mobility-obstacle.html

collects data regarding passenger activity on vehicles – both of these capabilities offer agencies an opportunity to monitor vehicle utilization and improve services. Some of the benefits of integrating AVL-APC systems include:

- Integrating on-board systems to free up storage space at agencies;
- Incorporating data sensors at vehicle doorways and odometers can provide better records of data; and
- Integrating AVL with fare-collection systems offers agencies an opportunity to analyze linked trips.

There are numerous case studies regarding the use of AVL-APC technology that have been deployed in the United States, Canada, and Europe; overall, these systems have been successful in the monitoring of transit systems and are useful tools for improving services.[61]

Mobile Data Terminals

In addition to AVL-APC technologies, agencies are also investing in other types of ITS technology, such as MDTs, electronic registering fare boxes, magnetic stripe cards, and smart cards.[62] AVLs, sensors, data communications, and security systems also use MDTs for communication. MDT infrastructure allows information to be communicated between transit vehicles and central information systems, which has been an effective tool to communicate directions, schedule changes, improve services, and also improve safety. MDTs may also incorporate passenger counting technology, the ability to count mobility aids used by passengers, fare technology (e.g. magnetic strip readers and smart card technology), and functions as an emergency alarm. Some potential challenges when deploying MDT technology may include:

- Different rates of location technology diffusion;
- Changes in communication technology;
- Uncertainties regarding manufacturers; and
- Issues regarding deployment in transit environments.[63]

Customer Communication Technology

To further enhance traveler information systems, more agencies are deploying electronic signage. Some of the challenges that agencies have faced with the implementation of electronic signage are the ongoing associated costs, data monitoring to ensure accuracy, and issues regarding the number and placement of signs deployed. Agencies have also reported a number of benefits associated with deploying passenger signage, such as:

- The ability to provide easily accessible information to riders (as opposed to constantly referring to information through an app on a mobile device);
- Providing information to all riders including people who don't have mobile devices;
- Providing real-time information, which affects the perception of wait times and services; and

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[61] TCRP, "Using Archived AVL-APC Data to Improve Transit Performance and Management," 2006

[62] TCRP, "Leveraging ITS Data for Transit Market Research: A Practitioner's Guidebook," 2008

[63] TCRP, "Mobile Data Terminals," 2007

- Increasing safety and security. Passenger signage has been deployed in a variety of cities, and it improves transit services across communities.[64]

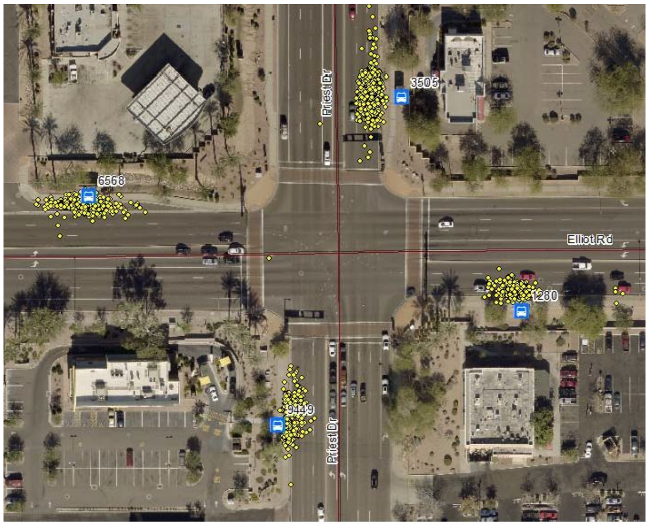
Mobile devices have proven to be a valuable tool for transit agencies to use to enhance traveler information systems and communication. Transit agencies have the option to use third parties to develop mobile applications to provide real-time information to customers. Mobile applications, as well as smart cards, can be designed to process fare payments, which is an option for customers to utilize services more efficiently. These tools provide an opportunity for agencies to increase communication and data sharing with one another to improve mobility and efficiency.[65]

Geographic Information System

Geographic Information System (GIS) technology (**Figure 4**)[66] is another well-developed tool that has been used in transportation fields since the early 1990s. GIS has advanced in user-friendliness and capabilities; some of the most common uses of GIS software in transportation fields include trip scheduling, trip itinerary planning, AVL applications, service planning, map production, market analyses, ADA compliance, and Title VI programs. Some of the challenges associated with using GIS in transportation may include difficulties integrating real-time information into transit systems, training requirements, barriers from sharing information with non-GIS users, system maintenance, and security concerns. However, there are many benefits to using GIS as well, such as allowing the exchange of complex data between agencies, improving communication through the visualization of data, identifying ways to improve transit services based on data (e.g. ridership/demand), and offering capabilities to monitor system utilization to improve efficiency by resolving scheduling issues and providing APC capabilities.

Figure 4: Example using GIS to measure ridership

Source: **esri.com**



Vehicle Guidance Systems

The Minnesota Valley Transit Authority (MVTA) worked with MTS Systems Corporation to develop a vehicle guidance system for the MVTA Bus on Shoulder (BOS) transportation program. They developed a Driver Assist System (DAS) which provides lane positioning information to the driver through graphic displays, virtual mirrors, vibrating seats, and actuated steering. The BOS program allows buses to use the shoulders along highways to alleviate congestion on roadways during peak hours; it is also an eco-friendly concept because it reduces fuel consumption and pollution. MVTA's primary goal in deploying this technology was to enhance driver confidence, especially

[64] Carol Schweiger, "Use of Electronic Passenger Information Signage in Transit," 2013

[65] TCRP, "Use and Deployment of Mobile Device Technology for Real-Time Transit Information," 2011

[66] TCRP, "Geographic Information Systems Applications in Transit," 2004

during adverse weather conditions; their secondary goals were to reduce transit travel times, increase reliability, enhance safety, and improve customer satisfaction. In late 2013, MVTA applied to receive funds to expand their DAS technology to additional buses through FTA's Innovative Safety, Resiliency, and All-Hazards Emergency Response and Recovery Research Demonstrations program (SRER). The BOS network in the Minnesota metropolitan area is approximately 250 miles long. The first generation of DAS was installed in 10 buses in 2010, and the second generation of DAS was installed in the buses with the existing technology plus an additional 11 buses in June 2016. Results from the first generation DAS showed that drivers stayed within their lanes 10% longer, drove 3 mph faster, and reduced side-to-side movement by 5.5 inches. Over 80% of passengers rated the BOS system highly, and over 95% of passengers were satisfied with its efficiency and reduced travel time. Additionally, 32% of drivers felt more confident operating the bus with DAS, and over 60% stated that DAS technology made driving safer and the experience less stressful.[67] [68]

Summary Crosswalk to Technology Use Cases

Table 5 provides an overview of the projects mentioned in the literature review in relation to the technology categories identified in this report. Most of these projects fall under more than one technology category.

Table 5: Summary Crosswalk to Technology Use Cases

Project / Technology	Safety	Mobility	Accessibility	Envir.	Traveler Information	Operations	Fare Collection and Processing	Emerging Service Models
AERIS	X			X		X		
IDTO		X	X		X	X		
MMITSS	X	X	X					
V2V/V2I	X	X				X		X
EnableATIS		X			X	X		
VAA	X	X				X		
All-Hazards Emergency Response		X	X	X				
Ohio SmartShuttle	X	X	X					X
E-TRP	X							
PTIDS	X					X		

[67] Joel Volinski, "Evaluation of Automated Vehicle Technology for Transit," April 2016, https://www.nctr.usf.edu/wp-content/uploads/2016/04/Evaluation-of-Automated-Vehicle-Technology-for-Transit-2016-Update-UPDATED-FINAL.pdf

[68] Brian Pessaro, Caleb Van Nostrand, FTA Report 0010, "Ceder Avenue Driver Assist System Evaluation Report," December 2011, https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Report_No._0010.pdf

Project / Technology	Safety	Mobility	Accessibility	Envir.	Traveler Information	Operations	Fare Collection and Processing	Emerging Service Models
TBEST		X				X		
ATSIM			X		X	X		
Q/LOS	X	X						
Scheduling Software					X	X		
Autonomous Transit	X	X	X	X		X	X	X
AVL-APC		X			X	X	X	
Customer Communication					X	X	X	X
GIS					X	X		
Driver Assist System	X	X		X				

Literature Review Summary

As exemplified in this section, there are many challenges and benefits associated with the technologies and projects mentioned. In general, many of the challenges associated with implementing these technologies are associated with a lack of resources, technological limitations, cost of integrations, concerns regarding cyber security and data management, and a lack of communication and data sharing amongst organizations. However, there are also many benefits that are anticipated from investing in advancing systems, such as increased safety along roadways, increased mobility across communities, and an opportunity to make transit systems more efficient through increased coordination and data sharing. Transit agencies may build upon this information by supporting prototypes and pilots to address use cases that are not yet addressed by commercially available products. Ultimately, the Literature Review serves as a way to inform agencies of some prominent technologies that are being used and developed today, which may inspire transit agencies to incorporate similar technologies.

ONGOING RESEARCH SUMMARY

Ongoing Research Summary

The Ongoing Research Summary provides an overview of the ongoing research activities and technology trials relevant to transit.

This section includes USDOT research programs, USDOT grant pilot programs, state DOT research programs, industry group and university research, and other organizations**.** The remainder of this section reviews these ongoing initiatives to highlight potential new technologies and their applicability to transit, with an emphasis on small-to-midsized agencies.

There are a number of federal and state DOT sponsored technology projects with significant transit involvement currently underway. Industry groups and universities provide additional funding and analysis of innovative ongoing research. Since these activities are not yet concluded, this section provides insight into areas of focus and promising trends to watch in the coming years.

Transit agencies are at the forefront of the emergence of transportation technology. Large transit agencies have the resources and internal staff expertise to meet with technology vendors, review products, and participate in state and national committees and events to stay abreast of existing and emerging technologies. Smaller agencies, whose need is every bit as great, typically do not have access to this same level of resources and are reliant upon published literature and "word-of-mouth" information exchanges. This results in a paradigm where large transit agencies predominate as "first adopters" with smaller transit agencies being "late adopters," who may not realize the full benefit of the technology before it becomes obsolete. At the same time, the challenges and issues facing small-to-midsized transit agencies may differ significantly from those of a large (typically urban) transit agency. To the extent that different technologies address unique issues, small-to-midsized agencies may not learn of specific technologies for several years since they do not fit the need profile of a large transit agency.

The technologies are changing rapidly with new technologies emerging on a daily basis. State-of-the-art technology from only a few years ago is already reaching obsolescence or has been surpassed by improved products. At the same time, agencies need to adopt proven, stable technologies with a definable benefit. With the advance and pace of technology adoption, agencies should be diligent to ensure that whatever technology they adopt is stable, cost effective, and provides tangible benefits.

USDOT Research Programs

Mobility on Demand (MOD) Sandbox Program

Mobility on Demand (MOD) describes an integrated and connected multi-modal network of safe, affordable, and reliable transportation options available to everyone. The FTA MOD Sandbox Program[69] supports 11 cities across the country as part of a larger USDOT research effort to help transit agencies and communities integrate new mobility tools like smartphone apps, bike-sharing, car-sharing and demand-responsive bus and van services. The 11 cities are listed in **Table 6**.

This demonstration program explores innovative approaches to integrate MOD solutions with public transportation; empower implementation of innovative business models to deliver high-quality, seamless and equitable mobility options; and inform FTA how to approach MOD and structure future MOD policies. In 2016, FTA announced $8 million of funding for applicants with bold and innovative projects with strong partnerships. Projects required 20-percent cost match and were awarded to the 11 grantees. The grants support all activities leading to the

[69] https://www.transit.dot.gov/research-innovation/mobility-demand-mod-sandbox-program.html

demonstration of the innovative MOD and transit integration concept, such as planning, software development, and conducting the demonstration. Each demonstration is a minimum of 12 months and should address equity and accessibility. Funding awards for each grantee range from $200,000 to $1.3 million.

Table 6: MOD Sandbox Grantees

Location	Project Sponsor	Description
Chicago, IL	Chicago Transit Authority (CTA)	Incorporate local bike sharing company into CTA's existing transit trip planning app so users can identify bike stations and pay for bike rentals.
Dallas, TX	Dallas Area Rapid Transit (DART)	Integrating ride-sharing services into its ticketing app to solve first and last mile issues; combining traveler applications to create a multimodal application that leverages ride-sharing services.
Lakewood, WA	Pierce County Public Transportation Benefit Area Corporation	An initiative connecting local service, regional service, and local ride-share companies in order to increase regional transit use.
Los Angeles, CA & Seattle, WA	Los Angeles County Metropolitan Transportation Authority	A two-region partnership with the car-sharing company, Lyft, in Los Angeles and Seattle to explore first/last mile solutions for trips originating and ending at select transit stops.
Montpelier, VT	Vermont Agency of Transportation	Statewide transit trip planner that will enable flex-route, hail-a-ride, and other non-fixed-route services to be incorporated in mobility apps.
Palo Alto, CA	City of Palo Alto	Aiming to reduce single-occupant vehicle driving from 75% to 50%, the project includes commuter trip reduction software and a mobility aggregation multimodal trip planning app.
Phoenix, AZ	Valley Metro Rail, Inc.	Smartphone mobility platform that integrates mobile ticketing and multimodal trip planning including ride-hailing, bike sharing, and car-sharing companies.
Portland, OR	Tri-County Metropolitan Transportation District (TriMet)	Building on existing trip planning app to incorporate shared use mobility options and more sophisticated functionality and interfaces.
San Francisco, CA	San Francisco Bay Area Rapid Transit (BART)	An integrated carpool to transit program that will provide a seamless way to reserve and pay for in-demand parking spaces at stations and allow preferential parking for carpoolers.

Location	Project Sponsor	Description
St. Petersburg, FL	Pinellas Suncoast Transit Authority	Set of partnerships with a taxi company, a paratransit service and a car-sharing company to develop a model to provide more cost-effective on-demand door-to-door paratransit service.
Tucson, AZ	Regional Transportation Authority of Pima County	Integrating fixed route, subscription based ride-sharing and carpooling into an existing data platform; incorporates shared services, open payment systems and advanced traveler information.

MOD Sandbox demonstrations focus on the following principles:

- System Integration: Operational integration of MOD products and services with existing transit service. Examples of this include open data platforms, common user interfaces, and practices and technologies that encourage and ensure system interoperability.
- Partnership Driven: Teaming efforts, from public and private sectors, with partners committed to supporting the proposed MOD project both technically and institutionally.
- Innovative Business Model: MOD solution providers and transit operators partner to collectively deliver better service to travelers, while mutually benefitting from the partnership.
- Equity of Service Delivery: Promote equitable mobility service for all travelers, including communities such as low income, the aging population, and persons with disabilities, including wheelchair users.

At a January 2018 USDOT workshop[70], participant take-aways included:

- Lessons learned and best practices are still emerging from the MOD Sandbox with respect to public–private partnerships. Questions remain pertaining to the structuring of public–private partnerships, revenue sharing, data sharing, and serving people with special needs.
- The management and understanding of pilot data including the protection of personal privacy and the safeguarding of proprietary data were identified as two prominent issues requiring standardization and guidance to support future MOD public–private partnerships.

Accessible Transportation Technologies Research Initiative

The Accessible Transportation Technologies Research Initiative (ATTRI) Program[71] (**Figure 5**) is leading efforts to develop and implement transformative applications to improve mobility options for all travelers, particularly those with disabilities. Nearly 20 percent of the U.S. population is comprised of individuals with disabilities, and the number of older Americans continues to increase. ATTRI research focuses on removing barriers to transportation for people with visual, hearing, cognitive, and mobility disabilities. Funded by ATTRI, emerging technologies and creative service models aim to offer enhanced travel choices and accessibility.

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[70] U.S. Department of Transportation's Mobility on Demand Initiative: Moving the Economy with Innovation and Understanding. Transportation Research Circular E-C231. February 2018.

[71] https://www.its.dot.gov/research_areas/attri/index.htm

Figure 5: ATTRI Vision

Source: www.its.dot.gov

ATTRI technology solutions include: wayfinding and navigation, pre-trip concierge and virtualization, safe intersection crossing, and robotics and automation:

- Wayfinding and Navigation helps travelers, particularly those with disabilities, safely and independently reach their destinations by providing real-time information, localization and situational awareness to assist in navigating indoor and outdoor environments, including path planning and detouring around blocked routes or hazards.
- Pre-trip Concierge & Virtualization provide pre-trip planning and en-route travel information to travelers with disabilities, their family members, and caregivers, including creating a virtual environment for users to familiarize themselves with their travel before the trip. This technology also offers the ability to pair transportation services based on user needs.
- Safe Intersection Crossings enable pedestrians to use their connected mobile devices to interface with vehicles, traffic signals, and other infrastructure to receive context-based information related to pedestrian and built environments. Guidance notification and alerts

in accessible communication formats optimize their travel experience and help them cross an intersection safely.

- Robotics and Automation could assist with activities of daily life such as walking. These technologies could also work with individual travelers and transportation service providers to deliver related services at different points of travel, thereby improving personal mobility across the transportation network.

ATTRI targets older adults and persons with disabilities. Vision, mobility, hearing, and cognitive disabilities can negatively impact quality of life and the ability to travel for millions of Americans. The ATTRI technology solutions are all reliant on foundational considerations, including a standard accessible data platform, universal design standards, integrated mobile payment, and leveraging existing technologies. Six grantees (**Table 7**) have been awarded the opportunity to create innovative new technologies to assist individuals with mobility challenges.

Table 7: ATTRI Grantees

Grantee	Application	Description
AbleLink	Pre-trip Concierge & Virtualization	A suite of assessment, self-directed learning, and trip execution technologies to support independent travel for individuals with cognitive disabilities.
AbleLink Smart Living Technologies	Wayfinding and Navigation	An open wayfinding media standard and related infrastructure to support the creation of geographically-specific, cloud-based libraries of routes that adhere to the SMART standard for users in different metropolitan or rural areas.
Carnegie Mellon University	Safe Intersection Crossing	Connect pedestrian travelers with disabilities to the traffic signal systems (and by extension to nearby connected vehicles and infrastructure), and use this connectivity to develop assistive services for safe intersection crossing and increased independent mobility.
City College of New York	Wayfinding and Navigation	Smart Cane for Assistive Navigation (SCAN), integrated with a smartphone application.
Pathways Accessibility Solutions	Wayfinding and Navigation	A wayfinding tool for wheelchair users and people with visual impairment that guides routes tailored to the user's preferences.
TRX Systems	Wayfinding and Navigation	A smart wayfinding and navigation system to obtain real-time location, en-route assistance, and situational awareness.

The execution of ATTRI is being conducted in three phases over six years: Exploratory and User Needs Research Phase (Year 1), Innovation and Prototype Phase (Years 2-4), and Demonstration Phase (Years 5-6), with completion around the year 2021.

USDOT Grant Pilot Programs

Connected Vehicle Regional Pilots

The Connected Vehicle (CV) Pilot Deployment[72] program is an initiative to support the development and testing of connected vehicle applications and technologies. The goals of the program are to support and accelerate early deployments of connected vehicle technologies, measure the impacts and benefits of the deployment, and enhance the development of the technologies by resolving issues throughout the deployment.

In 2016, the USDOT selected three locations to serve as initial pilot deployment sites: New York City, Wyoming, and Tampa. Each pilot deployment includes the implementation of multiple connected vehicle technologies and applications to improve the unique conditions of each location. Throughout an approximately four year schedule, the pilot sites will undergo concept development; design, deployment and testing; and operation, maintenance and evaluation. Performance measures are based on individual needs of each system.

Phase 1 of the program, the Pre-Deployment Phase, was completed during the first year of the program. This phase included the initiation of efforts to prototype and demonstrate connected vehicle applications. The prototype design and development were aimed at meeting the objectives and requirements determined as part of conceptual design. USDOT has published records related to the prototyping efforts for select connected vehicle applications including concepts of operations, system requirements, and design documents. Pilot site agencies have demonstrated and field tested to evaluate the safety, mobility and environmental impacts to gain insight regarding the potential impacts of widespread deployment. These prototypes were then finalized and carried forward into deployment efforts.

Real world deployments were initiated during the second phase of the CV Pilot Deployment program. Each of the three pilot programs incorporated concepts that leveraged research and advanced data collection and communication technology.

The New York City CV Pilot Deployment Program (**Figure 6**) builds upon the City's Vision Zero initiative with an aim to increase the safety of drivers, passengers, and pedestrians and greatly reduce associated injuries and fatalities. The project area includes sections of the densely populated boroughs of Manhattan and Brooklyn and was proposed to utilize DSRC technology to provide safety information and warnings to vehicles and pedestrians. This pilot supports the deployment of many safety-related CV applications that focus on using V2I and V2V technology to address specific concerns such as Curve Speed Compliance, Blind Spot Warning (BSW), Lane Change Warning/Assist (LCA), Pedestrian in Signalized Crosswalk, and an Intelligent Traffic Signal System (I-SIGCVDATA). In order to accomplish the pilot's goals, 353 Roadside Units (RSU), 8,000 vehicles, and 100 pedestrians will be equipped with connected vehicle communication technology or devices.

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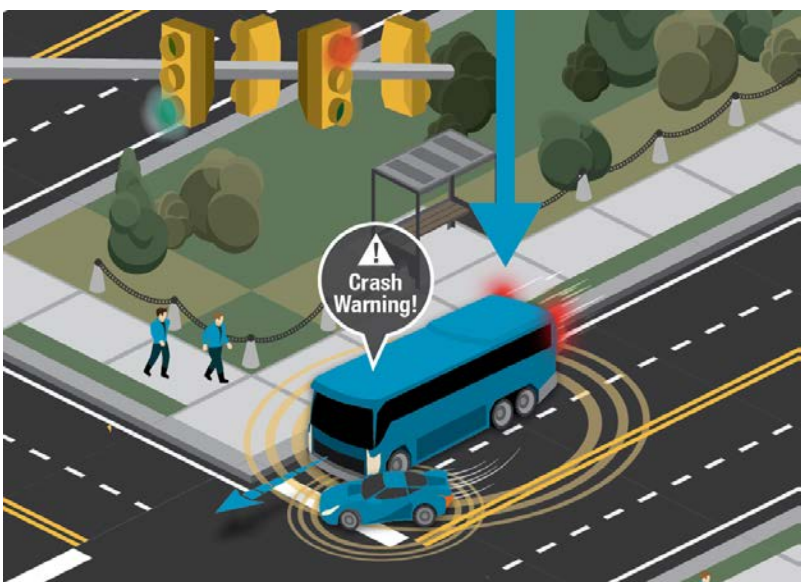
72 https://www.its.dot.gov/pilots

Figure 6: New York City Connected Vehicle Pilot Deployment Program

Source: www.cvp.nyc/project-status

In Tampa, the main transportation issues were identified to be peak-hour collisions, congestion, pedestrian safety, streetcar conflicts, and wrong-way drivers on the Selmon Reversible Express Lanes (REL). The pilot deployment program aims to address these safety and traffic issues with multiple connected vehicle applications including Wrong Way Entry (WWE), Vehicle Turning Right in Front of a Transit Vehicle (**Figure 7**), End of Ramp Deceleration Warning (ERDW), Intersection Movement Assist (IMA), and Probe-enabled Data Monitoring (PeDM). DSRC communication technology will be used by 40 RSUs and over 1,600 On-Board Units to achieve the goals of this CV pilot deployment program.

Figure 7: Tampa Pilot - Vehicle Turning Right in Front of Transit Vehicle CV Application



Source: www.tampacvpilot.com

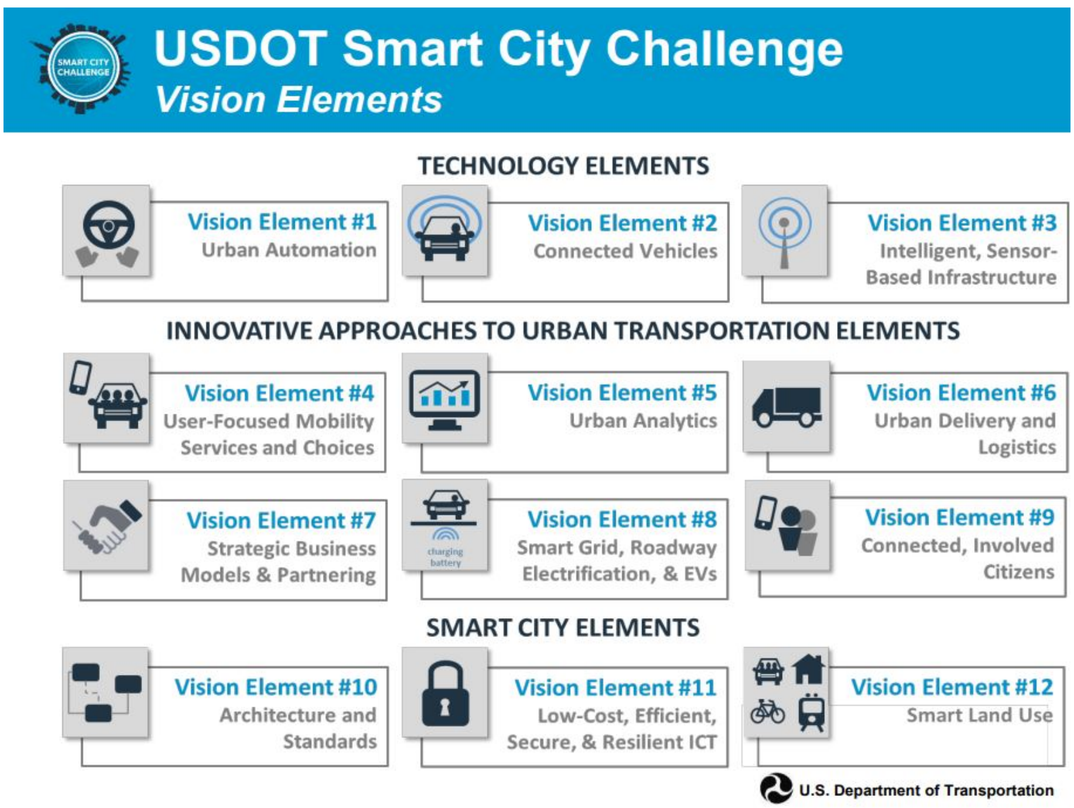
The focus of the Wyoming CV Pilot Program is the enhancement of I-80, the state's major east-west freight corridor that spans southern Wyoming. While this rural corridor is unrelated to transit, the connected vehicle technologies being piloted may be relevant to urban environments as well. The main issue in this pilot on I-80 is the extreme wind speeds during the winter months that significantly increase the number of truck collisions and turnovers that result in road closures. The CV applications proposed as a part of this effort are centered on the needs of commercial vehicles and include Distress Notification (DN), Spot Weather Impact Warning (SWIW), I2V Situational Awareness, and Forward Collision Warning (FCW). An estimated 75 RSUs and 400 On-Board Units will be utilized during this deployment.

These three pilot programs in New York City, Tampa, and Wyoming will be closely watched as they transition from Phase 2 to Phase 3 with full deployment and operations. The pilots should conclude around the year 2020.

Smart City Challenge

USDOT introduced the Smart City Challenge[73] in 2015 in order to solicit innovative solutions to enhance transportation systems using advanced techniques and new technologies. USDOT provided a list of 12 vision elements (**Figure 8**) for consideration.

Figure 8: Smart City Challenge Vision Elements



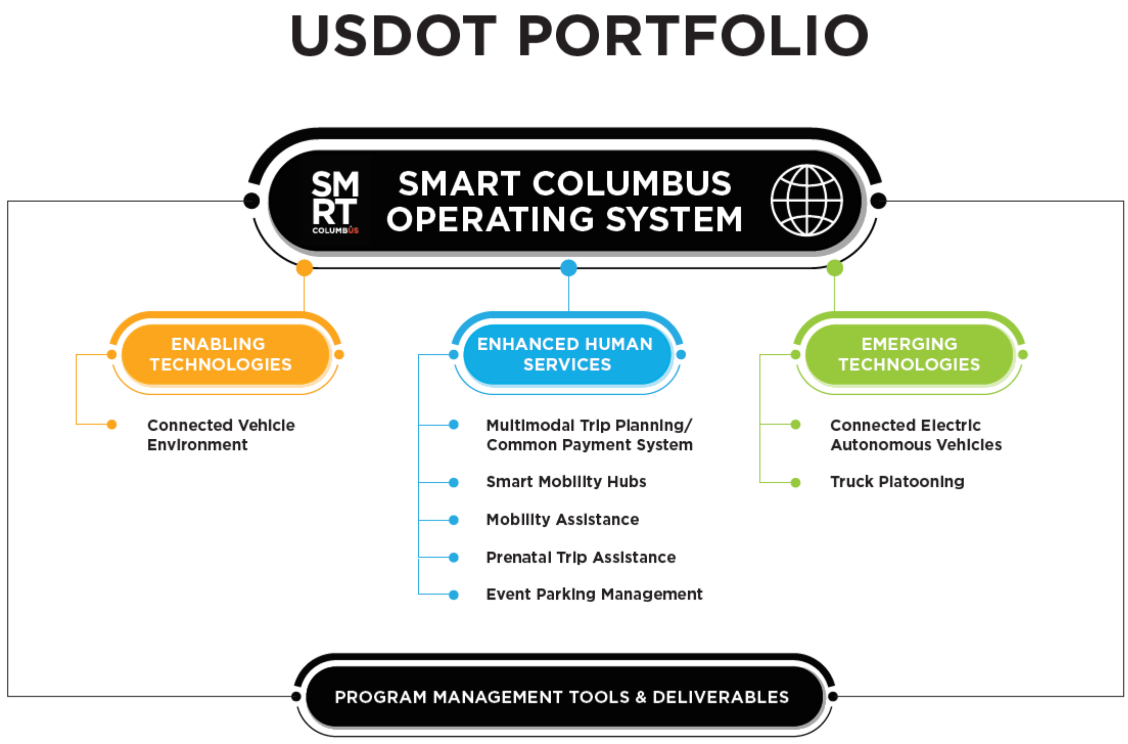
Columbus, Ohio (**Figure 9**) was announced as the winner in 2016 and received $40 million from USDOT and $10 million from Vulcan, Inc. Although only one city was selected as the winner of the USDOT's Smart City Challenge, the application process helped form many partnerships

[73] https://www.transportation.gov/smartcity

between public and private entities in cities across the country focused on smart city technologies. One main reason Columbus was selected was the inclusion of an initiative to provide an underserved community with one of the highest infant mortality rates in the country with access to healthcare through subsidized transportation options. Partnerships and additional funding opportunities also helped create a united group of community stakeholders dedicated to transform Columbus into America's first Smart City.

At the heart of Smart Columbus is the Smart Columbus Operating System (SCOS), envisioned as a web-based, dynamic, governed data delivery platform. It will ingest and disseminate data while providing access to data services from the planned Smart Columbus technologies, traditional transportation data and data from other community partners. The SCOS aims to be scalable and demonstrate the potential for serving city and private sector needs.

Figure 9: Smart Columbus Operating System



Source: www.columbus.gov/smartcolumbus/projects

Multiple projects are included in the Smart Columbus Operating System:

- **Connected Vehicle Environment**: To enhance safety and mobility throughout the city's transportation system, this project will utilize connected vehicle technologies and applications with an emphasis on congested and high-crash intersections and corridors. Safety applications are intended to be installed on public fleets and private vehicles.
- **Multimodal trip planning application and common payment system**: To make multimodal options easily accessible to all, this project will provide a robust set of transit and shared-use transportation options that users will be able to compare and pay for. Payment will be easily processed through an innovative Common Payment System.

- **Smart Mobility Hubs**: To enhance mobility and alleviate first/last mile challenges, it is planned to install kiosks at key Bus Rapid Transit stops in an economically disadvantaged neighborhood. These Smart Mobility Hubs will assist in travel planning and allow expanded transportation options via other modes.
- **Mobility assistance for people with cognitive disabilities**: The city plans to deploy a mobile application that will be a highly-accurate, turn-by-turn navigator designed to be intuitive such that older adults and groups with disabilities including the cognitively and visually disabled can travel independently on transit and other modes.
- **Prenatal Trip Assistance**: To provide flexible, reliable, two-way transportation to expectant mothers traveling to doctor's appointments, this project aims to improve health outcomes using Medicaid-brokered transportation services.
- **Event Parking Management**: This project will integrate parking information from multiple providers into a single availability and reservation services solution. This will allow travelers to plan and search for parking options at certain locations, as well as allow more direct routing of travelers during large events to reduce congestion.
- **Connected Electric Autonomous Vehicle (CEAV)**: To provide a first/last mile transit solution and reduce congestion, this project will deploy a fleet of multi-passenger CEAVs for job and entertainment destinations. The CEAVs will be deployed to meet these goals and are expected to operate in a mixed-traffic environment.
- **Truck Platooning**: Connected vehicle-enabled trucks will be deployed to reduce freight-induced congestion and queuing at a logistics hub near Columbus. Connected vehicle technology will allow freight signal prioritization. Trucks will be able to reduce their headways when traveling on freeways.

These Smart Columbus projects are planned to be deployed in 2019 and 2020.

Advanced Transportation & Congestion Management Technology Deployment

The Advanced Transportation and Congestion Management Technology Deployment (ATCMTD) program has provided $110 million to 18 projects in 13 states in 2016 and 2017. It provides grants to state and local entities to fund transportation technology projects, including the following:[74]

- Advanced traveler information systems;
- Advanced transportation management technologies;
- Infrastructure maintenance, monitoring, and condition assessment;
- Advanced public transportation systems;
- Transportation system performance data collection, analysis, and dissemination systems;
- Advanced safety systems, including vehicle-to-vehicle and vehicle-to-infrastructure communications;
- Technologies associated with autonomous vehicles, and other collision avoidance technologies, including systems using cellular technology;
- Integration of intelligent transportation systems with the Smart Grid and other energy distribution and charging systems;
- Electronic pricing and payment systems; or

[74] https://www.fhwa.dot.gov/fastact/factsheets/advtranscongmgmtfs.cfm

- Advanced mobility and access technologies, such as dynamic ridesharing and information systems to support human services for elderly and disabled individuals.

