GWINNETT COUNTY
CONNECTED VEHICLE TECHNOLOGY MASTER PLAN

Gwinnett

Prepared for:

Gwinnett County Department of Transportation

Prepared by:

AECOM
1360 Peachtree St NE
Suite 500
Atlanta, GA 30309
aecom.com

ACKNOWLEDGEMENTS

The Gwinnett County Department of Transportation would like to acknowledge the leadership provided by the Gwinnett County Board of Commissioners:

- Charlotte J. Nash, Chairman
- Jace W. Brooks, District 1
- Ben Ku, District 2
- Tommy Hunter, District 4
- Marlene M. Fosque, District 4

The Gwinnett County Department of Transportation would like to acknowledge the Georgia Institute of Technology's Georgia Smart Communities Challenge led by Debra Lam and Greg McCormick and the supporting partners of the challenge.

The Gwinnett County Department of Transportation would like to acknowledge the insights provided by the research team led by Dr. Angshuman Guin, Senior Research Engineer in Transportation Systems Engineering and Smart Cities at Georgia Institute of Technology. The team included Georgia Smart Community Corps Graduate Student Xixiu Fu of Georgia Institute of Technology and Civic Data Science Program Undergraduate Students Jason Chen of Purdue University, Angela Lau of Cornell University, and David Li of Stony Brook University.

The Gwinnett County Department of Transportation would like to acknowledge representatives from partner agencies who participated in thought sharing via interviews held early in the drafting of this plan. They include representatives from the following jurisdictions.

- City of Atlanta
- Cobb County Department of Transportation
- City of Marietta Fire Department

The Gwinnett County Department of Transportation would like to acknowledge the various stakeholders who helped in crafting this plan. They include representatives from the following jurisdictions.

- City of Braselton
- City of Buford
- City of Chamblee
- City of Dacula
- City of Duluth
- City of Lawrenceville
- City of Snellville
- City of Suwanee
- Gwinnett County Fire Department
- Gwinnett County Police Department
- Georgia Department of Transportation
- Evermore CID
- Gateway 85 CID
- Gwinnett Place CID
- Lilburn CID
- Sugarloaf CID

TABLE OF CONTENTS

FIGURES

TABLES

LIST OF ACRONYMS

Acronym	Definition
API	Application Programming Interface
ARC	Atlanta Regional Commission
AV	Automated Vehicle
BSM	Basic Safety Message
CA	Certification Authority
CAMP	Crash Avoidance Metrics Partnership
CCDOT	Cobb County Department of Transportation
CCTV	Closed Circuit Television
CID	Community Improvement District
CTP	Comprehensive Transportation Plan
CV	Connected Vehicle
C-V2X	Cellular Vehicle-to-Everything
CVTMP	Connected Vehicle Technology Master Plan
DR-OPT	Drayage Optimization
DSRC	Dedicated Short Range Communication
Eco-CACC	Eco-Cooperative Adaptive Cruise Control
EVP	Emergency Vehicle Preemption
FCC	Federal Communications Commission
FRATIS	Freight Advanced Traveler Information Systems
FSP	Freight Signal Priority

Acronym	Definition
GCDOT	Gwinnett County Department of Transportation
GCT	Gwinnett County Transit
GDOT	Georgia Department of Transportation
GPS	Global Positioning System
HMI	Human Machine Interface
IBL	Intermittent Bus Lane
IEEE	Institute of Electrical and Electronics Engineers
INC-ZONE	Incident Scene Work Zone Alerts for Drivers and Workers
I-SIG	Intelligent Traffic Signal System
ITS	Intelligent Transportation System
MAP	Map Message
MMITSS	Multimodal Intelligent Traffic Signal System
NEMA	National Electrical Manufacturers Association
NHTSA	National Highway Traffic Safety Administration
NPRM	Notice of Proposed Rule Making
NTCIP	National Transportation Communications for Intelligent Transportation System Protocol
NYCDOT	New York City Department of Transportation
OBU	On Board Unit
OEM	Original Equipment Manufacturer
PED-SIG	Pedestrian Signal System
PKI	Public Key Infrastructure
PPA	Pedestrian Presence Alert
PREEMPT	Emergency Vehicle Preemption

Acronym	Definition
REL	Reversible Express Lane
RCVW	Railroad Crossing Violation Warning
RESP-STG	Incident Scene Pre-Arrival Staging Guidance for Emergency Responders
RSE	Road Side Equipment
RSU	Roadside Unit
RSZW/LC	Reduced Speed Zone Warning/Lane Closure
RTOP	Regional Traffic Operations Program
SAE	Society of Automotive Engineers
SAV	Shared Autonomous Vehicle
SCMS	Security and Credentials Management System
SPaT	Signal Phase and Timing
SRM	Signal Request Message
SSM	Signal Status Message
TCC	Traffic Control Center
THEA	Tampa-Hillsborough Expressway Authority
TMC	Traffic Management Center
TSMO	Transportation Systems Management and Operations
TSP	Transit Signal Priority
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VTPI	Victoria Transport Policy Institute

Acronym	Definition
VTRFTV	Vehicle Turning Right in Front of a Transit Vehicle
WHWZ	Warnings about Hazards in a Work Zone
WUWZ	Warnings about Upcoming Work Zone
WYDOT	Wyoming Department of Transportation

EXECUTIVE SUMMARY

Project Overview

"Connected Vehicles Can Sense and Communicate Things Drivers Cannot" - USDOT

Connected vehicles and automated vehicles have the potential to improve safety and efficiency across a range of mobility options, including private vehicles, emergency vehicles, freight, transit, and pedestrians. Connected and automated vehicle technologies will transform transportation in the near future, so planning for their deployment is critical to maximize the benefits.

Connected Vehicles are vehicles that use wireless communication technologies to communicate with roadside infrastructure, vehicles on the road, and devices, such as mobile phones.

Automated Vehicles are vehicles that are capable of sensing their environment and navigating without human input.

To prepare for the transformation of transportation, planning efforts should include state, local agency, and transportation-related stakeholders. This planning effort was made possible in part by the Georgia Smart Communities Challenge ("Georgia Smart") led by the Georgia Institute of Technology's Institute of People and Technology in partnership with Georgia Power and the Atlanta Regional Commission (ARC).

Transportation planners and practitioners are finding it increasingly challenging to analyze what connected vehicle applications are available now and what should be tested for future application as technology evolves at a rapid pace. There also exists uncertainty about when connected and automated vehicle technologies will achieve mass adoption status for public sector, private sector, and personal end users. The potential for risk begins with a lack of coordination across jurisdictions. It is critical that state and local agencies collaborate to support interoperability and consistent benefits for all road users. Gwinnett County has initiated the Connected Vehicle Technology Master Plan (CVTMP) to lay the groundwork for maximizing the potential for transportation transformation.

The CVTMP focuses on a 5-year timeline that includes near-term (1-3 years), mid-term (5-3 years), and long-term (5+ years). The CVTMP process included input from over 25 stakeholders from cities within and neighboring Gwinnett County, community improvement districts (CIDs), and partner agencies from across the metro area and state.

GEORGIA SMART

Georgia Tech
CREATING THE NEXT

Georgia Smart Communities Challenge Partners

Project Team

The project team consisted of the Gwinnett County Department of Transportation (GCDOT) staff, AECOM staff, and a Georgia Institute of Technology Professor. Team members are listed in Table E1.

Table E1. Project Team

Staff Name	Title	Organization
Tom Sever, P.E. Project Lead	Deputy Director for Traffic Engineering, Operations, and Maintenance	Gwinnett County Department of Transportation
Alex Hofelich, P.E., PTOE	Division Director for Traffic Engineering	Gwinnett County Department of Transportation
Ken Keena, P.E.	Engineer V	Gwinnett County Department of Transportation
Angshuman Guin, PhD	Senior Research Engineer	Georgia Institute of Technology
Suzanne Murtha	National Lead for Connected and Automated Technologies	AECOM
Marc Start, P.E., PTOE	Senior ITS/Traffic Engineer	AECOM Atlanta
Sinan Sinharoy	Smart Cities and Mobility Technology Specialist	AECOM Atlanta
Leslie Langley	Smart Cities and Mobility Technology Specialist	AECOM Atlanta

Project Motivations and Goals

The goals of the CVTMP are as follows:

- Leverage the county's transportation system to improve economic vitality and quality of life
  - Identify the potential safety and mobility benefits available to all road users with deployment of connected vehicle infrastructure
  - Reduce congestion and crashes to improve quality of life and commute times
- Understand the needs and challenges to ensure regional and state-wide compatibility
  - Provide benefits to those using motorized modes (drivers, transit riders, and first responders), ensuring the benefits are seamless across the county and neighboring jurisdictions
  - Provide benefits to those using non-motorized modes (pedestrians, cyclists, and construction and maintenance workers), ensuring the benefits are seamless
- Establish guidelines for deploying a new and evolving technology
  - Understand the current state of connected vehicle technology and the plans of automakers for equipping future models with the technology
  - Understand the capabilities of connected vehicle applications to prepare Gwinnett County for deploying this technology county-wide and supporting it into the future
  - Deliver a transportation system that uses the most recent advances in technology
- Have broad applicability across the county, Atlanta region, and State of Georgia
  - Improve mobility for congested corridors that serve local and regional (inter-county) trips
  - Demonstrate the capabilities of connected vehicle technologies in a Smart Corridor project, which will prepare Gwinnett County for deploying similar technology county-wide
- Set the standard for implementing connected vehicle technology for a local government
  - Ensure the recommended connected vehicle system is compatible with the state's system, to maintain functionality at a regional scale
  - Evaluate scalability and design considerations for short-term needs as well as needs for long-term growth

Project Timeline

Figure E1 provides an overview of the project timeline by major tasks from the kick-off in September 2018 through the completion of this plan in September 2019.

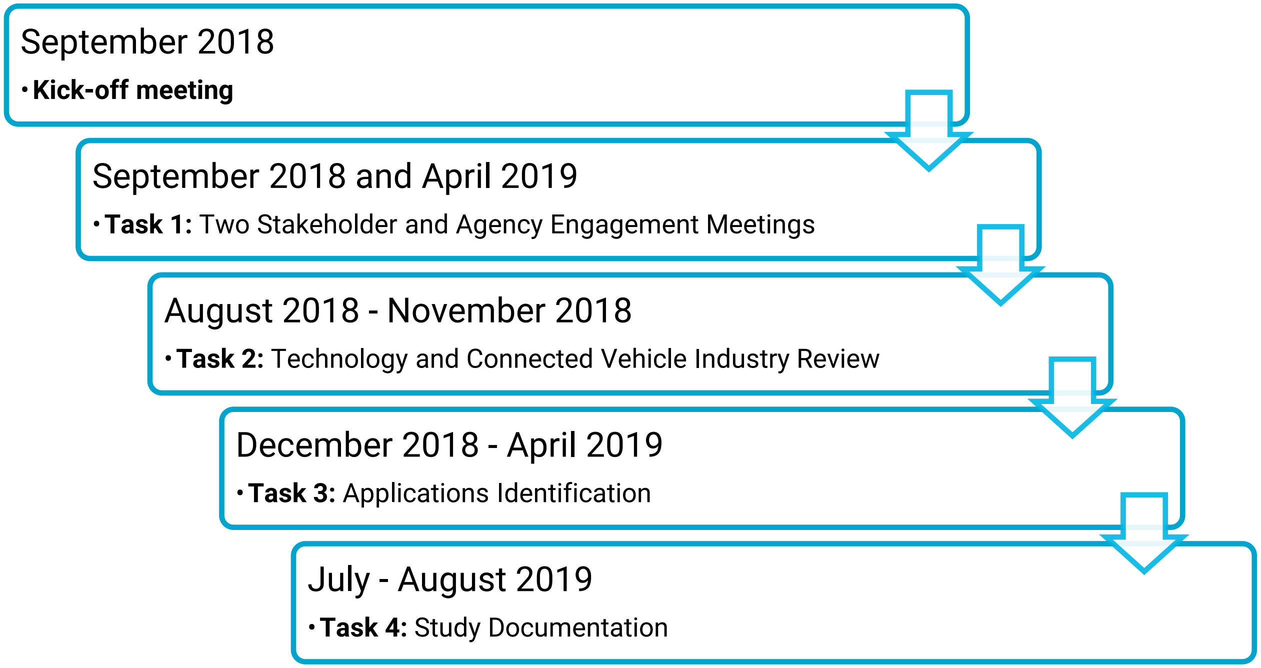


Figure E1. Project Timeline

Project Actions and Results

In addition to coordination with Gwinnett County staff, the project consisted of two stakeholder meetings with interested agencies, interviews with three peer jurisdictions, and coordination with Georgia Department of Transportation (GDOT). These meetings provided the background so that the plan addresses local needs, builds on lessons learned in other jurisdictions, and leverages opportunities that could have a state-wide impact.

The stakeholder meetings provided insights by local leaders on a variety of transportation issues, including where emergency vehicles or buses tend to be delayed. In addition, the project team leveraged lessons learned through interviews with peer jurisdictions that have implemented connected vehicle deployments since 2017.

Engagement with GDOT was helpful in amplifying the benefit of the forthcoming Smart Corridors deployment in Gwinnett County. Specifically, GDOT agreed to deploy dedicated short range communication (DSRC) at 56 intersections on state routes, in addition to the 36 originally planned for deployment on the Regional Traffic Operations Program (RTOP) corridors of SR 140 and SR 141. GDOT also agreed to share software as it becomes available to assist in deploying emergency vehicle preemption (EVP) and transit signal priority (TSP) at traffic signal locations.

The insight from stakeholders, jurisdictional peers, and GDOT will help implement the CVTMP recommendations at an accelerated pace with a greater potential for success and replicability in other communities throughout the State of Georgia.

Research Actions and Results

The research effort focused on evaluating intersections where emergency vehicles experience delay in Gwinnett County west of Interstate 85 (I-85). This geography is consistent with the focus area for the forthcoming Smart Corridor project. To best prepare for the deployment, the research focused on gaining insights on the current emergency response system by:

- Tracking live routes and evaluating where adjustments could be made to improve emergency vehicle response times
- Evaluating the emergency vehicle system dispatched from fire stations within the pilot project area
- Developing strategies for maximizing benefits and minimizing impacts

Emergency vehicle preemption is not a new concept. EVP is the ability for a traffic controller to change the lights from red to green or hold a green light longer when it receives a message from an emergency vehicle as it approaches the intersection. Non-connected vehicle systems depend on direct line of sight between the traffic signal and the emergency vehicle. A connected vehicle system allows for multi-signal preemption, meaning that a whole corridor or vehicle path can be cleared in advance of the emergency vehicle's arrival. This approach allows for better clearance of traffic and minimizes the impact to normal traffic flow.

The research included a bottleneck analysis to identify hotspots for both emergency vehicles and normal traffic flow and a delay pattern analysis of common paths used by emergency vehicles. These insights will help in prioritizing locations for focusing EVP hardware and software deployment.

PIB Intersections	Phase	Vehicle-days of data	Average of speed
PEACHTREE CORNERS EAST	4	70	7
REPS MILLER RD	6	79	2
TECHNOLOGY PKWY SOUTH	6	81	8
MEDLOCK BRIDGE RD	6	91	4
SOUTH OLD PEACHTREE RD	6	119	8
HIGHWOODS CENTER	6	117	13

Research Recommendations

Recommendations from the research include the following:

- The emergency response community is welcoming connected vehicle technology. Demonstration and quantification of benefits, through pilot field applications, will be critical to gaining acceptance from the public and convergence from the manufacturers that are both necessary for widespread success of connected vehicle in improving mobility, safety, and sustainability.
- Identifying key data needs early in the project is critical to the success of short-term data-heavy projects.

Georgia Tech Student Engagement

Part of the Georgia Smart Communities Challenge is the Smart Community Corps, a group of cross departmental college students who are placed in the communities to support research efforts during their summer break. Gwinnett County had such a student who worked in the GCDOT Traffic Control Center. Their work focused on streamlining the transfer of high resolution/high volume data between Gwinnett County and Georgia Institute of Technology (Georgia Tech) and developed a data fusion Application Programming Interface (API) data feed of the global positioning system (GPS) signal status data.

Students who were part of the Georgia Tech Civic Data Science Team also supported the research effort by providing data quality checks on the various data feeds and by identifying the intersections at which emergency vehicles experience maximum delays.

Challenges

One challenge in developing the CVTMP is the pace at which emerging transportation technology is evolving both from developers of the technologies and local agencies who deploy the technologies. A second challenge in developing the CVTMP is verifying that the community needs are being addressed as best as possible. The project team strove to develop content for the CVTMP that would not become outdated in the short term. The stakeholder meetings assisted the process of capturing the concerns and needs of the stakeholder community.