This highly competitive program provides $60 million in funding annually, typically in $2 million - $12 million increments, and requires a non-federal cost share. Funding is generally available for up to four years for each award. To date, one project in Florida has been funded: FDOT was awarded $11.9 million in 2017 to fund the Connecting the East Orlando Communities project, which will advance numerous ITS technologies–including PedSafe, an innovative pedestrian and bicycle collision avoidance system, GreenWay, which uses advanced traffic signal technology, SmartCommunity, for trip planning apps, and SunStore, which integrates FDOT data.

The program provided 18 awards in 2016 and 2017 as shown in **Tables 8 & 9**.

Table 8: ATCMTD 2016 Grantees

Project	Project Sponsor	Description[75]
A Connected Region: Moving Technological Innovations Forward in the NITTEC Region	Niagara / Buffalo, New York	The project will deploy technologies and strategies to improve border crossing performance and travel time and commercial vehicle operations and safety. It will enhance real-time information provided to travelers. It will expand Smart Mobility to major highways in the region to improve incident management and promote operational integration within Niagara Frontier Transportation Authority.
City of San Francisco ATCMTD Initiative	San Francisco, California	The project will make intersections safer and more accessible for pedestrians and cyclists by deploying smart connected traffic signals and encourages ridesharing and carpooling through the creation of dynamic pickup curbs and a regional carpool lane system.
ConnectSmart: Connecting TSMO and Active Demand Management	Houston, Texas	The project will deploy an advanced technology platform that integrates transportation operations and active demand management with a multi-modal approach. The ConnectSmart model platform will integrate various mobility technologies for carpooling, ridesharing and shared electric bicycles to provide reliable multi-modal travel time information.
Denver Smart City Program	Denver, Colorado	The project will implement three intelligent vehicle projects: a Connected Traffic Management Center (TMC) and Connected Fleets; Travel Time Reliability as a City Service for Connected Freight; and Safer Pedestrian Crossings for Connected Citizens. The technologies include DSRC in 1,500 city fleet vehicles.

[75] https://ops.fhwa.dot.gov/fastact/atcmtd/fy16awards/index.htm

Project	Project Sponsor	Description[75]
Freight Advanced Traveler Information System (FRATIS)	Los Angeles, California	The Los Angeles County Metropolitan Transportation Authority, supported by multiple partners, will implement a large-scale deployment of the Freight Advanced Traveler Information System (FRATIS) Project to help reduce truck congestion.
LA DOT Implementation of Advanced Technologies to Improve Safety & Mobility within the Promise Zone	Los Angeles, California	Large-scale deployment of technology to allow the traffic signal system to detect red light-violating vehicles, allow personal wireless devices to prioritize pedestrian travel and safety at intersections, and assist transit bus drivers to operate safely and efficiently.
NW 33 Smart Mobility Corridor	Cities of Marysville and Dublin and Union County, Ohio	The project will deploy corridor-focused connected vehicle applications across a wide range of connected fleets – city, county, transit, private fleets – in a mix of rural and suburban areas serving multiple communities to improve access and enhance economic development.
SmartPGH	Pittsburgh, Pennsylvania	The project will deploy "Smart Spine" corridors that layer environmental, communications, energy, and transportation infrastructure technologies to improve connectivity. The network of connected, real-time adaptive signal controllers will expand to provide optimized transit operations and the City will complete an LED smart streetlight conversion of nearly 40,000 street lights.

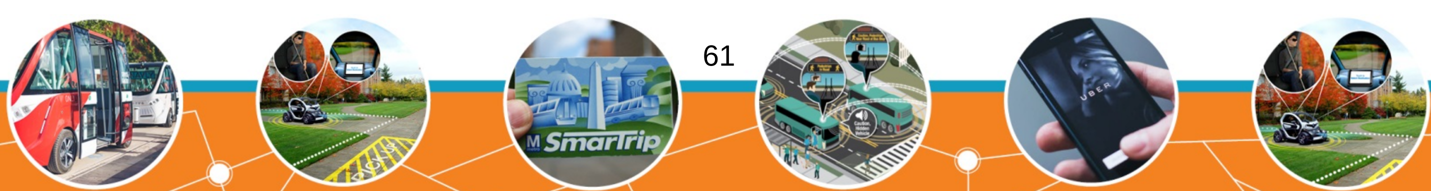


Table 9: ATCMTD 2017 Grantees

Project	Project Sponsor	Description[76]
Connecting Cleveland Project	Greater Cleveland Regional Transit Authority	The CCP will improve communications infrastructure, enhance rider and passenger safety and reduce rider travel time. It will also enhance the overall efficiency of the transportation system.
Connecting the East Orlando Communities	Florida DOT	The FDOT, MetroPlan Orlando and the University of Central Florida (UCF) will utilize the grant to advance numerous ITS technologies as part of PedSafe, GreenWay, SmartCommunity and SunStore.
Global Opportunities at the Port of Oakland Freight Intelligent Transportation System	Alameda County Transportation Commission	The GoPort Freight ITS project will deploy the nation's first integration of Freight Community System and advanced ITS technology that will include a new port-specific TMC, traffic sensors, advanced traveler information, traffic messaging, trucking information for mobile apps, rail grade warning and terminal queue information.
Greenville Automated (A-Taxi) Shuttles	County of Greenville	The deployment of an integrated system of Automated Taxi-Shuttles (A-Taxis) on public roads will be the first in the nation–improving access to transportation for disadvantaged and mobility impaired residents.
Improving Safety and Connectivity in Four Detroit Neighborhoods	City of Detroit	The funds will be used to increase mobility for residents in four target neighborhoods with high-traffic corridors.
Loop 101 Mobility Project	Arizona DOT	The funding will be used to improve safety and existing arterial capacity in the Loop 101 corridor by deploying technology and systems to support ICM, public transportation, SMARTDriveSM and other connected traffic management and real-time information technologies.
Multimodal Integrated Corridor Mobility for All	City of Seattle DOT	The MICMA project will leverage and enhance Intelligent Transportation System (ITS) and Mobility-as-a-Service (MaaS) platforms to create a multimodal operations environment that responds to all users.
SMART Arterial Management	Ada County Highway District	The funding will be used to replace traffic signal controllers and detection systems at 82 intersections to implement new traffic signal performance measures.

[76] https://ops.fhwa.dot.gov/fastact/atcmtd/2017/awards/index.htm

Project	Project Sponsor	Description[76]
The Texas Connected Freight Corridors Project	Texas DOT	The Texas Connected Freight Corridors project will deploy connected vehicle technologies in over 1,000 trucks and agency fleet vehicles that will be able to transmit data and receive warnings from 12 CV applications.
Truck Reservation System and Automated Work Flow Data Model	Virginia Port Authority	The project involves the design, implementation and deployment of a second-generation truck reservation system that builds on the successes of the Port of NY/NJ reservation system for access to container terminal.

As award funding is available for up to four years, many past grantees continue to prepare for future deployment to occur in the coming years. In April 2018, FHWA announced $60 million in grants available in the third round of the ATCMTD program. State departments of transportation, local governments, transit agencies, metropolitan planning organizations and other eligible entities are invited to apply for funds by June 2018. In accordance with the FAST Act, this grant program is authorized to fund another $60 million in 2019 and $60 million in 2020 as well.

State DOT Research Programs

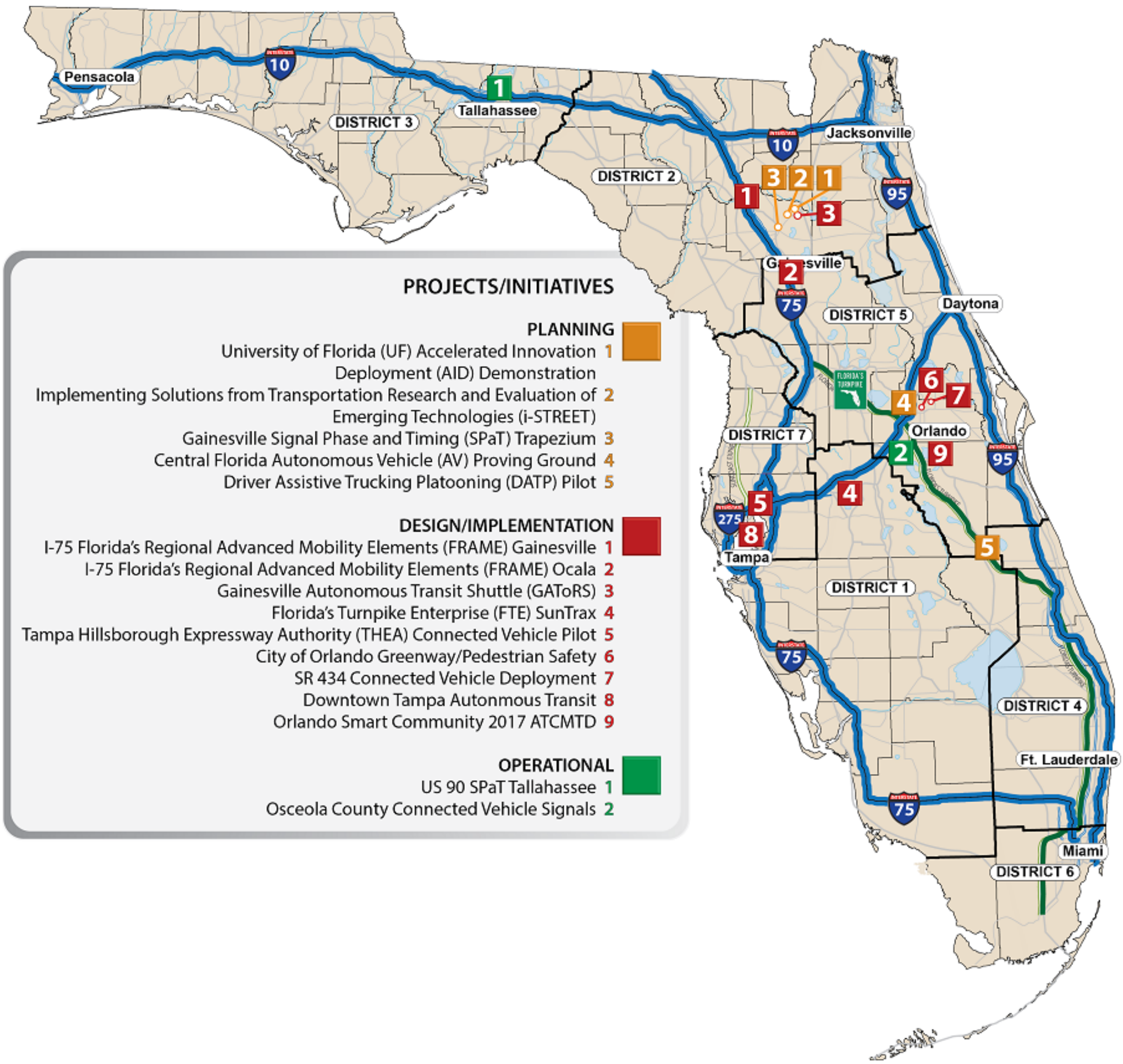
Florida

Florida has emerged as a national leader in embracing transportation technology testing and deployment. FDOT's Transportation Systems Management and Operations Division administers the Florida Connected Vehicle Initiative (**Figure 10**). The connected vehicle initiative technologies include:

- **Wireless Communications**
- **Signal Phase and Timing (SPaT)**
- **Roadside Units (RSUs)**
- **On-Board Units**
- **Freight Signal Priority**
- **Transit Signal Priority**
- **Emergency Vehicle Preemption**
- **Vehicle Sensors**
- **Global Positioning System Navigation**

The initiative includes five planning projects, nine design and implementation projects, and one operational project.

Figure 10: Florida Connected Vehicles Initiative Projects



Source: FDOT

Planning

University of Florida Accelerated Innovation Deployment

FDOT applied for the Federal Accelerated Innovation Deployment (AID) Demonstration program in April 2017 to pilot connected vehicle and pedestrian/bicyclist safety applications at 13 signalized intersections and 7 mid-block crossings within the University of Florida (UF) campus. The project will install at least 20 RSU's and 20 passive pedestrian detection systems for testing. It will test passive pedestrian/bicyclist detection via detection technologies; real-time notification to transit, motorists, and pedestrians/bicyclists; and signal phase and timing data broadcasting with active pedestrian/bicyclist detection via RSUs.

University of Florida I-STREET

The University of Florida (UF) Implementing Solutions from Transportation Research and Evaluation of Emerging Technologies (I-STREET) Test Bed is a collaboration of UF, FDOT, the City of Gainesville, and other public and private partners. The anticipated outcome is to transition from development to a realization of transportation safety and mobility benefits as quickly as possible. The UF I-STREET will leverage several ongoing efforts at FDOT, including the use of hardware and software solutions being deployed to realize the benefits from connected vehicle technologies to improve the safety and mobility of road users.

Gainesville SPaT Trapezium

This Signal Phase and Timing (SPaT) project[77] will deploy and test connected vehicle technologies and applications along 4 roads and 27 traffic signals around the University of Florida main campus. The goal of the project is to improve travel time reliability, safety, throughput, and traveler information. This project will also deploy pedestrian and bicyclist safety applications. Approximately 45 RSUs will be installed on the four roadways by late 2018.

Central Florida Autonomous Vehicle Proving Ground

The Central Florida Autonomous Vehicle Proving Ground[78] is approved by USDOT and aims to become one of the nation's premiere hubs for research and development of automated vehicle technology. It consists of multiple existing and planned facilities that will offer simulation at state-of-the-art universities, test tracks offering extreme environmental and controlled scenario testing, and open deployment on select roadways, among other capabilities. Central Florida Automated Vehicle Partners is an alliance including City of Orlando, FDOT, Central Florida Expressway Authority, University of Central Florida, Florida Polytechnic University, Florida A&M University, Florida State University, Lynx, and NASA.

Driver Assisted Truck Platooning (DATP) Pilot

FDOT is developing a pilot project to demonstrate Driver Assistive Truck Platooning (DATP) technologies and operations[79]. In response to Florida Legislative requirements, FDOT will demonstrate DATP on portions of the Florida Turnpike south and east of Orlando. The pilot project will highlight performance and safety considerations through a set of operational scenarios. Impacts on traffic, infrastructure, enforcement, and administration will be analyzed in a report for the Florida Legislature to use in determining next steps in permitting DATP operations.

Design/Implementation

I-75 Florida's Regional Advanced Mobility Elements (FRAME) – Gainesville & Ocala

These projects will deploy emerging connected vehicle technologies to better manage, operate, and maintain the multi-modal transportation system and create an Integrated Corridor Management solution on I-75 and state highway systems in the Cities of Gainesville and Ocala[80].

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[77] http://www.fdot.gov/traffic/ITS/Projects_Deploy/CV/MapLocations/Gains_Trapezium.shtm

[78] http://centralfloridaavpg.com/

[79] http://www.fdot.gov/traffic/ITS/Projects_Deploy/CV/MapLocations/DATP.shtm

[80] http://www.fdot.gov/traffic/ITS/Projects_Deploy/CV/MapLocations/I75_Frame.shtm

The projects aim to disseminate real-time information to motorists during freeway incidents in addition to utilizing Automated Traffic Signal Performance Measures, Transit Signal Priority, and Freight Signal Priority. Roadside units are deployed at traffic signals, pedestrian crossings, along transit routes, at railroad crossings, and along I-75.

Gainesville Autonomous Transit Shuttle (GAToRS)

This project will deploy an autonomous transit system to connect the City of Gainesville Innovation District and downtown with the University of Florida campus and student housing by means of frequent transit service. The goal of the Gainesville Autonomous Transit Shuttle (GAToRS) is to maintain a maximum headway of 10 minutes or less for the GAToRS buses. GAToRS routes include SW 4th Avenue, SW 13th Street, SW 2nd Avenue, and S Main Street. The project is anticipated to complete deployment by late 2018.

Florida's Turnpike Enterprise SunTrax

SunTrax[81] is a large-scale test facility that will be developed jointly by Florida's Turnpike Enterprise (FTE), Florida Polytechnic University, and industry partners. This facility will offer unique opportunities for testing emerging transportation technologies in safe and controlled environments from urban to rural contexts. SunTrax is part of the Central Florida Automated Vehicle (AV) Partnership, which is one of the ten USDOT-designated AV proving grounds in the nation. FTE is constructing a 2.2-mile oval track on a 400-acre site surrounding Florida Polytechnic University in Polk County, Florida. The facility will test toll equipment, CV, and AV technologies for Vehicle-to-Infrastructure, Vehicle-to-Vehicle, and Vehicle-to-everything communications.

Tampa Hillsborough Expressway Authority (THEA) Connected Vehicle Pilot

The Tampa CV Pilot Program[82], one of only three such programs, was awarded through the USDOT Connected Vehicle Pilot Program. This program, led by the Tampa-Hillsborough Expressway Authority, is now in the design and deployment phase. The Tampa CV Pilot Program includes various CV applications in and around downtown Tampa. The applications focus on safety and mobility for multiple modes of travel, including streetcars, buses, passenger cars, and pedestrians.

City of Orlando Greenway/Pedestrian Safety

The Ped Safe[83] project aims to implement a pedestrian and bicycle collision avoidance system that utilizes CV technologies to reduce the occurrence of pedestrian and bicycle crashes in City of Orlando. By optimizing traffic signal operations with implementation of technologies, the Greenway will increase throughput capacity and reduce congestion. The technology that will be deployed includes CV, dedicated short-range communications, on-board units, RSUs, audible basic safety messages, synchronous data link control monitoring device, and advanced sensor technology. This project will include approximately 250 RSUs and on-board units on emergency vehicles and University of Central Florida shuttles. The project is anticipated to complete deployment by early 2019.

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[81] http://www.fdot.gov/traffic/ITS/Projects_Deploy/CV/MapLocations/FTE_SunTrax.shtm

[82] http://www.fdot.gov/traffic/ITS/Projects_Deploy/CV/MapLocations/THEA_CVP.shtm

[83] http://www.fdot.gov/traffic/ITS/Projects_Deploy/CV/MapLocations/CoO_Greenway.shtm

SR 434 Connected Vehicle Deployment

The Connected Vehicle project on SR 434 from McCulloch Road to E Mitchell Hammock Road[84] aims to implement CV technology and Signal Performance Metrics (SPM) in Seminole County. This FDOT District 5 project will deploy RSUs and utilize Signal Phasing and Timing, Transit Signal Priority, and preemption applications along SR 434. Approximately eight RSUs are installed in this project. The project is anticipated to complete deployment by early 2019.

Downtown Tampa Autonomous Transit

Hillsborough Area Regional Transit Authority (HART) is preparing to deploy an autonomous shuttle in 2018 along an existing exclusive transitway on Marion Street[85]. The Marion Street project includes ten signalized intersections, one low-volume four-way stop, and an active railroad crossing. It will provide two electric self-driving vehicles along a half-mile north-south roadway in the center of downtown Tampa. During daytime hours on weekdays, the corridor is for exclusive use of buses and emergency vehicles, and therefore offers an opportunity to operate a low-speed, autonomous last-mile shuttle service out of mixed traffic.

Orlando Smart Community

Connecting the East Orlando Communities is a project that received a 2017 ATCMTD grant. FDOT, MetroPlan Orlando, the University of Central Florida, the City of Orlando, and Orange County are addressing programs focused on pedestrian and bicycle safety, advanced traffic signal management, and a smart community. SmartCommunity[86] is an integrated program that connects people to the places they need to go and the services they need to receive. Through a Mobility on Demand (MOD) framework, SmartCommunity leverages existing ridesharing and car-sharing products to offer residents access to cars when required. SmartCommunity's trip planning application, Transit AVL, and Transit Kiosks will provide real-time multimodal travel information to integrate trip planning with modal choice options. SmartCommunity will allow travelers in the same area to share information and coordinate trips.

Operational

US 90 SPaT Tallahassee

This Signal Phase and Timing (SPaT) project[87] using connected vehicle technology is currently underway. US 90 Mahan Drive has 22 signalized intersections equipped with DSRC. FDOT and the City of Tallahassee have installed roadside units to broadcast traffic signal information to vehicle on-board units. This project aims to advance knowledge related to connected vehicles and intersection safety, while also providing FDOT and the City the opportunity to gain experience in operations and maintenance of CV infrastructure and applications.

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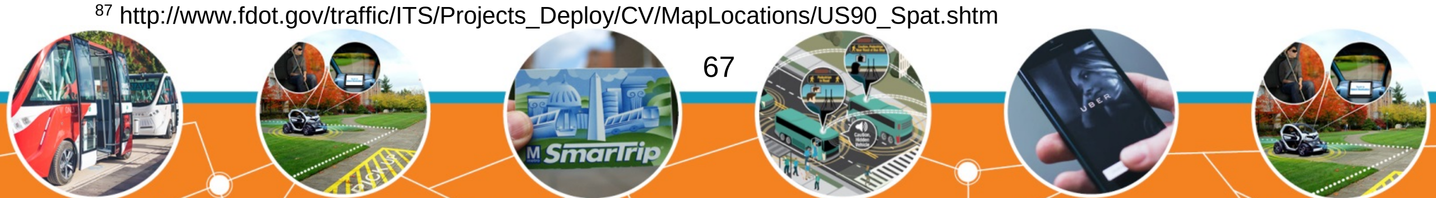
[84] http://www.fdot.gov/traffic/ITS/Projects_Deploy/CV/MapLocations/SR434_CVD.shtm

[85] http://www.fdot.gov/traffic/ITS/Projects_Deploy/CV/MapLocations/Tampa.shtm

[86] http://www.fdot.gov/traffic/ITS/Projects_Deploy/CV/MapLocations/ATCMTD_Orlando.shtm

[87] http://www.fdot.gov/traffic/ITS/Projects_Deploy/CV/MapLocations/US90_Spat.shtm



Osceola County Connected Vehicle Signals

Osceola County and FHWA have deployed CV technology with RSUs at two signalized intersections[88]. One intersection has a mast arm and the other has a span wire. This pilot project aims to test Dedicated Short Range Communications (DSRC) equipment and intersection processing equipment to gain experience and compile lessons learned in the deployment of CV infrastructure and applications.

Research Program Examples from Other State DOTs

Road X

The Colorado Department of Transportation (CDOT) created the Road X program with a vision of using advanced technologies to increase the safety and reliability of the state's transportation system. CDOT teamed up with public and private entities to invest in the most promising ideas focused on one or more of the defined action areas of commuting, sustainability, transport, safety, and connection. In 2016, the state committed $20 million to initiate the Road X program and plans to continue to provide funds as worthwhile projects that fit the program's mission are developed. Current projects include smart truck parking, smart pavement, communication systems and infrastructure, and developing a plan for statewide electric vehicle charging stations. CDOT continues to accept ideas from the public for consideration for the RoadX program through their website.[89]

Road to Tomorrow

In 2015, the Missouri Department of Transportation (MoDOT) introduced the Road to Tomorrow initiative that aims to prepare the state's transportation systems for emerging technologies and find innovative ways to fund the transformative projects. A mission of the program is to design the next generation of highways. Topics that have been considered as a part of this program are related to alternative energy, the Internet of Things, smart pavement, truck platooning, and electric vehicle infrastructure. In 2016, the Road to Tomorrow program was awarded with AASHTO's President's Award for its efforts to further MoDOT and advance the future of transportation.[90]

California PATH

In the 1980s, many universities developed programs to conduct research about emerging transportation technology. One of the most prominent programs was the California Program on Advanced Technology for the Highway (PATH), which was a collaboration between the University of California at Berkeley and the California Department of Transportation (Caltrans). This program aims to address issues with the state's transportation systems and continues to be an active leader in the research of transportation technology. A portion of PATH's research focuses specifically on connected and automated vehicles, including operational strategies, advanced driving features and systems, and contributing to the creation of a connected vehicle test bed along a signalized arterial between San Jose and San Francisco.[91]

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[88] http://www.fdot.gov/traffic/ITS/Projects_Deploy/CV/MapLocations/Osceolal.shtm

[89] Colorado DOT, "RoadX," Available at: https://www.codot.gov/programs/roadx/programs/roadx

[90] Missouri DOT, "Road to Tomorrow." Available at: http://www.modot.org/road2tomorrow/

[91] University of California, Berkley, "California Path – Partners for Advanced Transportation Technology," Available at: http://www.path.berkeley.edu/

I-95 Corridor Coalition

The I-95 Corridor Coalition is composed of transportation agencies, toll authorities, public safety organizations, and other related stakeholder groups along the I-95 corridor from Maine to Florida. Affiliate members are located in Canada. The purpose of the volunteer-based Coalition is to combine the forces of all of the partner agencies to address the key widespread issues with transportation system management and operations. The Coalition's structure includes four program track committees that include travel information services, incident management and safety, intermodal freight and passenger movement, and innovation in transportation. The organization aims to support the efficient transfer of people and goods across all modes of transportation and improve coordination between agencies during normal system operations as well as in response to regional incidents. Past and ongoing projects include focuses like the Regional Integrated Transportation Information System (RITIS), electronic tolling, interoperability and enforcement reciprocity, and connected and automated vehicles.

Industry Group and University Research

Some of the most exciting ongoing transit technology research is arising from philanthropic, non-profit, and university groups.

Bloomberg Philanthropies

Bloomberg Philanthropies' mission is to ensure better, longer lives for the greatest number of people. Bloomberg Philanthropies focuses on five key areas for creating lasting change: public health, environment, education, government innovation, and arts & culture.

Mayors Challenge

Grants to cities around the world strive to deploy new ideas to improve lives, with several past and ongoing grants addressing transportation challenges. In three Mayors Challenge rounds in 2012-2013, 2014, and 2016, over a dozen winners received millions of dollars in implementation funding and support. Transportation was addressed, among other issues, in Chicago's SmartData Platform, which improved its Open Data Portal in order to use analytics to improve city functions. Transportation was also addressed in Warsaw, Poland, which conducted planning regarding visually impaired navigation. Warsaw is preparing to deploy thousands of beacons around the city to communicate location data to the smartphones of the visually impaired, empowering them to navigate on their own.

The 2018 Mayors Challenge[92] resulted in 35 cities being selected as Champion Cities receiving up to $100,000 each. Of the 35 cities, six focus on new mobility and the future of transportation:

- Boston, MA: Bringing Equity to Street Repairs - The City of Boston will infuse equity into its approach to allocating resources for sidewalk and street maintenance by augmenting 311 dispatch requests with data on community need, pavement condition, and usage.
- Boulder, CO: Unlocking Access to Low Carbon Transport - The City of Boulder will conduct multiple experiments – including ridesharing, subsidies, and an electric car loan program – to determine the most effective way to improve low-income residents' mobility.

[92] https://mayorschallenge.bloomberg.org/

- Durham, NC: Encouraging Alternatives to Driving Downtown - The City of Durham will rigorously test four low cost methods that apply behavioral insights to nudge people away from single occupancy commutes.
- Lincoln, NE: Self-Driving Micro-Transit System to Reduce Downtown Congestion - The City of Lincoln will establish an on-demand autonomous vehicle service, the first of its kind in the U.S., which would reduce the number of cars driving around and parking in the city center, leading to reduced traffic congestion and improved air quality.
- South Bend, IN: Providing Affordable, Reliable Transport for Low-Income Workers - The City of South Bend will help low-income and part-time shift workers commute through a new, data-driven collaboration with ride-share companies and participating employers.
- Vallejo, CA: Clever Technology to Mind an Aging Infrastructure - The City of Vallejo will leverage ground-penetrating radar, autonomous vehicles, and a combination of sensors to identify broken pipes more effectively and efficiently.

These cities will refine their ideas through August 2018 with five winners announced in October 2018. The grand prize winner will receive $5 million and four other cities will each win $1 million.

The Bloomberg Aspen Initiative on Cities and Autonomous Vehicles

The Bloomberg Aspen Initiative on Cities and Autonomous Vehicles is one of Bloomberg Philanthropies' Government Innovation programs that equip mayors and other city leaders with the tools and techniques they need to solve urban challenges and improve citizens' lives. The Aspen Institute is an educational and policy studies organization. The initiative will help ten cities in the U.S. and around the world to better prepare for autonomous vehicles:

- Los Angeles
- Austin
- Nashville
- Washington D.C.
- Buenos Aires, Argentina
- São Paolo, Brazil
- London, England
- Paris, France
- Helsinki, Finland
- Tel Aviv, Israel

The ten cities participating in the Bloomberg Aspen Initiative represent urban areas that are preparing for the AV future in diverse ways. Bloomberg Philanthropies and the Aspen Institute are working with these cities' leaders, global policy experts, and representatives from the private sector to explore the intersections of autonomous vehicles with various policies and issues - from the opportunities autonomous vehicles can create to address inequality and improve mobility, to the potential challenges they pose to commuting and public transport. The initiative will publish resources and tools for other cities based on lessons learned.

Global Atlas of Autonomous Vehicles in Cities

Bloomberg Philanthropies and Aspen Institute published a global atlas of autonomous vehicles[93] in cities in 2017 (**Figure 11**). Cities with significant government support were highlighted. The atlas reveals approximately 40 cities in the U.S. and approximately 60 cities internationally in which local governments are actively planning for autonomous vehicles.

Figure 11: Bloomberg Global Atlas of Autonomous Vehicle Projects - 2017

Source: Bloomberg Philanthropies, Aspen Institute, Bloomberg New Energy Finance. Note: See Bloomberg Philanthropies' interactive "Global Atlas of Autonomous Vehicles (AVs) in Cities" (web). 'AV' stands for 'autonomous vehicle'. This map only covers AV pilots and policymaking efforts where city, municipal, or metropolitan governments are playing a substantial role.

Source: https://avsincities.bloomberg.org/

Universities

Universities are producing research on transit technology at a fast pace. In addition to published literature referenced in the literature review as part of this project, there are many ongoing research activities.

The FAST Act authorized $305 billion in spending from fiscal years 2016 through 2020 for the maintenance of existing and establishment of new initiatives in research, education and workforce development, and the facilitation of technology transfer. The USDOT expanded the long-running University Transportation Center (UTC) Program[94] with national, regional, and local research involvement. Five national UTC's include 24 universities with each UTC funded by USDOT for approximately $2.8 million through 2020:

- National University Transportation Center For Improving Mobility

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[93] https://avsincities.bloomberg.org/

[94] https://www.transportation.gov/utc/program-history

  - Carnegie Mellon University (Lead); Community College of Allegheny County; University of Pennsylvania; Ohio State University
- National Institute for Transportation and Communities
  - Portland State University (Lead); Oregon Institute of Technology; University of Arizona; University of Oregon; University of Texas at Arlington; University of Utah
- National Center for Sustainable Transportation
  - University of California, Davis (Lead); California State University Long Beach; Georgia Institute of Technology; University of California, Riverside; University of Southern California; University of Vermont
- Collaborative Sciences Center for Road Safety
  - University of North Carolina at Chapel Hill (Lead); Duke University; Florida Atlantic University; University of California, Berkeley; University of Tennessee, Knoxville
- Safety Through Disruption (Safe-D) National UTC
  - Virginia Polytechnic Institute and State University (Lead); San Diego State University; Texas A&M University

Seven regional UTC's include over 50 universities with each UTC funded by USDOT for approximately $2.6 million through 2020. The University of Florida leads the Southeastern Transportation Research, Innovation, Development and Education Center with a research focus on reducing congestion. In addition, local UTC's referred to as Tier 1 include over 90 colleges and universities, including several in Florida: University of Florida, Embry-Riddle Aeronautical University, University of Central Florida, University of South Florida, Florida Atlantic University, and Florida International University.

The University Transportation Center Program is utilizing USDOT funding and university resources to produce an ever expanding body of ongoing research regarding transit technology and the future of transportation.

Looking Ahead to New Ideas

The pace of transit technology change is rapidly moving ahead to ideas thought inconceivable just a few years ago. Some trends lean toward a continual merging of modes, with the potential for seamless integration between traditional mass transit and personal vehicles. Behind new ideas are the age-old desires of the traveling public – fast, easy, and comfortable transportation between point A and point B. The following sections describe the potential for exciting developments in transit technology.

Hyperloop

Rarely does a transit technology emerge so quickly in the public consciousness and receive so much media coverage as hyperloop has in the past few years. Simply put, hyperloop is a system composed of a vacuum and magnets to propel vehicle pods through a tube for long distances at speeds over 700 miles per hour. A prototype vehicle is shown in **Figure 12**. Since Elon Musk revived the longstanding concept of high speed travel in a vacuum in recent years, multiple companies have emerged and public agencies have taken notice.

Virgin Hyperloop One and Hyperloop Transportation Technologies are two of the companies beginning to partner with local governments on research and evaluation of potential routes. In 2016, Virgin Hyperloop One announced ten winners of a Global Challenge:

- U.S. routes
  - Chicago-Columbus-Pittsburgh
  - Miami-Orlando
  - Cheyenne-Denver-Pueblo
  - Dallas-Laredo-Houston
- Toronto-Montreal in Canada
- Bengaluru-Chennai in India
- Mumbai-Chennai in India
- Mexico City-Guadalajara in Mexico
- Edinburgh-London in UK
- Glasgow-Liverpool in UK

Local government agencies have announced partnerships for hyperloop feasibility studies and are beginning to provide public funds towards planning for this technology. For example, Cleveland officials recently announced an agreement with Hyperloop Transportation Technologies to provide funding to study a potential route between Cleveland and Chicago.