Data Collection

Connected vehicle systems provide a wealth of information that will need to be analyzed to provide benefits to the full spectrum of transportation mode users. Cross-jurisdictional coordination with neighbors and GDOT will be needed to ensure continuous benefits along corridors that may cross jurisdictional boundaries. Data analysis will provide greater understating to improve mobility and safety at a speed not previously accessible.

Recommendations

The deployment plan focused on a 5-year approach as summarized in Figure E2. By 2024, a significant number of vehicles are expected to be manufactured with connected vehicle-enabled capability. The 5-year plan is intended to provide a period of testing connected vehicle applications as Gwinnett County expands to a county-wide deployment, anticipating that the market saturation level in private vehicles will remain relatively low until 2024.

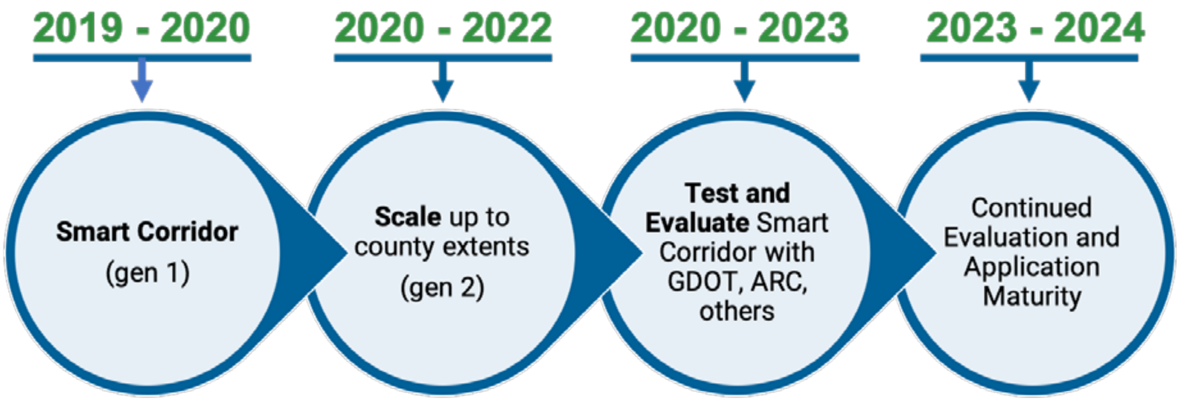


Figure E2. 5-Year Timeline

The deployment plan is summarized in Table E2. The approach begins with limited connected vehicle applications as part of the Smart Corridor project, which will demonstrate how connected vehicle applications can benefit a variety of users to improve safety and mobility and enhance traveler information. Then, Gwinnett County will coordinate with other agencies with respect to applications that have state-wide potential so that staff and financial resources are efficiently utilized. After testing and evaluating connected vehicle applications, the system can be expanded county-wide with applications that have proven benefits.

Table E2. 5-Year Deployment Plan

Application	Near-Term (2020) Smart Corridor project	Short-Term (2020-2022) In Coordination with ARC, GDOT	Long-Term (2020-2024) In Coordination with GDOT
1. All Solutions	• Deploy RSUs in the Smart Corridor area • Test connected vehicle data collection, analytics, and archiving	• State-wide; dashboard for intersection traffic signal operations (RR + EVP + TSP + FSP transition times) • State-wide; manage RR + EVP + TSP + FSP conditional requirements • Test connected vehicle-generated safety data alerts • Cybersecurity; deploy SCMS or similar system	• Deploy RSUs county-wide • Test county-wide connected vehicle data, analytics, and archiving • Deploy mission-critical connected vehicle-generated safety data alerts
2. Signal Phase and Timing (SPaT) Information	• Enable red light warning, phase termination/next signal phase, and green band speed applications	• Monitor benefits of safety applications related to fleet penetration of RSUs and cellular OBUs	• Monitor benefits of safety applications related to fleet penetration of DSRC/cellular OBUs
3. Emergency Vehicle Preemption (EVP)	• Enable EVP • Install OBUs on fire trucks	• State-wide; manage EVP conditional priority requirements	• Alerts for excessive transition time
4. Transit Signal Priority (TSP)	• Enable TSP • Install OBUs on transit vehicles	• Manage TSP conditional priority • Test schedule adherence conditional priority • Test bus occupancy conditional priority	• County-wide system development • Alerts for excessive transition time
5. Freight Signal Priority (FSP)		• Enable FSP • State-wide; manage FSP conditional priority • Develop commercial freight outreach program	• County-wide system development • Alerts for excessive transition time
6. Construction and Maintenance Vehicle Alert	• Enable alerts • Install OBUs and HMIs on select GCDOT vehicles	• State-wide; manage alert conditional requirements	• County-wide system development
7. Rail Intersection Blocked Alert	• Test railroad intersection blocked alert	• State-wide; evaluate railroad crossing safety applications • Evaluate railroad crossing prediction accuracy	• County-wide system development • Develop additional railroad crossing safety applications • **Enable predictive railroad crossing delay**
8. Mobile Accessible Pedestrian Presence Alert (PPA)	• Test alert from pedestrian push button activation at intersections	• Test transit and bus door open events • County-wide system development • Test applications for the visually impaired	• Test alert from pedestrian push button activation for mid-block pedestrians • County-wide system development

As part of the Smart Corridor project, Gwinnett County will deploy roadside units (RSUs), onboard units (OBUs), and test software, in collaboration with GDOT. The first applications to be developed and tested in 2020 are Signal Phase and Timing Information (SPaT), EVP, TSP, Construction and Maintenance Vehicle Alert, Railroad Intersection Blocked Alert, and Pedestrian Presence Alert (PPA).

The Smart Corridor project will include an "innovation solution" component, which is intended for the technology industry to showcase the most effective ways in which to apply connected vehicle technology and quickly provide benefits to the public. As part of the Smart Corridor project Request for Proposals, the contractor teams will be challenged to provide solutions that provide short-term public benefit, additional value, mobility benefits, and safety benefits. The outcome of the innovation solution is that Gwinnett County will improve the project value to the transportation users in Gwinnett County.

Before completing the Smart Corridor project, Gwinnett County will increase the level of technical staffing to support the goals for a successful connected vehicle program. The technical staffing level changes will occur in engineering and information technology (IT).

Years 2021 to 2022 will focus on further testing and evaluating the deployed solutions and developing additional applications, including pedestrian present at transit stops and Freight Signal Priority (FSP). An expansion of the connected vehicle-related communications system is also planned during this timeframe.

During this time period, the number of vehicles manufactured with connected vehicle-enabled capability will grow. Gwinnett County will experience first-hand learning about how drivers respond to messages generated by connected vehicle applications, as the market penetration of OBUs occurs over time.

Years 2023 to 2024 will focus on further evaluating and refining the developed applications and scaling the applications to other parts of Gwinnett County. A deployment timeline or the order of deployment to other parts of the county has not been determined but a strategy is outlined in Chapter 6.

By 2024, a significant number of new vehicles will be manufactured with connected vehicle capabilities. The applications that are appropriate and ready for county-wide deployment will be deployed, including further expansion of the connected vehicle-related communications system.

While all connected vehicle applications may not yet be fully mature, Gwinnett County will select and prioritize applications based on the results of the testing and evaluation phase. The anticipated safety and mobility benefits, number of users, cost, staffing, and amount of required hardware and software will be considered in making decisions regarding county-wide deployment.

Collaboration with GDOT and ARC will remain critical as technology and connected vehicle applications change. For instance, some applications may be better served by applications that can be displayed via human machine interface (HMI) installed in a vehicle, and some applications may be adequately served by a mobile device.

The mission-critical nature of providing first-line safety applications requires the connected vehicle system to be robust, redundant, and secure to the extent practical. To reduce pressure on the network communications system, applications that can be served at the "edge," such as by a local intersection, will be deployed first. Applications that require external triggers to be sent to the intersection through the network communications system will be considered supplementary.

As with any technology-oriented plan, potential exists for the plan to become obsolete before the horizon year occurs. As a result, the long-term recommendations will be considered advisory in nature. As Gwinnett County experiences the Smart Corridor project, the applications and communications approach will be reviewed to take advantage of the most beneficial methods of delivering connected vehicle benefits.

Gwinnett County and stakeholders understand that regional collaboration is critical to the success of connected vehicle deployments, especially when measured by value added to the general public. To ensure that investments made in deploying and developing connected vehicle solutions are responsible, strategic, and sustainable, the regional collaboration roadmap on Figure E3 was developed. The roadmap spans 5 years and identifies four areas of focus under one unified vision.

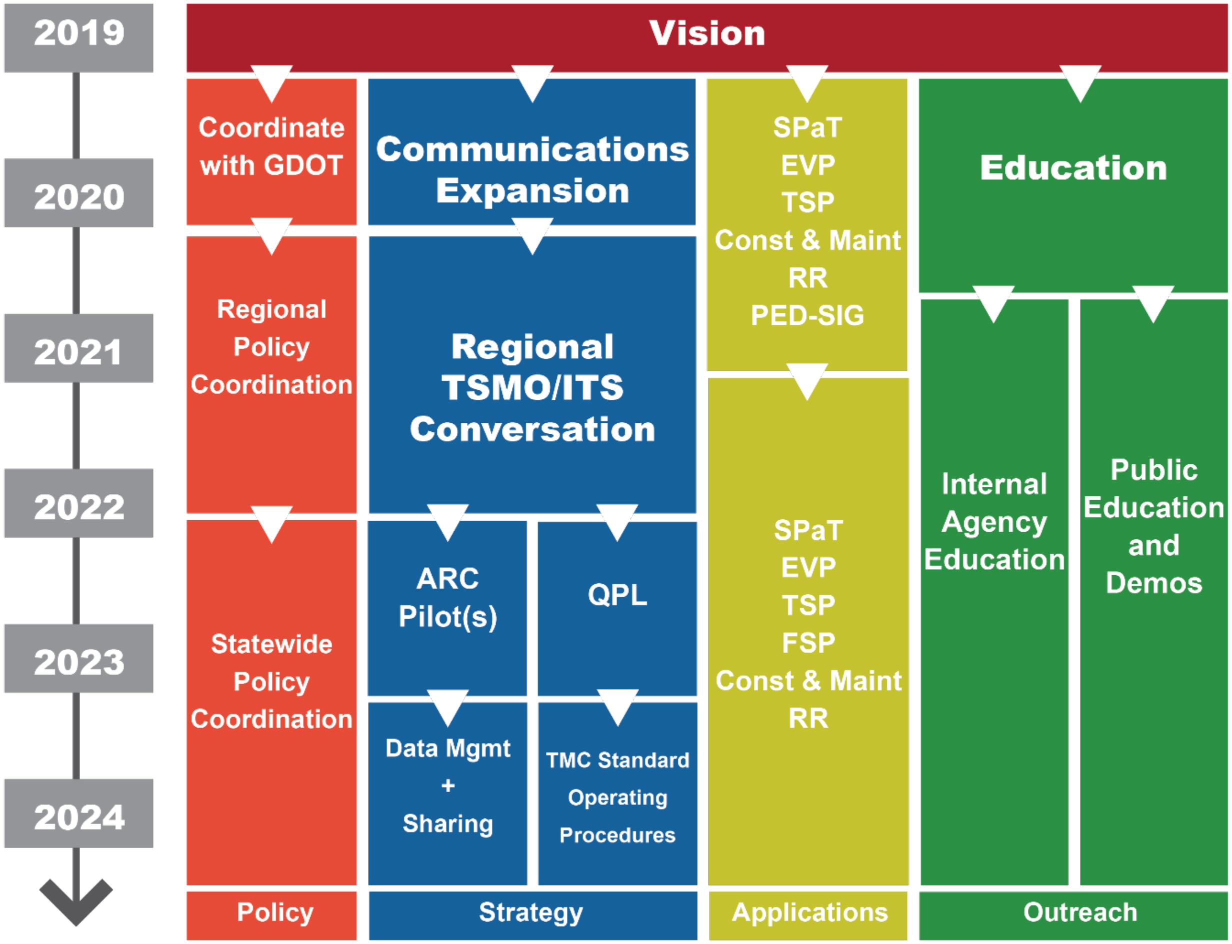


Figure E3. Regional Collaboration Roadmap

The first column, in red, focuses on coordination with GDOT and ARC for policy development. Policy coordination will focus on data governance, ensuring interoperability for the Atlanta region, and security of the system.

The second column, in blue, focuses on infrastructure and standards to be deployed and developed to ensure success. These tasks include expanding communications in areas to support connected vehicle deployments, developing performance-based standards for qualified product lists, continuing to collaboratively support innovation via efforts like the ARC pilots, and continuing regional TSMO and intelligent transportation system (ITS) conversations to establish data governance. For the plan for future fiber optic communications infrastructure, refer to the Gwinnett County *Intelligent Transportation Systems Master Plan* (2017).

The third column, in yellow, focuses on application development. Most communities across the State of Georgia have similar needs of improving safety for all roadway users and improving mobility for all modes. The focus will be on developing software that can be applied across a variety of community types with minimal cost and effort.

The fourth column, in green, focuses on education and marketing of the solutions first with the stakeholders of the CVTMP and the communities in which the first round of connected vehicle solutions will be made available. Before 2021, the deployed connected vehicle solutions will have been properly tested and calibrated so that communicating them across agencies and the general public can begin. For the connected vehicle solutions to have the greatest positive impact, mass adoptions of these solutions must be the main focus.

Future Plans

The current funding identified for the Smart Corridor project is $2.6 million. Expanding the connected vehicle system beyond the Smart Corridor area will require additional funding, which may be allocated via local funding and additional matching funds.

Expansion will need to be strategically prioritized to deliver the greatest benefit for road users with the available technology. For example, the county is made up of many cities, CIDs, fire districts, and transit routes, all of which must be considered.

CVTMP Contents

- Chapter 1 discusses the vision, goals, objectives, approach, application of the CVTMP to the State of Georgia, and overview of Gwinnett County.
- Chapter 2 provides a review of the industry both nationally and locally.
- Chapter 3 provides a technology review of connected and automated vehicles, including details such as communication methods, messaging capabilities, national considerations, and system-level considerations.
- Chapter 4 discusses the stakeholder engagement process and how the insights influenced the priority development process.
- Chapter 5 provides an overview of available connected vehicle applications.
- Chapter 6 discusses the connected vehicle deployment plan for Gwinnett County.
- **Appendix A** Interview Guiding Questions Regarding Recent Smart Mobility Deployments
- **Appendix B** Stakeholder Insights by Zone
- Appendix C Applications Being Tested Nationwide
- Appendix D CVTMP Presentation

CHAPTER 1 INTRODUCTION

CVTMP Vision

Gwinnett County aspires to identify and test the standard for the application of connected vehicle technology. The CVTMP will advance the use of technological enhancements in traffic management systems to improve traffic congestion and reduce crashes. The Peachtree Industrial Boulevard Corridor has been identified as a Smart Corridor project and will be the site of the first connected vehicle technology deployment as part of a separate effort.

A connected vehicle system will support economic development in Gwinnett County and will result in user cost savings associated with safety and mobility benefits, providing an attractive environment for business growth. County leadership envisions that the Smart Corridor project will be the first of several such projects to stem from this CVTMP and will have broad applicability not only in Gwinnett County, but in the Atlanta region and across the State of Georgia.

The CVTMP identifies how to set up a connected vehicle system, including costs, benefits, applications, equipment (both hardware and software), and personnel requirements. It will also help agencies charged with traffic safety and mobility manage expectations and costs and fully realize the benefits of these new technologies as envisioned in existing public documents published by the United States Department of Transportation (USDOT) (Figure 1).

Source: USDOT. Connected Vehicles Pilot Deployment Program

Figure 1. Visual Representation of Connected Vehicle Applications

CVTMP Goals and Objectives

The goals of the CVTMP are as follows:

- Leverage the county's transportation system to improve economic vitality and quality of life
  - Identify the potential safety and mobility benefits available to all road users with deployment of connected vehicle infrastructure
  - Reduce congestion and crashes to improve quality of life and commute times
- Understand the needs and challenges to ensure regional and state-wide compatibility
  - Provide benefits to those using motorized modes (drivers, transit riders, and first responders), ensuring the benefits are seamless across the county and neighboring jurisdictions
  - Provide benefits to those using non-motorized modes (pedestrians, cyclists, and construction and maintenance workers), ensuring the benefits are seamless
- Establish guidelines for deploying a new and evolving technology
  - Understand the current state of connected vehicle technology and the plans of automakers for equipping future models with the technology
  - Understand the capabilities of connected vehicle applications to prepare Gwinnett County for deploying this technology county-wide and supporting it into the future
  - Deliver a transportation system that uses the most recent advances in technology
- Have broad applicability across the county, Atlanta region, and State of Georgia
  - Improve mobility for congested corridors that serve local and regional (inter-county) trips
  - Demonstrate the capabilities of connected vehicle technologies in a Smart Corridor project, which will prepare Gwinnett County for deploying similar technology county-wide
- Set the standard for implementing connected vehicle technology for a local government
  - Ensure the recommended connected vehicle system is compatible with the state's system, to maintain functionality at a regional scale
  - Evaluate scalability and design considerations for short-term needs as well as needs for long-term growth

The 2017 Comprehensive Transportation Plan (CTP) effort collected insight from Gwinnett County citizens on what they prioritize when it comes to improving mobility within the county (Figure 2). The feedback was incorporated in this planning effort to ensure that the proposed solutions are a direct response to the needs of Gwinnett County citizens.

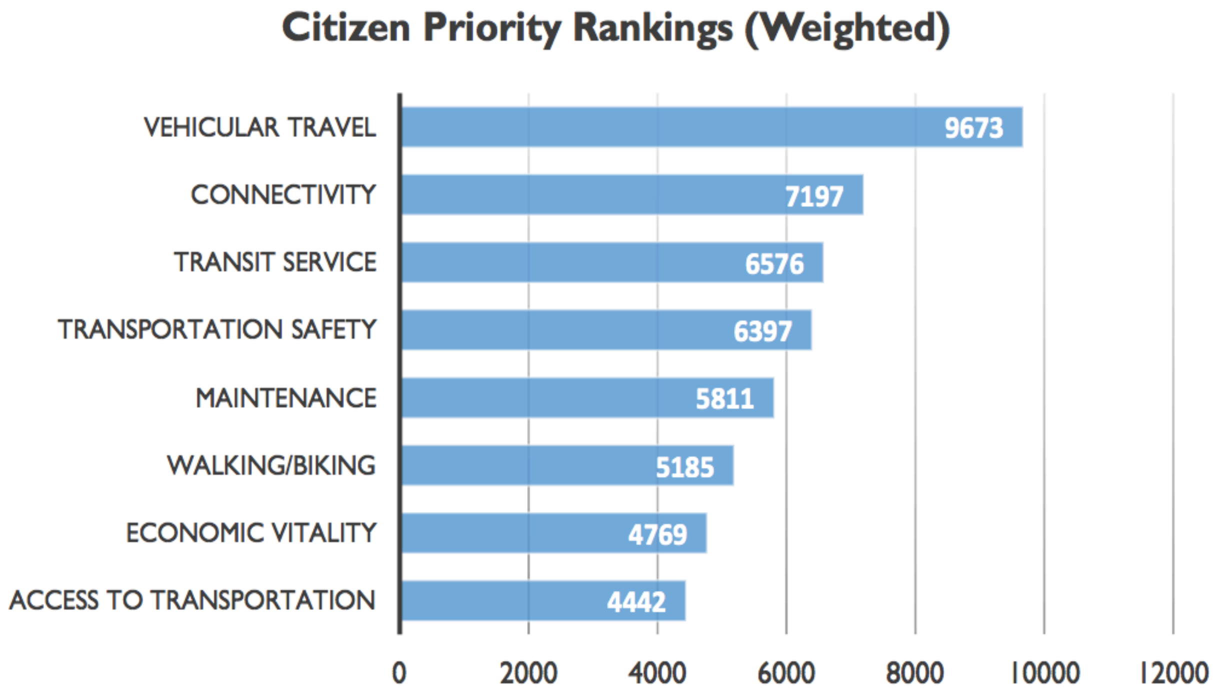


Figure 2. Citizen Priority Rankings from the 2017 CTP

In addition to incorporating citizen priority rankings, the CVTMP focuses on the following questions to ensure that all road users are considered. This allows for a focus on unintended impacts of new technology solutions. Some of the CVTMP considerations are illustrated in Figure 3.

- How can technology improve the balance between safety and efficiency?
- How can high vehicle market penetration be achieved for application usability?
- How can equitable access be provided to support relevant safety messages to all road users?
- How can data, system ownership, and security concerns be managed properly?

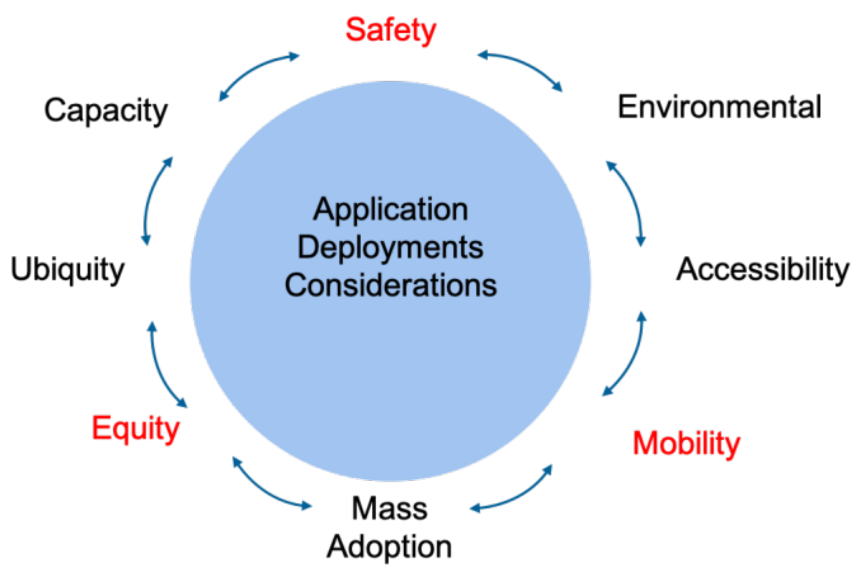


Figure 3. CVTMP Considerations

The objectives of the CVTMP are as follows:

- Meets Gwinnett County's needs based on stakeholder input and identified needs

- Supports the goals of the 2017 *Comprehensive Transportation Plan* (CTP), 2018 *Connect Gwinnett Transit Plan*, and 2017 *Intelligent Transportation Systems Master Plan*
- Is compatible with GDOT deployments so that the system operates seamlessly within the county, Atlanta region, and State of Georgia
- Is compatible with the vision of USDOT and supports the national conversation about the future of transportation
- Is interoperable using the protocols and standards adopted by industry
- Can be replicated by other jurisdictions
- Is scalable and flexible with respect to expanding the system with future deployments
- Is deployment friendly in that system expansion can be planned, designed, constructed, and operated efficiently

CVTMP Approach

The CVTMP has a phased approach for deploying connected vehicle technology solutions based on opportunity and need in three zones of the county, as shown in Figure 4.

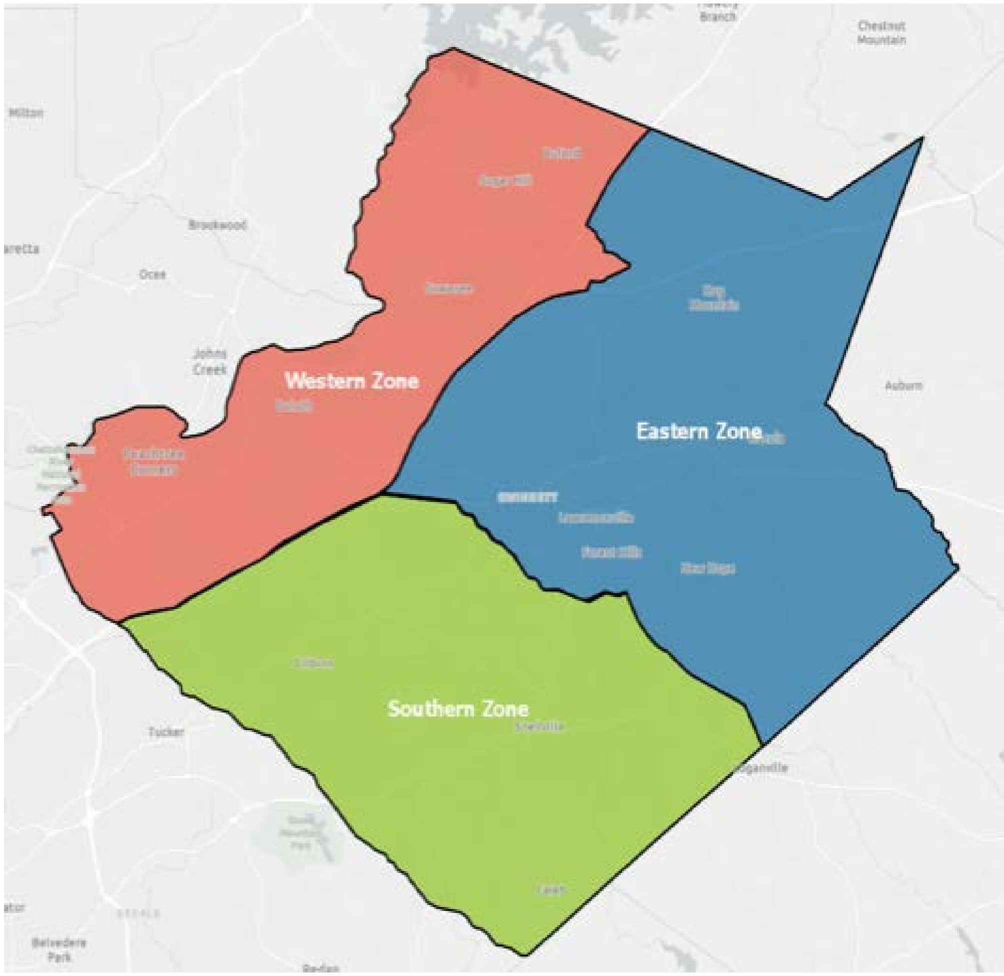


Figure 4. Deployment Zones

The Smart Corridor project covers most of the western zone. The eastern and southern zones will build on the findings of the Smart Corridor project but do not have identified timelines associated with deployment of connected vehicle technology. The deployment of traffic signals could be divided in a similar manner, should project funding be available in amounts that support wide-scale deployment.

The approach is to deploy and test connected vehicle technology and application as part of the Smart Corridor project before expanding to the rest of Gwinnett County based on a strategy detailed in Chapter 6. A recommended strategy is to identify where and when to expand the connected vehicle system. This includes:

- Coordinate with GDOT to outfit additional intersections with RSUs
- Deploy connected vehicle infrastructure in batches of 75 to 175 traffic signals per phase
- Focus on outfitting signals that serve FSP and TSP

If funding is available in smaller increments, then deployments will be targeted at:

- Area surrounding the Mall of Georgia and Coolray Field
- Area surrounding Gwinnett Place Mall
- Major commuter corridors, such as Sugarloaf Parkway
- Downtown areas, such as Lawrenceville, Lilburn and Snellville

Deployments will need to be cognizant of Fire District boundaries

Application to the State of Georgia

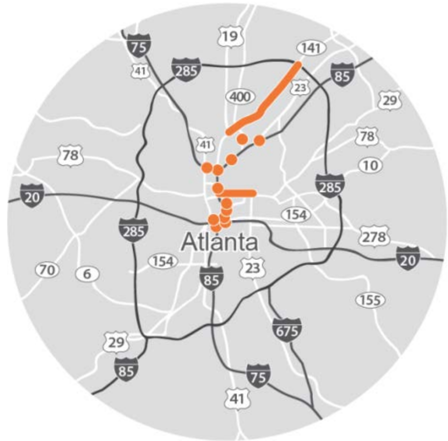
One of the main goals of the project is to develop connected vehicle-based solutions that meet the needs of Gwinnett County and can be easily replicated across the State of Georgia. State-wide application will also meet one of the goals of the Georgia Smart Communities Challenge program.

GDOT has initiated the deployment of infrastructure that supports connected vehicle technology. The GDOT approach focuses on four primary areas: safety, mobility, freight, and partnerships. Through the process of developing the CVTMP, GDOT and Gwinnett County coordinated extensively to coordinate interoperability of the connected vehicle systems deployed by each jurisdiction. This collaborative approach has the potential to leverage additional funding and begin to standardize configurations and processes from which other jurisdictions would benefit.

GDOT's goals related to connected vehicles are as follows:

- Primary goal: Develop back-end infrastructure, network components, and business processes to support broad vehicle-to-infrastructure (V2I) and infrastructure-to-vehicle applications that are broadcast-medium agnostic, scalable, and sustainable.
- Secondary goal: Begin broad installation of RSUs and equipped vehicles to facilitate applications that improve safety and mobility.

To this end, GDOT has deployed RSUs at the locations illustrated on Figure 5. GDOT is moving forward with deploying RSUs along RTOP corridors shown on Figure 6.



Source: GDOT

Figure 5. GDOT Phase 1 Pilot Deployment of RSUs

Source: GDOT

Figure 6. GDOT Phase 2 Planned RSU Deployments

Overview of Gwinnett County

Gwinnett County is a diverse and vibrant county located approximately 30 miles northeast of Atlanta (Figure 7). The county is approximately 433 square miles and has 105 miles of Chattahoochee river front. Gwinnett County contains 16 cities and 5 CIDs (Figure 8, Table 1).