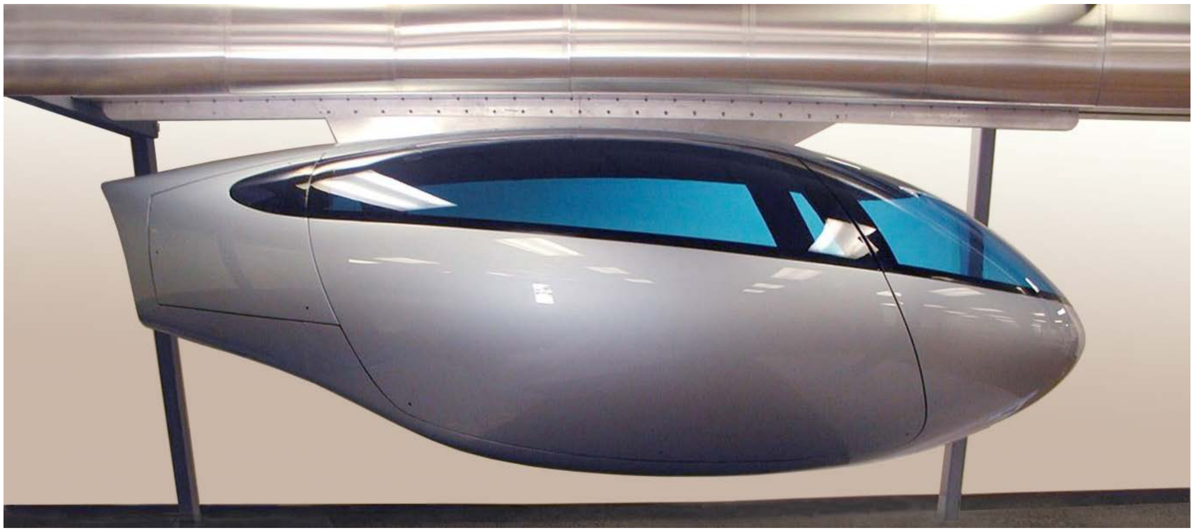
Figure 12: Hyperloop One Prototype Vehicle

Source: https://www.wired.com/story/virgin-hyperloop-one-engineering/

Aerial Personal Rapid Transit

In Clearwater, Florida, a company called skyTran (**Figure 13**) has introduced an idea for technology that uses magnetic levitation to move two-person passenger pods along an elevated guide rail. The system would be on-demand, with passengers using a phone app to order a pod for a trip. This system does not exist anywhere in the world yet, and it is not yet known how funding and right-of-way approvals would be resolved.

Figure 13: skyTran Prototype Vehicle



Source: https://www.nasa.gov/centers/ames/researchpark/partners/industry/skytran/

A separate company called Transit X is promoting its aerial pods as part of a solar-powered, privately-funded shared mobility network with the convenience, capacity, and cost to replace buses, trains, cars, trucks, and even short flights. **Figure 14** provides an illustration of the proposed Transit X vehicle. It promotes travel at 45 mph along main roads and 150 mph along highways or railways. It plans to have fares that are comparable to traditional mass transit. The company states that pods, each carrying a single passenger or up to a family of five, quietly cruise above traffic under a narrow track, with trips booked through a smartphone or kiosk. Once again, this technology is not yet operational so there is not yet an opportunity to test the company's claims.

Figure 14: Transit X Prototype Vehicles

Source: http://www.transitx.com/

Autonomous Flying Taxi

Unlike skyTran and Transit X, which plan for pods traveling along an aerial track, other companies are testing an idea that is more in line with a combination of a car and a helicopter. UberAIR is being jointly developed by Uber and NASA, with prototypes (**Figure 15**) that include four rotors on wings that will allow the vehicles to fly 1,000 to 2,000 feet in the sky. A competitor is named Kitty Hawk and is backed by Alphabet, the parent company of Google. Uber plans to test its UberAIR service in 2020 in the Dallas-Fort Worth and Los Angeles regions, with commercial service beginning in 2023.

Figure 15: UberAir's eVTOL Prototype Vehicle

Source: https://www.cnet.com/roadshow/news/

The list of technologies under development that aim to transport people in new ways, big and small, is seemingly endless. While emerging concepts are often untested and many questions remain, excitement for new technologies abounds.

Summary of Ongoing Research

This section provided an overview of ongoing research activities and technology trials relevant to transit. There are a number of federal and state DOT sponsored technology projects with significant transit involvement that are currently underway. Industry groups and universities provide additional funding and analysis of innovative ongoing research. Since these activities are not yet concluded, this section gave insight into areas of focus and promising trends to watch in the coming years.

STAKEHOLDER AND VENDOR OUTREACH

Stakeholder and Vendor Outreach

In order to assess the state of current and emerging technology available to transit agencies, transit agencies (stakeholders) and technology vendors were engaged. This section summarizes how the stakeholders and vendors were selected, the strategies to reach them, the questions that were asked, and their responses. Based on the responses, follow-up questions and case studies were requested from the respondents. The results of the outreach show that transit agencies recognize the need for transit technology but challenges remain in identifying the funding and/or developing a strategic plan to pursue them. Vendor outreach, likewise, shows the value of transit technology and how it improves the operation of a transit system.

Methodology

There are two parties involved in the research and development of the Transit Technology Primer: transit agencies (stakeholders) and technology vendors (vendors). The stakeholders and vendors that were selected for participation represent a broad cross-section of the public transit industry. The specific methodology for how the stakeholders and vendors were selected is provided below.

Stakeholder Selection

Three groups of stakeholders were selected to participate in the outreach portion of the Transit Technology Primer. The groups are:

- Transit agencies in Florida;
- The ten largest transit providers in North America by ridership; and
- Ten transit agencies that have a high mode share and represent a cross-section of the types of agencies found in Florida.

The Florida agencies were selected by using the Florida Public Transportation Association Member (FPTA)[95] list and the 2016 Florida Transit Information and Performance Handbook.[96] The top ten transit agencies by ridership in North America were determined by using the American Public Transportation Association website and Governing Magazine.[97] The selection of the cutting edge peers was more subjective in the selection of agencies. All of the agencies, except for one (TheComet), are listed in the SmartAsset Article “The Best Cities for Public Transportation.”[98] The article looked at the U.S. Census Bureau data on the use of public transportation in U.S. cities with a population of 175,000 or more. The following metrics were used to determine cutting edge peers:

- The average commute time for transit users.
- Percentage difference between average commute times of car commuters and transit users.
- Percentage of commuters who use public transit.
- Total number of commuters who use public transit.

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95 https://floridatransit.org/membership/corporate

96 http://www.fdot.gov/transit/Pages/2016_Florida_Transit_Information_and_Performance_ Handbook%20FINAL.pdf

97 http://www.governing.com/gov-data/transportation-infrastructure/public-transportation-agency-ridership-statistics-cities-metro-areas.html

98 https://smartasset.com/mortgage/best-cities-for-public-transportation

- The difference between the citywide median income and the median income of transit users.

This list identified 25 transit agencies. From here, those agencies found on the first two lists were excluded leaving 15 to choose from. The nine that were selected are those agencies that would be considered peers of Florida agencies (for example, Tallahassee and Madison, Wisconsin are both college towns and state capitals) or have been identified in other research projects (Minneapolis and Bus on Shoulder). TheComet (Columbia, South Carolina) was selected as the tenth cutting edge stakeholder because a sales tax referendum was passed in 2012 to rebrand their system and implement new technology, such as mobile fare, Wi-Fi, and real-time bus location. Each of the agencies selected was categorized based on their annual operating budget.

Table 10: Operating Budget Tiers

Tiers	Definition
Tier I	Any agency whose operating budget exceeds $36 million
Tier II	Any agency whose operating budget is between $4 to $36 million
Tier III	Any agency whose operating budget is less than $4 million

The tier definitions found in **Table 10** are the categories employed by FPTA for corporate members.[99] These tiers were applied to all transit agencies selected for stakeholder outreach. Budget levels were determined either by the FPTA website member directory[100] or by reviewing online budget documents for transit agencies outside of Florida. **Tables 11 - 13** provide the list of all stakeholders selected using this methodology.

[99] https://floridatransit.org/membership/corporate

[100] https://floridatransit.org/membership/transit-system-members

Table 11: Florida Transit Agencies

Agency Name	Category	2015 Annual Ridership	Address	City, State, Zip	Phone	Website
Broward County Transit	Tier I	39,759,952	1 N University Dr, Ste 3100A	Plantation, FL 33324	(954) 357-8301	http://www.broward.org/bct
HART	Tier I	15,291,574	1201 E 7th Ave	Tampa, FL 33605	(813) 384-6550	http://www.gohart.org/
JTA	Tier I	12,950,091	100 N Myrtle Ave	Jacksonville, FL 32204	(904) 632-5500	http://www.jtafla.com/
Lynx	Tier I	28,858,525	455 N Garland Ave	Orlando, FL 32801	(407) 841-2279	http://www.golynx.com/
Miami-Dade	Tier I	105,198,299	701 NW 1st Court, Ste 1700	Miami, FL 33136	(786) 469-5675	http://www.miamidade.gov/transit
PalmTran	Tier I	10,773,438	3201 Electronics Way	West Palm Beach, FL 33407	(561) 841-4200	http://discover.pbcgov.org/palmtran/Pages/default.aspx
PSTA	Tier I	14,578,488	3201 Scherer Dr	St. Petersburg, FL 33716	(727) 540-1800	http://psta.net/
South Florida Regional Transportation Authority	Tier I	5,363,719	800 NW 33rd St, #100	Pompano Beach, FL 33064	(954) 788-7936	http://www.tri-rail.com/
SunRail	Tier I	959,037	719 S Woodland Blvd	DeLand, FL 32720	(352) 620-3031	http://www.sunrail.com/
Collier Area Transit	Tier II	1,094,103	Public Transit & Neighborhood Enhancement Division, 3299 Tamiami Trail E, Ste 103	Naples, FL 34112	(239) 252-5841	http://colliergov.net/
ECAT	Tier II	1,494,210	1515 W Fairfield Dr	Pensacola, FL 32501	(850) 595-3221	http://www.goecat.com/
Gainesville RTS	Tier II	10,251,248	PO Box 490, Station 5	Gainesville, FL 32602-0490	(352) 334-2600	http://www.go-rts.com/
Lakeland Area Mass Transit	Tier II	1,355,697	1212 George Jenkins Blvd	Lakeland, FL 33815	(863) 688-7433	http://www.ridecitrus.com/
LeeTran	Tier II	3,759,763	3401 Metro Pkwy	Fort Myers, FL 33901	(239) 533-8726	http://www.rideleetran.com/





Agency Name	Category	2015 Annual Ridership	Address	City, State, Zip	Phone	Website
MCAT	Tier II	1,760,490	2411 Tallevast Rd	Sarasota, FL 34243	(941) 747-8621	http://www.mymanatee.org/mcat
Pasco County Public Transportation	Tier II	868,242	8620 Galen Wilson Blvd	Port Richey, FL 34668	(727) 834-3200	http://www.ridepcpt.com/
Polk County Transit Services Division	Tier II	220,261	1290 Golfview Avenue, Building F	Bartow, FL 33830	(863) 534-5500	www.polk-county.net
SCAT	Tier II	2,742,108	5303 Pinkey Ave	Sarasota, FL 34233	(941) 861-1006	http://www.scgov.net/SCAT/
Space Coast Area Transit	Tier II	2,517,701	401 S Varr Ave	Cocoa, FL 32922	(321) 635-7815	http://www.ridescat.com/
StarMetro	Tier II	3,732,277	555 Appleyard Ave	Tallahassee, FL 32304	(850) 891-5200	http://www.talgov.com/starmetro/starmetroHome.aspx
Votran	Tier II	3,487,760	950 Big Tree Rd	South Daytona, FL 32119	(386) 756-7496	http://www.votran.org/
Bay Town Trolley	Tier III	656,505	PO Box 11399	Pensacola, FL 32524	(850) 595-8910	http://www.baytowntrolley.org/
Charlotte County Area Transit	Tier III	195,154	25490 Airport Rd	Punta Gorda, FL 33950-5746	(941) 833-6236	http://www.charlottecountyfl.gov/services/transportation/Pages/
Hernando County	Tier III	92,986	1525 East Jefferson	Brooksville, FL 34601	(352) 754-4444	http://www.hernandobus.com/
Indian River County Transit	Tier III	1,425,065	694 14th St	Vero Beach, FL 32960	(772) 569-0903	http://www.golineirt.com/
Lake County Public Transportation	Tier III	307,566	PO Box 7800	Tavares, FL 32778-7800	(352) 323-5713	http://www.ridelakexpress.com/
Martin County Public Transit	Tier III	38,320	2401 SE Monterey Rd	Stuart, FL 34996	(772) 288-2860	http://www.martin.fl.us/transit





Agency Name	Category	2015 Annual Ridership	Address	City, State, Zip	Phone	Website
Okaloosa County/Emerald Coast	Tier III	139,389	600 Transit Way	Fort Walton Beach, FL 32547	(850) 609-7003	http://ecrider.org/
St. Johns County	Tier III	293,239	4040 Lewis Speedway	St. Augustine, FL 32084	(904) 209-0613	http://www.sjcfl.us/
St. Lucie County	Tier III	187,142	437 N 7th St	Fort Pierce, FL 34950	(772) 464-8878	http://www.treasurecoastconnector.com/
SunTran	Tier III	417,920	1805 NE 30th Ave, Bldg 900	Ocala, FL 34470	(352) 401-6999	http://www.suntran.org/

Table 12: Top 10 Transit Agencies by Ridership

Agency Name	2015 Ridership	Address	City, State, Zip	Phone	Website
New York	743,763,755	2 Broadway	New York, NY 10004	212-878-7000	http://www.mta.info/nyct
Toronto Transit Commission	534,005,000	1900 Yonge Street	Toronto, Ontario, M4S 1Z2	416-393-3030	http://www.ttc.ca/
METRO	318,380,729	One Gateway Plaza	Los Angeles, CA 90012-2952	213.922.6000	https://www.metro.net/
Chicago Transit Authority	274,288,766	CTA Headquarters, 567 W. Lake Street	Chicago, IL 60661	1-888-968-7282	http://www.transitchicago.com/
SEPTA	171,287,633	1234 Market Street, 4th Floor	Philadelphia, PA 19107	(215) 580-7800	http://www.septa.org/
New Jersey Transit	150,769,395	1 Penn Plaza East	Newark NJ 07105	(973) 491-7000	http://www.njtransit.com/hp/hp_servlet.srv?hdnPageAction=HomePageTo
WMATA	132,870,013	600 5th Street, NW	Washington, DC 20001	202-637-7000	https://www.wmata.com/
MBTA	121,594,214	10 Park Plaza, Suite 3910	Boston, MA 02116	(617) 222-3200	https://www.mbta.com/

Agency Name	2015 Ridership	Address	City, State, Zip	Phone	Website
BART	95,005,347	P.O. Box 12688	Oakland CA 94604-2688	510 464-7134	https://www.bart.gov/
MTA	78,865,850	6 St. Paul St.	Baltimore, MD 21202-1614	(410)-539-5000	https://mta.maryland.gov/

Table 13: Cutting Edge Peer Cities

Agency Name	Category	Ridership	Address	City, State, Zip	Phone	Website
King County Metro	Tier I	120,754,383	201 S. Jackson St.	Seattle, WA 98104-3856	206-553-3000	http://kingcounty.gov/depts/transportation/metro.aspx
Metro Houston	Tier I	68,835,095	1900 Main St.	Houston, TX 77002	713-635-4000	https://www.ridemetro.org/Pages/index.aspx
Metro Transit	Tier I	68,835,095	560 Sixth Avenue North	Minneapolis, MN 55411-4398	612-373-3333	https://www.metrotransit.org/default.aspx
Niagara Frontier Transit	Tier I	26,122,148	181 Ellicott Street	Buffalo, New York 14203	716.855.7300	http://www.nfta.com/
RTD	Tier I	78,379,651	1660 Blake Street	Denver, CO 80202	303.299.6000	http://www.rtd-denver.com/
TriMet	Tier I	99,861,896	1800 SW 1st Ave #300	Portland, OR 97201	(503) 238-7433	https://trimet.org/
UTA	Tier I	46,132,031	669 West 200 South	Salt Lake City, UT 84101	(801) 743-3882	https://www.rideuta.com/
GRTC	Tier II	8,340,232	301 East Belt Boulevard	Richmond, Virginia 23224	(804) 358-4782	http://ridegrtc.com/
Madison Metro	Tier II	14,358,261	1245 E. Washington Ave, Suite 201	Madison, WI 53703	(608) 266-4466	http://www.cityofmadison.com/metro/
TheComet	Tier II	2,059,884	3613 Lucius Rd	Columbia, SC 29201	(803) 255-7100	http://catchthecomet.org/

Vendor Selection

The vendor selection is more straightforward than the methodology employed to identify stakeholders. The Transit Technology Primer evaluates technology options available in the following categories:

- Safety;
- Mobility;
- Accessibility;
- Environmental;
- Fare Collection & Processing;
- Traveler Information;
- Operations; and
- Emerging Service Models.

Once this list was approved, an internet search was performed to identify vendors in these categories. Project staff also attended two conferences (the FPTA and Georgia Transit Association Annual Meetings) to see demonstrations of the available products. Forty-six technology vendors that provide products in one or more of the eight technology categories have been identified so far. A list of the firms is found in **Table 14**. This list by no means represents every potential vendor, and the nature of technology is that new vendors will emerge continually over time.

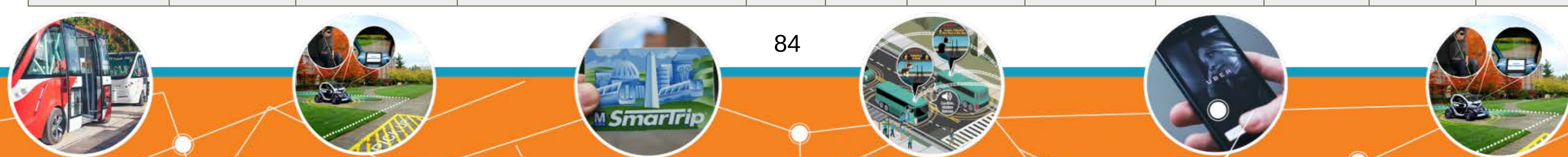
Table 14: Technology Vendors

Vendor Name	Address	City, State, Zip	Website	Safety	Mobility	Accessibility	Environmental	Traveler Information	Operations	Fare Collection and Processing	Emerging Service Model
AngelTrax	119 S. Woodburn Drive	Dothan, AL 3605	www.angeltrax.com					X	X		
ApolloVideo	24000 35th Ave SE	Bothell, WA 98021	www.apollovideotechnology.com/					X	X		
Auro Autonomous Vehicles/Ridecell	514 Bryant St	San Francisco, CA 94107	https://ridecell.com/autonomous.html		X						X
Avail Technologies	1960 Old Gatesburg Rd #200	State College, PA 16803	www.availtec.com/						X	X	
Byd Motors	1800 S. Figueroa St.	Los Angeles, CA 90015	www.byd.com/				X				
Cambridge Systematics	101 Station Landing # 410	Medford, MA 02155	https://www.camsys.com/						X		
Citilabs	2005 N Street	Sacramento, CA 95811	www.citilabs.com/						X		
CleverDevices	300 Crossways Park Drive	Woodbury, NY 11797	www.cleverdevices.com/			X		X	X		
CTS Software	PO Box 57	Swansboro NC, 28584	https://tripmastersoftware.com/			X			X		
Cubic NextBus	5900 Hollis Street, Suite X	Emeryville, CA 94608	https://nextbus.cubic.com/						X	X	√
DoubleMap	429 N Pennsylvania St. Suite 401	Indianapolis, Indiana, 46204	https://www.doublemap.com/					X	X		
Easy Mile	8 rue des 36 Ponts	31400 Toulouse, France	http://www.easymile.com/		X						X





Vendor Name	Address	City, State, Zip	Website	Safety	Mobility	Accessibility	Environmental	Traveler Information	Operations	Fare Collection and Processing	Emerging Service Model
Ecolane	940 W. Valley Rd. Suite 1400	Wayne, PA 19087	https://www.ecolane.com/						X		
Engie	1990 Post Oak Boulevard, Suite 1900	Houston, Texas 77056-3831	https://www.engie.com/en/	X				X	X		
ETA Transit	1223 Villa Ln	Boynton Beach, FL 33435	http://etatransit.com/		X			X	X		
Eye Ride Online	2520 SW 30th Ave	Hallandale Beach, FL 33009	https://www.eyerideonline.com/	X					X		
FotressMobile	3801 Rose Lake Dr.	Charlotte, NC 28217	https://www.fortressmobile.com/	X					X		
Gatekeeper	301-31127 Wheel Ave	Abbotsford, BC V2T 6H1	http://www.gatekeeper-systems.com/	X					X		
GenFare	800 Arthur Avenue	Elk Grove Village, IL 60007	https://www.genfare.com/							X	
Giro - Hastus	75, rue de Port-Royal Est, bureau 500	Montréal Québec H3L 3T1	http://www.giro.ca/en/			X			X		
GTT	7800 Third Street North, Bldg 100	St. Paul, MN 55128-5441	http://www.gtt.com/		X				X		
ISR Transit	7771 W Oakland Park BLVD , suite 175	Sunrise , FL 33351	http://www.isrtransit.com/	X					X		
Local Motors Autonomous Vehicles	1576B S Nelson Dr,	Chandler, AZ 85226	https://localmotors.com/		X						X
Lytx	9785 Towne Centre Dr	San Diego, CA 92121	https://www.lytx.com/en-us/	X					X		
Navya Autonomous Vehicles	1 rue du Dr Fleury-Pierre Papillion	69100 Villeurbanne	http://navya.tech/en/		X						X



Vendor Name	Address	City, State, Zip	Website	Safety	Mobility	Accessibility	Environmental	Traveler Information	Operations	Fare Collection and Processing	Emerging Service Model
Passio	6100 Lake Forest Drive, Suite 410	Atlanta GA 30328	http://passiotech.com/					X	X	X	
Passport	128 S. Tryon St #2200	Charlotte NC 28202	https://passportinc.com/							X	
PathVu	6024 Broad Street	Pittsburgh, PA 15206	http://www.pathvu.com/	X		X					
PCTrans	2699 Salisbury Lane	Ann Arbor, MI 48103	http://pctrans.com/	X		X			X		
Protran	2401 Edmund Road, Box 20	West Columbia, SC 29171-0020	http://protrantechnology.com/	X		X			X		
REI	6534 L St	Omaha, NE 68117	https://radioeng.com/	X				X			
Remix	1128 Howard St	San Francisco, CA 94103	https://www.remix.com/						X		
Reveal	10551 Barkley Street, Suite 300	Overland Park, KS 66212	http://revealmanagementservices.com/		X				X		
Rosco Vision	90-21 144th Pl	Jamaica, NY 11435	https://www.roscovision.com/	X					X		
RouteMatch	1201 West Peachtree Street NW Suite 300	Atlanta, GA 30309	https://www.routematch.com/					X	X	X	
Safety Vision LLC	6100 W. Sam Houston Pkwy. N.	Houston, TX 77041-5113	http://www.safetyvision.com/	X					X		





Vendor Name	Address	City, State, Zip	Website	Safety	Mobility	Accessibility	Environmental	Traveler Information	Operations	Fare Collection and Processing	Emerging Service Model
Syncronmatics	2400 Research Blvd #390	Rockville, MD 20850	http://www.syncromatics.com/					X	X		
TokenTransit	3425 19th St #17	San Francisco, CA 94110	https://www.tokentransit.com/							X	
TrackItTransit			https://www.trackittransit.com/			X			X		
Trapeze	5800 Explorer Drive, 5th Floor	Mississauga, ON Canada L4W 5K9	http://www.trapezegroup.com/solutions	X				X	X	X	
TrustCommerce	1 MacArthur Place, Suite 400	South Coast Metro, CA 92707-5927	http://www.trustcommerce.com/							X	
TSO	7791 NW 46th Street, Suite 306	Miami, FL, 33166	http://www.tsomobile.com/	X				X	X		
United Data Technologies/ Cisco Systems	8825 NW 21 Terrace	Doral, FL 33172	https://udtonline.com/		X				X		
UZURV	2816 W Broad St	Richmond, VA 23230	https://uzurv.com/		X				X		

Stakeholders

This section discusses the outreach strategy used to reach transit agency stakeholders, the questions asked, and provides a summary of the results.

Outreach Strategy

The outreach strategy for stakeholders is divided into three parts:

- Outreach to Florida Agencies;
- Outreach to agencies outside of Florida; and
- Follow-up communications.

The outreach strategy for each part is described below. The initial contact with each of the transit agencies included an email from the FDOT summarizing the importance of the study, how the information would be used, and guaranteeing the participants a copy of the final report. It also provided information on how to participate in the study. The email is provided in **Figure 16**.

For those agencies in Florida, the Outreach Plan used the following process:

1. Send the initial contact email to all transit directors in Florida as identified on the list in **Table 11**. FDOT District Staff will be copied on the email to make sure they are aware of the study
2. Send information on the study to members of the Florida Transit Listserv and Florida Planning Network.

For the 20 transit agencies outside of Florida, the project team relied on agency websites and other online resources to obtain contact information for the key personnel at each of the agencies. Once the contact information was obtained, the team sent an email similar to what was sent to the Florida agencies to the appropriate staff.

Figure 16: FDOT Email to Transit Agencies

From:	Gabrielle Matthews
To:	Florida Transit Planning Network
Cc:	Waterman, Brian; Roy, Santanu
Subject	Transit Technology Survey

Dear All,

The Florida Department of Transportation (FDOT) is evaluating the state of transit technology employed by transit agencies across the state as part of developing a Transit Technology Primer. The purpose of this effort is to determine:

- What technology is currently being used by transit agencies;
- How transit agencies are using the technology to improve customer service and efficiency of the system;
- What new technology opportunities agencies are pursuing or should be pursuing; and
- How to develop a technology roadmap for your agency.

We are reaching out to request your participation in a survey to identify what technology you currently have, your experience with it, and your future technology plans. The survey is available online at https://hdrinc.co1.qualtrics.com/jfe/form/SV_00v3Pvx6TkxGt4V and should take approximately 15 minutes of your time. We request that you answer these questions or forward this email to the appropriate member of your staff who is best able to answer these questions.

We plan to close the survey on March 30, 2018. Once our research is complete, we will send you a copy of the final report.

If you have any questions, please do not hesitate to contact me at 850-414-4803 or gabrielle.matthews@dot.state.fl.us.

Sincerely,

Gabe Matthews
Transit Planning Administrator
Florida Department of Transportation
605 Suwannee Street, MS 26
Tallahassee, FL 32399
(850)414-4803
gabrielle.matthews@dot.state.fl.us

Questions and Outreach Results - Stakeholders

The initial questions that were asked of the stakeholders are provided in **Appendix A**. These questions were used to establish a correlation between technology investment and budgets, assess their experience or interest with different technologies, and to identify those firms for further communication.

Of the 51 stakeholders contacted to complete the survey, 21 responses were received from:

- Bay Town Trolley;
- Broward County Transit;
- Charlotte County Transit;
- Collier County Transit;
- HART;
- JTA;
- Lake County;
- LeeTran;
- Lynx;
- MCAT;
- MTA – Maryland;
- Pasco County Public Transportation;
- RTD – Denver;
- SCAT;
- SEPTA;
- SFRTA;
- Space Coast Transit Agency;
- StarMetro;
- TheComet;
- UTA; and
- VoTran.

The responses were received from agencies located both in and out of the State of Florida, different sizes, different experiences with transit technology, and that are good cross-section of the transit industry. The stakeholder responses to the initial survey questions are also summarized in **Appendix A**.

The initial survey illustrates the positive impact transit technology has on customer service, operations, decision making, and asset management. Technology, however, is not indicated to significantly improve fare collection and management with only 50 percent reporting some sort of improvement in those areas. This finding along with the desire of the majority of the agencies to pursue mobile payment options suggests that fare technologies are not reducing the reliance on cash fare, causing the reliance on back end operations for account reconciliation. In the other areas where technology is shown to have no impact or a negative impact, it is possible that the agency is not using the technology to its fullest capability, or there are interoperability conflicts where different technologies are not working well together. This reasoning is supported by the results of Question 10 where a plurality of agencies report either a lack of staff time for training or a level of unfamiliarity with new technology. Another possible explanation for the 'No Change' response is there could already be adopted procedures in place that are supplemented by the transit technology. As shown by the responses to Questions 5 and 7, there is considerable desire by all the participants to pursue new existing and emerging technologies. Funding, especially lack of recurring funds, and strategic planning is what is holding many of these agencies back from pursuing the opportunities.

Follow Up Interviews

Based on the responses to the survey, the following questions were sent to all of the responding stakeholders:

1. Are you aware of the different types of technology available to transit agencies? If so, what technology are you the most interested in or are planning to pursue?
2. What is keeping you from embracing new technology?
3. Do you have a technology investment plan? If so, what are your funding options? How much funding do you need to pursue your ideal system?
4. How has the lack of some components impacted staff performance and/or efficiency? Are you spending more time on certain tasks than you would like to?
5. How do you generate system reports and respond to changing demand levels?
6. What led you to pursue transit technology?
7. How has the technology improved your system performance measures (ridership, on-time performance, etc.)?
8. Overall, are you satisfied with your level of technology? Why or why not?
9. Is there additional technology you are interested in? What is your timeline to get them? What's holding you back?
10. What percent of your budget is set aside to maintaining your current technology and pursuing new opportunities? What funding did you use to start and grow your program?
11. Where do you see transit technology going in the next 5 years? 10 years? Do you feel you are prepared to handle it? Why or why not?
12. How has the technology improved your system performance measures?
13. What lessons would you pass on to transit agencies that are just starting out investing in transit technology or are growing their program?

The goal of these questions was to further delve into the decision-making process in selecting new technology and experience with the programs. These questions can be divided into four categories: the absence of desired technologies, the impact of transit technology, future technology pursuits, and lessons learned. Responses were received from: Bay Town Trolley (FL), HART (FL), LeeTran (FL), MTA (MD), RTD – Denver (CO), TheComet (SC), and UTA (UT). The respondents to follow-up interviews provide a cross-section of the transit industry with responses from small to large agencies. The full responses to each of the questions are provided in **Appendix B**.

Absence of Desired Technologies

The first five questions focus on how the lack of technology or desired technologies has affected the operations of the transit systems. **Question 1** evaluates the respondents on their level of awareness of current or emerging transit technology options. All of the respondents were aware of the available technology. As for desired technology, the majority of the respondents were most interested in pursuing upgrades to their fare system such as new collection systems and/or mobile payment applications. The remaining agencies were most interested in pursuing automatic passenger counters, automatic vehicle location, and transit signal prioritization. HART (Tampa) expressed an interest in pursuing autonomous and connected vehicle technologies. These responses show relative agreement that the basic technologies a transit system needs include automatic passenger counters, trip planning, and real-time bus location.

Question 2 asks for the reasons as to why transit agencies are not pursuing the technology options they mentioned in the previous question. Six of the seven responses stated their reasons include funding or lack of resources (i.e. staff) to invest in new technology. There are two explanations given on funding that best summarize the challenges faced by transit agencies: lack of funding to pay for the recurring costs (Bay Town Trolley) and the rapidly evolving marketplace making agencies hesitant to pursue certain technologies (UTA). To overcome this obstacle, any new technology product suggested should produce significant long term benefits before an agency would invest in them. TheComet, however, reported nothing at this time holding them back from pursuing new technology.

When it comes to the strategy to obtain new technology (**Question 3**), five respondents list their technology needs either in a strategic plan, technology master plan, or capital investment plan. The other two agencies either do not have a technology plan or update the appropriate documents when a technology need is identified. Three of the agencies stated that federal funds, such as Section 5307 or Section 5339, are used to acquire these technologies. Two of the agencies provided information on their funding shortfall between where they are now and their ideal system: $150,000 for Bay Town Trolley and $10 million for HART. The responses show the changing technology needs as a system grows in size and the value of a strategic technology plan to guide investments.

The intent of **Question 4** was to determine if the lack of technology has adversely impacted the performance of the agency. Some of the responses, however, indicate even the use of technology if not properly maintained or integrated into the system adversely impacts operations and performance. Specifically, TheComet mentions that changes to the system involve making time consuming changes to the programs associated with the affected service, such as trip planning, real time bus location, and stop announcements. This concern was echoed by HART who stated the lack of interoperability between software requires manual processes to keep the system up to date. Bay Town Trolley's response followed more of the original intent of the question by saying the lack of key components (APCs, AVLs, and Stop Annunciators) does affect system performance and reporting.

Question 5 builds upon the previous question to see how transit agencies obtain the necessary reports for performance monitoring and reporting. Four of the agencies (RDT, Bay Town, UTA, and LeeTran) mention using specific programs to generate reports such as ridership and on-time performance. MTA stated they use an ad-hoc process that is dependent on what data they are requesting. Only Bay Town Trolley mentioned cross-referencing the reports with bus operators on a regular basis to get a better understanding of the system.

Impact of Transit Technology

Questions 6, 7, 8, and 12 evaluate how well using transit technology has improved the respondent's system. Starting with **Question 6**, the agencies were asked what prompted them to pursue investments in transit technology. Three agencies specifically mention customers or customer service as a main driver to pursue technology. Both Bay Town and UTA made the decision to acquire new technology to get data quickly and get a better understanding of the system. HART and MTA both saw adding new technology as a part of a general goal to improve the overall system. These responses show that the issue to pursue new technology is out of a desire to help the customer and better understand the transit system.

Question 7 asks the agencies to identify areas where they have seen system performance improvement due to investing in new technology. Four of the respondents specifically identified areas of improvement due to new technology with improvements seen in better customer service, reliability, and decision making. Two agencies (RTD and Bay Town Trolley) stated that it is too early in the process to make a quantifiable decision on this issue. TheComet expressed dissatisfaction with technology with one vendor being called out for not meeting expectations. Similarly, overall satisfaction with their level of transit technology is the focus of **Question 8**. Four of the respondents stated that they were satisfied with their current level of investment. The remaining three agencies identified needing more investment.

The last question in this area, **Question 12**, asks how the transit technology has improved system performance. Bay Town Trolley stated that it's too early in the process for them to make a judgment statement. UTA highlighted technology improved reliability, validation of ridership, and information for customers. LeeTran mentioned improved on-time performance and better data collection/analysis. Overall, responses to Questions 7 and 12 show there is a measured benefit to investing in transit technology.

Future Technology Pursuits

Questions 9 to 11 ask the agencies to look to the future to identify what technology they want to pursue, how it would be funded, and what the future of transit technology holds. **Question 9** asks what new technologies they are interested in and what is holding them back from pursuing them. This question focuses on specifically what technology is next on their acquisition list. Two of the agencies are actively pursuing APCs as a means to improve system reporting and where demand is greatest. Other agencies are pursuing signal prioritization, real-time surveillance of the fleet, fare systems, and upgrading back end operations. As with **Question 2**, funding is the limiting factor.

Going a little deeper on technology expenditures, **Question 10** asks the agencies to provide what percent of their budget is set aside for technology and how their technology program was initially funded. Four of the respondents were not sure. Bay Town Trolley dedicates about 15 to 20 percent of their budget on technology with the initial funds coming from Section 5307. For UTA, about 5 percent is dedicated to technology with LeeTran setting aside 10 percent. Both of those agencies also use Section 5307 funds to maintain the program.