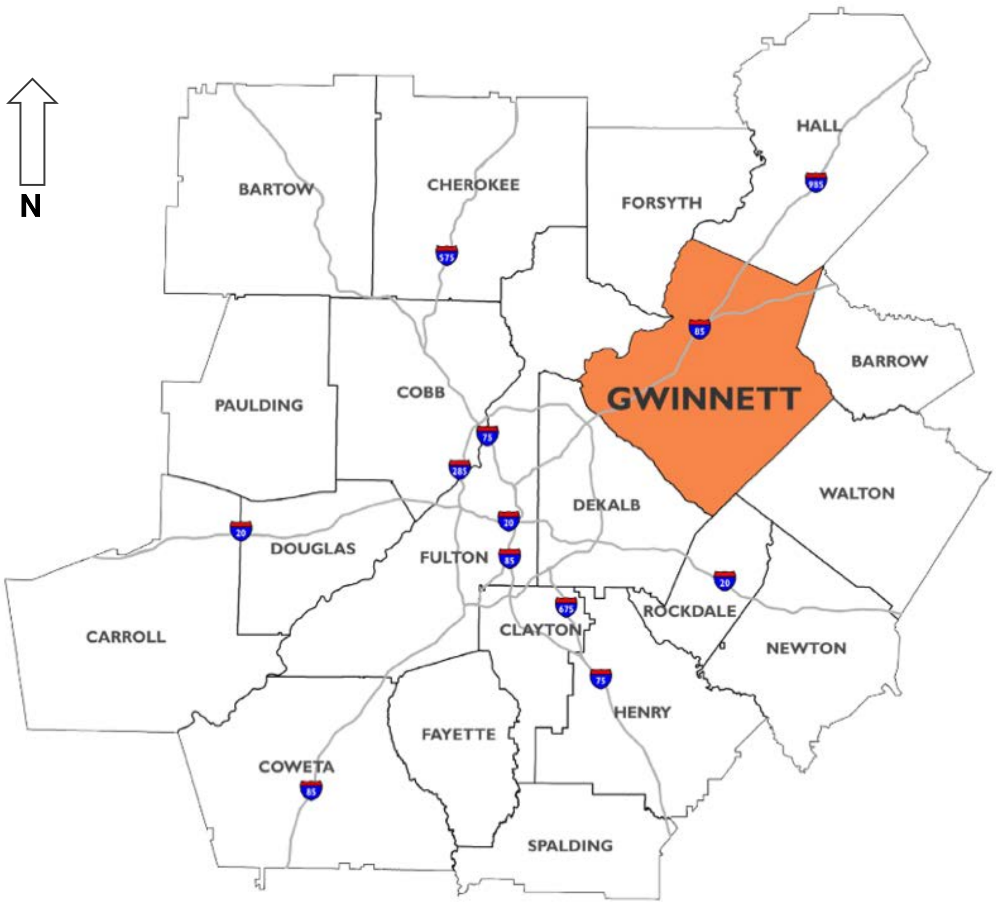


Figure 7. Location of Gwinnett County in Relation to Metro Atlanta

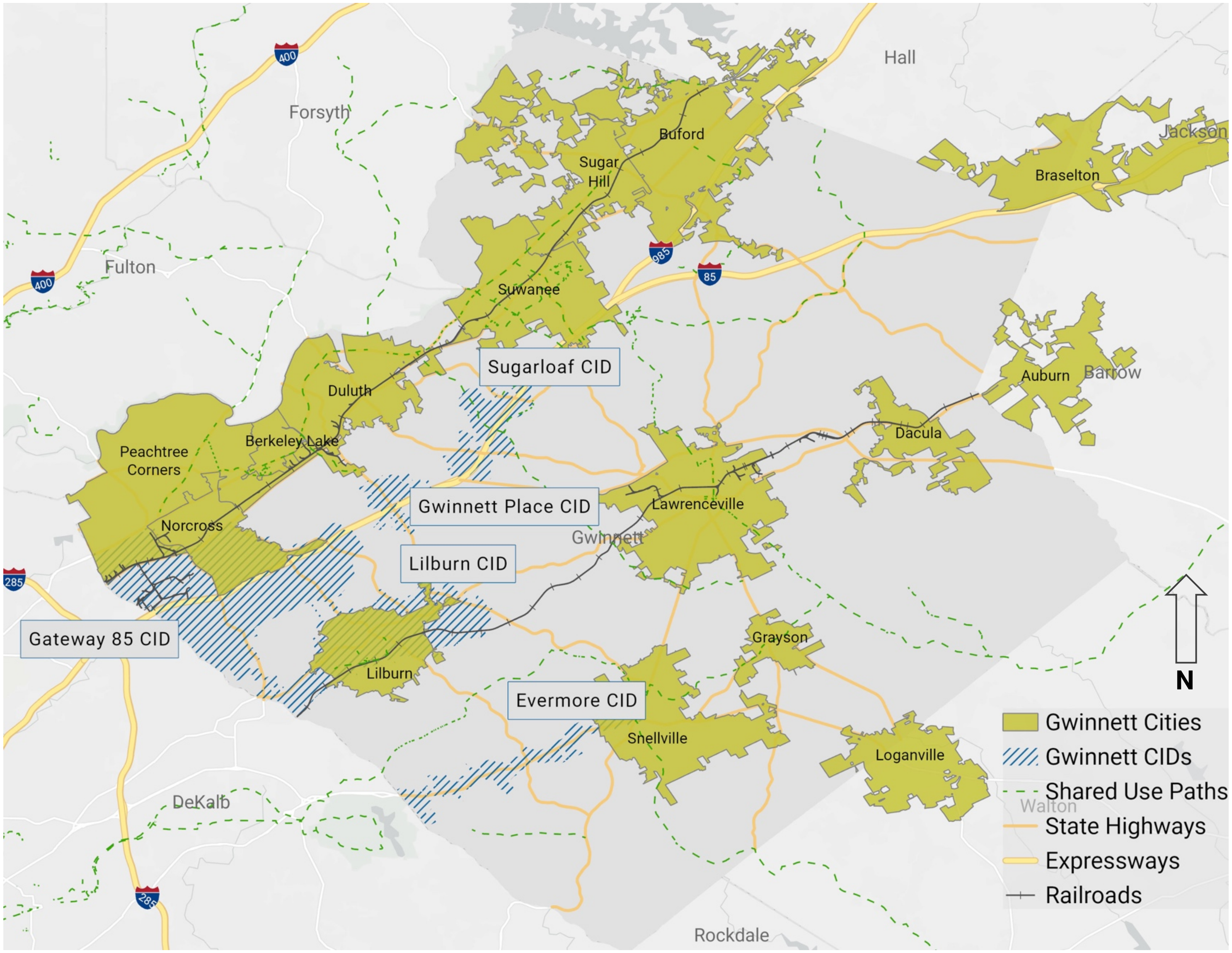


Figure 8. Overview Map of Gwinnett County

Table 1. Cities and CIDs in Gwinnett County

Cities	Cities	CIDs
Auburn	Lilburn	Evermore
Berkeley Lake	Loganville	Gateway 85
Braselton	Norcross	Gwinnett Place
Buford	Peachtree Corners	Lilburn
Dacula	Rest Haven	Sugarloaf
Duluth	Snellville	
Grayson	Sugar Hill	
Lawrenceville	Suwanee	

Planning Efforts

Over the past few years Gwinnett County has developed several planning documents each of which was referenced for insight during this planning effort. The referenced plans include:

- *Destination 2040 – Gwinnett's Comprehensive Transportation Plan* (CTP), 2017[1]
- *Gwinnett Countywide Trails Master Plan*, 2018[2]
- *Connect Gwinnett Transit Plan*, 2018[3]
- *2040 Unified Plan*, 2018[4]
- *Intelligent Transportation Systems Master Plan,* 2017

[1] https://www.gwinnettcounty.com/web/gwinnett/departments/transportation/comprehensivetransportationplan.
[2] https://www.gwinnettcounty.com/static/upload/bac/52/20180220/m_2018.02.20%20-%20Briefing%20Unofficical%20Minutes%201030am.pdf.
[3] https://www.gwinnettcounty.com/web/gwinnett/departments/transportation/connectgwinnett.
[4] https://www.gwinnettcounty.com/web/gwinnett/Departments/2040UnifiedPlan.

Growth

Gwinnett County has experienced rapid growth over the past few decades. From 2000 to 2010, the population grew 36% from 588,488 to 805,321 people and is expected to grow by 66% to 1,341,000 people by 2040.

Employment has increased by 8,700 jobs annually since 2013. Based on the historical growth rate, 120,000 jobs are expected to be added by 2030. Retail trade currently has the largest share (15%) of current jobs in the county. The largest employment growth sectors between 2003 and 2015 are education, healthcare, professional and scientific, retail, accommodations and food services, public administration, and information.

Mobility

Gwinnett County currently manages over 2,600 miles of public roadways and 729 traffic signals. Approximately 550 traffic signals communicate with the Gwinnett County Traffic Control Center (TCC). There are also 230 miles of fiber optic cable, approximately 260 closed circuit television (CCTV) cameras, and approximately 220 flashing beacons. The transportation assets are shown on Figure 9.

Two top concerns for Gwinnett County as mitigating congestion and ensuring public safety, the ITS Master Plan focused on strategies to address both. The 2017 ITS master planning effort identified 8 short-term projects, 11 mid-term projects, and 6 long-term projects. Identified projects of relevance to Gwinnett County are identified in Chapter 6.

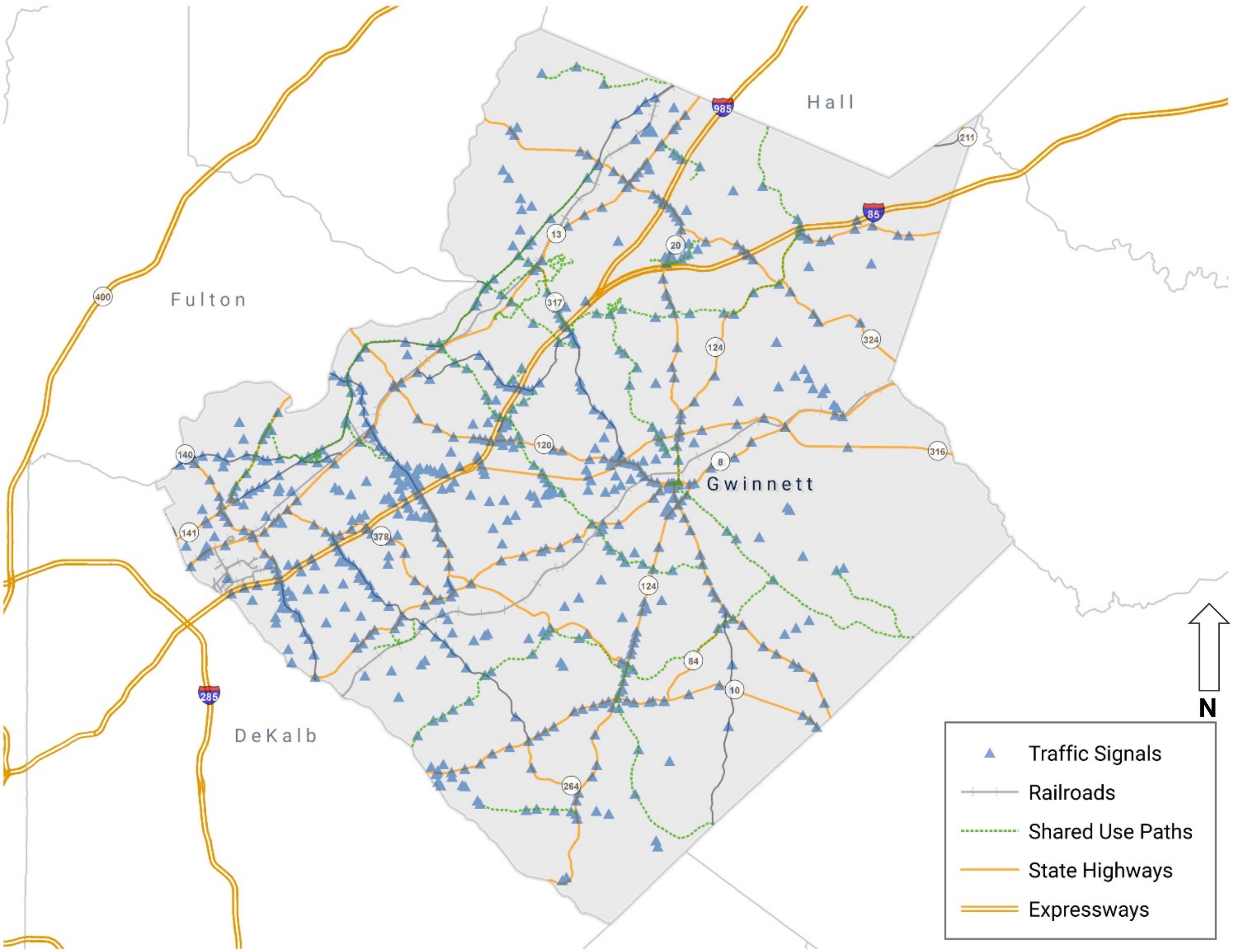


Figure 9. Map of Traffic Signals in Gwinnett County

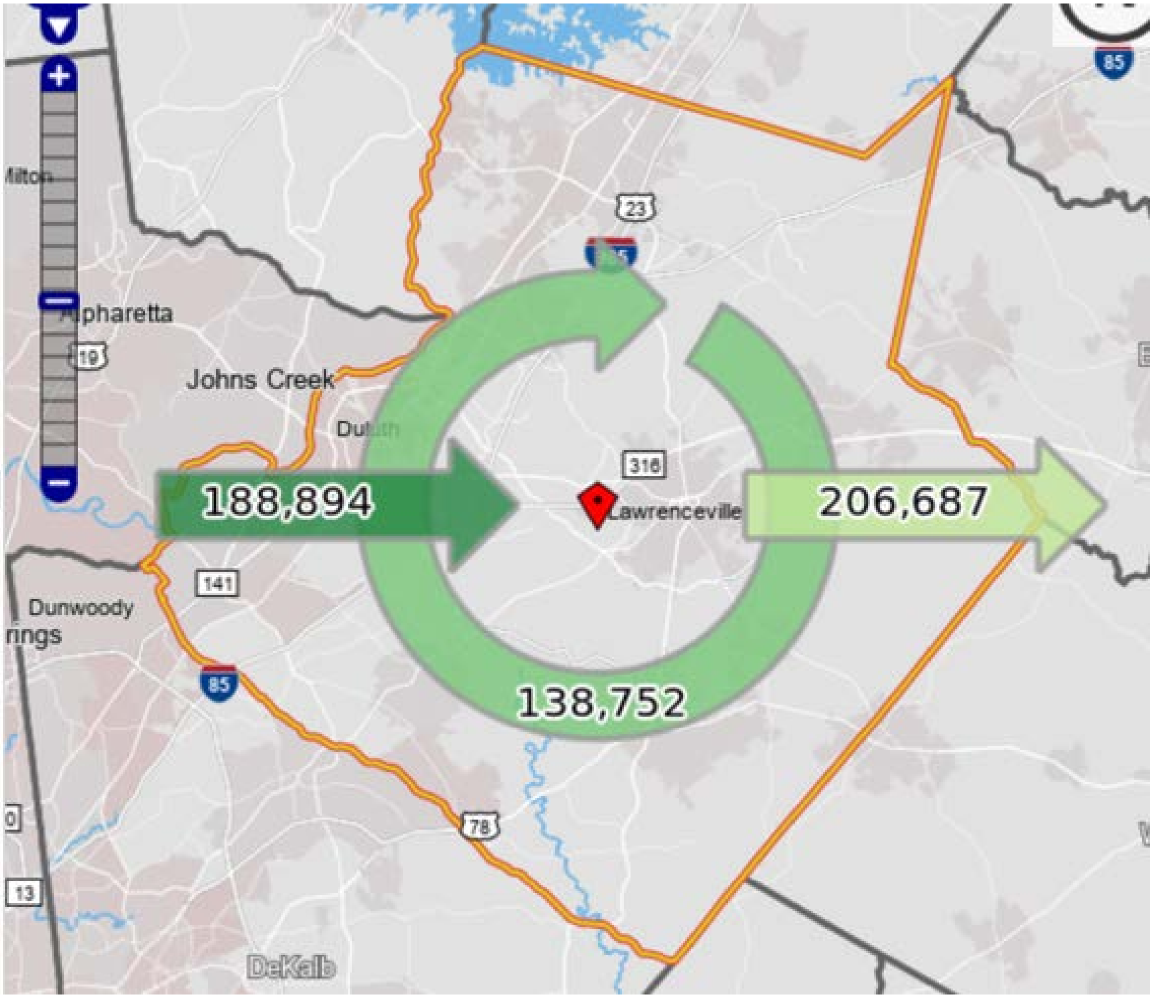
As documented in the CTP, Gwinnett County serves a significant amount of freight activity to and through the county. Gwinnett County has six major freight distribution facilities and 141 miles of truck routes.

OnTheMap (US Census) provides insights about mobility characteristics for where people work and live. Figure 10 shows work-based trips for Gwinnett County. In 2015, 327,646 people were employed in Gwinnett County. Of those employed, 58% (188,894) employed in Gwinnett County lived outside of the county and 42% (138,752) worked and lived in Gwinnett County. Of those who lived in Gwinnett County, 60% (206,687) were employed outside of the county and 40% (138,752) were employed within the county.

Gwinnett County Transit (GCT) operates seven local bus routes, five express commuter bus routes, and a microtransit pilot project in Snellville. GRTA Xpress runs four routes from Gwinnett County. The *Connect Gwinnett Transit Plan* needs assessment found that in 2015 184,000 people were served by fixed route transit (express service excluded) and that by 2040, if the transit plan is implemented, the population served could increase to 294,000.[5]

See Figure 11 for the railroad system in Gwinnett County, which includes 55 miles of railroad lines.[6]

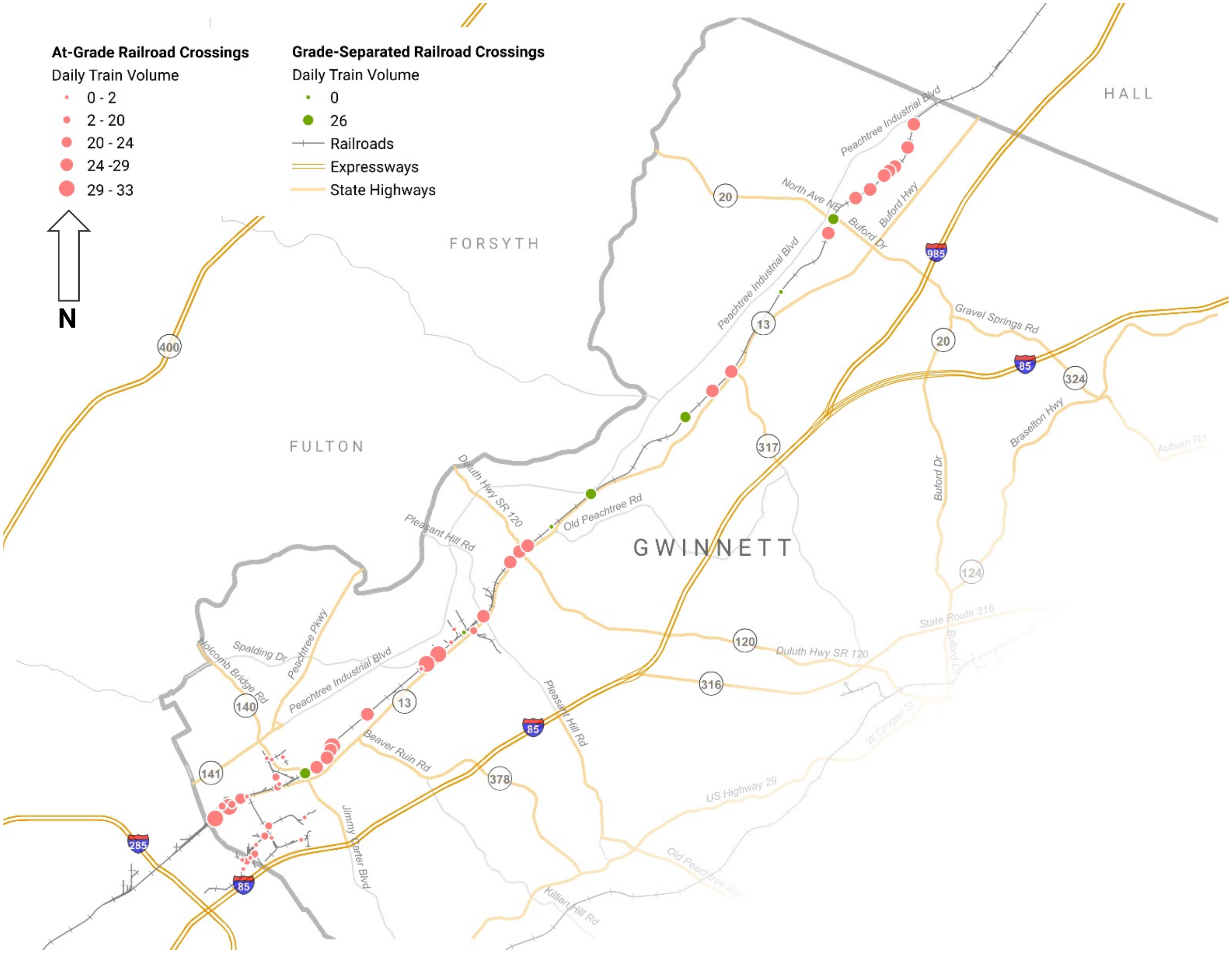
[5] https://www.gwinnettcounty.com/static/departments/transportation/pdf/Connect_Gwinnett_Needs%20Assessment_Report.pdf.
[6] https://www.gwinnettcounty.com/static/departments/transportation/CTP/pdf/CTP%20Existing%20Conditions%20Report%20-%20December%202016.pdf.



Source: U.S. Census Bureau, Center for Economic Studies

Commuter movements in Gwinnett County: 188,894 trips travel into the county for work, 138,752 stay within the county, and 206, 687 trips leave the county for work.

Figure 10. Work-Based Origin and Destination Trip Flows for Gwinnett County (2015)



Source: GDOT Office of Transportation Data

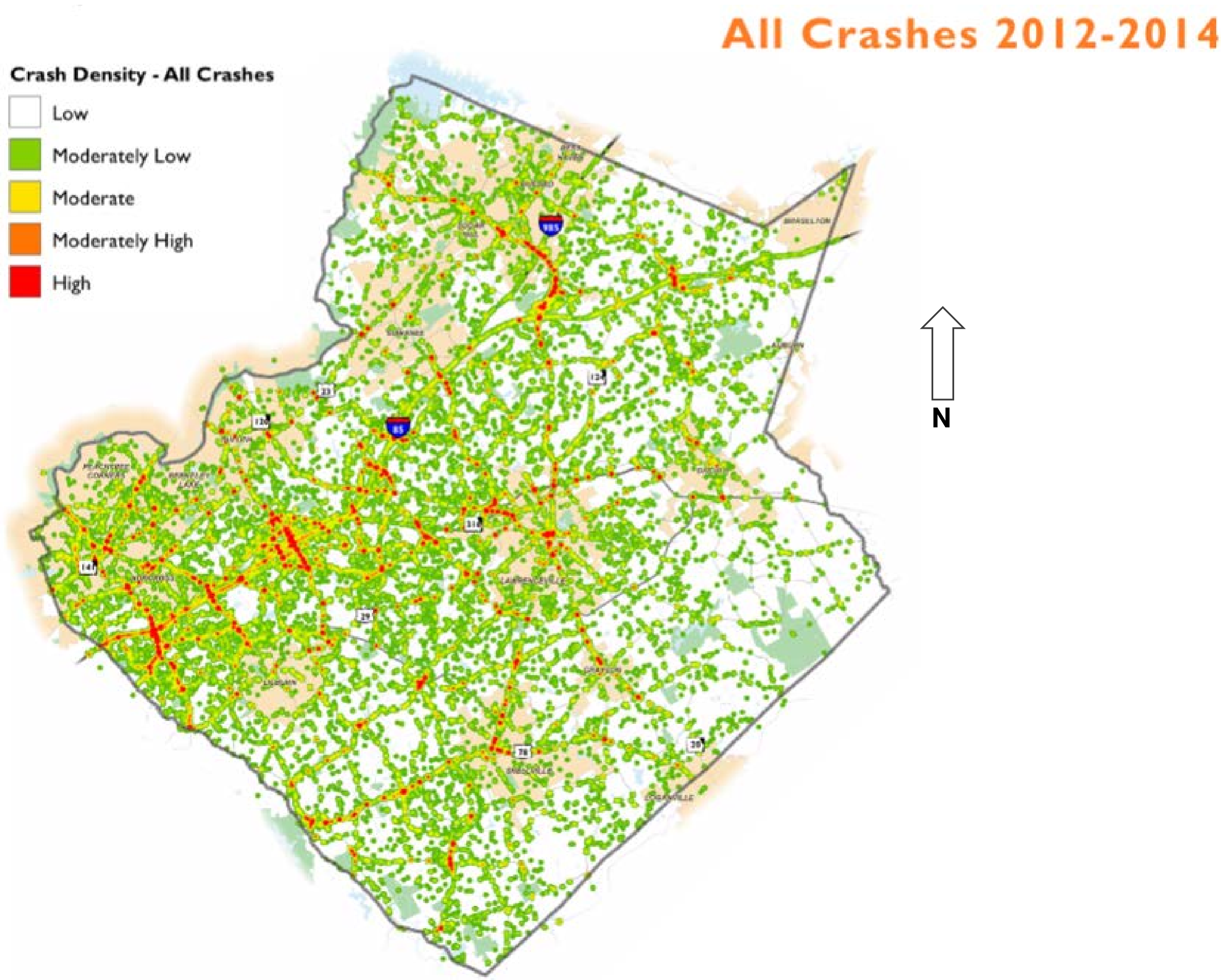
Figure 11. Map of At-Grade Rail Crossings in Western Gwinnett County

Safety

In 2016, automobile-related crashes claimed 38,758 lives in the US.[7] Vehicle crashes are a leading cause of death for people under the age of 45.[8] Over time, connected and automated vehicle deployments are anticipated to have a significantly positive impact on transportation safety.

The Gwinnett County CTP analyzed three years of crash data (2012 to 2014). A total of 94,022 crashes and 257 fatalities were reported during the three-year period. Figure 12 illustrates the distribution of all reported crashes in Gwinnett County. In total, 4,754 (5%) involved a truck, 822 (1%) involved a pedestrian, and 167 (0.2%) involved a bicyclist.

[7] McKinsey & Company. "Gauging the disruptive power of robo-taxis in autonomous driving." October 2017. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/gauging-the-disruptive-power-of-robo-taxis-in-autonomous-driving.
[8] CDC Nonvital Statistic Reports. https://www.cdc.gov/nchs/data/nvsr/nvsr67/nvsr67_05.pdf.



Source: Gwinnett County CTP

Figure 12. Crash Density Across all Crashes in Gwinnett County (2012-2014)

CHAPTER 2 INDUSTRY REVIEW

United States Department of Transportation Connected Vehicle Pilot Deployment Program

USDOT is supportive of deploying connected vehicle technology, including DSRC technology, and testing cellular vehicle-to-everything (C-V2X) technologies, to support safety, mobility, and automation. The USDOT connected vehicle research program is a multimodal initiative to enable safe, interoperable, networked wireless communications among vehicles, infrastructure, and personal communications devices. USDOT has funded connected vehicle deployments in Tampa, Florida; New York City, New York; and Wyoming. Those deployments support hundreds of RSUs and thousands of in-vehicle units. Below are descriptions of the three pilot deployments.

Tampa Hillsborough Expressway

Tampa's tolling agency, Tampa-Hillsborough Expressway Authority (THEA), is hosting another USDOT DSRC deployment. The deployment includes the Selmon Reversible Express Lanes (REL), which has a morning commute endpoint intersection on major routes into and out of the downtown Tampa commercial business district. The THEA pilot (Figure 13) will deploy a variety of vehicle-to-vehicle (V2V) and V2I applications to relieve congestion, reduce collisions, and prevent wrong way entry at the REL exit. THEA also plans to use connected vehicle technology to enhance pedestrian safety and speed bus operations and reduce conflicts between street cars, pedestrians, and passenger cars at locations with high volumes of mixed traffic. The THEA Connected Vehicle Pilot will employ DSRC to enable transmissions among approximately 1,600 cars, 10 buses, 10 trolleys, 500 pedestrians with smartphone applications, and approximately 40 RSUs along city streets.

Figure 13. THEA Connected Vehicle Pilot Area Overview

New York

The focus of this pilot is intersections in a major urban area. New York City will be deploying nearly 500 RSUs and roughly 8,000 OBUs. The New York City Department of Transportation (NYCDOT) Connected Vehicle Pilot Deployment project area encompasses three distinct areas in the boroughs of Manhattan and Brooklyn (see Figure 14). The first area includes four one-way corridors in Manhattan. The second area covers a 1.6-mile segment of Flatbush Avenue in Brooklyn. The third area includes a 4-mile segment of Franklin D. Roosevelt (FDR) Drive in the Upper East Side and East Harlem neighborhoods of Manhattan. The fleet will include approximately 5,800 cabs, 1,250 Metropolitan Transit Authority buses, 400 commercial fleet delivery trucks, and 500 city vehicles that will be fit with the connected vehicle technology. Using DSRC, the deployment will include approximately 310 signalized intersections for V2I technology. In addition, NYCDOT will deploy eight RSUs along the higher-speed FDR Drive to address challenges such as short-radius curves, a weight limit, and a minimum bridge clearance and 36 RSUs at other strategic locations throughout the City to support system management functions.

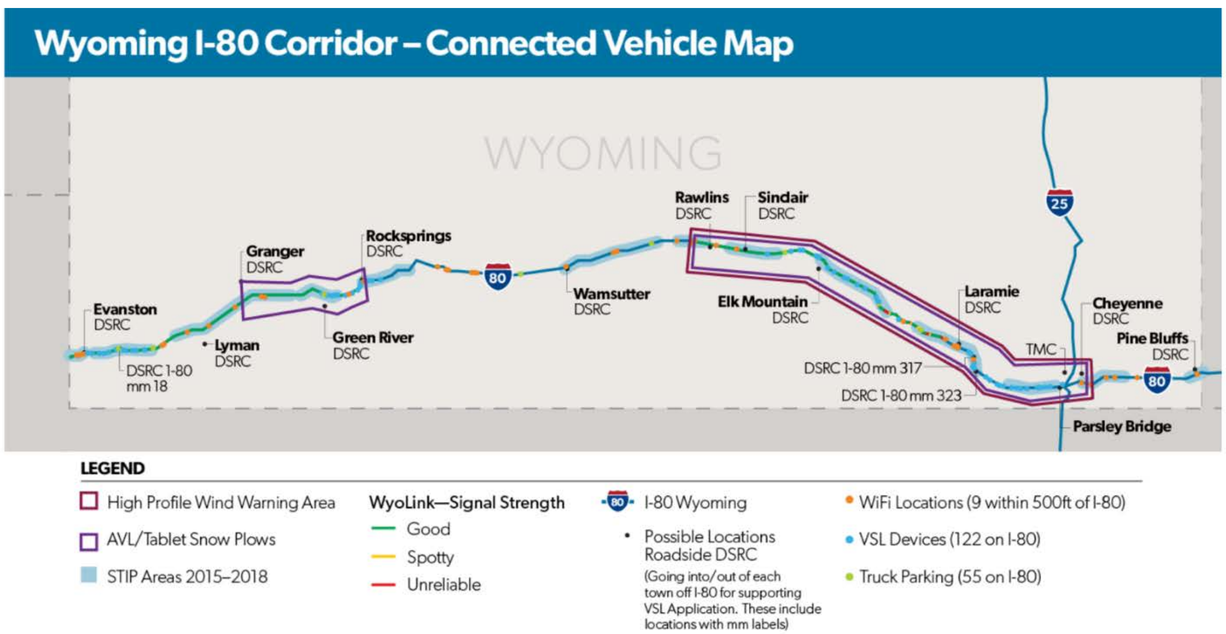
Manhattan Grid *Central Brooklyn – Flatbush Avenue* *Manhattan – FDR Drive*

Source: USDOT

Figure 14. New York City Connected Vehicle Pilot Area Overview

Wyoming

Interstate 80 (I-80) in southern Wyoming is a major corridor for east-west freight movement and moves more than 32 million tons of freight per year (Figure 15). During winter seasons when wind speeds and wind gusts exceed 30 mph and 65 mph, respectively, crash rates on I-80 have been found to be three to five times as high as summer crash rates. Wind speeds resulted in 200 truck blowovers within 4 years and often led to road closures. This pilot site focuses on the needs of the commercial vehicle operator in the State of Wyoming and will develop applications that use V2I and V2V connectivity to support a flexible range of services from advisories including roadside alerts, parking notifications, and dynamic travel guidance. The Wyoming Department of Transportation (WYDOT) Connected Vehicle Pilot is expected to reduce the number of blowover incidents and adverse weather-related incidents in the corridor to improve safety and reduce incident-related delays.



Source: USDOT

Figure 15. Wyoming Connected Vehicle Pilot Area Overview

WYDOT will develop systems that support connected vehicle technology along the 402 miles of I-80 in Wyoming. Approximately 75 RSUs that can receive and broadcast messages using DSRC will be deployed along various sections of I-80. WYDOT will equip around 400 vehicles, a combination of fleet vehicles, and commercial trucks with OBUs. Of the 400 vehicles, at least 150 would be heavy trucks that are expected to be regular users of I-80. In addition, of the 400 equipped-vehicles, 100 WYDOT fleet vehicles, snowplows, and highway patrol vehicles will be equipped with OBUs and mobile weather sensors.

Connected Vehicle Projects in Georgia

The past few years have proven to be exciting in the Metro Atlanta area as municipalities and local agencies have begun deploying and testing connected vehicle applications and automated vehicles. Projects involving connected vehicle technology are identified on Figure 16.

- In 2018, GDOT announced that by 2020 the agency would install 1,700 RSUs across the Metro Atlanta area.[9]
- In 2017, the City of Atlanta released a request for proposal for a Smart Corridor deployment on North Avenue, which has culminated in several deployments, including RSUs that communicate with DSRC and cellular technology along and near the corridor highlighted in orange.[10]
- In March 2018, the City of Chamblee published Phase 1 planning work for a shared autonomous vehicle (SAV) shuttle to operate in mixed traffic along Peachtree Street. The City of Chamblee is also part of the inaugural Georgia Smart cohort. As part of the challenge, the City of Chamblee will "produce a 'Best Practices Manual,' a set of recommendations for Chamblee and other local governments to follow as they introduce SAVs onto public streets."[11]
- In 2018, the City of Peachtree Corners announced that they were preparing to deploy an automated vehicle shuttle along Tech Parkway. Since then, the City of Peachtree Corners has announced that DSRC OBUs would be installed at traffic signals within the City.
- In 2019, ARC along with other critical partners including GDOT began efforts to deploy at least 1,000 C-V2X devices throughout Metro Atlanta via an initiative called CV1k.

All of these projects have been considered in the development of the CVTMP and the leaders of those projects have been engaged during the CVTMP process. In addition to these projects, which are in the vicinity of Gwinnett County and along which many vehicle trips in Gwinnett County originate or terminate, other initiatives have also begun. For example, Cobb County and the City of Marietta have deployed and plan to deploy more connected vehicle projects.

[9] https://traffic.transportation.org/wp-content/uploads/sites/26/2018/07/GDOT-Connected-Vehicles.pdf.
[10] https://www.govtech.com/civic/Atlantas-Smart-Corridor-to-Serve-as-Living-Lab-for-Smart-Transportation.html.
[11] https://www.chambleega.com/530/Georgia-Smart-Communities-Challenge.