The future of transit technology and level of preparedness is the focus of **Question 11**. Each of the seven respondents provided a different answer to this question. RTD, in their response, stated that the entire agency is learning about new technology options so they are in a better position to pursue different opportunities. TheComet sees consolidation of data and programs into single transit apps, where trip planning, AVL, and mobile fare are all in one application. MTA sees consolidation of services and providers into a single technology platform, and they feel they are not prepared for it. Bay Town Trolley envisioned their system getting better with new technology being acquired as they grow. LeeTran sees more technology that is available to help agencies automate and monitor the system. UTA provided a more comprehensive list of new technologies including mobility on demand, mobile ticketing, connected vehicles, and improved customer service.

Lessons Learned

The last question of the stakeholder interviews asked for lessons that agencies have learned in their pursuit of transit technology. The lessons learned are:

- **Plan Ahead** – Four of the respondents called for some level of planning before pursuing a technology program. Transit agencies should set technology goals, identify priorities and funding, and determine what problem(s) are trying to be solved. These elements lead to a master technology plan that incorporates all of the technology needs for the agency. This allows for leveraging of resources and investing in complementary, not competing components.
- **Set Aside Extra Resources** – Likewise, agencies should set aside additional staff and resources to prepare for and effectively implement the new technologies. This means having the talent in agency or hiring outside assistance to have a better understanding of what is being purchased, solve problems, and successfully implement the programs. Once the technology is in place, more staff time will be needed to maintain the system.
- **Go Slow** – Since technology can be a costly upgrade to the system, UTA encourages others go slow when acquiring new technology. Agencies should make sure they are addressing a true need to address deficiencies in the system.
- **Learn from Others** – There are numerous transit agencies across the country each in a different state of technology investment. In addition, there are lots of vendors with different solutions to transit problems. Before investing in new technologies, obtain copies of contracts, watch product demonstrations, and ask questions.

The follow up interviews with stakeholders provided useful insights as to why transit agencies pursued transit technology, how they funded their investments, what benefits they experienced, and what lessons they learned. All of the agencies expressed a positive outcome by implementing new technology through improved customer service and more information to help decision makers. Going forward, investing in transit technology is valuable to a successful transit system.

Vendors

This section discusses the outreach strategy that was used to reach vendors and the questions they were asked.

Outreach Strategy

The outreach strategy for vendors included reviewing conference attendee lists, the APTA Member Directory, and reaching out to business partners/colleagues of the project team. A list containing the contact information of the vendors was developed and maintained by the project team. Vendors were contacted by the project team using email as found in **Figure 17**. The goal was to have at least half of the vendors in each of the technology categories respond to the survey.

Figure 17: Email to Vendors

From: Brian Waterman
To: Technology Vendor
Cc: Gabrielle Matthews; Santanu Roy
Subject FDOT Transit Technology Survey

The Florida Department of Transportation (FDOT) is evaluating the state of transit technology employed by transit agencies across the state as part of developing a Transit Technology Primer. The purpose of this effort is to determine:

- What technology is currently being used by transit agencies;
- How transit agencies are using the technology to improve customer service and efficiency of the system;
- What new technology opportunities agencies are pursuing or should be pursuing; and
- How transit agencies can develop a technology roadmap.

We are requesting your participation in a survey to learn about what technology you provide, how this technology helps transit agencies, and what new technology you are developing. Here is the link to the survey site - https://hdrinc.co1.qualtrics.com/jfe/form/SV_9tqwd2xkf9fmoGV. If you elect to participate in the survey, we will list your firm/ product as a participating company in the final report. We also request you forward to us any brochures, specification sheets, and/or marketing brochures for our review.

We plan to close the survey on March 30, 2018. Once our research is complete, we will send you a copy of the final report.

If you have any questions, please do not hesitate to contact me by email or call.

Sincerely,

Brian S. Waterman, AICP
Senior Transportation | *Transit Planner*
HDR
315 South Calhoun Street
Suite 800
Tallahassee, FL 32301
D 850-329-1443 **M** 850-339-9969
brian.waterman@hdrinc.com
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Questions & Outreach Results - Vendors

The general questions that were asked of the vendors and their responses are provided in **Appendix C**. As with the stakeholder questions, the purpose of these was to confirm the technology classification made by the project team and to identify vendors for follow-up communications. The requests for participation in the survey were sent by the project team on March 20, 2018, with a response deadline of March 30, 2018. Of the 44 vendors contacted to complete the survey, 15 responses were received. This outreach helped to support the information found on vendor websites and other sources.

Questions 1 and **2** asked the vendors to identify what technology categories they operate in and what components they use. **Question 3** of the Vendor Surveys requested information on some of the key features of their products. The responses provide a wide range of technology features for the transit properties to choose from. Below is a sample of their key features:

- Visualization, Scenario Analysis, and Web applications;
- Flexible and/or Modular options for transit agencies to purchase only what they need;
- Route planning, demographic analysis, and travel time isochrones;
- Multi-modal trip planning applications for both fixed route and paratransit riders;
- Back office connectivity over cellular connections;
- Products to cover all areas of transit system administration and operations;
- Pedestrian detection;
- Customer financial security;
- Traveler behavior and information analysis;
- Bus pass distribution; and
- Vehicle preemption.

All of the vendors were receptive to follow-up interviews on their products and case studies (**Q4**). Their responses are provided in the next section.

After reviewing the responses to the survey, the project team requested case studies from the vendors to help document the benefits associated with implementing the different transit technologies. Responses were received from: Citilabs, ETA Transit, GTT, Passport, Remix, Routematch, and Trapeze Group.

Case Studies

A summary of the case studies cited by the vendors is provided below.

Citilabs

Relatively new to the transit technology space is Citilabs. Citilabs began by providing transportation planning and analytics solutions for governments, businesses, and other entities. Recently, they expanded their software suite to include Flow – a transit planning solution that allows for scenario planning and evaluation of other performance metrics. Flow is unique since it also uses fare card data and bus GPS information to provide detailed stop level analysis. Since Flow is a recent addition, only one case study was provided. The City of Cape Town, South Africa has implemented Flow. The use of Flow provides the agency an overview of system performance and a more accurate commuter experience. The program allows them to respond to changes in demand quickly, and provides a unique view into revenue and ridership.

ETA Transit Solutions

Since 2003, ETA Transit Solutions (ETA) works to increase the use of public transportation by providing features such as passenger information, mobile video surveillance, voice annunciation, and transit public displays. They also employ open architecture solutions that allow for expansion, customization, and a lower cost of entry that packs more features into the tighter budgets of small- to mid-sized agencies, universities, and paratransit fleets. ETA provided three case studies showing what their programs offer.

- Florida Atlantic University (Boca Raton, FL) – FAU operates two fixed routes with six shuttles. As the enrollment and ridership grew, the frequencies advertised by the university were becoming unreliable and there was a call for reliable tracking technology. In the fall of 2012, the university began searching for a reliable CAD/AVL (Computer Aided Dispatch/ Automatic Vehicle Location) system. ETA offered its ITS Solution, S.P.O.T. (Spatial Position On Transit). S.P.O.T. provides vehicle location information to both students and transportation staff. In addition, ETA offers a fully integrated technology package where at any time FAU can add additional transit style technology as their budget and needs expand.
- University of Memphis (Memphis, TN) - There are only a handful of buses that serve the students and faculty at the University of Memphis campus. When an AVL app was introduced in 2009, ridership started to grow. Due to the success of the app, the school began searching for ITS to build on the momentum of the rider app. The desire was to add on-board announcements and APCs to help track and justify the increased ridership of these technological improvements. The solutions provided by ETA Transit and their S.P.O.T. Intelligent Transit System (ITS) were able to offer a proposal and pricing option that gave the school what it wanted within the approved budget. All of these tools allowed for the installation of variable message boards on UM buses and in campus shelters. The ITS system allowed UM to evaluate improvements to its service by analyzing patterns and trends in ridership. It also improved its rider experience by providing shelter signage that integrated with its existing phone app and on-board vehicle announcements.
- Lassen Rural Bus (Lassen, CA) – LRB also employs ETA's SPOT with similar successes as the previous case studies. LRB, however, did experience another benefit by using this software. The Office of Health and Social Services discovered the importance of knowing the real-time location of vehicles. Previously, the office would dispatch a county van to pick up a rider in need, but now with access to Lassen's new S.P.O.T. ITS, they can view the location and status of vehicles nearer to the customer and re-route to assist riders more quickly. It's a service that had delivered direct returns to Lassen County in the form of fuel savings, depreciation, and payroll expenditures. Additional improvements include using ETA's GPS analytic software to provide records of speed, location, idle, arrival times, and more. It's a new set of metrics that will not only help improve driver behavior, but ultimately guide changes in its training process.

These case studies from ETA show the benefit of implementing transit technology is not limited to the large providers, but small, rural, and university systems also see efficiency and customer service improvements.

GTT

Global Traffic Technologies, LLC (GTT) is the manufacturer of Opticom priority control systems and Canoga traffic-sensing systems. For transit providers, GTT specializes in transit signal priority

(TSP) solutions to improve the operations of the system. Two case studies are summarized to show the value of these systems.

- Société de transport de Laval (Laval, Quebec, Canada) - STL provides more than 20 million passenger trips a year with plans to grow 40 percent by 2022. While they have tried numerous approaches to increase ridership, the efforts were not having the desired effect due to on-time performance issues. They felt the best way to increase the speed and reliability of the system was to implement a large-scale TSP system. The Opticom TSP system allows public transportation agencies to extend or truncate green cycle times at traffic signals for more accurate schedule adherence and to get riders to their destinations faster. STL began testing the TSP system in 2013 on five buses and at seven intersections. The results of the pilot showed time savings were between 8 and 10 percent during morning peaks. Now, there is TSP on over 200 intersections, 300 buses, and 20 paratransit vehicles.
- Memphis Area Transit Authority (Memphis, TN) – MATA also employed TSP to improve the operation of its routes in the Downtown Core. To implement the program, MATA officials sought a grant for installing TSP at key intersections. Buses include Opticom GPS equipment to request from up to 400 feet away or 30 seconds before reaching the intersection. MATA also uses the Opticom Central Management Software (CMS) to ensure the TSP system worked consistently. Opticom CMS offers built-in intelligence, from real-time alerts to automated diagnostics to customized reports, so MATA personnel can check activity logs, update firmware and even troubleshoot equipment from a remote location. The system improved travel times by almost 20 percent and could save MATA about $200,000 annually.

Here transit technology is shown to improve ridership through better reliability and overall system performance.

Passport

Passport, Inc. is a mobile ticketing company that allows commuters to “plan, track, and pay for their trip in one simple secure app.”[101] Passport provided two case studies highlighting the capabilities of their product.

1. Charlotte Area Transit System (Charlotte, NC) – Charlotte Area Transit System (CATS) launched a pilot mobile fare app in July 2017[102] to address overreliance on Ticket Vending Machines (TVM) for the light rail system. The TVMs required customers to travel to specific locations and possibly wait in long lines during peak hours. The app (CATS Pass) allowed the customers to purchase tickets anywhere, at any time, with the use of their smartphones. In addition, the CATS Pass allowed customers to purchase trips with Transportation Network Companies to extend their transit trips. Within six months of implementation, more than 60 percent of tickets were purchased through the app.
2. Jacksonville Transportation Authority (Jacksonville, FL) – JTA launched the MyJTA App in 2015. The app allows customers to ride, plan, track, and pay their fares. Since the

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[101] https://passportinc.com/transit/

[102] http://www.charlotteobserver.com/news/politics-government/article164512267.html

launch of MyJTA, JTA has seen a 550 percent increase year over year in bus fare purchased via the app and has seen a $40,000 savings in print and paper costs.

Some lessons learned from implementing mobile fare include:

- Adoption of the mobile ticketing application is directly tied to the method of transportation. Environments featuring rail, ferry, or commuter bus see a much higher adoption rate than environments that are fixed route bus.
- Significant buy-in is needed from the bus operators. The bus operators are the individuals interacting with the ridership base on a regular basis and if they understand the application and the benefits it brings, they quickly become the biggest advocates for the technology. In turn, this leads to higher adoption/utilization rates.
- A key benefit with private label mobile ticketing applications is the ability to increase the communication with customers. Rather than having physical fare media, a mobile application can be updated to include push notifications, external links, and more. This type of communication brings value and draws customers to the applications. However, this doesn't have the same impact if the application is built on a platform to serve multiple agencies.

Implementation of mobile fares typically costs between 5 to 10 percent of the farebox revenue paid to the provider, unless the program is done in-house.

Remix

Remix is a transit and transportation software provider that focuses on scenario planning, scheduling, and concept development. Transit agencies can use their software to plan and design new routes and determine their impact on both the general public and overall budget in real-time. Recent additions to the Remix software suite include transit scheduling and street design. They highlighted three examples of where their programs were implemented.

- Greater Lynchburg Transit Company (Lynchburg, VA) – Implemented the scheduling software in 2016. The software allows the GLTC to have fine-tuned control over their output and can work through multiple iterations of bid sheets in minutes, eliminating suboptimal outcomes early on. Other benefits include saving $102k annually in operating costs, time savings, and customer service fees and eliminating all split shifts while maintaining the same level of service;
- Hillsborough Area Regional Transit (Tampa, FL) – HART used Remix Transit to develop new hurricane evacuation routes with many of the routes drawn in less than a minute as compared to over an hour with geographic information software programs.
- Pinellas Suncoast Area Transit (St. Petersburg, FL) – PSTA was able to update their scenario planning process by using the software by making it more accessible in the agency through cloud-based computing.

Remix is not the only public transportation planning software on the market, but these examples show the integrated approach of combining sketch planning, budgeting, and analytics into one suite is a benefit to the industry.

RouteMatch

Started in 2000, RouteMatch provides a flexible technology platform that covers paratransit, fixed route, payment, and on-demand services. Products offered by Routematch include MDTs, automatic vehicle location, bus stop signage, and scheduling services. Routematch reported the following case studies:

- An increase in average revenue per vehicle through better scheduling of paratransit trips (Cleveland QLD, Australia);
- A decrease in demand response no-shows from 20 percent to 6.1 percent with more engaged riders, better reporting, and efficient customer service with the Fairbanks North Star Borough Bus System (Fairbanks, AK);
- Implemented a centralized, one-call/one-click regional mobility management center with greater data management, more accurate reporting, and improved communications between drivers and dispatchers at Pelivan Transit (Big Cabin, OK);
- A 35 percent decrease in demand response operational costs, 22 percent fixed route ridership increase, and 80 percent decrease in "where's my bus" calls reported at Porterville Transit (Porterville, CA); and
- Savings of $17,000 in administrative costs yearly due to move to paperless environment with Coast Transit Authority (Gulfport, MS).

These case studies show that better coordination and management of resources with transit technology could lead to operational savings for transit agencies.

Trapeze

Trapeze provides software solutions and services to help transportation agencies manage complex, day-to-day business operations. They provide a broad selection of programs that help with dispatch, scheduling, runcutting, fare systems, and other support systems. Eight case studies were provided by the firm across four product areas; however, only one per area is discussed below.

- Operations Workforce Management - At PalmTran (West Palm Beach, FL), staff used Trapeze software called OPS to move away from creating reports by hand and on paper. With the help of OPS, the operator bid process became automated and a considerable amount of time was saved, improving the efficiency of the system.
- Transit Asset Management – SoundTransit (Seattle, WA) uses Enterprise Asset Management (EAM) to create an automated process to track assets and run reports. The program allows staff to save 3 to 4 hours per week on administrative tasks and spend more time on preventative maintenance.
- Intelligent Transportation System (ITS) – ITS is employed with systems like Capital Area Transit Authority (Lansing, MI) to create accurate and efficient operations for the agency. CATA uses ITS to capture better information about the health of the fleet to quickly respond to maintenance issues they may face.
- Paratransit Scheduling – In Canton, OH, Stark Area Regional Transit Authority (SARTA) employed Trapeze's Paratransit Software to reduce costs, enhance the customer service experience and bus operator morale, and improve on-time performance (OTP) to above

90 percent. To achieve these results, SARTA installed CAD/AVL on-board MDTs which provided coach operators with electronic manifests and implemented new paratransit software modules to improve passenger communication.

The Trapeze Software Suite and similar vendor solutions show the value of interoperability with transit technology. Whether the agency purchases software from one vendor or many, it is important to make sure the programs work together to maximize performance and avoid conflicting operations.

Summary of Stakeholder and Vendor Outreach Results

In order to fully assess the impact of technology on transit agencies, it is important to learn from stakeholders and vendors about available products and their experience with them. This document summarized the strategy used to reach out to many stakeholders and vendors, asking for information on their experience with technology (stakeholders) and what product they offer (vendors). The initial outreach provided the current state of the market and established a roadmap for documenting information about specific products and/or product applications.

The survey of stakeholders showed overall support for transit technology. Technology improves the system, provides information to help make decisions, and removes obstacles to customers using the system. While there is strong desire to pursue new technologies, the problem is new technology can be expensive. In addition, many transit agencies have not planned or set aside the staff time to prepare for new technology.

As the stakeholders reflected on their implementation of transit technology, they provided valuable lessons for other agencies to take into consideration. The lessons are:

- Plan Ahead;
- Set Aside Extra Resources;
- Go Slow; and
- Learn from Others

All of the agencies expressed a positive outcome by implementing new technology through improved customer service and more information to help decision makers. Going forward, investing in transit technology is valuable to a successful transit system.

Vendors also participated in the outreach efforts and summarized some of their products. After compiling the results of the survey, the vendors who participated were asked to provide case studies illustrating how their products helped transit systems. The transit agencies highlighted in the case studies experienced:

- An increase in ridership;
- Decrease in operating costs; and
- More efficient operations and processes.

All of this illustrates the value of transit technology and how it can help agencies do more with available resources. For agencies to benefit from technology, assistance is needed to help them navigate the process, identify funding opportunities, and summarize the benefits of these products. This is the goal of the Transit Technology Assessment Framework Tool that accompanies this report.

TECHNOLOGY ASSESSMENT FRAMEWORK

Technology Assessment Framework

To establish a framework for presenting information to stakeholders, this section provides an overview of technology assessment methodologies and how they might be utilized for transit technology.

Transportation technologies are changing rapidly, with new technologies emerging on a regular basis. State-of-the-art technology from only a few years ago has reached obsolescence and is being surpassed by improved products. With the advance and pace of technology, transit agencies must be diligent to ensure that whatever technology they adopt is stable and provides clear benefits comparable to the cost of the product.

Transit agencies are at the forefront of the emerging transportation technology. Large transit agencies[103] may have the resources and internal staff expertise to meet with technology vendors, review products, and participate in State and National committees and events to stay abreast of existing and emerging technologies. Smaller agencies, typically do not have access to this same level of resources and are reliant on published literature and “word-of-mouth” information exchanges. This results in a paradigm where large transit agencies predominate as “first adopters” with smaller transit agencies being “late adopters,” who may not realize the full benefit of the technology before it becomes obsolete. At the same time, the challenges and issues facing small-to-medium transit agencies may differ significantly from those of a large (typically urban) transit agency. To the extent that different technologies address unique issues, small-to-medium agencies may not learn of specific technologies for several years if they do not fit the need profile of a large transit agency.

The Federal Transit Agency (FTA) does sponsor and make available information on transit technologies as part of its Transit Technology Program. For example, FTA leads innovative research in safety, asset management/innovation, and mobility. The $8 million in funding for Mobility on Demand (MOD) Sandbox Program is a recent example of this research. The MOD Sandbox is a research effort that supports transit agencies and communities as they integrate new mobility tools like smartphone apps, bike- and car-sharing, and demand-responsive bus and van services. The Accessible Transportation Technologies Research Initiative (ATTRI) is another such research project with specific findings on the use of technology within the transit community to serve persons with disabilities and older adults. “Every-Day-Counts” or EDC is the signature program of the USDOT’s Center for Accelerating Innovation. EDC is conducted by “FHWA in cooperation with the American Association of State Highway and Transportation.

Officials (AASHTO) to speed up the delivery of highway projects and to address the challenges presented by limited budgets. EDC is a state-based model to identify and rapidly deploy proven but underutilized innovations to shorten the project delivery process, enhance roadway safety, reduce congestion and improve environmental sustainability.”

Although there is research being conducted and reported upon at conferences and through traditional journal articles, an equivalent EDC for transit technologies is not available. This leaves an information gap for transit agencies that are struggling with ridership, safety of waiting

[103] American Public Transportation Association refers to larger transit agencies as those with more than 2 million boardings per year. http://www.apta.com/resources/links/unitedstates/Pages/FloridaTransitLinks.aspx

pedestrians and bicyclists, and maintaining travel time reliability among other challenges. The overall goal of this project is to begin to fill this gap through combining information from literature, conferences, and direct interaction with vendors and transit agencies.

A Technology Assessment Framework (TAF) is a blueprint and structured process for identifying and systematically evaluating transit technologies and systems by agency staff. There are many different potential frameworks and processes that could be effectively employed to conduct a technology evaluation for a specific purpose. For this primer, a customized TAF and process has been developed to serve as a guide for agency staff in identifying and evaluating technologies.

Review of Historical Technology Readiness Assessment Frameworks

TAFs are not a new concept and have been employed in a variety of different industries to conduct technology evaluation. In particular, Technology Readiness Levels (TRLs) are a framework that allows agencies to assess technological developments at different phases in order to classify its maturity and estimate its timeline for deployment. The traditional TRL framework is comprised of nine levels; TRL 1 describes the initial stages of development while TRL 9 characterizes a fully-functional system. There are many agencies that use this TRL framework when evaluating technologies. Some of the most prominent organizations include: the National Aeronautics and Space Administration (NASA), the U.S. Department of Energy (USDOE), the U.S. Department of Defense (USDOD), and the U.S. Department of Transportation (USDOT). **Table 15** illustrates the nine TRLs employed by each of these agencies to assess and compare technologies.

Table 15. Summary of Test Readiness Levels to Assess Technologies

Level	NASA[1]	USDOE[2]	USDOD[3]	USDOT[4]
TRL 1	A technology is in the beginning stages of research and development.	Basic principles related to the developing technology are being researched and identified. This stage is purely research.	At this level, basic principles are being researched and reported. This is the lowest level of technology readiness.	Preliminary research is being conducted.
TRL 2	Basic concepts and principles are being established, but there is minimal experimental proof.	Research is beginning to be applied and experiments begin to support theories formed during the initial research stage.	The invention of the technology concepts begin. Applications are still speculative at this stage.	The application has been formulated.
TRL 3	When the research and design stages begin; a proof-of-concept model is typically constructed at this stage.	Active research and development begins at this stage; the research moves beyond paper to experimental work.	Active research and development begin in order to validate initial predictions about the technology.	A proof of concept has been developed.
TRL 4	A technology reaches this stage once a concept model has been completed and researchers are able to test different components.	Basic technological components are assembled to ensure that they will function as a system.	Basic technological components are integrated together to ensure their functionality.	The technology components have been validated in a laboratory environment.
TRL 5	The technology will undergo more rigorous testing. Technologies at this stage will be tested in a relevant environment.	The technology is tested further to analyze its accuracy and consistency.	The accuracy of basic components increases at this stage; these components begin testing in a simulated environment.	The components have been demonstrated in a laboratory environment.

Level	NASA[1]	USDOE[2]	USDOD[3]	USDOT[4]
TRL 6	The technology will have a fully-functional prototype.	The prototype is tested in a relevant environment on a laboratory scale.	A prototype of the system is tested in a relevant environment; these environments are typically simulated and within a laboratory setting.	The prototype has been demonstrated in a relevant environment.
TRL 7	This level requires the prototype to be tested in a relevant environment.	A full-scale prototype is tested in a relevant environment.	The prototype is required to be demonstrated in a relevant operational environment.	The prototype has been demonstrated in an operational environment.
TRL 8	After testing, the technology may be implemented into existing technology systems.	System testing has been completed through demonstration. This level depicts the end of system development.	The technology has proven to be qualified after testing and demonstrations. This level is considered to be the completion of system development.	The technology has been proven in an operational environment.
TRL 9	Once a technology has had a successful deployment, it is advanced to TRL 9 classification.	At this level, the technology has been successfully operating under a range of environmental conditions.	The system has been proven through many successful deployments.	The technology has been refined and fully adopted.

1. https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html
2. https://energy.gov/sites/prod/files/em/Volume_I/O_SRP.pdf
3. http://www.acqnotes.com/Attachments/Defense%20Acquisition%20Guidebook.pdf
4. https://www.fhwa.dot.gov/advancedresearch/pubs/17047/17047.pdf

The U.S. Department of Transportation recently developed a guidebook which discusses how agencies conduct TRL assessments within the transportation field[104]. Technology readiness is measured across various federal transportation programs and projects – below are a few examples:

- The National Science Foundation (NSF) & Other Federal Science Programs
- The Federal Highway Administration (FHWA) Exploratory Advanced Research Program
- FHWA Research and Development Programs
- Small Business Innovation Research (SBIR) Phase I
- Small Business Innovation Research (SBIR) Phase II
- Accelerated Innovation Deployment (AID) Grants (FHWA)
- Every Day Counts (FHWA)
- The National Cooperative Highway Research Program (NCHRP)
- NCHRP Innovations Deserving Exploratory Analysis (IDEA)
- State Planning & Research Program (generally)
- Transportation Pooled Fund Program (FHWA)

As summarized in the FHWA TRL Guidebook, "TRL Assessments are a tool for determining the maturity of technologies and identifying next steps in the research process." The TRLs adopted by each of the four agencies listed in **Table 15** have been successfully used to evaluate

[104] Nate Deshmukh Towery, Elizabeth Machek, Anthony Thomas; "Technology Readiness Level Guidebook;" FHWA-HRT-17-047; September 2017

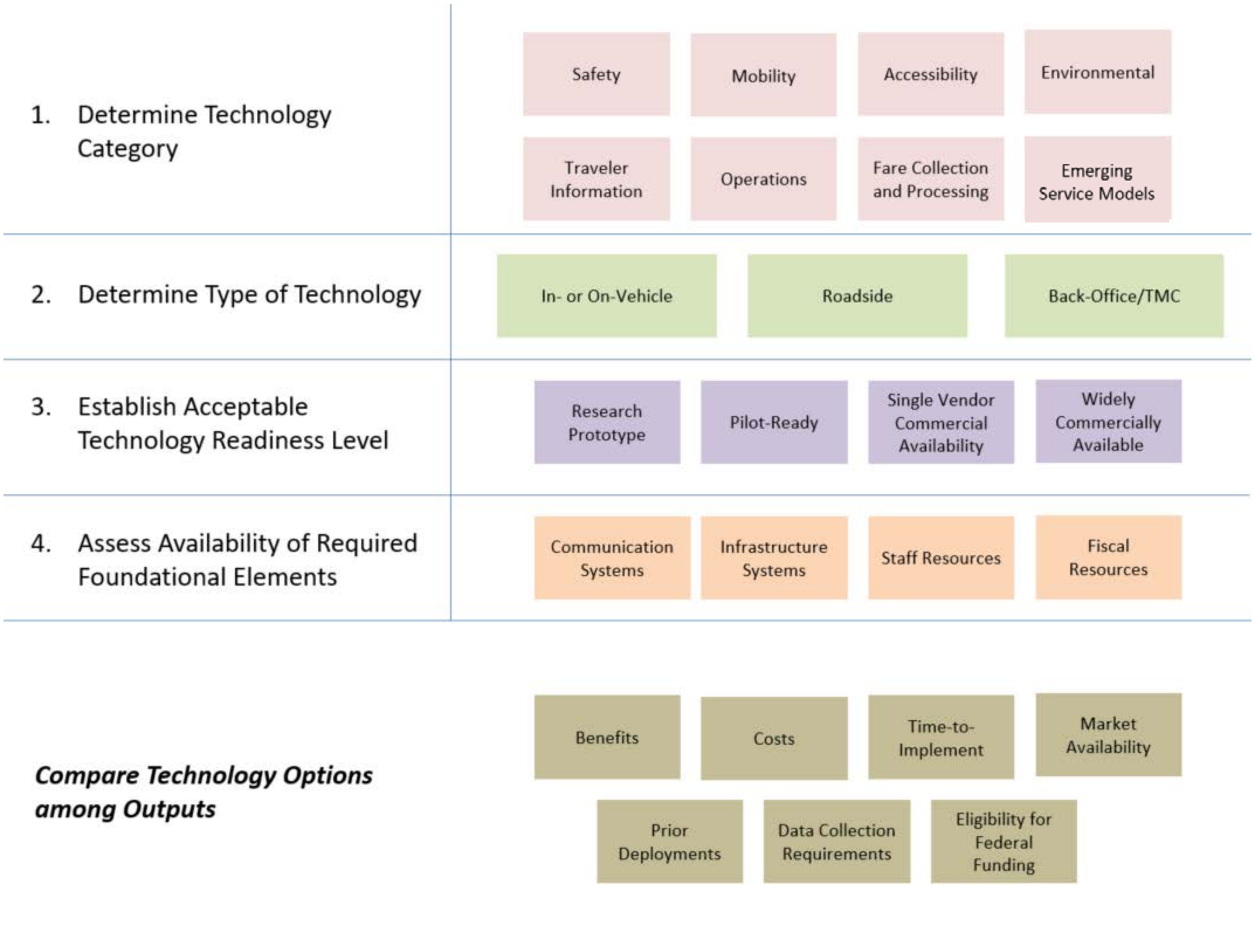
technology systems for deployment and they cover the breadth of the technology development lifecycle. However, as they are geared primarily towards identifying the maturity and next steps in the research process they do not naturally lend themselves to the identification of suitable technologies to solve specific issues, nor do they provide differentiation between technologies at the same technical readiness level.

Overview of a Transit Technology Assessment Framework Tool

The Transit Technology Assessment Framework Tool (TTAFT) consists of a series of options that agency staff can evaluate to identify a select number of transit technologies for comparison. The process and choices in the TTAFT are illustrated in **Figure 18**.

Each choice in the process is designed to inform and provide a filter for the subsequent options. The process begins with the identification of a specific opportunity or issue that the transit agency wishes to address. It proceeds through a series of steps designed to narrow the potential list of technologies as a function of the type-of-technology, the acceptable readiness level of the technology to the agency, and the availability of required functional elements needed to implement the technology. The output in the process is for the framework to provide a list of suitable technologies that fit the criteria identified in the previous steps along with a standardized and consistent set of comparison metrics for each of the potential technologies.

Figure 18. Overview of Transit Technology Assessment Framework Tool



The remainder of this document discusses each of the choices, filtering criteria, and technology comparisons in the TTAFT.

Technology Categories

For the purposes of this section and the TTAFT, transit technologies have been defined according to use cases as follows:

- **Safety** systems design to reduce collisions with vehicles, cyclists, and pedestrians;
- **Mobility** enhancing technologies that increase access to transit options, and increase trips speed and travel time reliability while completing trips;
- **Accessibility** features and services that makes trips easier for older adults and travelers with disabilities;
- **Environmental** technologies that reduce fuel consumption and emissions;
- **Fare Collection and Processing** systems that enable easier payments across multiple modes, as well as enhance access for unbanked households;
- **Traveler Information** technologies that provide users with actionable trip planning options prior to and while completing transit trips;
- Back office facing **Operations** systems that support transit agencies in planning, operating, and maintaining their transit systems and assets; and

- **Emerging Service Models** that may complement traditional transit service in the future.

Figure 19 shows where to select the technology category in the TTAFT.

Figure 19: Technology Category

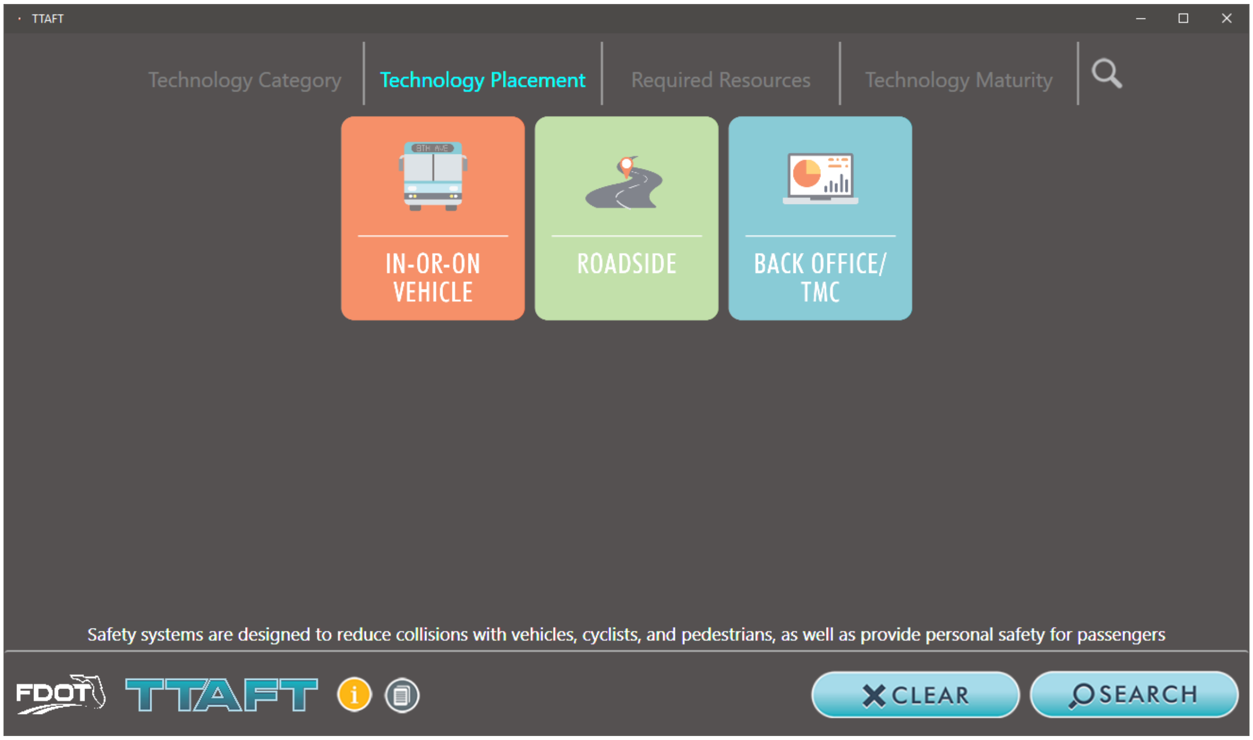
Type of Technology

As described previously, the developed TTAFT consists of a series of options that agency staff can engage in to identify a select number of transit technologies for comparison. One option in the framework is to determine the type of technology. The TTAFT identifies attributes of technology type as follows:

- In- or On-vehicle
- Roadside
- Back-Office

Figure 20 illustrates the selection of the technology type.