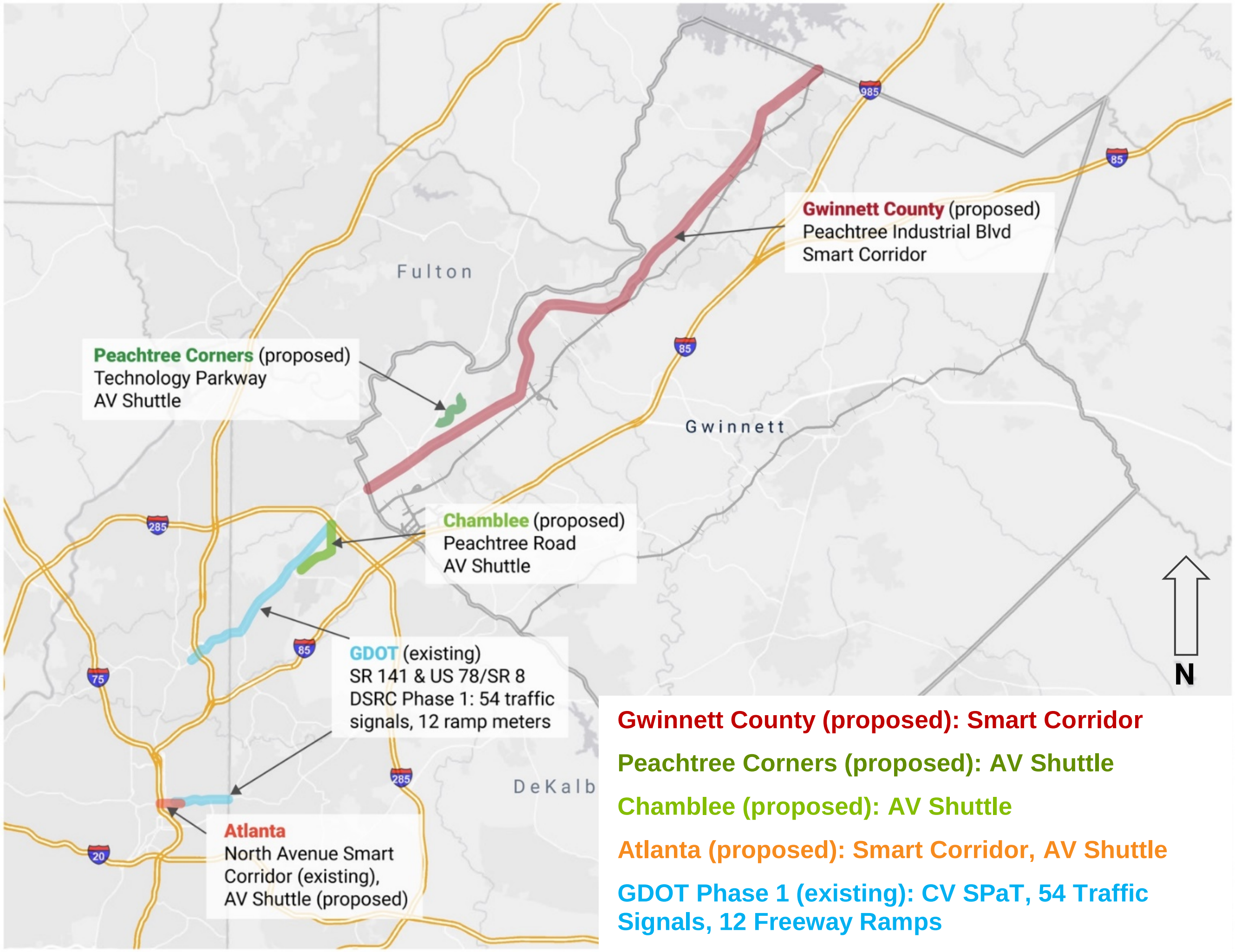


Figure 16. Existing and Proposed Connected Vehicle Projects near the Smart Corridor Area

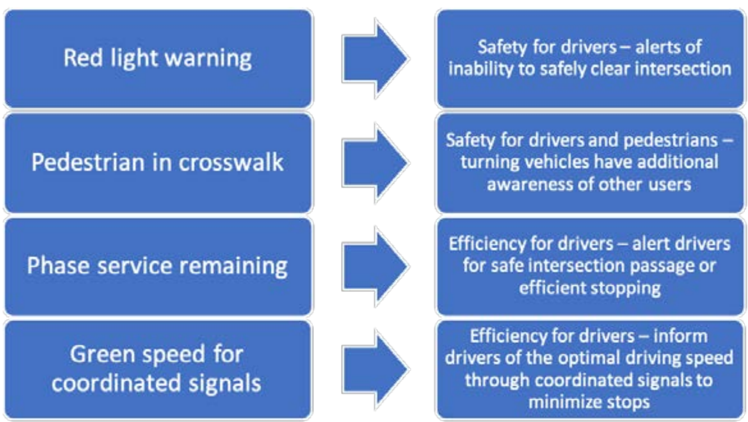
Georgia Department of Transportation

GDOT plans to deploy 1,700 RSUs within the corridors managed by the RTOP as shown on Figure 17. The system is designed to support connected vehicles through communication with infrastructure.

The first phase deployment is intended to focus on the safety and mobility applications listed in Figure 18. GDOT was awarded an Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) grant in the summer of 2019 to distribute and install 950 RSUs and 1,000 OBUs. This will allow for safety information from RSUs to be received by a limited number of road users: those who have a GDOT-issued OBU and cars with built-in DSRC communications like the 2017 Cadillac CTS and newer.12 As more vehicles are able to receive broadcasted information from infrastructure, whether through DSRC or cellular communications, the benefits related to connected vehicle applications will emerge and grow over time. Collaboration across private and public agencies is critical to the success of the connected vehicle applications.

Source: GDOT

Figure 17. RTOP Corridors in Metro Atlanta



Source: GDOT

Figure 18. GDOT Phase 1 SPaT Applications

[12] https://media.cadillac.com/media/us/en/cadillac/news.detail.html/content/Pages/news/us/en/2017/mar/0309-v2v.html.

Partnerships

GDOT is partnering with providers of connected vehicle technology as well as local jurisdictions to ensure the interoperability of deployed systems. GDOT is open to connected vehicle technology that is proven, available, and interoperable and conforms to national standards. Throughout development of the CVTMP several coordination meetings were held with GDOT staff. GDOT has agreed to partner with and support Gwinnett County in deploying connected vehicle solutions by:

- Filing Federal Communications Commission (FCC) license for GDOT RSUs
- Providing guidance on FCC filing requirements associated with GDOT RSUs
- Obtaining laboratory results of DSRC compatibility testing from the Southwest Research Institute
- Providing guidance with the intersection permitting process at intersections under GDOT's jurisdiction, which is managed by the GDOT Office of Traffic Operations
- Providing EVP/ TSP software that functions in coordination with DSRC and OBUs
- Providing controller interface technology (MaxTime CV) to local agencies at no cost
- Providing web feed application of CV (MaxView CV) to local agencies at no cost

Freight

Freight is a key part of advanced transportation deployment. Due to the value of time to the freight industry, freight fleets are most likely to purchase and deploy quantities of in-vehicle equipment. Freight-related connected vehicle solutions will improve freight company profitability through mobility improvements in safety and efficiency. Freight movers have historically been early adopters of telematics and connected vehicle systems. Given the geography of Georgia with respect to freight movement, Georgia is a logical location to continue this trend. GDOT previously conducted planning studies for freight connectivity and is considering dedicated lanes for freight movement, including integration with the major shipping ports. For example, the Port of Savannah is an opportunity for more intensive technology applications for multimodal freight movement.

Atlanta Regional Commission

Transportation Systems Management and Operations (TSM&O)

ARC serves as the Metropolitan Planning Organization for Metro Atlanta and has supported TSM&O projects since the announcement that Atlanta was to host the 1996 Olympics. The extensive preparation for the 1996 Atlanta Olympics was the catalyst for deploying the advanced transportation management system called NaviGAtor.

In 2016, ARC hosted a TSM&O Capability Maturity Model Self-Assessment Workshop to help move TSM&O efforts in local jurisdictions forward. In 2017, ARC published the *Transportation Technology Policy Document* to assess how emerging technologies could help move TSM&O efforts forward while assessing the uncertainty that exists with new technologies like connected and autonomous vehicles, drone delivery, and new data opportunities. ARC plotted the area of interest based on whether emerging technologies would have a positive or negative impact and the certainty of the impact.[13] For example, the report found that the impact of emerging technologies on safety will likely be positive and there is a high level of certainty that the technologies will be deployed.

All the research and planning efforts undertaken by ARC serve to guide local jurisdictions in how to prepare to best manage traffic operations on Metro Atlanta roadways with all users in mind.

Regional TSM&O/ITS Plan Update

To build on the TSM&O work completed to date, in 2018 ARC began an update to the *Regional TSM&O and ITS Plan*. The project team coordinated with ARC to ensure that the two efforts supported one another. The *TSM&O and ITS Plan* update will have a 20-year vision with a 5-year action plan, which matches up well with the 5-year horizon of this plan. Other aspects of the update are as follows:

- Develop a regional TSM&O vision
- Document current TSM&O inventory

[13] http://atlantaregionsplan.org/wp-content/uploads/2017/03/ARC-Transportation-Technology-Policy-Document-2017.pdf.

- Research data governance best practices
- Update regional ITS architecture
- Identify pilot concepts for advanced technology deployment
- Develop local agency deployment guide
- Develop regional technology assessment and strategic deployment plan

Of particular interest to the connected vehicle technology planning effort are data governance best practices and pilot concepts for advanced technology deployment. The data effort is of great importance because sharing insights from connected vehicle data obtained from edge devices will help improve operations and planning efforts. The pilot effort could help further test solutions identified in this planning effort that may have a regional impact.

CHAPTER 3 TECHNOLOGY REVIEW

Connected Vehicle Technology

Connected vehicle technologies transform self-contained, independent vehicles by enabling the transfer of vital transportation and safety information via various communication platforms.[14] Currently two types of communication transfer are prevalent: DSRC and cellular network connections. DSRC is similar to Wi-Fi in that it transfers data on a two-way network broadcasted on the 5.9 GHz spectrum to provide a low latency, secure, and reliable link between devices. Cellular network connections utilize current cellular spectrums, with anticipation of the forthcoming 5G network for lower latency communications. Connected vehicle technologies are applicable to infrastructure, vehicles, and all connected devices.[15]

Connected vehicle technology is critical to support future deployment of fully automated vehicles. The CVTMP does not include deployment details of automated vehicles; however, the foundational elements upon which a successful automated vehicle deployment will operate are provided.

Types of connected vehicle applications are discussed in the following sections.

Vehicle-to-Vehicle

Vehicle-to-vehicle (V2V) technology allows vehicles to share information between V2V-equipped vehicles. Vehicles can communicate and avoid conflicts while making intended movements on the road. V2V can be used to help traffic flow smoother through an information sharing mechanism. On-board DSRC devices are used to transmit basic safety message (BSM) and other messages that include data about a vehicle’s speed, direction, brake status, and other vehicle information to surrounding vehicles, and receive the same information from them.

Vehicle-to-Infrastructure

Vehicle-to-infrastructure (V2I) technology allows mutual communication between vehicles and devices in the infrastructure. It allows the sharing of real-time information such as traffic

[14] USDOT, “Connected Vehicles.” https://www.its.dot.gov/cv_basics/. Accessed October 2018.
[15] CAAT, “Connected and Automated Vehicles.” http://autocaat.org/Technologies/Automated_and_Connected_Vehicles/.

condition, roadway condition, roadway signage, and downstream traffic signals. This eliminates the need for drivers to capture and interpret the information. V2I can also serve as a traffic management hub, where agencies can use the collected real-time information to reroute traffic to optimize the system.

Vehicle-to-Everything

Vehicle-to-everything (V2X) includes V2I and V2V and can be vehicle-to-pedestrian, vehicle-to-device, and vehicle-to-grid. This technology allows the surrounding environment to have a better understanding of the intentions of a vehicle and help to reduce injuries and fatalities. For example, pedestrians receive notification of when it is safe to cross the street by connected vehicles or infrastructure and could transmit their own location to improve safety of the various users of the right-of-way.

Automated Vehicle Technology

Connected vehicles are equipped to communicate with something external whether it is roadway infrastructure or other vehicles. Automated vehicles are designed for the vehicle to perform some or all driving tasks such as braking, steering, and changing speeds, replacing the driver's role for managing control of the vehicle. The combination of connected vehicles and automated vehicles will lead to improving safety outcomes on our roadways.

The USDOT National Highway Traffic Safety Administration (NHTSA) has adopted the six-level definition of automated vehicles as published by the Society of Automotive Engineers (SAE International). The definitions summarized on Figure 19 divide vehicles into levels based on the capability of the automated system and when it is implemented.[16]

[16] NHTSA, "Automated Driving Systems 2.0: A Vision for Safety," https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf.

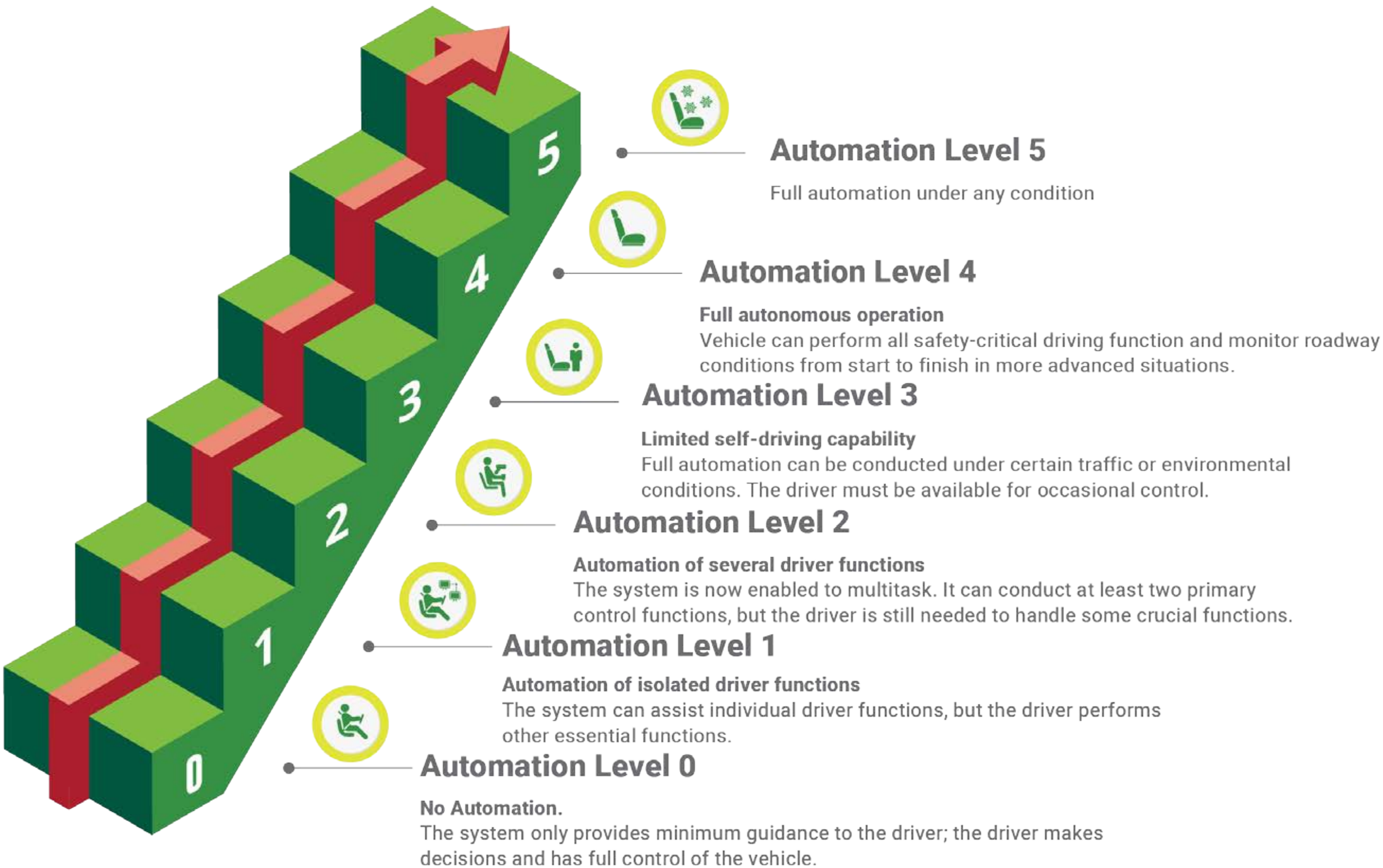


Figure 19. Society of Automotive Engineers Levels of Automation

Connected Vehicle Communications Technology

Three communication technologies currently exist that make it possible for vehicles to communicate with other vehicles, infrastructure, and other things. Each technology has positives and negatives, which makes it a challenge to navigate how the technologies will compare and experience adoption in the future. In 2019, the FCC decided to consider opening the 5.9 GHz spectrum for C-V2X.[17] The opportunity to consider an alternative technology allows automakers greater flexibility. This section discusses some of the capabilities of the communications technologies.