Figure 20: Type of Technology



In- or On-Vehicle

Transit buses include abundant technologies within and on the vehicle, such as acceleration and deceleration monitors coupled with driver cameras. Some technologies are self-contained to assist the bus operator in real time to do his or her job, while other technologies connect to a central hub for monitoring. For example, wide-angle security cameras are placed at strategic locations both inside and outside the buses to provide 360 degree view of what is going on in the transit system. Information is transmitted back to a central hub and/or downloaded each day for record keeping. The benefits of these systems is improving the safety of the system by monitoring and preventing incidents. It also provides a recording of an incident to give to law enforcement or for training purposes.

As another example, Pedestrian & Turn Notifications consist of sensors placed around the transit vehicle to provide the vehicle operator with warnings if there is a pedestrian in a vehicle blind spot. These sensors do not require active monitoring but use radar or similar technology to scan around the transit vehicle for potential hazards. If there is a hazard, the operator is notified. Similarly, an audible warning is provided to notify pedestrians and cyclists when the vehicle makes a turn. On-vehicle technologies such as these can benefit transit operators by providing early notification of potential conflicts with pedestrians or other hazards.

Roadside

Roadside technologies provide the ability to enhance transit service through communication with infrastructure at an intersection, along a corridor, or at a bus stop. One example is transit signal priority (TSP). TSP often uses dedicated short-range communication (DSRC) to enable vehicle-to-infrastructure communication.

TSP is a set of technology improvements that reduces the dwell time at traffic signals for transit vehicles by either holding green lights longer or shortening the red lights[105]. TSP systems require a vehicle location system on the bus; priority request generator located either on the vehicle, at the intersection control box, or at the traffic management office; strategy for prioritizing requests; and an overall TSP system. The main benefit of implementing TSP is reduced travel times and improved schedule adherence. Experience from other jurisdictions has shown a 10% reduction in overall travel time and a 50% reduction in delay at specific intersections[106]. By providing travel time reductions, roadside technologies such as these can improve the efficiency and reliability of the system which leads to an increase in ridership and decreased operating costs for the transit agency.

Another example of roadside technology is next bus arrival information on roadside signage. GPS technology and location data work in conjunction with real-time traffic updates and transit agency schedules to communicate to passengers. Roadside technology can communicate real-time arrival information on signage as well as through lighting and auditory announcements to improve safety and awareness for waiting pedestrians.

Back-Office / Transportation Management Center

Even at relatively small transit agencies, back-office operations such as computer-aided dispatch can involve complicated deployment of vehicles and efficient utilization of bus operators in order to serve customers with timely and safe service. Coordination between vehicle dispatch, transportation supervisors, vehicle maintenance, coach cleaners, and similar functions can be improved through technology. As one example, vehicle diagnostic systems observe the operation of the vehicle and report back to the central hub any problems, concerns, or system warnings. This information gives valuable insight into how a vehicle is performing, operating at the proper speed, and whether it is adhering to the defined route. Any deviation from the adopted standards is reported back to the dispatchers where it is disseminated to the right department or individual to correct the problem. Active monitoring of the system allows for incidents to be quickly identified and addressed before they become problems that disrupt the operation of the system.

Acceptable Technology Readiness Level

As discussed previously, the TTAFT consists of a series of options that agency staff can choose to identify a select number of transit technologies for comparison. TRL are a type of measurement system used to assess the maturity level of a particular technology[107]. Depending on an agency's funding, community preferences, and unique challenges, transit agencies may differ on their willingness to engage with technologies at varying levels of readiness. While many transit agencies may want to wait until technologies are widely commercially available, it is important for planning future improvements to be knowledgeable of upcoming technologies as they proceed

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[105] https://www.transitwiki.org/TransitWiki/index.php/Transit_signal_priority_(TSP)

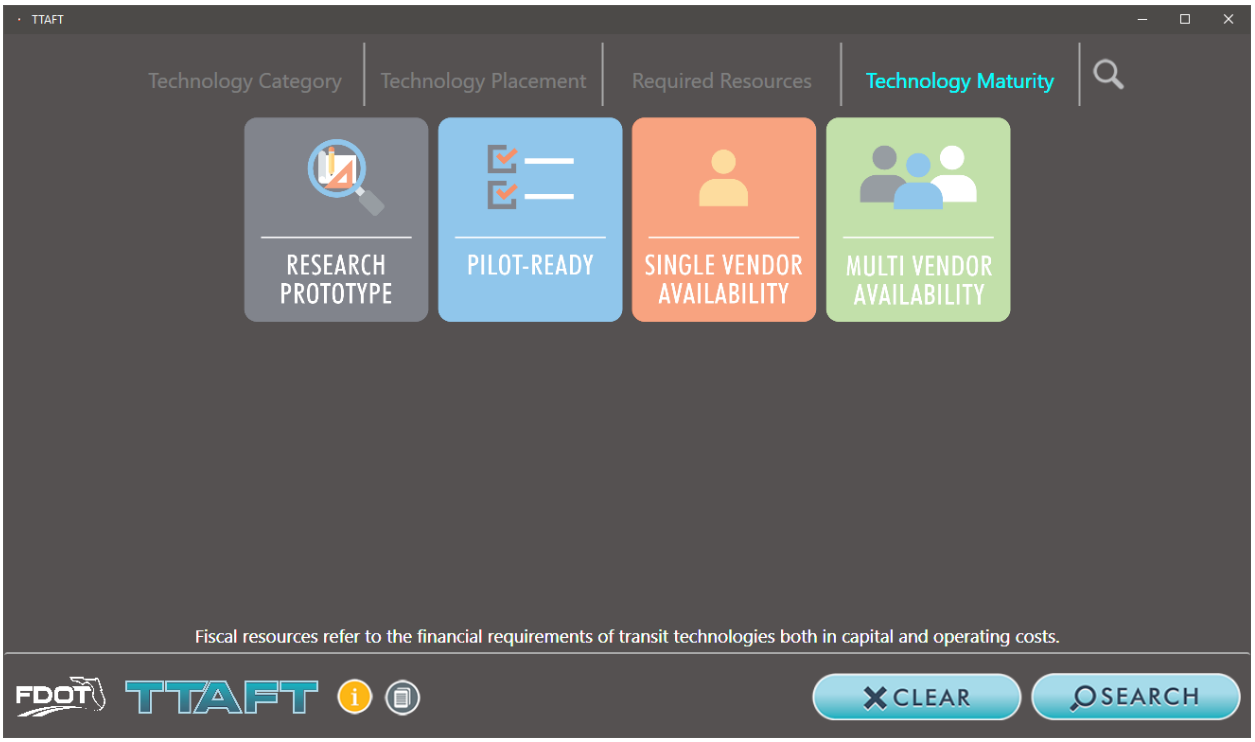
[106] https://nacto.org/publication/transit-street-design-guide/intersections/signals-operations/active-transit-signal-priority/

[107] https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

from concept to mainstream use. The TTAFT (**Figure 21**) identifies technology readiness levels as follows:

- Research prototype
- Pilot-ready
- Single vendor commercial availability
- Widely commercially available

Figure 21: TTAF Acceptable Technology Readiness Levels



Research Prototype

A research prototype is a model of a technology released to test an idea and learn from after iterative improvements. Research prototypes can be tested on closed systems. A prototype may have a promising solution to a problem, but may have bugs or defects to be worked out as well. A prototype may be tested in limited situations, but have minimal ability to scale or function in a real-world environment.

Pilot-Ready

A technology is pilot-ready when a research prototype has been sufficiently developed into a potentially viable product. For example, autonomous microshuttles are currently being piloted in a small number of real-world environments in 2018. Pilots often have limited capabilities and are expected to experience challenges as technology is tested and refined. An autonomous microshuttle today may be slow or have difficulty navigating all roadway situations, but it can successfully pick up/drop off customers and travel along the roadway without a driver, for instance. Given time, technology such as this will move beyond the pilot stage.

Single Vendor Commercial Availability

After a concept has begun as a research prototype and moved through pilot readiness, it starts to become commercially available. Transit agencies have procurement policies to allow for competition and open selection among many vendors, so early adoption of new technology could be difficult. Transit agencies may benefit from procurement processes that allow for purchase of new technology from a single vendor if only one vendor is available. At this stage of commercial availability, it is possible that new technology is costlier due to its newness and limited competition that would lower prices. Public/private partnerships could be beneficial at this stage. In this way, transit agencies could achieve low prices and low risk, while a vendor with a new technology can receive publicity for successful deployment.

Widely Commercially Available

As technology becomes proven and offers value to agencies, technology options often become abundant. At this phase, transit agencies can choose among multiple vendors, prices, and contract terms. For example, transit asset management programs are offered by a variety of vendors. Recent updates to federal law under the Fixing America's Surface Transportation Act require all recipients of federal funds to develop and submit a transit asset management plan. Technology exists to meet these requirements by serving as a clearing house and maintaining the asset inventory, documenting maintenance activities, and reporting the condition of the asset. Due to technological advancements over time, technology such as this is widely commercially available for transit agencies.

Required Foundational Elements

Transportation technologies often require basic levels of infrastructure and resources in order to ensure successful deployment. The TTAFT (**Figure 22**) identifies required foundational elements as follows:

- Communication systems
- Infrastructure systems
- Staff resources
- Fiscal resources

Figure 22: TTAFT Required Foundational Elements

Communication Systems

Technology deployment requires communication systems that are integrated and provide the foundational support for the technology. Communication systems are required for almost everything a transit agency does. Communication systems between buses, drivers, Transportation Management Center, and customers, for example, can include fiber-optic cables, radio, cellular technology, Wi-Fi, dedicated short-range communications, automatic vehicle location, and more. Communication systems are regularly getting faster and able to communicate more information, allowing transit agencies to achieve efficiencies and enhanced service.

Infrastructure Systems

Sufficient infrastructure is often necessary to successfully deploy technology. Infrastructure requirements can include power, access to traffic signal cabinets, and transit stop technology. Infrastructure systems are often closely interwoven with communications systems, and may include back-office servers, storage, switches, routers, and network appliances. Security for IT infrastructure needs to be accommodated as well, in addition to cloud resources that are increasingly essential elements of infrastructure systems. By understanding all components, an agency can guide an investment strategy that addresses current and upcoming needs.

Staff Resources

A transit agency must have sufficient staff resources to manage, procure, monitor, and update technology. Internal staff resources include an IT department that can work closely with operations, planning, finance, legal, and other departments to ensure integrated and seamless connections across the agency. If staff resources are not present or are not technically skilled, then it is possible for multiple agencies or governments to pool resources or outsource IT support.

While some new technologies require little technical skills and minimal oversight, such as a third-party trip planner, other technologies such as fare box upgrades require significant time and effort. Agencies should assess whether a high or low level of staff resources are needed to deploy a given technology.

Fiscal Resources

The financial requirements of transit technologies can vary significantly both in capital cost and operating costs. Fiscal resources include not just cash on hand; it also refers to the capability to receive grants from FTA or other sources. While grant funds are available to assist agencies with one-time capital costs, it is less likely that ongoing operational and maintenance costs will be covered. An agency needs to assess its finances in relation to its goals to decide whether new technologies are worth procuring in relation to the cost. Given the predominance of technology, certain efficiencies such as providing trip data to customers through smartphone apps can be a relatively low cost initiative. Other transit upgrades, such as switching to new fuel technology, can cost millions of dollars.

Output of Technology Options

The output in the process is for the framework to provide a list of suitable technologies along with a consistent set of comparison metrics for each of the potential technologies. Those metrics are:

- Benefits;
- Costs;
- Time-To-Implement;
- Market Availability;
- Prior Deployments;
- Data Collection Requirements; and
- Eligibility for Federal Funding.

Figure 23 shows the outputs from the TTAFT. **Table 16** provides a sample Literature Abstract where above metric are provided.

Figure 23: TTAFT Output of Technology Options

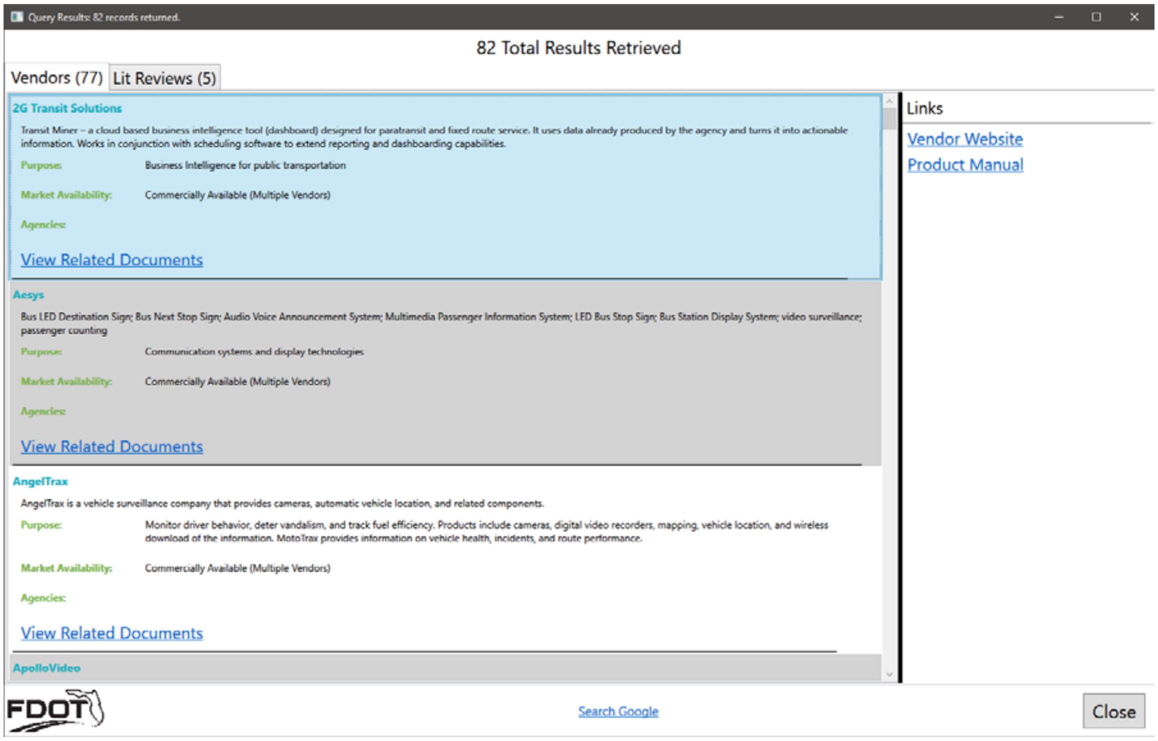


Table 16: Sample Technology Literature Review Abstract

Deployment Name	**Enhanced Transit Safety Retrofit Package (E-TRP) Bus Safety Platform**
Purpose for Deploying Technology (What Problem are they Trying to Solve?)	The Greater Cleveland Regional Transit Authority is working with the Battelle Memorial Institute to test technologies that can reduce pedestrian and vehicle collisions. Connected vehicle technology can prevent accidents caused at crosswalks and intersections when people are distracted by their phones.
Description of Technology Components (Summary of what was deployed)	The Enhanced Transit Safety Retrofit Package (E-TRP) uses vehicle-to-infrastructure (V2I) connected vehicle (CV) technology to prevent collisions with pedestrians who are in or near intersections or crosswalks. E-TRP also uses vehicle-to-vehicle (V2V) technology which will alert the bus when vehicles are anticipated to turn in front of it. The system will also improve the accuracy of bus location, storage capabilities, and it will allow remote system management. The ultimate objective is to determine if Dedicated Short Range Communications (DSRC) can be combined with on-board safety technologies to alert drivers of real-time potential safety hazards.

Deployment Name	Enhanced Transit Safety Retrofit Package (E-TRP) Bus Safety Platform
Technology Category	• **Safety** • Mobility • Accessibility • Environmental • Traveler Information • Operations • Fare Collection and Processing • Service Model
Types of Technology Components Involved	• **In/On-Vehicle** • Roadside/Infrastructure Based • Back-Office/TMC
Market Availability	• Research Prototype • **Pilot-Ready** • Commercially Available (Single Vendor) • Commercially Available (Multiple Vendors)
Required Foundational Elements	• **Communications Systems** • **Infrastructure Systems** • Staff Resources • Fiscal Resources
Types of Technology Components Involved	• Cellular Technology • 5G cellular • **Dedicated Short Range Communications (Connected Vehicle)** • Wi-Fi • Bluetooth • Radar • RFID • Ultrasonic Sensors • Farecard system • Mobile Payments • Autonomous Vehicle Systems • Alternative fuel systems • Wayfinding • Navigation • On-board traveler information system • Infrastructure traveler information system • Traffic signal priority/pre-emption • ADA Systems • CAD/AVL System

Deployment Name	Enhanced Transit Safety Retrofit Package (E-TRP) Bus Safety Platform
	OTHER ________________________________
Benefits of the Technology	This technology will reduce collisions with pedestrians and other vehicles along roadways.
Cost of the Technology	Total Cost including Installation $2,741,617 This grant was awarded February 2015 and will likely last through the end of 2017.
Time to Implement	N/A – no information found.
Data Collection Requirements (i.e., does the technology collect data – if so, how? Or does it require existing data as an input to function?)	Data was collected through the on-board Driver Acquisition System (DAS), surveys, and focus groups.
Eligibility for Federal Funding	This project was funded by FTA through a federal grant.
Describe any Issues Encountered	There was a high rate of false alerts for the Pedestrian in Signalized Crosswalk Warning (PCW) and the Vehicle Turning Right in Front of Bus Warning (VTRW) systems due to limitations within the GPS and pedestrian detector technologies. The Doppler microwave-based crosswalk detectors were insufficient for the PCW system because it could not distinguish between pedestrians and slow-moving vehicles within the crosswalks.
Proof of Success (i.e., what evidence or data was collected to demonstrate that they achieved their objective)	The TRP system was originally deployed in 2013 at the University of Michigan. The system was installed into 3 transit vehicles; data was collected and analyzed for a period of 8 months. Based on the study completed in Michigan, researchers found that the TRP system was effective at providing alerts to bus drivers and the DSRC system worked well.

Deployment Name	Enhanced Transit Safety Retrofit Package (E-TRP) Bus Safety Platform
Details of Deployment	
Agency	Battelle Memorial Institute
Geographic Location	Cleveland, OH
Transit Mode	• **Bus** • BRT and/or BRT Lite • Streetcar • Light Rail • Heavy Rail • Micro-transit
Year Technology First Deployed	Testing began in 2017.
Number of Transit Units Where the Technology was deployed (i.e., # of vehicles, # infrastructure sites, etc.)	91 RTA buses and 5-10 intersections will be used to test the connected vehicle technology.
Other Information	Funding was received to test two programs: The Enhanced Transit Safety Retrofit Package (E-TRP) and the Transit Bus Stop Pedestrian Warning (TSPW).
Sources(s) Reviewed (Citation)	Edwin Adilson Rodriguez, Avital Barnea, Office of Research Management, Innovation, and Outreach Federal Transit Administration, “FTA Annual Report on FY 2016 Public Transportation Innovation Research Projects (FTA Report No. 0102),” FEBRUARY 2017, https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/FY2106%20Section%205312%20Report.pdf Project #8: Connected Vehicle Infrastructure: Urban Bus Operational Safety Platform (Table 6, Row 8) The City of Columbus, “Beyond Traffic: The Smart City Challenge,” MAY 2016, https://www.columbus.gov/WorkArea/DownloadAsset.aspx?id=2147487896 RTA, “RTA to develop new vehicle safety technology with FTA grant,” OCTOBER 2016,

Deployment Name	Enhanced Transit Safety Retrofit Package (E-TRP) Bus Safety Platform
	http://www.riderta.com/news/rta-develop-new-vehicle-safety-technology-fta-grant Ginger Christ, "RTA bringing connected vehicle technology to its bus fleet," OCTOBER 2016, http://www.cleveland.com/metro/index.ssf/2016/10/rta_bringing_connected_vehicle.html USDOT, "Transit Safety Retrofit Package Development," JULY 2014, https://rosap.ntl.bts.gov/view/dot/3511

Benefits

Transit agencies aspire to serve the general public with transportation that is reliable, effective, on-time, safe, efficient, easy-to-use, and customer-friendly. To understand the potential benefits of technologies is to assess whether they improve on the transit agency's service. It is essential to acknowledge what technology can and cannot do for an agency. For example, technology can improve on-time performance monitoring, provide more cost-effective processes for staff, and help customers better understand their trip. However, technology alone cannot be a silver bullet to solve larger institutional or organizational issues. The ideal technology deployment is one that achieves measurable benefits and fits within the context of the larger goals of the agency. The TTAF provides an overview of benefits of potential technologies as an output.

Costs

Capital costs, operating costs, and ongoing maintenance costs must be considered when assessing new technology. Some improvements cost relatively nothing to either the transit agency or to the customer. However, other technologies require massive expenditures over multiple years. For example, there are clear benefits by moving away from a diesel powered vehicle in terms of lower costs and emissions. The challenge with implementing alternative fuel is up-front capital costs associated with building the new infrastructure and transitioning of vehicles to those that are more expensive than a diesel powered bus. It may take many years of using the alternative fuels before the investment is recouped through lower operation costs. Issues such as these should be assessed prior to pursuing new technologies. The TTAF provides an overview of costs of potential technologies as an output.

Time-To-Implement

Barriers to implementation can vary. In some cases, such as traveler information, the rapid adoption of smartphones and seamless integration of information allows agencies to deploy new tools with ease. One of the greatest technological advances in the way that traveler information systems are evolving is through the use of personal smartphones. Many transit agencies are providing real-time transportation data through mobile services, such as mobile websites and applications managed by the agency. These services also allow agencies to communicate to riders more efficiently, such as providing updates and alerts to customers regarding operations so riders are able to plan their trip in advance. Simple technology upgrades for issues such as these can be adopted in a short time frame. The TTAFT provides an overview of time-to-implement of potential technologies as an output.

Market Availability

Technology deployment becomes mainstream after initial pilot demonstrations, successful utilization by early adopters, and, if applicable, when the regulatory environment favors market penetration. Early market availability might be predominantly overseas in other countries, for example, which can be challenging for local procurement processes. Market availability can also influence transit agency confidence in a vendor. When limited vendors exist for new products, it can be difficult to ascertain whether the transit agency will be taking on more risk than it would like. If all things are equal, it is generally preferable for an agency to procure a technology product after multiple bids from a variety of vendors. The TTAF provides an overview of market availability of potential technologies as an output.

Prior Deployments

Transit agencies often want to know that new technology has been tested and has provided benefits during real-world operations. One output from the tool is a listing of agencies that have deployed the technology so an interested agency can contact others to learn more. For example, there are many projects that have been implemented through transit agencies to enhance safety features in their systems, including Driver Assist Systems (DAS), Vehicle Assist and Automation (VAA), and Platform Track Intrusion Detection Systems (PTIDS). Many of these systems are using the enhancements of radar, global positioning systems (GPS), light detection and ranging (LiDAR), vehicle sensors, and cellular technologies to improve transit performance and vehicle safety. As these technologies become more widespread, opportunities to learn from prior deployments become more abundant as the industry reshapes transit safety. The TTAF provides an overview of prior deployments of potential technologies as an output.

Data Collection Requirements

Data collection, analysis, and integration into transit procedures can provide meaningful efficiencies to an agency. On the other hand, when systems are implemented and operated separately in silos, the full potential of benefits is not realized. Transit agencies can pay for costly technology but not be able to sufficiently process the data collected. The TTAF provides an overview of data collection requirements of potential technologies as an output.

Eligibility for Federal Funding

Many transit agencies simply cannot afford to implement new technologies without support from federal funding. The framework tool provides information on federal funding available and through which programs. Based on inputs into the framework tool, outputs identify federal funding opportunities and parameters for an agency to apply. Some federal funding programs are specified for agencies of a certain size or that serve a certain population in need. By utilizing federal funding and federal funding programs, transit agencies can enhance their services to their communities. The TTAF provides an overview of federal funding eligibility of potential technologies as an output.

Vendor Abstract

Vendor abstract forms do not contain these metrics. Rather they provide information on other agencies that have used the selected vendor, the vendor's website, and brochures or other marketing information.

Technology Assessment Framework Summary

In order to establish a framework for presenting information to stakeholders, this section has provided an overview of technology assessment methodologies. The TTAFT is a blueprint and structured process for identifying and systematically evaluating transit technologies and systems by agency staff. For this primer, a customized TAF and process has been developed to serve as a guide for agency staff in identifying and evaluating technologies.

The developed TTAFT consists of a series of options that agency staff can engage to identify a select number of transit technologies for comparison. The process begins with the identification of a specific opportunity or issue that the transit agency wishes to address. It proceeds through a series of steps designed to narrow the potential list of technologies as a function of the type-of-technology, the acceptable readiness level of the technology to the agency, and the availability of required functional elements needed to implement the technology.

The output in the process is for the framework to provide a list of suitable technologies that fit the criteria identified in the previous steps along with a standardized and consistent set of comparison metrics for each of the potential technologies. This framework allows transit agencies to become informed of transit technologies and their potential to improve the lives of people in their communities.

CONCLUSION

Conclusion

The Transit Technology Primer is comprised of a series of technical memorandums that provide background research, stakeholder outreach, and a technology assessment framework, as well as an innovative tool to communicate the information gathered and analyzed during this project. It is the goal of this work to demystify the established, new, and emerging technology to available transit agencies. The goal is accomplished through summarizing the current transit technology landscape, highlighting new and emerging technology trends, and providing tools for transit agencies to conduct further research.

Policymakers at Federal, State and Local levels have struggled to keep pace with emerging technology with states having a little more success by enacting a patchwork of legislation to bridge the gap in the meantime. Here are the five key considerations that are important for FDOT to consider as it seeks to assist Florida transit agencies deploying new technologies in their systems:

- Revisions to Federal Motor Vehicle Safety Standards are required to ensure the nascent AV industry grows with consistent safety requirements. Exemptions to certain requirements should also be allowed to ensure that microtransit vehicles may enter pilot or permanent deployments within local jurisdictions;
- Despite a large body of Federal research and standards on connected vehicle technology, uncertainty still remains about the pending V2V communication requirements on new vehicles which affects the future adoption rates and the corresponding benefits to transit agencies;
- Both traditional ITS and emerging AV/CV applications provide an unprecedented means of real-time monitoring of individual and vehicular movements. While there are some privacy protections exist at the Federal level, states may be pressured to pass more regulations in response to citizen concerns, and should be proactive about these conversations;
- Transportation technology provides many opportunities to meet the needs of travelers with disabilities while addressing different provisions of ADA. Some of these technologies, however, remain in research and development stages, or are not yet cost-effective at the scale and may not be ready for small to medium transit agencies to pursue; and
- Florida is in the unique position of regulating TNCs at the statewide level. As transit agencies enter the market to integrate these companies to provide first and last mile service, state regulators should ensure that TNC policy remains flexible enough to account for the needs of the local agencies while remaining consistent to meet Federal requirements, such as ADA.

As demonstrated in this report, there are many challenges and benefits associated with the technologies and related projects. Many of the challenges, in general, associated with implementing these technologies are caused by a lack of resources, technological limitations, cost of integrations, concerns regarding cyber security and data management, or a lack of communication and data sharing amongst organizations. However, there are also many benefits with investing in transit technology, such as increasing safety along roadways, providing greater mobility for individuals with disabilities across communities, and making transit systems more efficient through coordination and data sharing. In many cases, transit agencies build upon the available research through supporting prototypes and pilot projects to address use cases that are not yet addressed by commercially available products and to advance the state of practice.

The survey of agencies showed overall support for deploying transit technology within their transit systems. Respondents agree technology improves system performance, provides information to help make decisions, and removes obstacles to customers using the system. However, pursuing new hardware and software is expensive and many transit agencies have not planned or set aside the appropriate funds or staff time.

Regardless of where they are in the process of implementing new technology, some agencies summarized their experience with new technology and provided lessons learned. The lessons are:

- Plan ahead;
- Set aside extra resources;
- Go slow; and
- Learn from others.

As for technology vendors, they also showed through case studies that through the use of transit technology transit agencies experienced:

- Increased ridership;
- Decrease operating costs; and
- More efficient operations and processes.

These findings illustrate the value of transit technology and how it can help agencies do more with available resources. For agencies to benefit from technology, assistance is needed in navigating the process, identify funding opportunities, and summarizing the benefits of these products for decision-makers. The TTAFT that accompanies this report helps to provide this additional assistance.

The TTAFT provides structured process for identifying and systematically evaluating transit technologies and systems by agency staff. The TTAFT consists of a series of options that agency staff can engage to identify a select number of transit technologies for comparison. The process begins with the identification of a specific opportunity or issue the transit agency wishes to address. It proceeds through a series of steps designed to narrow the potential list of technologies as a function of the type-of-technology, the acceptable readiness level of the technology to the agency, and the availability of required functional elements needed to implement the technology. The output in the process is a list of suitable technologies that fit the criteria identified in the previous steps along with a standardized and consistent set of comparison metrics for each of the potential technologies. The TTAFT allows transit agencies to become informed of transit technologies and their potential to improve the lives of people in their communities.

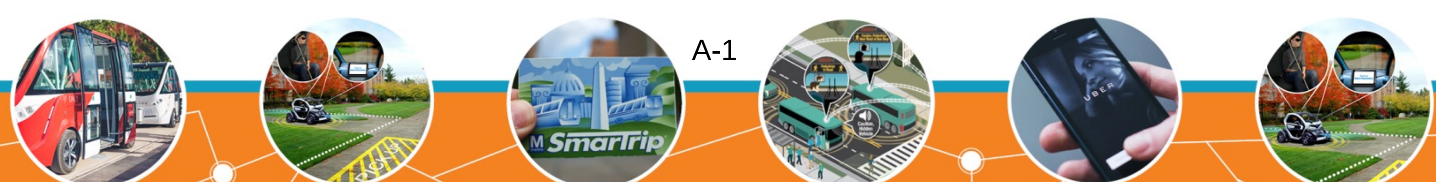
APPENDICES

Appendix A – Stakeholder Responses to Initial Survey

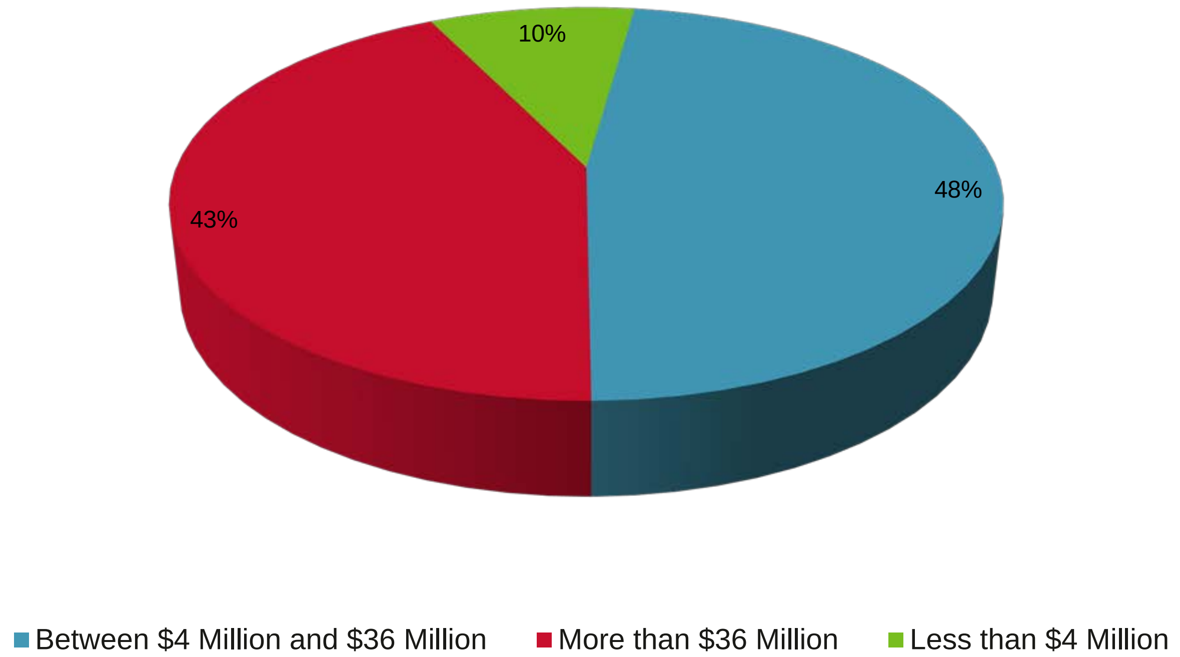
1. What is the operating budget for your transit agency?

- Less than $4 Million
- Between $4 Million and $36 Million
- More than $36 Million

Agency	Budget
Bay Town Trolley	Between $4 Million and $36 Million
Broward County Transit	More than $36 Million
Charlotte County	Less than $4 million
Collier County	Between $4 Million and $36 Million
HART	More than $36 Million
JTA	More than $36 million
Lake County	Less than $4 million
LeeTran	Between $4 Million and $36 Million
Lynx	More than $36 Million
Manatee Transit	Between $4 Million and $36 Million
MTA Maryland	More than $36 million
Pasco County Public Transportation	Between $4 Million and $36 Million
RTD Denver	More than $36 million
SCAT	Between $4 Million and $36 Million
SEPTA (Philadelphia, PA)	More than $36 Million
SFRTA	More than $36 Million
Space Coast	Between $4 Million and $36 Million
StarMetro	Between $4 Million and $36 Million
TheComet	Between $4 Million and $36 Million
UTA (Salt Lake City)	More than $36 Million
VoTran	Between $4 Million and $36 Million



Transit Agency Total Budget

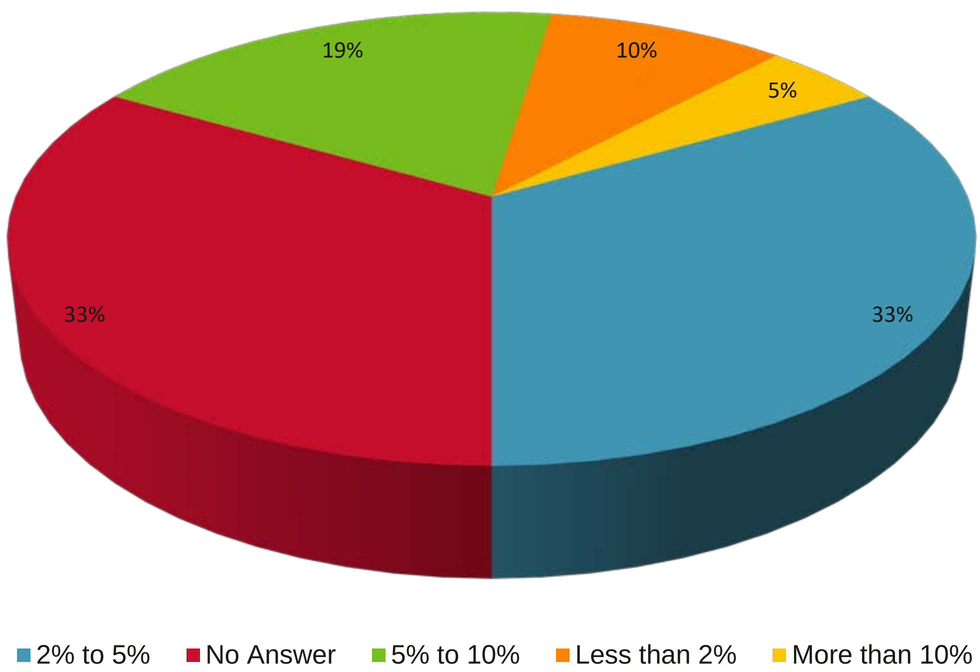


2. What percent of your budget is set aside for maintaining current technology and pursuing new opportunities?

- 0%
- Less than 2%
- 2% to 5%
- 5% to 10%
- More than 10%

Agency	Amount Dedicated
Bay Town Trolley	2% to 5%
Broward County Transit	5% to 10%
Charlotte County	More than 10%
Collier County	2% to 5%
HART	No answer
JTA	2% to 5%
Lake County	5% to 10%
LeeTran	No answer
Lynx	5% to 10%
Manatee Transit	2% to 5%
MTA Maryland	No answer
Pasco County Public Transportation	2% to 5%
RTD Denver	No answer
SCAT	2% to 5%
SEPTA (Philadelphia, PA)	No answer
SFRTA	No answer
Space Coast	Less than 2%
StarMetro	Less than 2%
TheComet	No answer
UTA (Salt Lake City)	2% to 5%
VoTran	5% to 10%

Percent of Budget Dedicated to Technology

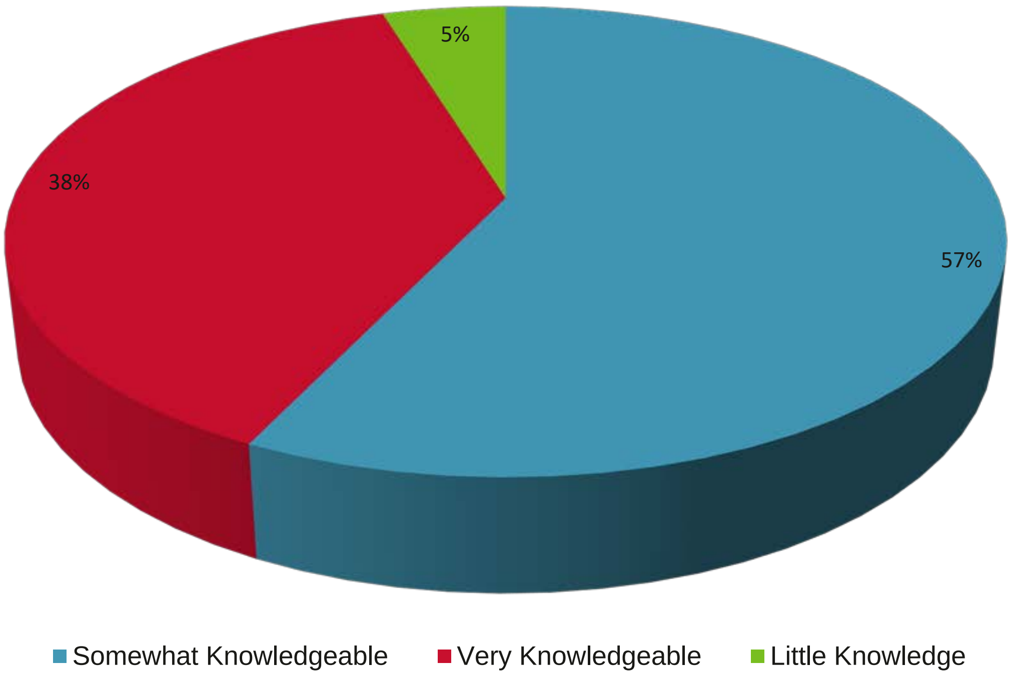


3. How knowledgeable do you consider your agency regarding the policies and regulations associated with implementing transit technology?

- Very Knowledgeable of transit technology policies and regulations
- Somewhat Knowledgeable of transit technology policies and regulations
- Little knowledge of the policies and regulations
- Not at all knowledgeable

Agency	Knowledge Level
Bay Town Trolley	Somewhat
Broward County Transit	Somewhat
Charlotte County	Somewhat
Collier County	Very
HART	Very
JTA	Very
Lake County	Somewhat
LeeTran	Very
Lynx	Very
Manatee Transit	Somewhat
MTA Maryland	Somewhat
Pasco County Public Transportation	Somewhat
RTD Denver	Very
SCAT	Somewhat
SEPTA (Philadelphia, PA)	Somewhat
SFRTA	Somewhat
Space Coast	Somewhat
StarMetro	Little
TheComet	Very
UTA (Salt Lake City)	Very
VoTran	Somewhat

Knowledge of Technology Regulations



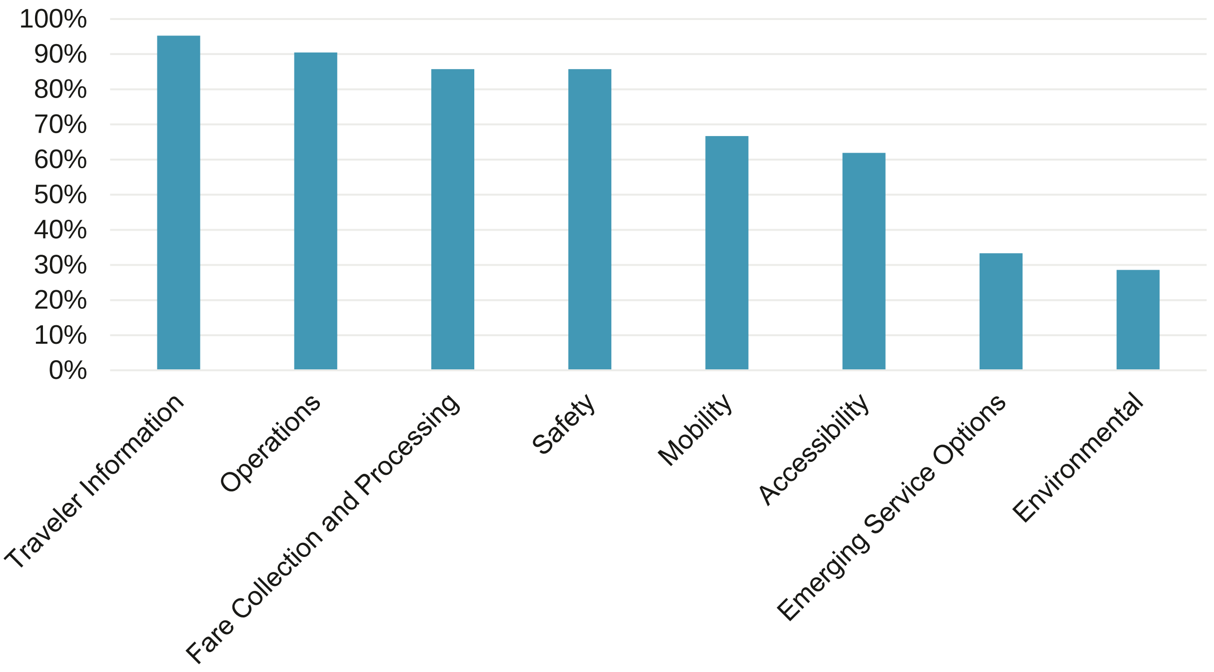
4. What areas are you using technology to improve your system's performance? Check all that apply.

- [ ] Safety
- [ ] Mobility
- [ ] Accessibility
- [ ] Environmental
- [ ] Fare Collection and Processing
- [ ] Traveler Information
- [ ] Operations
- [ ] Emerging Service Options such as autonomous vehicles, partnering with Transportation Network Companies (Lyft/Uber), etc.
- [ ] None of These
- [ ] Other (please specify)

Agency	Safety	Mobility	Accessibility	Environmental	Fare	Traveler	Ops	Emerging	None	Other
Bay Town Trolley	X	X	X		X	X	X			
Broward County Transit	X	X	X		X	X	X			SaaS*
Charlotte County	X	X	X			X				Cust. Svc**
Collier County		X			X	X	X			
HART	X	X	X	X	X	X	X	X		
JTA	X	X	X	X	X	X	X	X		Cybersecurity***
Lake County						X	X	X		
LeeTran	X		X	X	X	X	X			
Lynx	X	X			X		X	X		
Manatee Transit	X	X	X		X	X	X			
MTA Maryland	X	X	X	X	X	X	X	X		
Pasco County Public Transportation	X	X	X			X	X			
RTD Denver	X	X	X	X	X	X	X			
SCAT	X				X	X	X			
SEPTA (Philadelphia, PA)	X				X	X	X			
SFRTA	X	X	X		X	X	X			
Space Coast					X	X				
StarMetro	X				X	X	X	X		
TheComet	X				X	X	X			Passenger Counting****
UTA (Salt Lake City)	X	X	X	X	X	X	X	X		Reliability*****
VoTran	X	X	X		X	X	X			

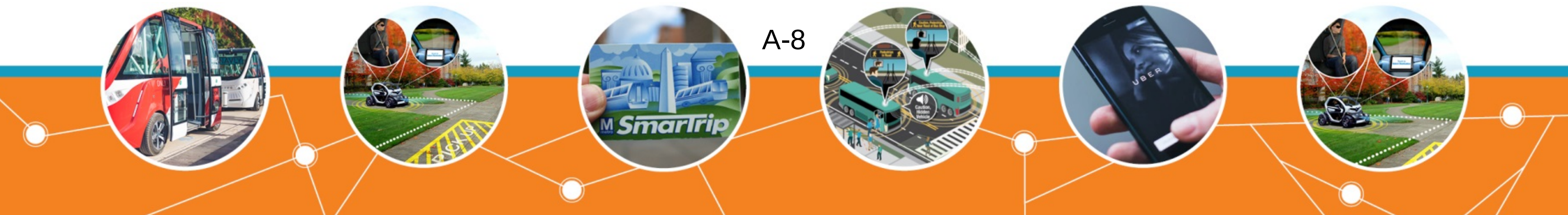
*Reclassified to mobility; ** Reclassified to traveler information; *** Reclassified to security; **** Reclassified to OPS; ***** Reclassified to Accessibility.

Technology Areas Employed by Agency



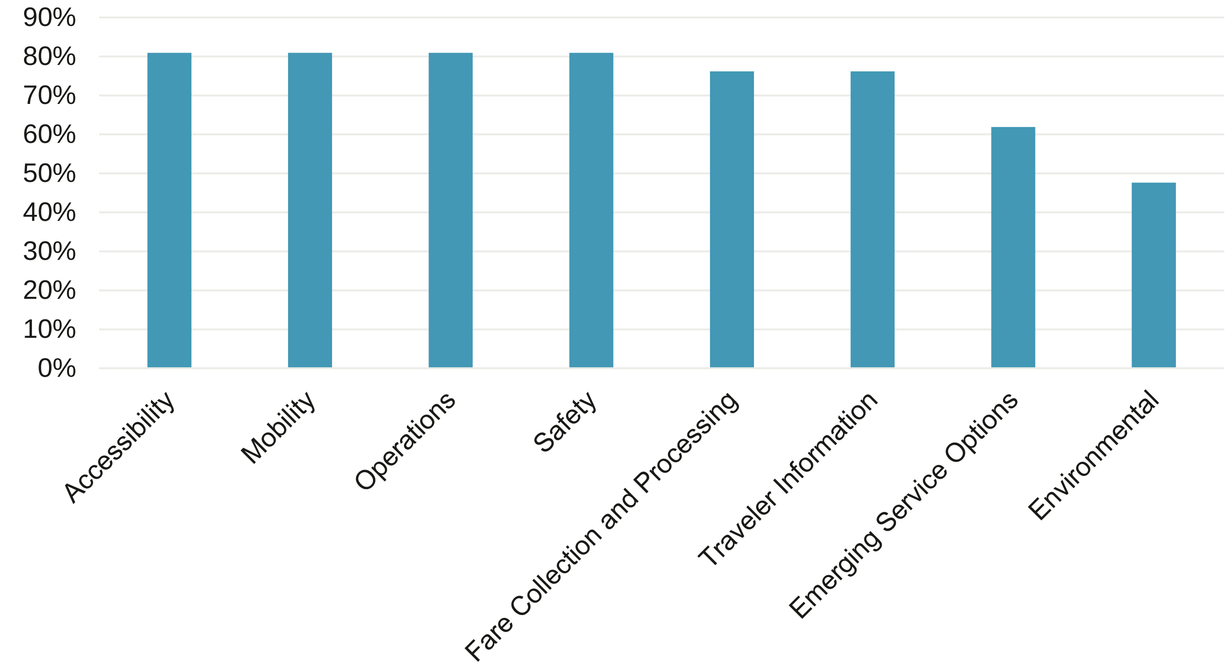
5. For which of the following use cases do you envision your agency using technology to improve your system's performance in the next five years? Check all that apply.

- ☐ Safety
- ☐ Mobility
- ☐ Accessibility
- ☐ Environmental
- ☐ Fare Collection and Processing
- ☐ Traveler Information
- ☐ Operations
- ☐ Emerging Service Options such as autonomous vehicles, partnering with Transportation Network Companies (Lyft/Uber), etc.
- ☐ None of These
- ☐ Other (please specify)



Agency	Safety	Mobility	Accessibility	Environmental	Fare	Traveler	Ops	Emerging	None	Other
Bay Town Trolley	X	X	X		X	X	X			
Broward County Transit	X	X	X	X	X	X	X			
Charlotte County		X	X			X	X			
Collier County	X	X	X		X	X	X	X		
HART	X	X	X	X	X	X	X	X		
JTA	X	X	X	X	X	X	X	X		
Lake County	X	X			X					
LeeTran	X	X	X	X	X	X	X	X		
Lynx	X	X	X		X	X	X	X		
Manatee Transit	X	X	X		X	X	X			
MTA Maryland	X	X	X	X	X	X	X	X		
Pasco County Public Transportation				X				X		
RTD Denver	X	X	X	X	X	X	X			
SCAT	X		X		X	X	X	X		
SEPTA (Philadelphia, PA)	X	X	X	X	X	X	X	X		
SFRTA	X	X	X	X	X	X	X	X		
Space Coast	X	X	X		X	X	X	X		
StarMetro	X	X	X							
TheComet							X			
UTA (Salt Lake City)	X	X	X	X	X	X	X	X		
VoTran								X		

Technology Areas Being Pursued by Transit Agencies



6. Which of the following types of transit technologies do you currently use? Check all that apply.

- ☐ Automatic Vehicle Location
- ☐ Online Trip Planner
- ☐ Online Credit Card Fare Purchase
- ☐ Automatic Passenger Counters
- ☐ Computer Aided Dispatch
- ☐ Security Cameras/System
- ☐ Asset Management
- ☐ None of these
- ☐ Other (please specify)

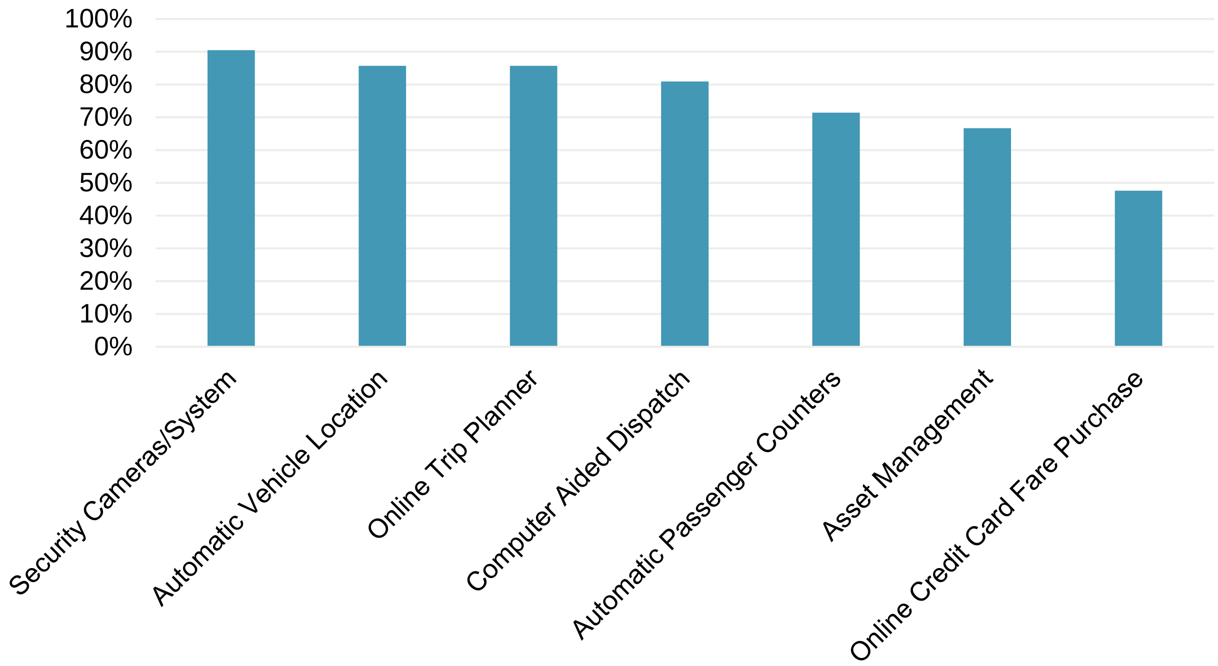
Agency	AVL	Online Trip Planner	Online Credit Card	APC	CAD	Security	Asset	None	Other
Bay Town Trolley	X	X			X	X	X		
Broward County Transit	X	X		X	X	X	X		
Charlotte County	X		X			X	X		
Collier County	X			X	X	X	X		
HART	X	X	X	X	X	X			
JTA	X	X	X	X	X	X	X		TSP*
Lake County	X	X		X	X	X			
LeeTran	X	X	X	X	X	X			
Lynx	X	X		X	X	X	X		Realtime Scheduling*
Manatee Transit		X		X	X	X	X		
MTA Maryland	X	X	X	X	X	X	X		
Pasco County Public Transportation	X			X					
RTD Denver	X	X	X	X	X	X	X		
SCAT	X	X		X		X			
SEPTA (Philadelphia, PA)	X	X	X	X	X	X	X		
SFRTA	X	X			X	X	X		
Space Coast		X							
StarMetro		X			X	X	X		
TheComet	X	X	X		X	X			Camera w/ WiFi**
UTA (Salt Lake City)	X	X	X	X	X	X	X		
VoTran	X	X	X	X	X	X	X		

*Reclassified to CAD; **Reclassified to Security





Technology Currently Used by Transit Agencies



7. Which of the following types of emerging technologies do you envision your agency deploying in the next five years? Check all that apply.

☐ Cellular Technology

☐ 5G Cellular

☐ Dedicated Short Range Communication (Connected Vehicles)

☐ Wi-Fi

☐ Bluetooth

☐ Radar

☐ RFID

☐ Ultrasonic Sensors

☐ Farecard systems

☐ Mobile Payments

☐ Autonomous Vehicle Systems

☐ Wayfinding

☐ Navigation

☐ On-Board Traveler Information Systems

☐ Infrastructure traveler information systems

☐ Traffic signal priority/preemption

☐ ADA Systems

☐ CAD/AVL Systems

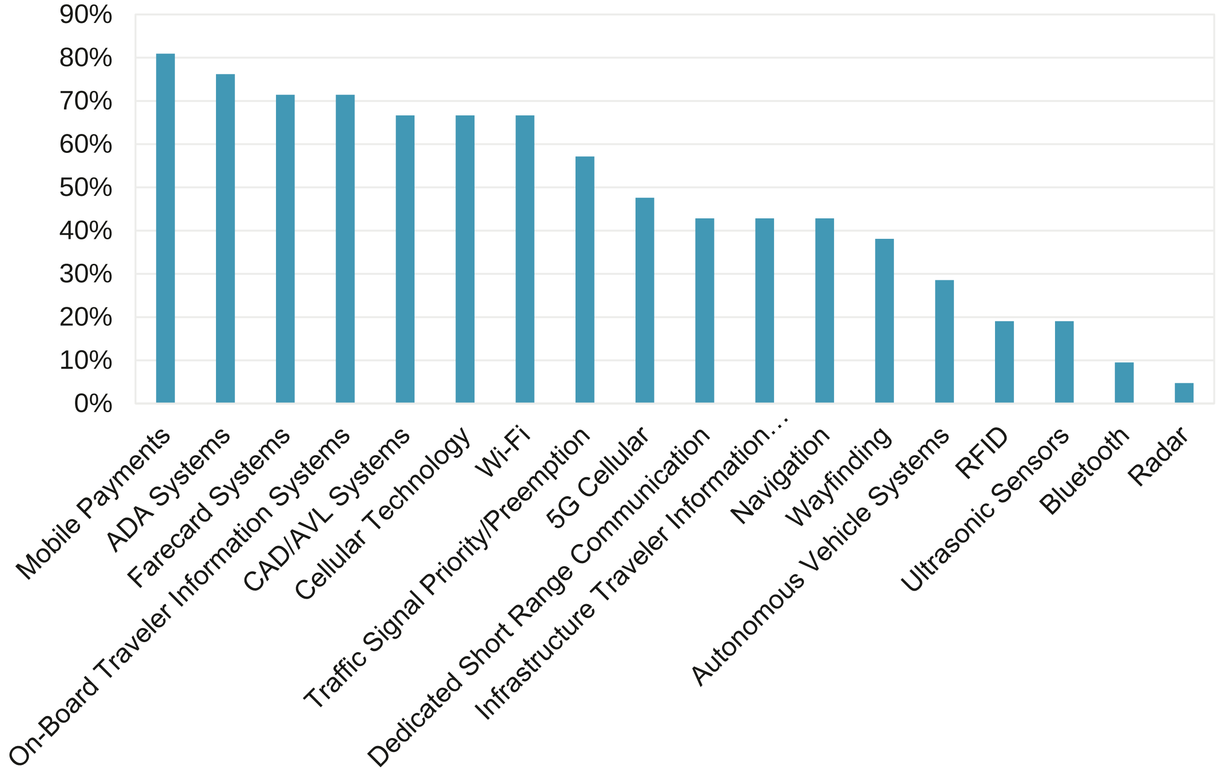
☐ None of These

☐ Other (please specify)

Agency	Cell	5G	DSRC	WiFi	Blue	Radar	RFID	Ultrasonic	Fare	Mobile	AV	Wayfinding	Nav	Traveler	Infra	TSP	ADA	CAD	Other
Bay Town Trolley*				X				X		X							X		X
Broward County Transit**	X	X	X	X	X				X	X		X	X	X	X	X	X	X	X
Charlotte County	X	X		X									X				X	X	
Collier County	X			X				X	X	X	X			X		X	X	X	
HART		X	X						X	X	X								
JTA	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	
Lake County														X	X		X	X	
LeeTran		X							X	X						X	X		
Lynx	X	X	X	X					X	X	X			X	X	X	X	X	
Manatee Transit	X			X						X		X	X	X	X		X	X	
MTA Maryland	X		X				X	X	X	X	X	X	X	X	X	X	X	X	
Pasco County Public Transportation		X							X	X				X					
RTD Denver	X			X					X	X				X		X	X	X	
SCAT	X			X					X	X					X		X	X	
SEPTA (Philadelphia, PA)	X			X					X	X		X	X	X		X	X	X	
SFRTA***	X		x						X	X		X	X	X					X
Space Coast		X		X			X							X	X		X	X	
StarMetro	X	X	X	X					X	X		X	X	X	X	X	X	X	
TheComet							X		X							X			
UTA (Salt Lake City)	X	X	X	X	X		X		X	X	X	X	X	X		X	X	X	
VoTran	X		X	X						X				X		X			

*Other – APC (Reclassified as Ultrasonic Sensors); **Other – Ultra wideband for yard management system (Reclassified as DSRC); ***Other – Positive Train Control (Reclassified as DSRC)

Emerging Technologies Being Pursued

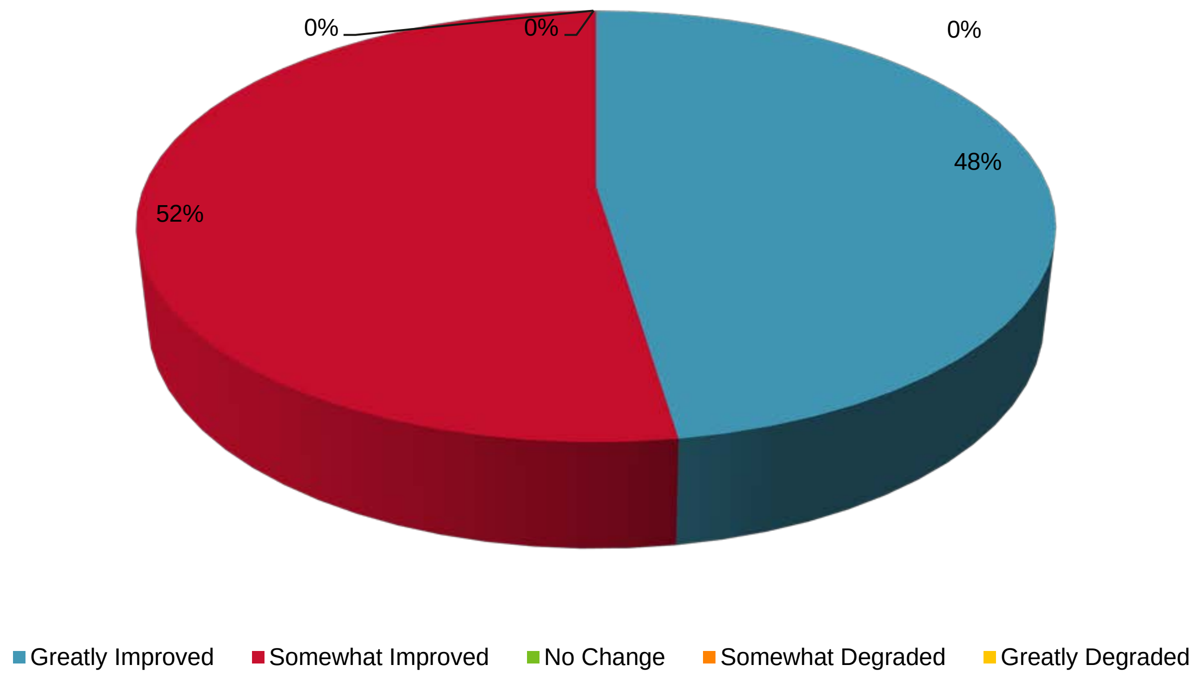


8. Based on your experience, how has using transit technology impacted agency operations?

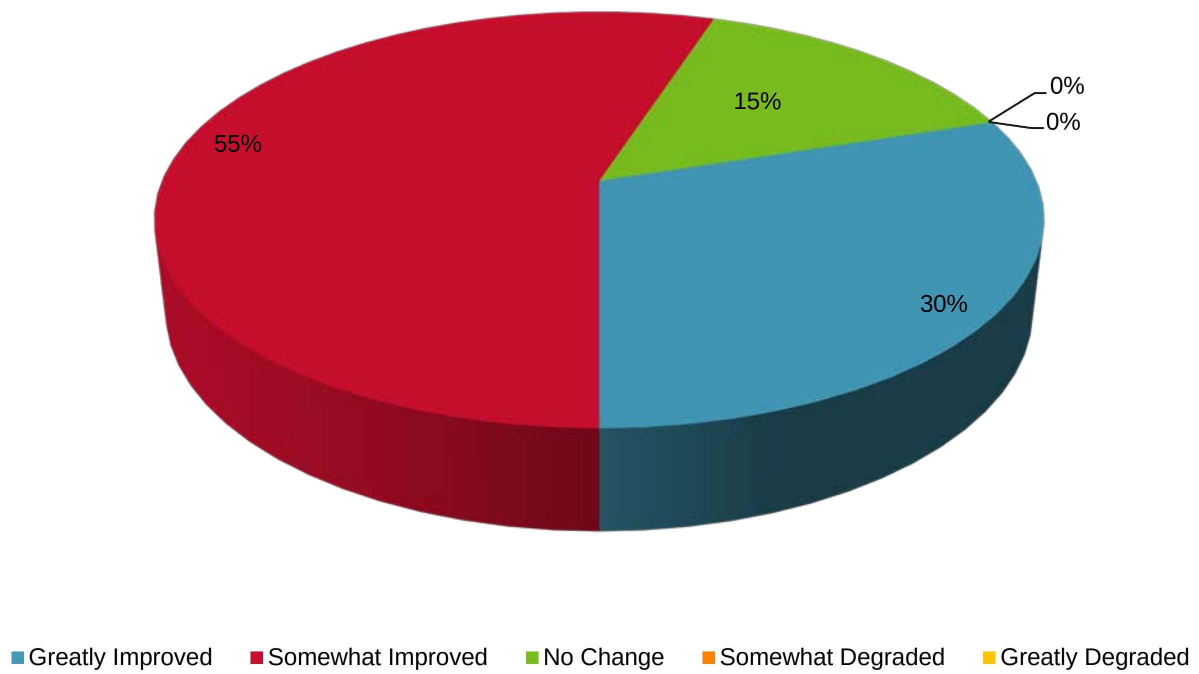
	Greatly Improved	Somewhat improved	No Change	Somewhat degraded	Greatly degraded
Customer Service	☐ Greatly Improved	☐ Somewhat improved	☐ No Change	☐ Somewhat degraded	☐ Greatly degraded
On Time Performance	☐ Greatly Improved	☐ Somewhat improved	☐ No Change	☐ Somewhat degraded	☐ Greatly degraded
Operating Costs	☐ Greatly Improved	☐ Somewhat improved	☐ No Change	☐ Somewhat degraded	☐ Greatly degraded
System Reporting	☐ Greatly Improved	☐ Somewhat improved	☐ No Change	☐ Somewhat degraded	☐ Greatly degraded
Decision Making by Stakeholders	☐ Greatly Improved	☐ Somewhat improved	☐ No Change	☐ Somewhat degraded	☐ Greatly degraded
Staff time to prepare analysis/reports	☐ Greatly Improved	☐ Somewhat improved	☐ No Change	☐ Somewhat degraded	☐ Greatly degraded
Compliance with FTA/State Regulations	☐ Greatly Improved	☐ Somewhat improved	☐ No Change	☐ Somewhat degraded	☐ Greatly degraded
Record keeping and/or Asset Management	☐ Greatly Improved	☐ Somewhat improved	☐ No Change	☐ Somewhat degraded	☐ Greatly degraded
Cash handling and reconciling accounts	☐ Greatly Improved	☐ Somewhat improved	☐ No Change	☐ Somewhat degraded	☐ Greatly degraded
Ability to attract new customers	☐ Greatly Improved	☐ Somewhat improved	☐ No Change	☐ Somewhat degraded	☐ Greatly degraded

Agency	Cust Svc	OTP	Ops	Sys	Decision	Staff	Comply	Record	Cash	Attract
Bay Town Trolley	1	1	2	1	1	1	1	1	2	2
Broward County Transit	1	2	2	2	2	1	2	2	2	3
Charlotte County	2	2		2	2	2	1	1	3	2
Collier County	1	3	2	1	2	1	2	2	1	3
HART	1	1	1	2	1	1	1	2	3	2
JTA	1	2	2	1	1	2	2	1	1	2
Lake County	2	2	2	2	3	1	1	1	2	2
LeeTran	1	2	4	2	1	2	2	2	3	2
Lynx	2	2	3	1	2	2	3	2	2	2
Manatee Transit	2	1	3	1	1	2	2	2	3	3
MTA Maryland	1	1	2	1	1	2	2	2	2	2
Pasco County Public Transportation	2	2	4	2	3	3	3	3	4	4
RTD Denver	2	2	2	2	2	2	2	2	2	2
SCAT	1	2	1	2	2	4	1	1	1	5
SEPTA (Philadelphia, PA)	2	2	2	2	2	2	2	2	1	2
SFRTA	1	2	2	2	2	1	1	2	3	2
Space Coast	1	1	2	1	1	1	2	1	3	1
StarMetro	2	3	3	2	3	3	3	2	3	3
TheComet	2	3	3	3	2	2	3	3	4	3
UTA (Salt Lake City)	2	1	2	1	2	2	2	1	3	3
VoTran	2									