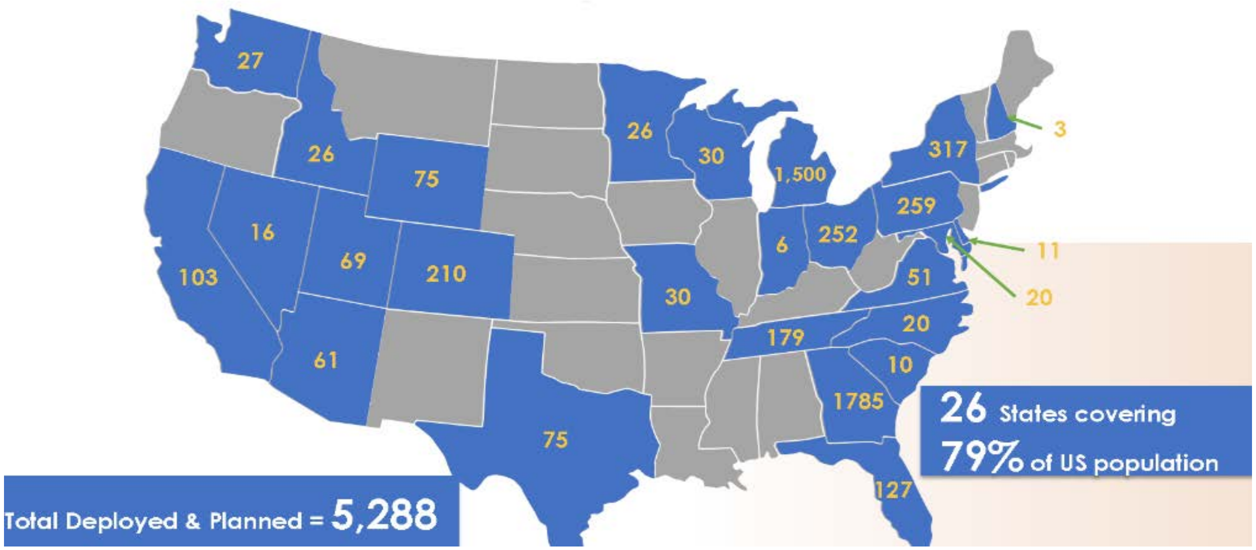
Dedicated Short Range Communication (DSRC)

DSRC has been available since the FCC allocated the 5.9 GHz spectrum for DSRC use in 1999. DSRC is a low-latency technology that makes it possible to automate data collection about traffic and roadway status using probe vehicles. DSRC offers more security and privacy than traditional wi-fi and works well in a moving vehicle environment. The main goal for developing DSRC is to enable vehicular safety applications. Since 1999 a wealth of Institute of Electrical and Electronic Engineers (IEEE) specifications and SAE standards have been developed to ensure DSRC delivers the possibilities V2V, V2I, and V2X offer.

DSRC is the leading proven technology for connected vehicle technology. Both General Motors and Toyota had initiatives to begin deploying DSRC as part of upcoming model years. More recently, Toyota released a statement on April 26, 2019, that they are pausing the deployment of DSRC-based OBUs in its fleet,[18] but also reaffirmed its support of DSRC as its long-term technology selection for OBUs.

Figure 20 shows existing and planned deployments of DSRC technology at intersections in the US.

[17] https://www.rcrwireless.com/20190514/policy/pai-puts-dsrc-spectrum-in-fccs-sights.
[18] https://static1.squarespace.com/static/596fb16003596e0fa70a232f/t/5cc36cda0d92970826c3655b/1556311258955/4-26-2019+Toyota+FCC+Comment.pdf.



Source: Toyota. September 2018

Figure 20. Operational and Planned National DSRC Deployments.

Cellular

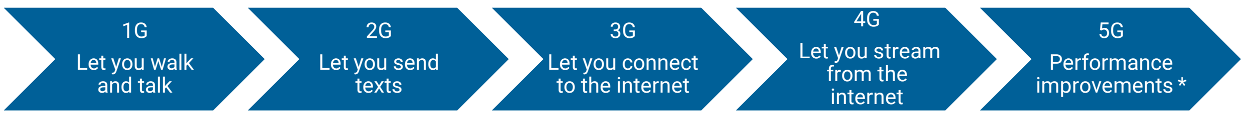
Cellular technologies are also used to connect vehicles. 4G technology is currently used for telematics applications, including the following:

- Audi works with a company called Traffic Technology Services (TTS) to enable intersection SPaT data for select vehicles. TTS partners with local jurisdictions to predict SPaT and then communicates that cycle to vehicles over 4G via a product called Personal Signal Assistant.[19]
- Vehicle manufacturers use 4G-based telematics systems to understand the status of new equipment and systems in vehicles and to execute post-crash assistance messages as with OnStar.

[19] https://www.psrc.org/sites/default/files/rtoc20180104-pres-ttspersonalsignalassistantsupplier.pdf.

- Most new vehicles have some level of cellular connectivity and provide access to vehicle data to select providers. Currently, the data set obtained from vehicles is not intended for use in safety applications, and typically has a minimum of a 30 second delay before the data is available.

Figure 21 provides a high-level view of how cellular network capabilities have improved over a relatively short period of time.



* Performance improvements including but not limited to reduced latency and higher bandwidth which translates to dramatically reducing download speeds to nearly eliminate buffering of videos and similar media. This can lead to really launching the internet of things industry.

Source: MIT Technology Review

Figure 21. Progress in Cellular Communications

Cellular Vehicle-to-Everything

Cellular vehicle-to-everything (C-V2X) provides connected vehicle functionality similar to DSRC, with the difference being that it works over the cellular network instead of a dedicated short-range spectrum. This technology is supported by the 5G Automotive Association (5GAA), a global, cross-industry organization comprised of over 120 automakers, mobile operators and equipment suppliers.

C-V2X is currently a 4G LTE-based technology and is being tested in a USDOT facility in Aberdeen, Maryland, and in Colorado. Early outcomes indicate the technology works well.[20] However, cellular

[20] https://www.nhtsa.gov/speeches-presentations/traffic-safety-and-59-ghz-spectrum.

testing has not been completed and communication standards are slowly being developed. Ford has announced that it will begin installing OBUs that use C-V2X across its 2022 model line.[21] Other automotive manufacturers are concerned that there has not been enough testing and that cellular-based applications may not be sufficiently robust for safety-oriented applications.

The timeframe for widespread deployment of 5G technology that would support expanded C-V2X functionality is unclear. 5G networks are currently deployed by individual telecom companies at small pilot scales in some cities including but not limited to Atlanta, Georgia; Providence, Rhode Island; and Chicago, Illinois[22].; however, they are not available for vehicle-based communication. The advantage of 5G is that it will be device-to-device-based communication, which is a change from 4G-based systems, which require connectivity via a network of cellular towers and/or small cells. The device-to-device communication will enable communications directly between vehicles and between vehicles (V2V) and the infrastructure (V2I). Current concerns related to deploying a 5G network include 5G cells can only communicate short distances and do not communicate well through physical barriers, like buildings, which requires a high number of cells to be deployed, spectrum licensing, and more robust testing to alleviate concerns about impact to other frequencies.

Globally, China has embraced 5G and is building toward making it commercially available in 2020.[23] The European Union was facing the same questions as the FCC: should the spectrum currently dedicated for short-range communications (DSRC in the US, ITS-G5 in the EU) be shared with cellular communications? The European Union's Electronic Communications Committee (ECC) has recommended to not share the spectrum, but rather supports a hybrid approach in which ITS-G5 remains the standard baseline for V2I and V2V communications and cellular to provide additional communications via remote infrastructure and/or cloud services.[24]

6G technology will be device-to-device, and the deployment horizon is not known. There have also been concerns of the mobile device manufacturers' willingness to take on the liability of safety-based applications. Vehicle communications using mobile devices may be postponed to 6G,

[21] https://www.cnet.com/roadshow/news/ces-2019-ford-c-v2x/.
[22] https://www.lifewire.com/5g-availability-us-4155914.
[23] https://www.technologyreview.com/s/612617/china-is-racing-ahead-in-5g-heres-what-it-means/.
[24] https://iot.eetimes.com/europe-has-defined-dsrc-wifi-as-the-v2x-standard-and-now-faces-5g-vendors-revolt/.

although chipset manufacturers indicate that 5G will be ready to enable low latency communications between vehicles and mobile devices.[25]

Connected Vehicle Applications

A large number of applications have been researched, tested, and/or deployed across the nation that have relevance for Gwinnett County. Chapter 6 discusses applications identified for Gwinnett County to research, test, and deploy in the near-term, short-term, and long-term.

Table 2 lists the applications identified for testing and deployment by several agencies across the country over the next 5 years. The list is divided into three sections based on implementation timeline: near-term (1-3 years), short-term (3-5 years), and long-term (5+ years). The list presents a "snapshot in time," and it is likely that application deployment will be accelerated or relaxed as the needs and priorities of agencies change over time.

Appendix C lists near-term and short-term applications and includes a description, potential benefits, and deployment status from agencies across the country. Applications in the long-term list have not yet reached advanced planning and deployment stages.

[25] https://arxiv.org/pdf/1901.03239.pdf.

Table 2. Connected Vehicle Applications to be tested over the next 5 Years by Agencies across the US

Near-term (1-3 years)	Short-term (3-5 years)	Long-term (5+ years)
Curve Speed Warning	Advanced Traveler Information Systems	Eco-Traffic Signal Timing
Emergency Vehicle Preemption (PREEMPT)	Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)	Freight Advanced Traveler Information System (FRATIS)
Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)	Vehicle Turning Right in Front of Bus Warning	Freight Drayage Optimization
Intelligent Traffic Signal System (I-SIG)	Work Zone Traveler Information	Freight-Specific Dynamic Travel Planning and Performance
Mobile Accessible Pedestrian Signal System (PED-SIG)		Intermittent Bus Lanes (IBL)
Multimodal Intelligent Traffic Signal System (MMITSS)		In-Vehicle Signage
Pedestrian in Signalized Crosswalk Warning		Pedestrian in Signalized Crosswalk Warning
Red Light Violation Warning		Pedestrian Mobility
Reduced Speed/Work Zone Warning		Railroad Crossing Violation Warning (RCVW)
Transit Signal Priority (TSP) and Freight Signal Priority (FSP)		Reduced Speed Zone Warning (RSZW)
		Restricted Lane Warning
		Road Weather Information and Routing Support for Emergency Responders
		Road Weather Information for Freight Carriers
		Road Weather Information for Maintenance and Fleet Management Systems
		Transit Pedestrian Indication
		Transit Stop Request
		Transit Vehicle at Station/Stop Warnings
		Warnings about Hazards in a Work Zone (WHWZ)
		Warnings about Upcoming Work Zones (WUWZ)

Source: AECOM

Connected Vehicle/Automated Vehicle Messaging

Table 3 provides the standard messages used by a connected vehicle system. Most of these messages have been standardized by dictionaries and protocols developed by the industry for a DSRC-based communications system. The messages are currently not standardized for a C-V2X (cellular) communications system.

Table 3. Connected Vehicle Applications

Acronym	Name	Definition
BSM	Basic Safety Message	Provides a vehicle's speed, direction, brake status, and other vehicle information
SPaT	Signal Phase and Timing	Provides the current signal/phase timing data (times at which signals will change) for one or more signalized intersections
MAPs	Map Message	Provides intersection and roadway lane geometry data for one or more locations
SRM	Signal Request Message	Used by authorized parties to request services from an intersection signal controller
SSM	Signal Status Message	Serves as a means to acknowledge signal requests
Traveler Information Message	Traveler Information Message	Provides the means to inform the public about both incidents (traffic accidents) and pre-planned roadwork events

Source: SAE J2735 Dedicated Short Range Communications (DSRC) Message Set Dictionary

To illustrate how information from BSMs can be used, Figure 22 shows the location of hard braking events from the Tampa Connected Vehicle Pilot.[26]

[26] Sample BSM data from Tampa CV Pilot. https://data.transportation.gov/Automobiles/Longitudinal-Deceleration-Map-for-Tampa-CV-Pilot-B/4bmy-af6s.

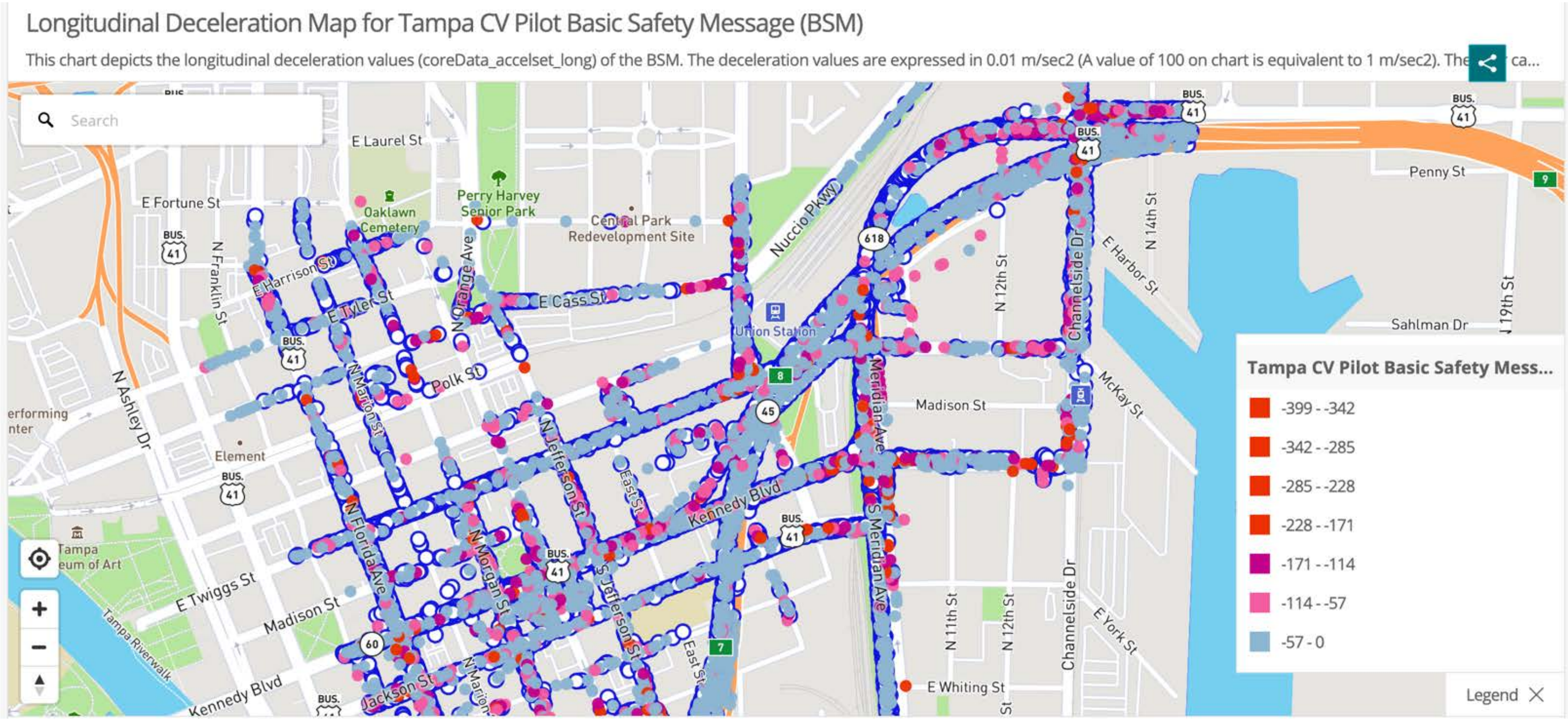


Figure 22. BSM Data Highlighting Brake Events in Tampa Connected Vehicle Pilot

National Considerations

Market Forecast

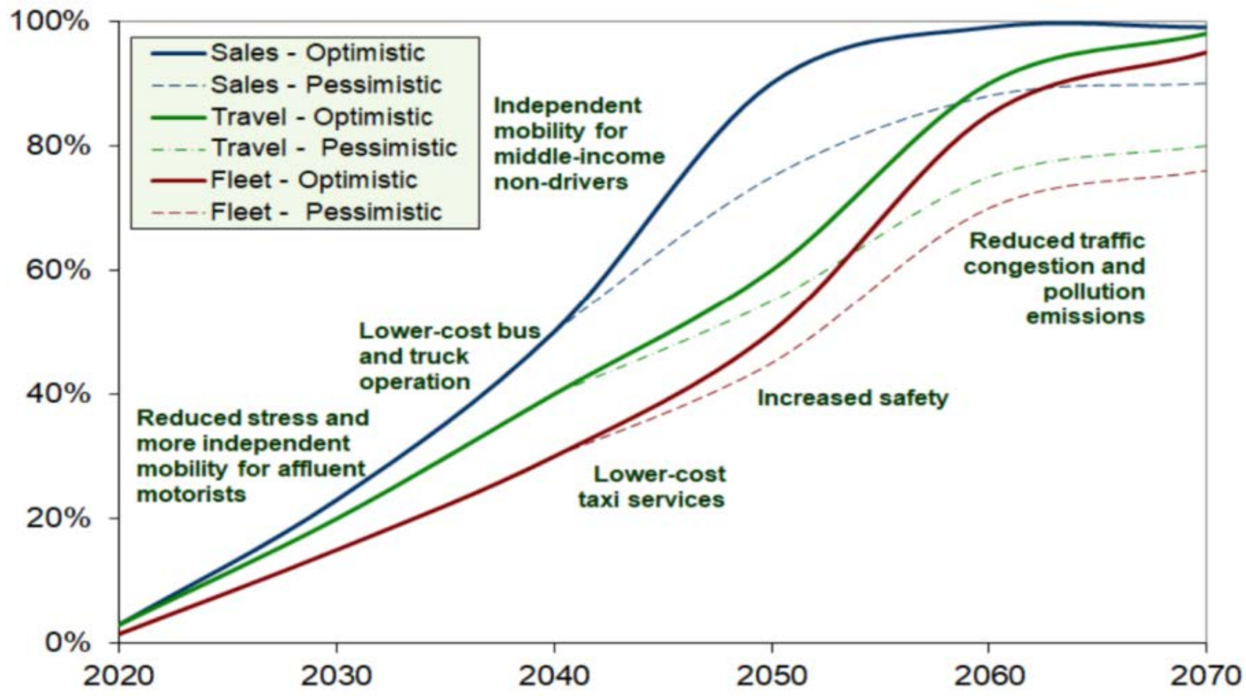
The vehicle connectivity market forecast in the United States is dynamic; however, it is expected that within 5 years most new vehicles will have some connectivity. Table 4 includes a market forecast for DSRC technology in the automotive industry, based on announcements issued by automobile manufacturers. Currently, Ford Motor Company has approximately 14% market share in the United States and has fully committed to C-V2X (cellular) communication. Toyota and General Motors have also committed to using DSRC communications for OBUs for safety applications, though their deployment timelines have slowed until the FCC provides clarity on whether the 5.9 GHz will remain dedicated for DSRC or opened up to C-V2X.