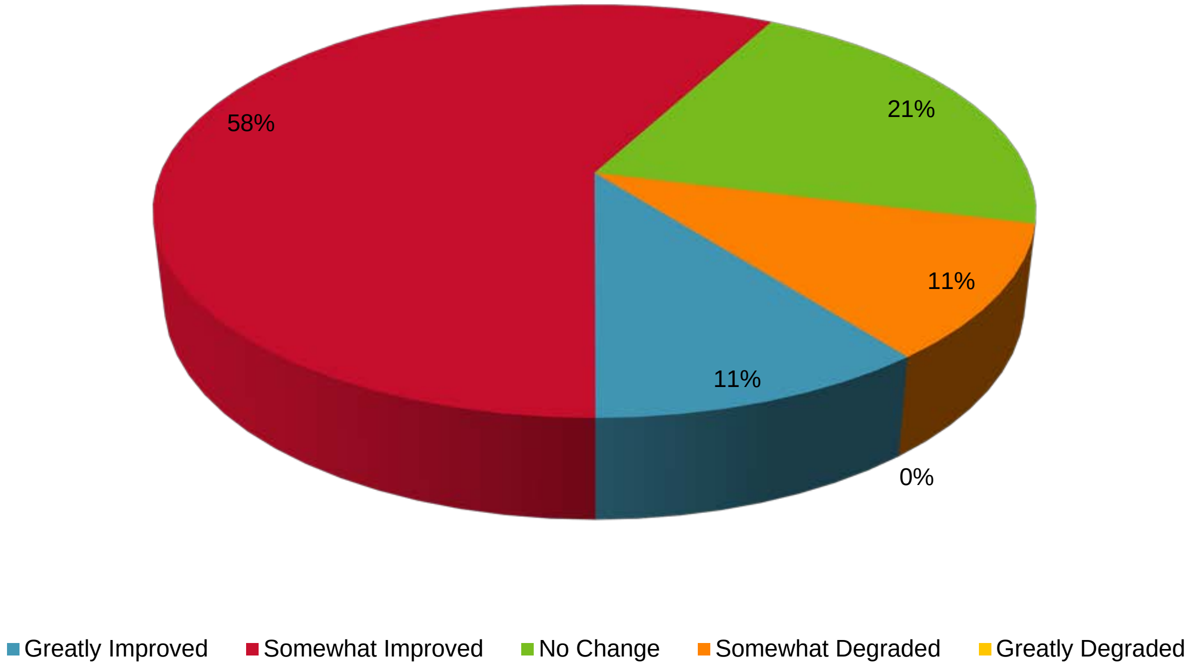
Technology Impact on Customer Service



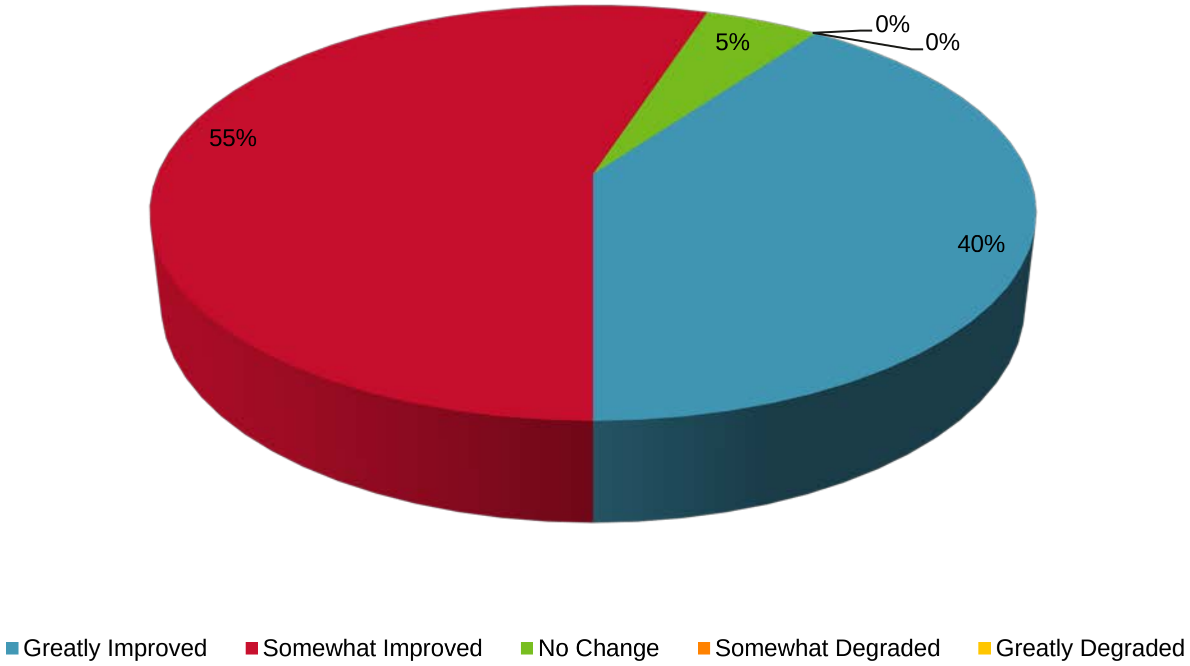
Technology Impact on On-Time Performance



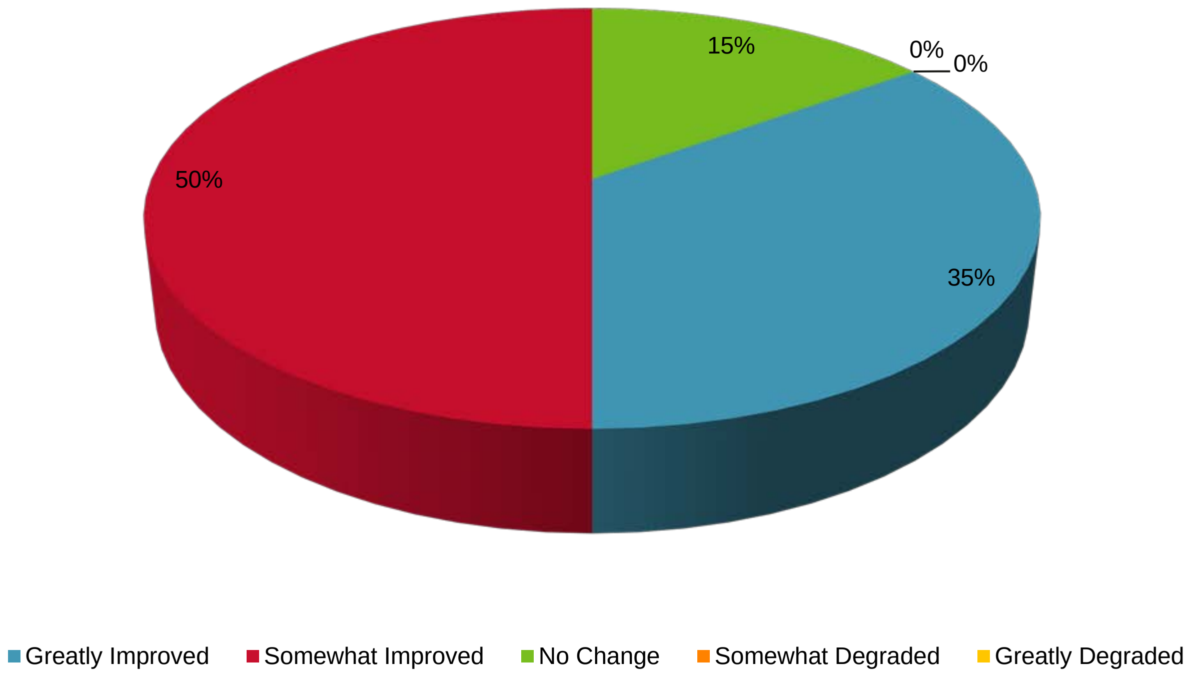
Technology Impact on Operating Costs



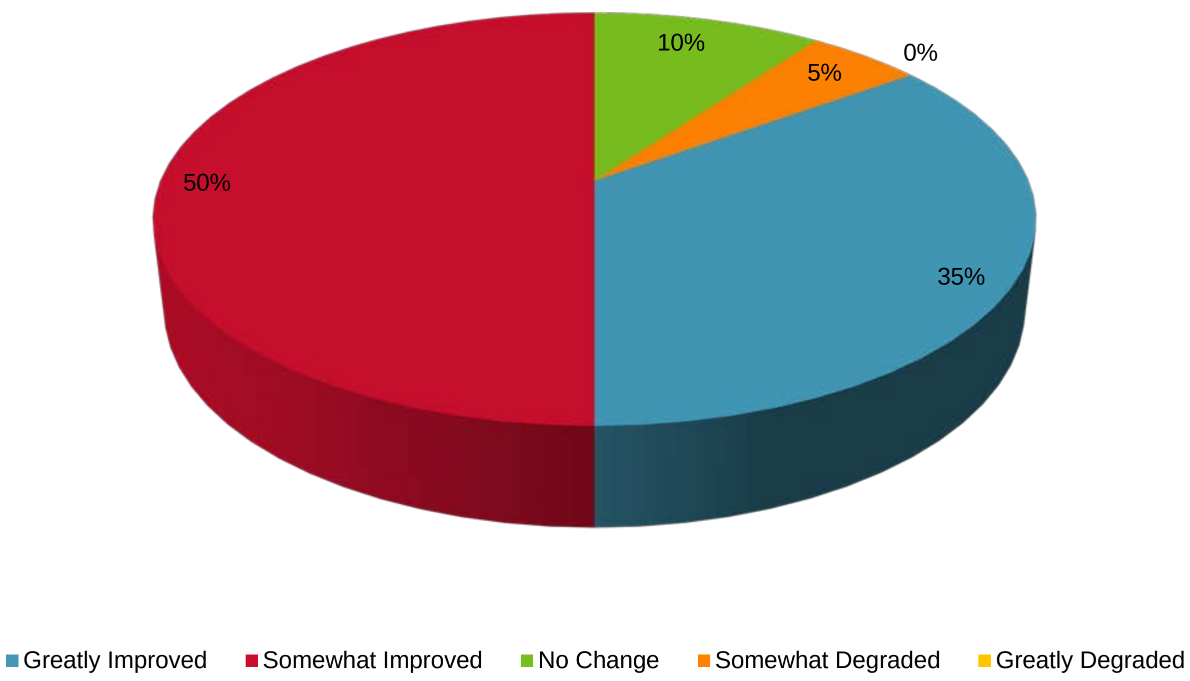
Technology Impact on System Reporting



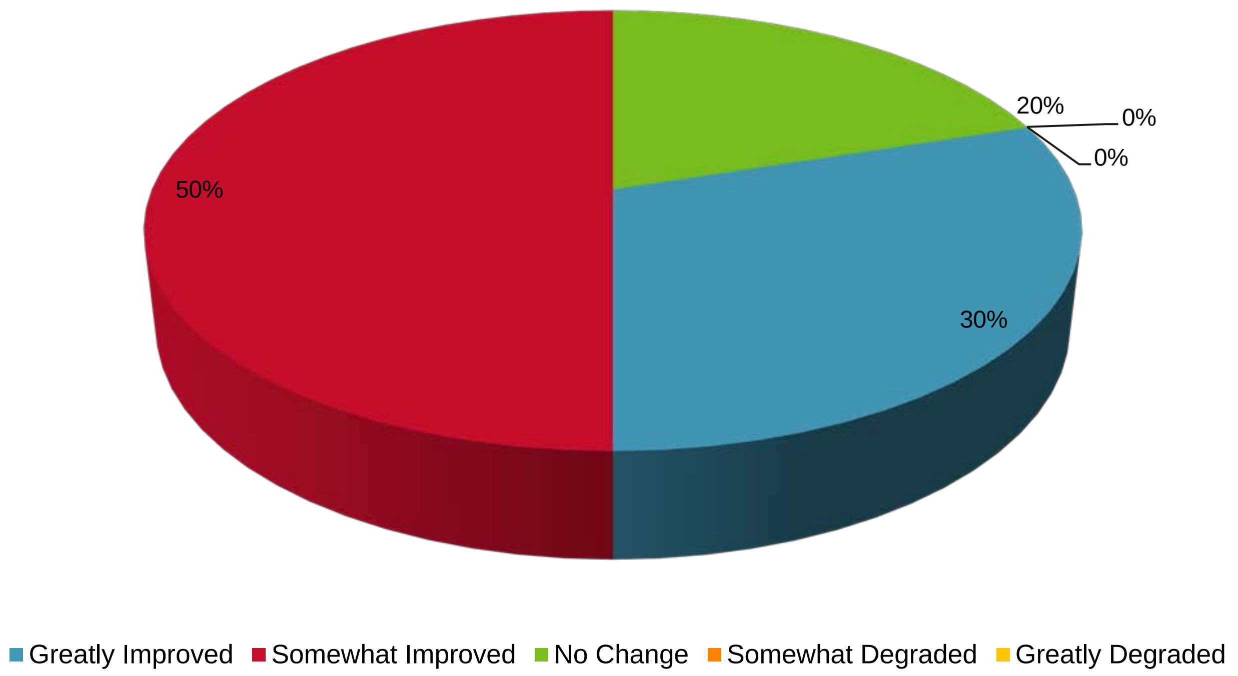
Technology Impact on Decision Making



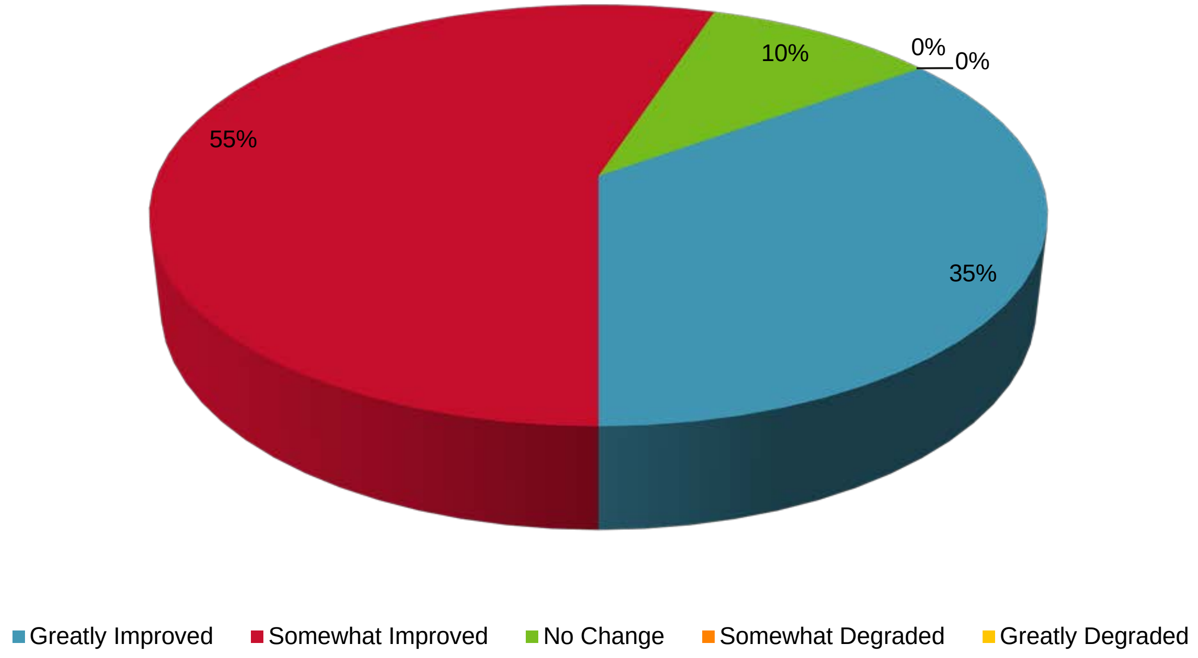
Technology Impact on Staff Time



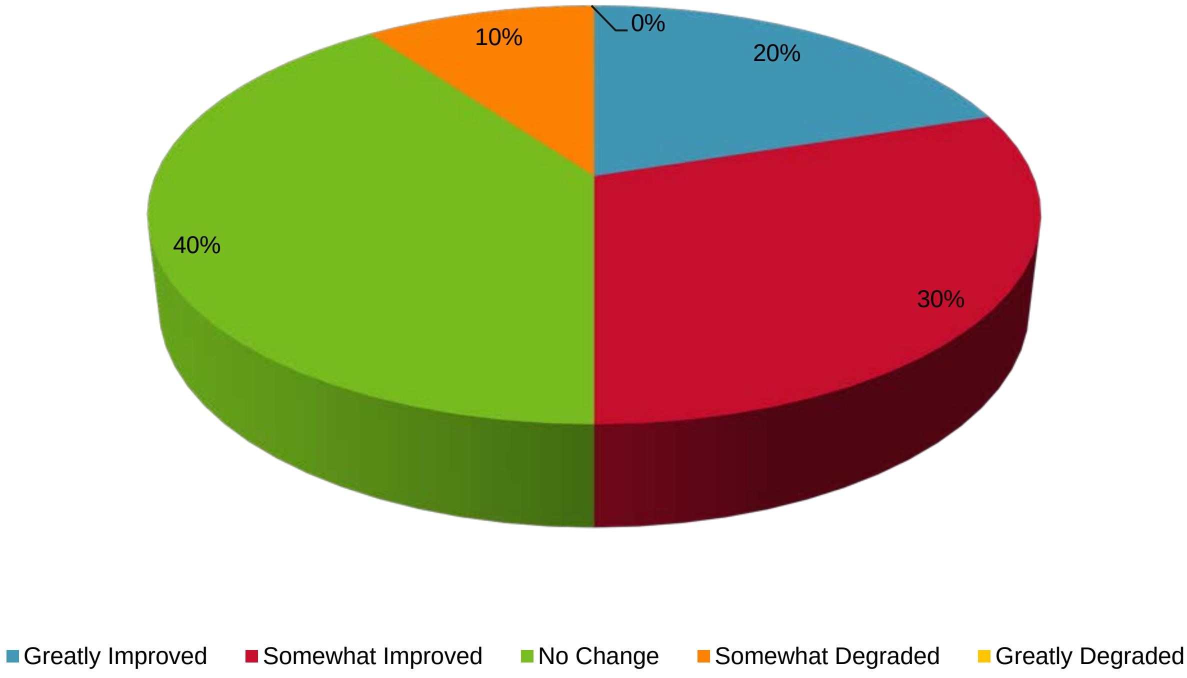
Technology Impact on Federal/State Compliance



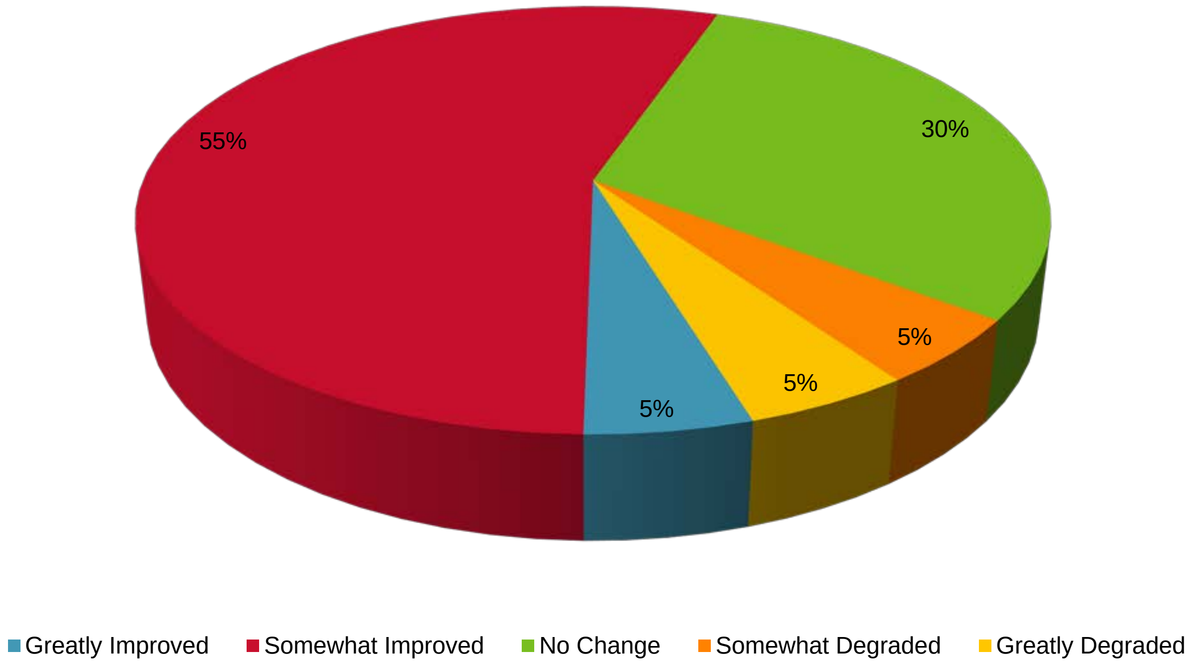
Technology Impact on Record Keeping/Asset Management



Technology Impact on Cash Handling & Reconciliation



Technology Impact on the Ability to Attract New Customers

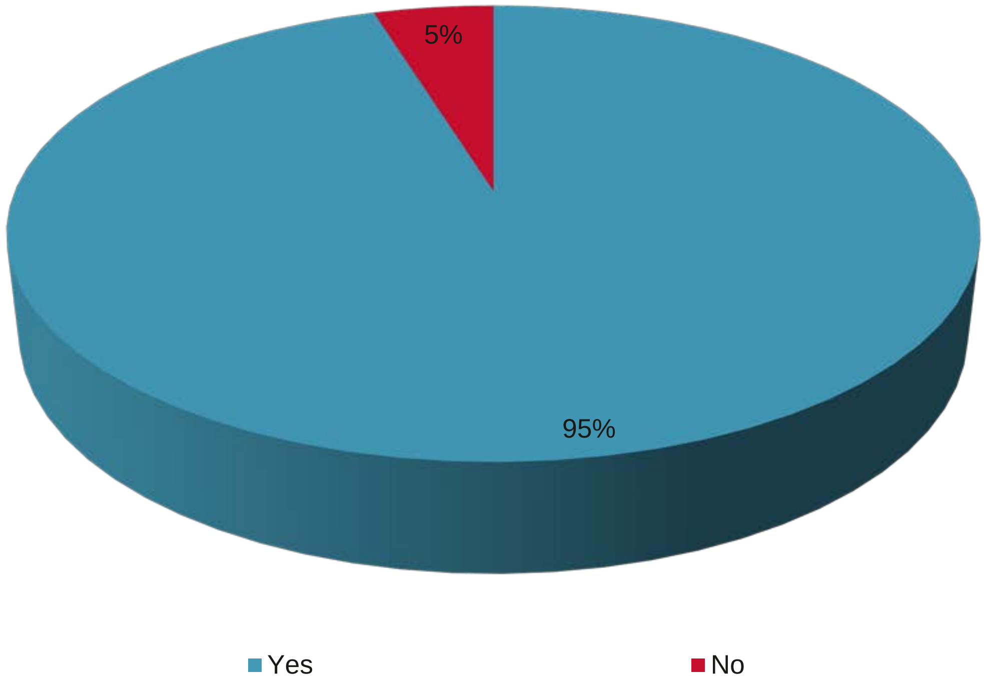


9. May we follow up with you if we have more questions?

- Yes
- No

Agency	Contact
Bay Town Trolley	Yes
Broward County Transit	Yes
Charlotte County	Yes
Collier County	Yes
HART	Yes
JTA	Yes
Lake County	Yes
LeeTran	Yes
Lynx	Yes
Manatee Transit	Yes
MTA Maryland	Yes
Pasco County Public Transportation	Yes
RTD Denver	Yes
SCAT	Yes
SEPTA (Philadelphia, PA)	No
SFRTA	Yes
Space Coast	Yes
StarMetro	Yes
TheComet	Yes
UTA (Salt Lake City)	Yes
VoTran	Yes

Follow Up Interview

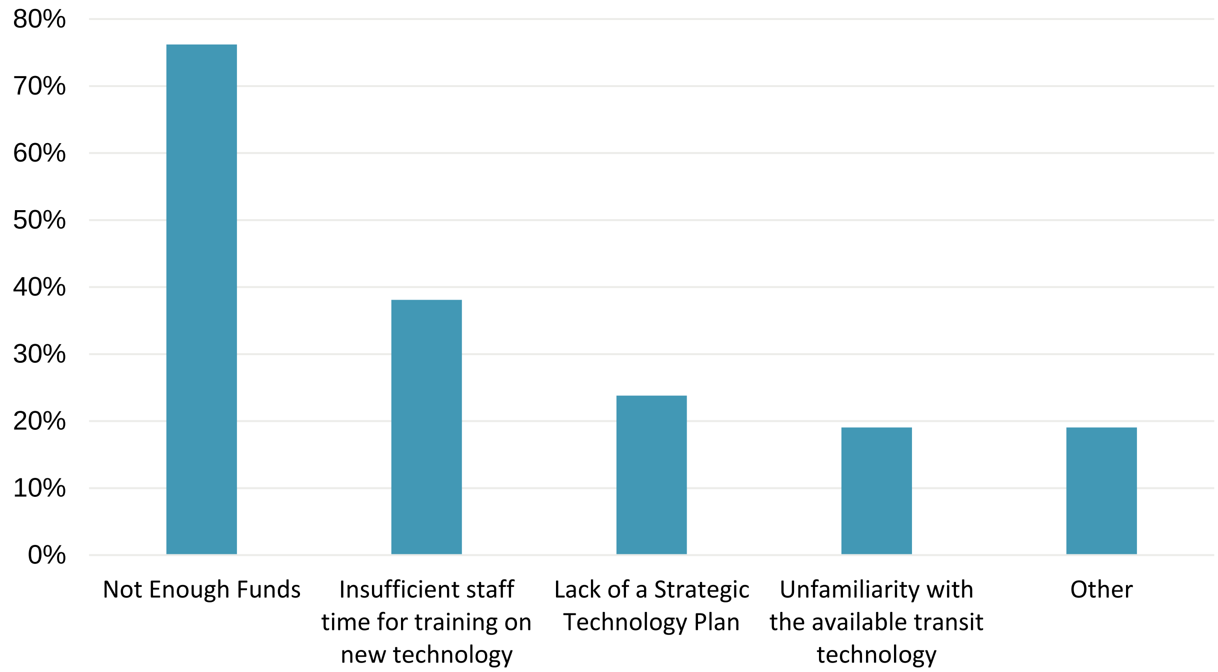


10. What is keeping you from pursuing new transit technology? Check all that apply.

- ☐ Not enough funds
- ☐ Unfamiliarity with the available transit technology
- ☐ Lack of a Strategic Technology Plan
- ☐ Insufficient staff time for training on new technology
- ☐ Other (please specify)

Agency	Funding	Unfamiliar	No Plan	Staff Time	Other
Bay Town Trolley	X				Lack of funds for recurring costs
Broward County Transit	X	X	X	X	
Charlotte County					Lack of Detailed time sensitive plan
Collier County	X			X	
HART	X				
JTA					Lack of resources to tackle more projects
Lake County	X		X		
LeeTran					N/a
Lynx	X			X	
Manatee Transit	X			X	
MTA Maryland	X	X	X	X	Lack of resources to research, analyze, and deploy
Pasco County Public Transportation		X		X	
RTD Denver	X				
SCAT	X		X		
SEPTA (Philadelphia, PA)	X			X	
SFRTA	X				
Space Coast	X				
StarMetro	X	X	X	X	
TheComet					
UTA (Salt Lake City)	X				
VoTran	X				

Reasons for Not Pursuing New Technology



Appendix B – Stakeholder Follow-Up Questions and Full Responses

1. Are you aware of the different types of technology available to transit agencies? If so, what technology are you the most interested in or are planning to pursue?

Bay Town Trolley:	We are familiar with many different types of technology that is currently available. In the future we plan to add APC's and Annunciators on our fixed route buses. We are currently installing a real-time application on our fixed route buses.
HART:	Autonomous and Connected Vehicle Technologies.
LeeTran:	Yes; Fare Payment System
MTA (Maryland):	Improved real-time arrival tracking, internal data/performance management BI solutions.
RTD – Denver:	Integrated mobile payment, on-demand, performance analysis apps, TSP, trip planning, OCCTV, ERP upgrades, Customer Relationship Management System, PIDs support, bus perking app, etc.
TheComet:	Automatic passenger counters is the technology I am most looking forward to getting. #2 would be signal prioritization.
UTA:	New Electronic Fare Collection System; Transitioning our in-house designed Mobile Data Center (MDC) system to tablets

2. What is keeping you from embracing new technology?

Bay Town Trolley:	The main issue we are experiencing is the lack of funding to pay the recurring cost associated with implementing new technology.
HART:	Funding.
LeeTran:	Ability of limited staff to manage projects & need to plan for funding well in advance.
MTA (Maryland):	Long-term contracts, proprietary systems, lack of resources.
RTD – Denver:	Priorities, budget, understanding
TheComet:	Nothing.
UTA:	Funding Market place continually evolving and improving, so hesitant to invest large funds into technology that will change.

3. Do you have a technology investment plan? If so, what are your funding options? How much funding do you need to pursue your ideal system?

Bay Town Trolley:	Yes, we have allotted approximately $14,000 of funding in our 5307 grant. We will need approximately $125,000 to $150,000 if funding to provide all of the needed technology in the future.
HART:	We have a 5-Year ITS Master Plan that is not funded; 10 Million.
LeeTran:	We have a capital investment plan that includes technology projects; Federal 5307 & 5339 grants primarily; Depends on the project; currently we have funded most planned technology projects.
MTA (Maryland)	No.
RTD – Denver:	Plan and options are incorporated into our 6-year strategic budget plan.
TheComet:	We have secured the technologies we want for the foreseeable future. We account for capital needs in our annual budgeting, almost always with a federal match.
UTA:	We have a 5 year development plan, and will allocate resources towards those objectives. Annual maintenance costs are approx. $6 M for software alone Capital budgets for new software fluctuate, but approx. $5 M available annually for coming years

4. How has the lack of some components impacted staff performance and/or efficiency? Are you spending more time on certain tasks than you would like to?

Bay Town Trolley:	As a result of not having APC's installed on buses we have difficulty obtaining accurate rider counts for reporting requirements etc. We further believe that the addition of the real-time application and annunciators will ensure that all drivers are maintaining route headways and properly announcing required points of interest.
HART:	There are manual processes and an overlap of technologies that due to a lack of interoperability of some software platforms.
LeeTran:	In the past, gathering data for service changes & performance; currently maintenance costs of older farebox system.
MTA (Maryland):	Data analysis and problem identification.
RTD – Denver:	Both staff and customers would be better off.
TheComet:	Changes to transit services are heavily laden with technology work for the staff. If no changes, no problem, but when we make changes the technology component adds tremendous strain—Transloc info sheet, updating Clever Devices AVL and announcements, GTFS for Bing, Google, Apple—these are very time consuming.
UTA:	Collecting and utilizing existing data is our biggest time impact. Maximizing use of Business Intelligence (Info Builder) to extract and present pertinent information. We have all the collection methods (automatic passenger counters, AVL) and utilize them to optimize routes, systems – but always believe we can be better / faster.

5. How do you generate system reports and respond to changing demand levels?

Bay Town Trolley: We currently contract with First Transit to operate both our fixed route and demand response systems. We pull data from our CTS Software for demand response and out of software provided by First Transit for fixed route. We meet with our operator every two weeks to address performance issues and changes that need to be made within the systems.

HART: Not quite sure of the question….

LeeTran: Scheduling software, APC's, farebox data and CAD/AVL Data.

MTA (Maryland): Ad-hoc.

RTD – Denver: We have Ridecheck Plus, TrTAPT, GIS, custom queries and reports.

TheComet: Not sure.

UTA: Reports generated in IB and Excel Dashboards routinely.
Officially three change days a year to respond to routine demand.
Track local events (football, JAZZ, conventions) to stage and respond to impact demands.
Collect daily ridership (APC) on major routes to evaluate performance.

6. What led you to pursue transit technology?

Bay Town Trolley: The need to have data quickly and easily without having to rely on consultants.

HART: HART invites, inspires, and implements sustainable and innovative transportation.

LeeTran: Need for automated access to data, response to customer needs.

MTA (Maryland): The need to improve.

RTD – Denver: Both staff and customers would be better off.

TheComet: Customer service improvements (we do not purchase things like maintenance tracking software as we have a contract operator). Our technologies are for the riders.

UTA: Better understanding of the system
More easily respond to questions / inquiries
UTA was first to develop Account based EFC system in 2007.

7. How has the technology improved your system performance measures (ridership, on-time performance, etc.?

Bay Town Trolley:	Because we are in the process of installing the new real-time application, we do not have any real data to determine performance system measures currently.
HART:	A direct result of technology has been increased levels of customer satisfaction and increased safety measures.
LeeTran:	Yes, we just beginning to use data for on-time performance management, technology has helped identify areas where we need to focus our efforts.
MTA (Maryland):	OTP, communication, management efficiencies.
RTD – Denver:	Not always quantifiable just yet.
TheComet:	Has not. Clever has not worked in the 4.5 years I have worked here.
UTA:	Better tracking of ridership with 100% APC coverage Better reliability tracking so as to address root cause issues Better tracking of vehicles through AVL to know where vehicles are – and provide that information to customers

8. Overall, are you satisfied with your level of technology? Why or why not?

Bay Town Trolley:	No, we have the need for more technology.
HART:	Yes.
LeeTran:	Yes; Except for fare system, all other technology is up to date & functioning as expected.
MTA (Maryland):	No. we're not there yet. Improving…but not there yet.
RTD – Denver:	Could always use more.
TheComet:	There are some other items I would like to have (noted above) but otherwise I am satisfied with the level of technology (but not with the technology: Clever is bad)
UTA:	Satisfied – but always pursuing improvements

9. Is there additional technology you are interested in? What is your timeline to get them? What's holding you back?

Bay Town Trolley: We currently plan on procuring APC's and annunciators over the next 24 months. The biggest obstacle is funding for recurring monthly cost.

HART: Real-Time video surveillance on our fleet. A lack of funding is holding us back.

LeeTran: Fare Collection System;
Within the next 12 months;
N/A, project is Underway

MTA (Maryland): Answered above.

RTD – Denver: See above.

TheComet: APC, signal prioritization. Both in the works. Nothing preventing us from getting them.

UTA: Likely transitioning some of our in-house developed programs, to industry available systems that were not around, or advanced to satisfactory levels when we were in need.
We are currently implementing call-out and dispatch system (Trapeze) for our paratransit system.
Only time and funding hold us back.

10. What percent of your budget is set aside to maintaining your current technology and pursuing new opportunities? What funding did you use to start and grow your program?

Bay Town Trolley: Approximately 15% to 20% annually. 5307 grant.

HART: I would need more time to research this.

LeeTran: Estimate 10% of Operating Budget, variable capital allocation;
Primarily FTA 5307 Funds

MTA (Maryland): Not sure.

RTD – Denver: Don't know.

TheComet: No answer.

UTA: UTA Budget as a whole is approx. $300 M. IT Department is $14 M, to include computer replacements and software maintenance. Additional Capital budget of approx. $5 M.

11. Where do you see transit technology going in the next 5 years? 10 years? Do you feel you are prepared to handle it? Why or why not?

Bay Town Trolley: Like with any technology things are always getting better. We hope to increase the amount of technology we use on both systems and to add or upgrade certain technologies as we purchases new vehicles. We are prepared to handle technology in the future and have begun looking for funding opportunities to help facilitate paying for the necessary upgrades in the future.

HART: No answer.

LeeTran: More technology will be developed to assist transit agencies automate & monitor our systems further;
Automated vehicle

MTA (Maryland): Going toward full integration with outside stakeholders and providers. We're not equipped currently to handle this.

RTD – Denver: Entire organization is becoming attuned to the available technologies and will adapt at a pace commensurate with knowledge, availability and funding.

TheComet: I am anticipating consolidation around smart phones. We have three pieces of telemetry now but I think that will go away in a few years. Big Tech will make these things work more easily the way Google now has transit trip planning for everyone and getting it is easy (was very hard at first). New smartphone fare payment companies like Token Transit do not have the same hardware needs than the Passport system we installed four years ago (TT uses only smartphones and a small receiver that gets glued into the farebox, not hard wired).

UTA: Mobility on demand (working on it)
Mobile ticketing (have it)
Connected vehicles (have a corridor with UDOT developed, implementing components on new BRT 10 mi route)
More responsive information for customers (have elements in place to provide the information (AVL, time), just addressing requests as they are submitted)

12. How has the technology improved your system performance measures?

Bay Town Trolley: Because we are in the process of installing the new real-time application, we do not have any real data to determine performance system measures currently.

HART: No answer.

LeeTran: Improving on-time performance, scheduled running times, simpler data collection & analysis

MTA (Maryland): Keener eye leads to a better view of issues.

RTD – Denver: See 7 above.

TheComet: No.

UTA: Yes. Reliability
Better validation of ridership
Better information to customers

13. What lessons would you pass on to transit agencies that are just starting out investing in transit technology or are growing their program?

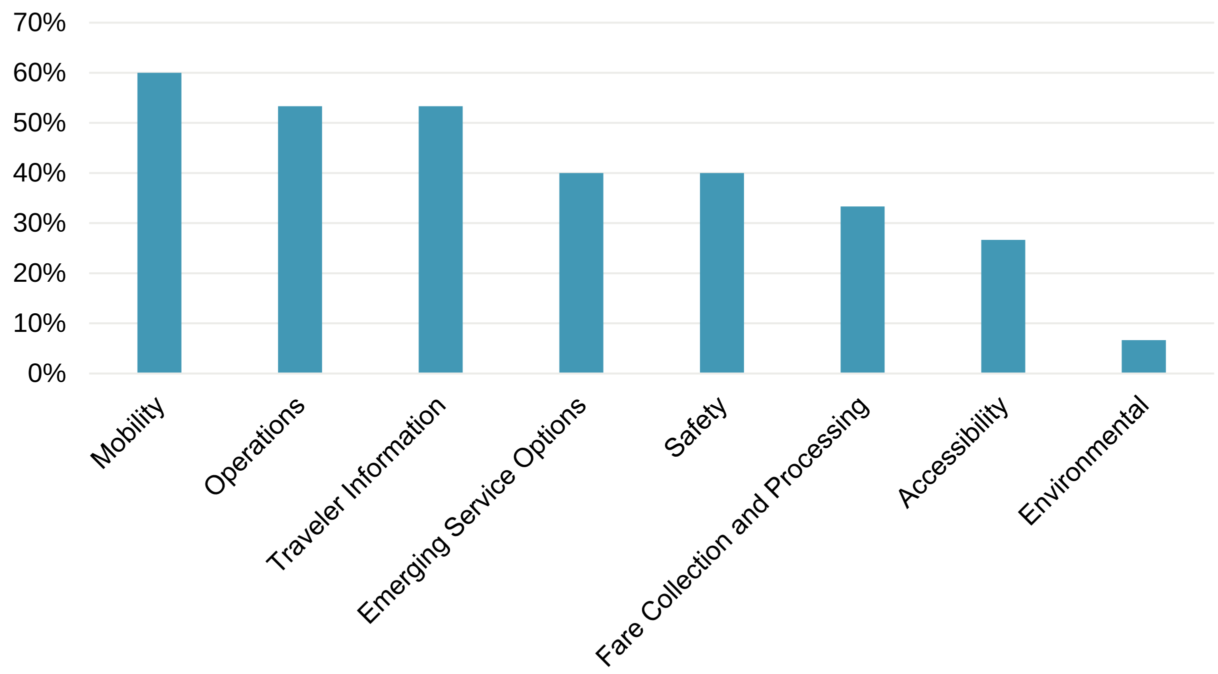
Bay Town Trolley:	Determine your priorities and focus available funding on those technologies that will benefit your system the most and provide clients with the best possible customer service.
HART:	Create a master plan that incorporates all technologies across the agency so that it can be properly leveraged with the technology life-cycles.
LeeTran:	These systems are very complex; don't expect to plug & play, you need to invest significant staff time in bringing them on-line; write solid specifications, and employ subject experts if you don't have them in-house. Be prepared to expand more staff time in maintaining the systems, both hardware & software.
MTA (Maryland):	Set goals and a doctrine of what you are actually trying to accomplish with technology.
RTD – Denver:	First determine what problem you're trying to solve, then inform yourself as to what technology is available, get demos and assess viability, assess risks and life cycle, then consider procurement.
TheComet:	Be prepared for additional staff time. Have someone available who can "bulldog" a problem, someone who understands the technology and can get to the root of a problem when problems arise. Get sample contracts from other agencies that feel confident they have done a high quality RFP and contract. NEVER BE FIRST! Use a system only if at least six other agencies have tried it.
UTA:	Go slow. Make sure you are addressing a true need / desire – not just implementing technology. It doesn't get cheaper.

Appendix C – Vendor Responses

1. What areas do you provide technology for transit agencies? Check all that apply.

- ☐ Safety
- ☐ Mobility
- ☐ Accessibility
- ☐ Environmental
- ☐ Fare Collection and Processing
- ☐ Traveler Information
- ☐ Operations
- ☐ Emerging Service Options
- ☐ Other (Please Specify)

Technology Categories Provided by Vendors



Vendor	Safety	Mobility	Accessibility	Environmental	Fare	Traveler	Ops	Emerging	Other
Citilabs						X	X		Planning*
ETA Transit						X	X		
GTT	X	X		X				X	Vehicle Priority**
Harris	X						X		Wireless Communication*
Navya	X	X						X	
PassioTech	X	X	X			X	X		
Passport		X			X	X		X	Data Analysis*
Remix		X					X		Planning*
Rosco Vision	X								
RouteMatch		X	X		X	X	X		Trip Planning***
Token Transit					X			X	
Transloc		X	X			X		X	GTFS***
Trapeze	X	X	X		X	X	X	X	
TrustCommerce					X				Tokenization solution that includes storing credit card data, recurring payments, installment payments, and account updater****
UDTOnline		X				X			

*Reclassified to Operations; **Reclassified to Mobility; ***Reclassified to Traveler Information; ****Reclassified to Fare Systems

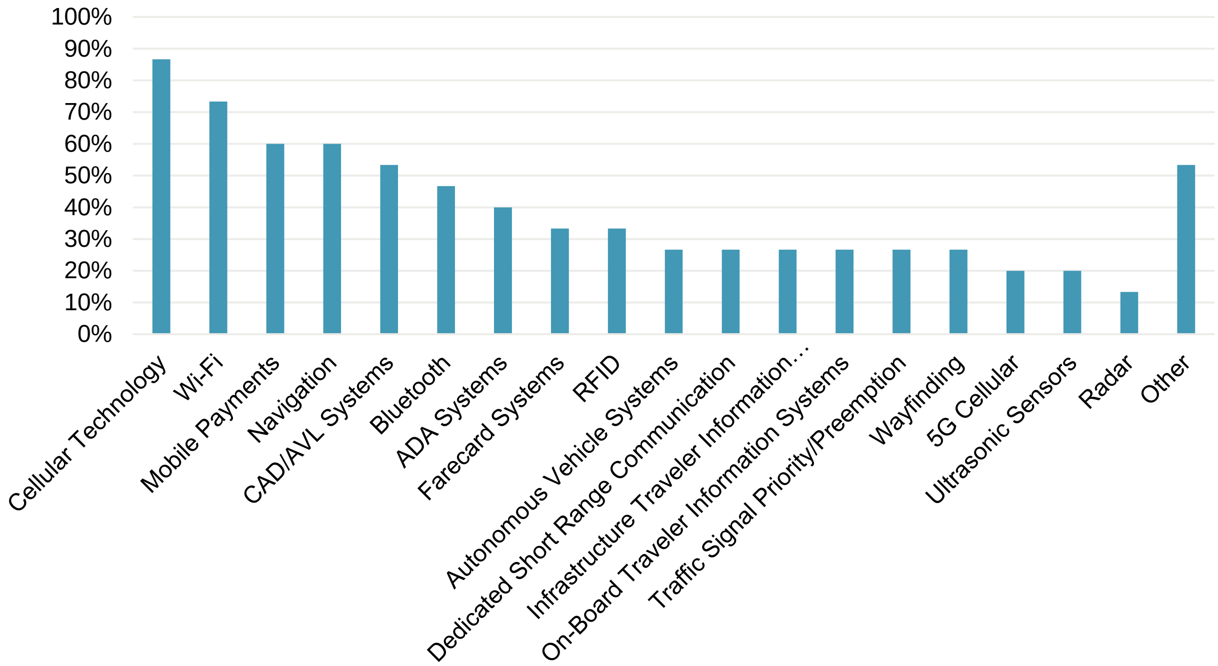
2. What technology components do you use? Check all that apply

- ☐ Cellular Technology
- ☐ 5G cellular
- ☐ Dedicated Short Range Communications (Connected Vehicles)
- ☐ WiFi
- ☐ Bluetooth
- ☐ Radar
- ☐ RFID
- ☐ Ultrasonic Sensors
- ☐ Fare card systems
- ☐ Mobile Payments
- ☐ Autonomous Vehicle Systems
- ☐ Alternative Fuel Systems
- ☐ Wayfinding
- ☐ Navigation
- ☐ On-board traveler information system
- ☐ Infrastructure traveler information system
- ☐ Traffic signal priority/pre-emption
- ☐ ADA Systems
- ☐ CAD/AVL System
- ☐ Other (Please Specify)

Vendor	Cell	5G	DSRC	WiFi	Blue	Radar	RFID	Ultrasonic	Fare	Mobile	AV	Wayfinding	Nav	Traveler	Infra	TSP	ADA	CAD
Citilabs	X								X	X			X	X				X
ETA Transit	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X
GTT	X	X	X	X												X		
Harris	X			X	X								X					X
Navya	X		X	X	X	X	X			X	X		X			X	X	
PassioTech	X			X	X		X					X	X	X			X	X
Passport	X			X					X	X			X				X	
Remix				X														X
Rosco Vision	X			X				X			X							
RouteMatch	X			X			X		X	X			X		X		X	X
Token Transit	X			X	X					X								
Transloc	X									X		X	X					X
Trapeze	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TrustCommerce										X								
UDTOnline	X			X	X										X			

Vendor	Other
Citilabs	GTFS, On Board Survey, ridership forecasts
GTT	Analytics
Harris	Two-way radio communications, land mobile radio
Passport	Trip Planning
Remix	GTFS
Rosco Vision	4G
PassioTech	WiFi, Card Reader System
TrustCommerce	Online payments, data storage, recurring payments, tokenization solution that includes Storing Credit Card Data, Recurring Payments, Installment Payments, and Account updater.

Technology Components Used by Vendors



3. What are the key features of the products you offer?

1.

2.

3.

4.

5.

6.

7.

8.

9.

Vendor	Key Features
Citilabs	Reporting; Visualization; Scenario Analysis; Web Applications; No data processing; Historical performance; Future demand/supply
ETA Transit	APC's; OBA's; intuitive and feature-rich traveler information system; infotainment; digital displays and infortainment; CAD/AVL; fixed route and paratransit dispatch; advanced analytics; public websites and mobile applications.
GTT	Vehicle preemption; vehicle priority; conditional priority; relative priority; schedule adherence; headway management; data analytics; central management; priority control as a service;
Harris	Dispatch communications; two-way voice communications; GPS tracking; LTE/Cellular Data connectivity; Bluetooth connectivity; WiFi connectivity; AVL; Interoperability with public safety
Navya	Level 4 AVs; no pedals, no steering wheels; first mile and last mile transportation solution; first robot taxi; autonomous vehicle commercialization on the market
PassioTech	Single platform/configuration file for all components; modular options – only purchase what you need; advanced analytics; reporting access – ease of use/point and click; card swipe technology for access control; active route management; developing dispatch modules and tools for AVs;
Passport	Flexible product offerings – off the shelf to fully configurable solutions; future proofing fare collections –visual inspection to electronic validation; active smart card integration; Open API Architecture; Custom Development Solutions – Solve Agency Specific Problems; Progressive login – faster registration times; integration with TNCs; interoperability with Parking Operations; Security – PCI DSS Level 1 Certified
Remix	Route planning; demographic analysis; travel time isochrome; title vi analysis; operating cost estimates; public share of maps; timetable creation; blocking, runcutting, rostering; scheduling
Rosco Vision	Pedestrian detection; live video feeds; integration of vision safety products; cellular download; continuous recording; forward collision warning; wireless installation; immediate operator feedback; expandable platforms
RouteMatch	Scheduling, dispatch, AVL/MDC, optimization, reporting, verification; route authoring, dynamic, dispatching, deviations; real time traveler information for both ADA paratransit riders and fixed route riders; payment technology through smartcards, mobile devices, account based fared collection for ADA; multi-modal trip planning mobile applications for both fixed and paratransit riders; MDC integration for real time AVL tracking; push to talk voice communication through MDC
Token Transit	Mobile Ticketing; pass distribution; rider information
Transloc	OnDemand – complete platform for agency-owned microtransit (passenger app, driver app, dispatch tools, administrative); Passenger mobile applications for fixed and demand-response transit; automated or human-assisted dispatch for demand-response services;

Trapeze	AFC: Our fare collection technology offers a complete solution to make fare collection easier, reduce fraud, decrease the cost of collecting cash, and provide a better rider experience; OPS: an integrated operations management solution that streamlines many frequently performed operational tasks, including bidding, dispatching, timekeeping, workforce management and yard management. Optional enhancement technologies include automated sign-in, operator self service module, employee appraisals, and accrual calculations; Traveler Information - To support transit agency customer experience objectives, provide scheduled and real-time transit information to riders over various channels and to improve rider satisfaction through information delivery and engagement. A suite of Traveler Information solutions that help agencies interact and engage their riders through various communication channels (web, mobile app, IVR, SMS, Email, digital signage, etc.). Supporting both Fixed Route and Demand Response use cases; Enterprise Asset Management: Trapeze Enterprise Asset Management (EAM) allows agencies to reduce the cost of owning and operating vehicles/infrastructure, while extending their life, and keeping them safe to operate. Trapeze EAM is used by over 100 transit agencies in North America including six of the top 10 largest rail agencies in the U.S; Business Intelligence: Real-time, analytical BI tool that enables proactive operational decisions that lead to improved transit operations. Designed to visualize key service metrics in multi-functional dashboards and alert managers to any risk to service delivery based on thresholds and limits defined by the user; Demand Response: Demand Response provides transit agencies with a reliable and scalable scheduling & dispatching solution that produces quality, cost effective, schedules. Successfully deployed in most major cities across North America; Intelligent Transportation Systems: The Intelligent Transportation Systems (ITS) suite of products provided by Trapeze encompasses many possible components and integrations depending on the needs of the situation. Within vehicles, an Integrated Vehicle Logic Unit (IVLU) and Mobile Data Terminal (MDT) are standard equipment to be installed, along with the items defined below and many more. Within the dispatch center, technologies are provided to assist staff utilizing a Transit Operations Decision Support System we call Intelligent Decision Support (IDS) that incorporates your standard operating procedures into the software, automating alerts and actions to ensure dispatch is working on the things that matter most. Tools in the dispatch center allow for disruptions in service to be quickly and easily managed with the information being disseminated in real-time to internal and external stakeholders in real time via e-mail, social media, signage, and mobile applications.

TrustCommerce	Security - TrustCommerce has been the leader in payment security from the day we started in 2000. We were first company to offer tokenization for payment transactions and have helped pioneer P2PE (2004) and encrypted devices (2005). Protecting our client's payment data is our number one core value; Scope Reduction - we remove the sensitive payment data from the client's environment and as a result the client has fewer compliance requirements; Custom Fields - For credit card and ACH transactions, custom fields can be configured for specified field types, lengths, and default values. Additionally, users can set these fields to be required; TC Citadel - Our complete tokenization solution that includes Storing Credit Card Data, Recurring Payments, Installment Payments, and Account updater; Dynamic Reporting - On-Demand Reporting Services enables merchants to instantly access transaction detail and batch settlement reporting information. Reporting is consolidated and configurable; TC IPA " Integrated Payment Application" TC IPA is a payment processing solution built to greatly reduce clients' PCI scope. It relieves the cost and burden of complex and time consuming PCI audits and EMV certification, while reducing clients' risk, liability and exposure when accepting electronic payments. Unlike any other solution available, TC IPA provides the tools to manage hardware assets with security and compliance in mind; TC Trustee Premier - Allows merchants to accept e-commerce payments securely by keeping payment data out of the merchant's web server. In addition, TC Trustee Premier provides complete branding continuity without extensive developer involvement. TC Trustee Premier can be used for mobile, text, and email payments as well as online; Bank Neutral "TrustCommerce has certified to all of the major merchant bank platforms in the market (Vantiv, Chase, Elavon, First Data, etc.). This greatly decreases the friction of change for new clients coming on board that want to keep their current merchant processing relationship and also for existing clients that need a new merchant processor.
UDTOnline	Multi Solution Support; Remote Branch office connectivity for mobile and remote application via 4G 5G connections; reduced cost for infrastructure

4. May we follow up with you for more information on your products and for case studies? If so, please provide the email address of the person you would like us to contact.

- ○ Yes
- ○ No
- ○ Email address of contact person

Vendor	Contact?	Name	Email
Citilabs	Yes	Katie Brinson	kbrinson@citilabs.com
ETA Transit	Yes	Jim Regate	jredgate@etatransit.com
GTT	Yes	Mark Ignatoski	mark.ignatowski@gtt.com
Harris	Yes	James Potter	jpotte03@harris.com
Navya	Yes	Pierre Elliot Petit	pierre-eliott.petit@navya.tech
PassioTech	Yes	Mitch Skyer	mitch@passiotech.com
Passport	Yes	Tom Wiese	tom.wiese@passportinc.com
Remix	Yes	Claudia Preciado	claudia@remix.com
Rosco Vision	Yes	Scott Coleman	scottc@roscovision.com
RouteMatch	Yes	Tim Flanigan	Tim.Flanigan@Routematch.com
Trapeze	Yes	Vicky Abishira	vicky.abihsira@trapezegroup.com
Transloc	Yes	Joel Bush	joel.bush@transloc.com
Token Transit	Yes	Zach Browne	zbrowne@tokentransit.com
TrustCommerce	Yes	Trisha Cinquini	trisha.alexandrou@trustcommerce.com
UDTOnline	Yes	Joseph Goleniowski	jgoleniowski@udtonline.com

Appendix D – Transit Technology Assessment Framework Tool User Guide

Download and Installation

To access the Transit Technology Assessment Framework Tool, navigate to http://www.fdot.gov/transit/Pages/NewTransitandTechnology.shtm and use the following instructions:

1. Download the zip file containing the tool from the FDOT website into a local folder.

2. Right click the zip file and then select “Extract All…” and select a location to extract the files to.

3. Finally, run the “setup.exe” file in the folder where the files were extracted to.

This will extract all the necessary files to run the FDOT Transit Technology Assessment Framework Tool and place a shortcut on your Desktop to access the tool.

Search by Category

The FDOT Transit Technology Assessment Framework Tool has one main interface to query information regarding vendor and literature review abstracts in the transit technology space. There are four main categories to filter by:

- Technology Category
- Technology Placement
- Required Resources
- Technology Maturity

A screenshot is shown in **Figure 1**.

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Figure 1 - Search Tool Form

To switch between categories, click the label for each category shown in Box 1. To include filters in the query, click an item in Box 2. A selected item will become darker to show that it's active in the filter. Hover the mouse cursor over each item in the category to see a description.

Searching

Once all the desired filters have been selected by the user, click the SEARCH button to yield results. A screenshot of the results is shown in **Figure 2**. The results are divided into two groups: Vendors and Literature Reviews. To view more information regarding a particular Vendor, select the Vendor to view the website/document links in the right pane of the Results Window. To view more information regarding a particular Literature Review, select "View Abstract" to open a separate window containing the abstract.

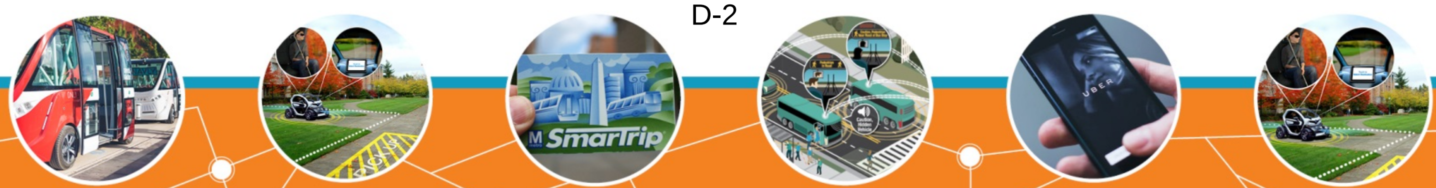
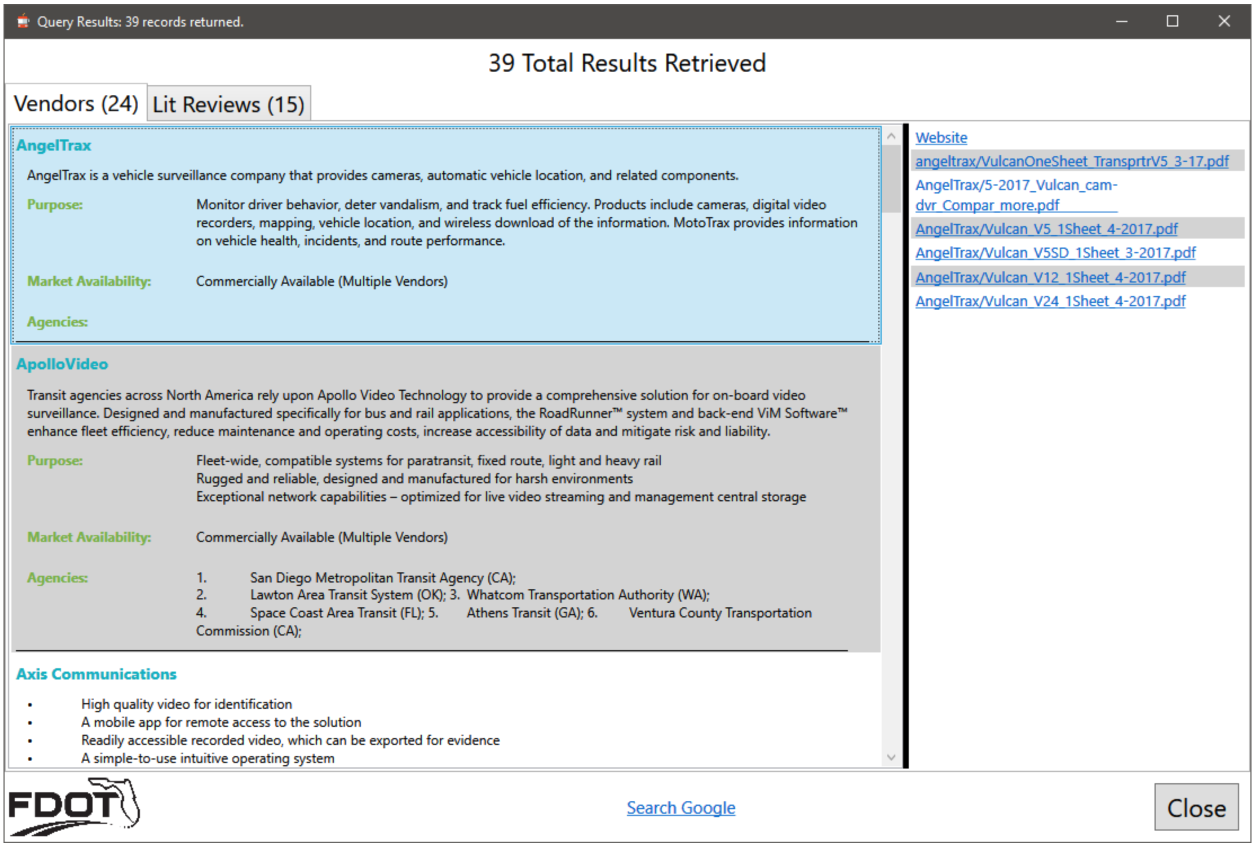


Figure 2 - Example Results Window



Keyword and Internet Search

In addition to the filter based search, a separate keyword search tool is added to search for a specific piece of technology such as automatic passenger counters. Click on the icon in the upper right corner to display a textbox to enter search text. Once the desired technology is entered in the textbox, click the SEARCH button to yield results (**Figure 3**). The keyword search results are in the same format as shown in **Figure 2** above. If more information on a topic or product is desired, select the "Search Google" link at the bottom of the Results Window. This will open a separate window with the internet search (**Figure 3**) of the keyword. If no keyword is entered, the term 'Transit Technology' will be used.

Figure 3 – Keyword Search

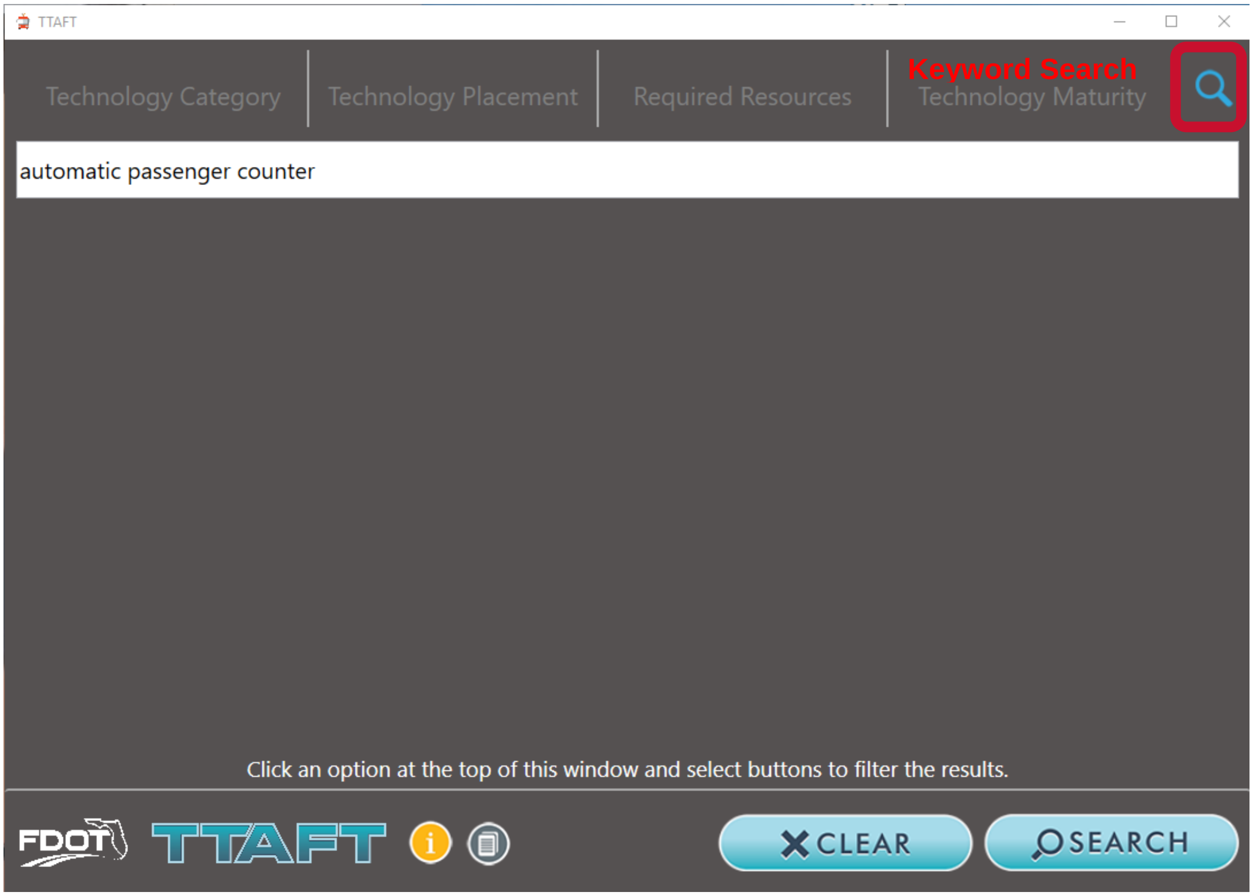
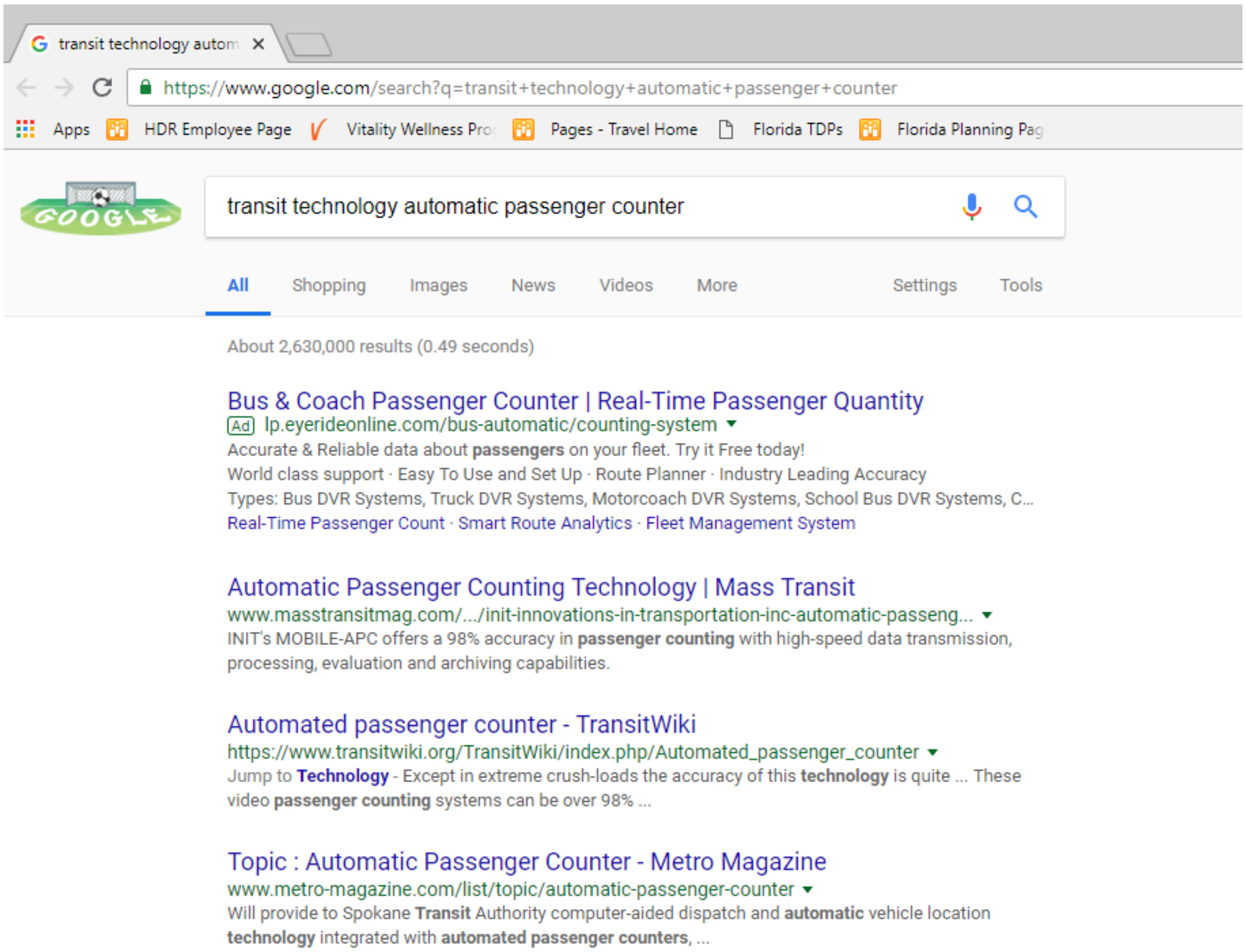


Figure 4 –Search Google Results

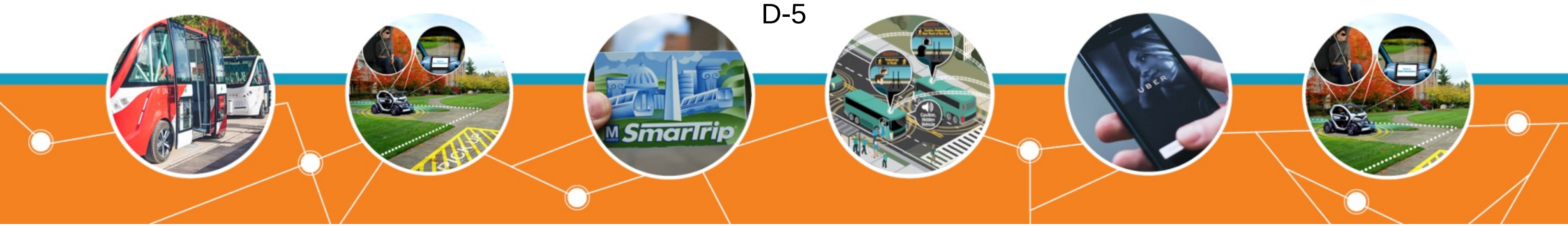


Clearing the filter

If you would like to start over and perform a new query, close the results form and press the ✕ CLEAR button, which will unselect all the filters and clear the text search.

More information

If you'd like to view more information regarding this project in general, click the button which will open up a PDF to the Transit Technology Primer.



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