Table 4. Market Forecast of Commitment by OEMs

Automaker Commitments	Market Share
Ford Motor Company (C-V2X)	14%
General Motors (DSRC)	17%
Toyota (DSRC)	13%

Source: AECOM

The chart created by the Victoria Transport Policy Institute (VTPI) in Figure 23 shows predictions of benefits as autonomous vehicles make their way on our roads between now and 2070. VTPI predicts full market saturation with benefits such as increased safety and lowered costs of operating services before 2060.



Source: Litman. VTPI. November 2018. https://www.vtpi.org/avip.pdf

Figure 23. Autonomous Vehicle Sales, Fleet, Travel, and Benefit Projections

Connected Vehicle Communications

Market uncertainty regarding communications options affects the decisions made by the product manufacturers and the agencies that seek to operate connected vehicle systems. In general, a sound investment indicates that the solutions reach the right people, are scalable across jurisdictional boundaries, and are going to last a long time. The characteristics of DSRC and cellular communication have been classified as technical and non-technical and are described in this section.[27]

Technical Considerations

Technology Maturity

5G cellular technology is being tested and developed in various countries because it can increase communication bandwidth and lower latency compared to current cellular deployments. In the United States, 5G is in the early stages of deployment testing but has been marketed extensively. 5G requires deployment of a network of small cells to reach network coverage maturity.

DSRC has been available for nearly 20 years and has been tested extensively. It provides lower latency and higher communication bandwidth compared to current cellular technology. DSRC also requires a deployment of devices in a relatively dense arrangement, since the radius of communication is typically 1,000 feet (300 meters) and latency is low.

Uncertainty about Future Federal Communications Commission Action

For several years, the FCC has been considering a potential change to the communication spectrum currently dedicated for DSRC, which is 5.9 GHz band. The NHTSA issued a Notice of Proposed Rule Making (NPRM) that ran from December 26, 2018, to February 25, 2019, in which they invited the public to provide comments on how connected vehicle developments impact V2X in general, and USDOT's role in encouraging the integration of V2X. As a result, over 56 companies, jurisdictions, original equipment manufacturers (OEMs), organizations, and members of the general public responded with a range of responses. The NPRM responses indicate the complexity of the matter and the challenging position for both USDOT and the FCC with respect to rendering a final decision regarding the 5.9 GHz spectrum.

Network Operations and Maintenance Responsibility

One of the potential impacts regarding the DSRC (5.9 GHz) spectrum is whether the spectrum remains exclusively available for V2X application, or whether the spectrum is open for non-vehicle

[27] https://www.regulations.gov/document?D=DOT-OST-2018-0210-0001.

safety/mobility use. The outcome results in whether the public sector (such as agencies having roadway jurisdiction) will have control of the connected vehicle deployment or whether they will need to purchase access from a telecommunications broker. There are advantages and disadvantages for both scenarios. Sharing the spectrum between the public and private sectors is understood to be challenging because of the impact to communication speed and standards, since there is the potential for interference between the public-facing and private-facing applications.

Privacy and Data Security

Data ownership and privacy is also a concern. Data is now a commodity that can be sold, leaving the consumer potentially vulnerable if the personal data is not first anonymized. As a result, the companies and agencies that have access to the data may choose to monetize the data, or at minimum those companies and agencies become a potential point of entry for data theft. For DSRC systems, USDOT has been developing a Security Credential Management System (SCMS) to support the operation of a connected vehicle system in a safe, secure, and privacy-protective manner.[28] Over the years, many standards have also been developed by consortiums like Crash Avoidance Metrics Partnership (CAMP), SAE, and IEEE to ensure that safety, security, and privacy exist in messages sent between connected devices.[29] For cellular systems, the work of developing a full suite of standards continues, and there are existing industry standards such as IEEE802.11.[30]

CAMP was formed in 1995 by Ford Motor Company and General Motors with the objective of improving traffic safety by accelerating the implementation of crash avoidance countermeasures. CAMP facilitates interaction with other OEMs, the Federal Highway Association, NHTSA, and local DOTs to coordinate cooperative research projects.

[28] https://www.its.dot.gov/resources/scms.htm.
[29] https://www.its.dot.gov/factsheets/pdf/ITSJPO_Connected_Vehicle_Standards.pdf.
[30] https://futurenetworks.ieee.org/standards.

Non-technical Considerations

Social Justice Related to Speed of Vehicle Fleet Penetration

Vehicles capable of communication with connected vehicle infrastructure will be produced at accelerating rates by OEMs, which will be a great benefit for those who purchase new vehicles. Existing vehicles that do not have any devices built in to communicate with connected vehicle infrastructure will need an after-market device installed. Such a barrier will require an incentive to ensure that all cars on our roadways have access to connected vehicle communications.

Social Justice Related to Cost of a Mobile Device

Until the vehicle market penetration of OBU devices with a built-in HMI naturally occurs, connected vehicle applications will depend on mobile phones to transmit messages to the driver. A defacto requirement for drivers to use their cellphone to receive safety messages may pose a social justice issue for some system users regarding the funding of a mobile device and cellular subscription. Or, as more vehicles are equipped at the factory cellular connections, two issues arise. The first is, will safety messages over connected vehicles cost more than some can afford? The second is, how long will it take before these vehicles become available to low-income populations?

Manufacturer Marketplace Tactics

To improve the vehicle market penetration of connected vehicle-enabled devices, vehicle manufacturers will need to make the connected vehicle-enabled devices standard equipment or provide incentives for vehicle owners.

Dependency on Communicating to Drivers via Multiple Apps

Cell phone use in vehicles is a primary cause of distracted driving, which poses a challenge for safety on the roadways. Eliminating distracted driving is a key objective for reducing crashes on the roads and is the reason for the hands-free law in Georgia. To support this initiative, the connected vehicle-enabled devices that are located inside the vehicle must be designed to minimize the potential for distracted driving.

Connected Vehicle Devices

Roadside Units

The definition of an RSU was first established by the FCC as part of the allocation of the 5.9 GHz band for ITS, and refers to a DSRC device versus roadside equipment (RSE), which has been used synonymously with RSU, but refers to a broader set of ITS equipment, such as signal controllers, and to functionality including applications. The USDOT encourages the use of the term “RSU” when referring to the DSRC roadside hardware and applications; however, interchangeable use between the RSU and RSE terminology still occurs. The purpose of the RSU is to act as a fixed point of contact within a dynamic network of communication devices, such as those embedded within vehicles, and a back-office supervisory system.

RSUs, as illustrated in Figure 24, reside at intersections and other roadside locations and receive and send communications from and to vehicles, pedestrians, or bicyclists. RSUs have varying levels of computational capability depending on the manufacturer and model. While DSRC and cellular communications are not inherently interoperable, some manufacturers can create secondary interoperability with computational capability inside the RSU that translates data from one communications protocol to the other.

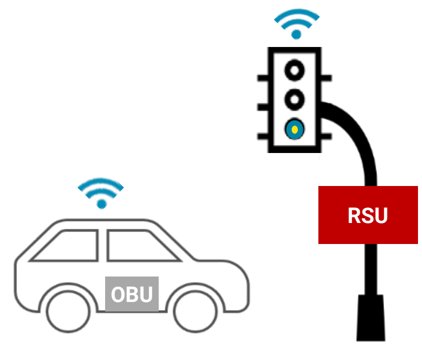


Figure 24. RSU Concept

Currently, three manufacturers of RSUs and three manufacturers of OBUs have achieved certification by OmniAir. OmniAir is a trade association that independently tests devices and provides certification that demonstrates for interoperability of connected vehicle systems. RSUs may also include equipment to execute edge computation to help limit the amount of data pulled back to command centers. Both C-V2X and DSRC protocols use RSUs like the sample in Figure 25.

Figure 25. Sample RSU

The current manufacturers of RSU devices are listed in Table 5. RSUs are enclosed in a secure and waterproof enclosure and are mounted on a pole or mast arm, often at signalized intersections. The standards governing the performance of these devices dictate functional characteristics such as their transmit power, but also functionality such as store-and-repeat, where received messages are passed along to other devices in a network. This provides the flexibility for the RSU to process messages onboard or simply serve as a pass-through, enabling applications that reside on other network devices to intelligently process the incoming data. One critical role the RSU plays is as a connection point between a transportation management and operations system, such as the Gwinnett County TCC, and the dynamic network of connected vehicles.

To date, standards and certifications for C-V2X devices comparable to those developed for DSRC have not been established in the US. There are several manufacturers; however, these systems tend to be proprietary in nature, and their ability to communicate with other devices is managed exclusively by the manufacturer. As a result, interoperability between devices is likely to be limited, and the growth of the connected vehicle system may be limited by the fact that the manufacturer has full control over the system's interoperability. Devices with dual technology, DSRC and C-V2X are being developed and hold great promise in supporting the deployment of CV systems.

Table 5. DSRC RSU and OBU Companies and Certifications

Company	Device Type	OmniAir Certified?
Cohda Wireless	OBU, RSU	No
Commsignia	OBU, RSU	Yes – OBU
DanLaw	OBU, RSU	Yes – OBU and RSU
Intersect	OBU, RSU	Yes – RSU
Lear	OBU, RSU	Yes – OBU
Siemens	OBU, RSU	Yes – RSU
Kapsch	OBU, RSU	No
TrafficCast	OBU, RSU	No

Note: All certifications can be found on the OmniAir Consortium's website; https://omniair.org/certified-products/. Devices are continuously being added. See the OmniAir Consortium's website for the latest list of certified devices.

On-board Units

OBUs, as illustrated in Figure 26, are devices that use communications technology installed inside a vehicle. With the exception of a few automobiles that are being manufactured with built-in DSRC technology, OBUs are typically "aftermarket" devices, meaning they are stand-alone devices that must be installed into a vehicle after the vehicle has been manufactured. As vehicle manufacturers begin to include factory installed OBUs in vehicles, the OBU becomes another component included in the vehicle assembly process, along with the GPS and communications antennae.

The manufacturers of RSUs typically produce OBUs, since similar communications technology is applied to both devices.

Until vehicle communications become embedded in most of the vehicle fleet, aftermarket devices are available. Aftermarket safety device equipment can be acquired and used for fleets and individual vehicles. Depending on the level of connectivity to the vehicle (connection to the vehicle's computer systems or independent function of the vehicle), the price and size of the device vary. Figure 27 shows one such aftermarket OBU.

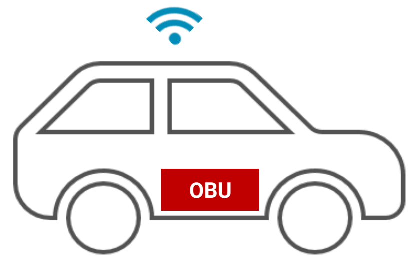


Figure 26. OBU Concept

Figure 27. Sample OBU

As OBUs are installed inside a vehicle, their enclosures do not need to be environmentally hardened. However, care must be taken to protect the OBU from accidental damage or theft, so they are often installed in a place that requires minor disassembly of vehicle interior panels or are enclosed inside a locked case. Additional considerations with an OBU installation are power and cable management.

The OBU must be powered by the vehicle's electrical system, but it must also be protected from voltage spikes, which is typically addressed through an inline fuse. The OBU must also not be allowed to drain the vehicle's power source, so the power management must also include a "key-on" detection mechanism such that when the vehicle is powered off, the OBU loses power. Cable management must be considered within the context of the type of installation – permanent or temporary. The cabling involved is for the power and antennas, and if the installation is permanent, the cables should be routed such that they are not visible and cannot be easily damaged or disconnected. A permanent antenna mount can be achieved by creating a pass-through hole in the vehicle's roof and sealing properly.

For a portable installation, the cables should be routed to minimize the possibility of damage or disconnection, and the antenna can be mounted on the roof of the vehicle using a magnetic mount, and the cables can pass through an open window, or through the weather sealing of a closed door, although this raises the possibility of damaging the cables over time.

Human Machine Interface

The HMI is a visual display that provides the driver with information from the connected vehicle system, which will help the driver make decisions. HMI systems are currently available as after-market products, and over time HMIs that make use of data from connected vehicles will be designed and installed by the automobile manufacturers. Other HMI systems are currently run via conventional tablets.

As the HMI systems become integrated with screens available in vehicles, they will likely be different for each manufacturer and may also vary by vehicle model, depending on how the manufacturer has researched the needs of the drivers of that vehicle model. Secondly, standards are under consideration for how to deliver data from connected vehicles to drivers. Currently, the design of the HMI varies by equipment manufacturer and software programmer and the needs of users. As one example, the THEA Connected Vehicle Pilot used rearview mirror after-market HMI devices such as the one in Figure 28.

Source: THEA Connected Vehicle Pilot

Figure 28. HMI in Rear-View Mirror

Edge Devices

Edge devices are a critical component for ensuring the safety of all road users in connected vehicle and autonomous vehicle systems where the speed of information transferred is critical. The speed at which information is communicated to a driver or a self-driving car can be the difference between properly managing intersection movements and causing a crash. Edge devices help manage the flow of data at the edge of a network as close to the data source as possible instead of having to run information back to a data warehouse before executing a decision. Instead of transferring information to a data warehouse or server every time new information is captured, activity can be programmed to push data at certain frequencies (hourly, daily, after peak commute times). Figure 29 provides an example of a barebones single board computer that can be programmed, and custom built as an edge device. Some RSU manufacturers include similar devices in their products.

Source: www.raspberrypi.org/products

Figure 29. Single Board Computer Common in Edge Devices

Cost Considerations

Table 6 provides high-level cost estimates for installing hardware for a connected vehicle deployment. The estimates are based on various cost points from existing deployments that used hardware from Lear and Cohda. Because devices are constantly improving and being tested with features such as over-the-air updates, device prices are expected to decrease over time.

The RSU cost estimate includes the cost for mapping the intersection in addition to purchasing RSUs and installing them in the field.

Table 6. Connected Vehicle Hardware and Install Cost Estimates

Device	Device with Installation Cost Estimate
DSRC RSU System	$4,000 - $6,000 per intersection
Edge Device	$250 - $450 per intersection
DSRC OBU System	$1,000 - $5000 per unit
HMI	$1,000 - $3,000 per unit
C-V2X Device	$6,000 - $7,000 per intersection
Operations and Maintenance – DSRC devices	TBD
Operations and Maintenance – C-V2X devices*	TBD
Operations and Maintenance – HMI	TBD

** These costs are sometimes included in the C-V2X device purchase cost.*

System-level Considerations

Vehicle Credentials

USDOT has developed a security system that involves a Public Key Infrastructure (PKI) system. This is called the Security Credential Management System (SCMS), and it involves each piece of equipment in the system having matching credentials. Each OBU or RSU or broadcasting/receiving device in the system needs to have credentials to participate in the system. Similar to log-in credentials for banking, emailing, and shopping websites, vehicles will need to prove they are trusted, and traffic signals will need to prove they are trusted by showing their credentials before they begin to communicate and exchange sensitive information.

Personal Data Security

The protocol standards that define the data that moves between and among vehicles does not include identifying characteristics in them. Standards under development will allow a user to select "opt-in" applications. The connected vehicle protocols that currently exist do not transfer personal data and are designed to maintain users' privacy.

Connected Vehicle Security

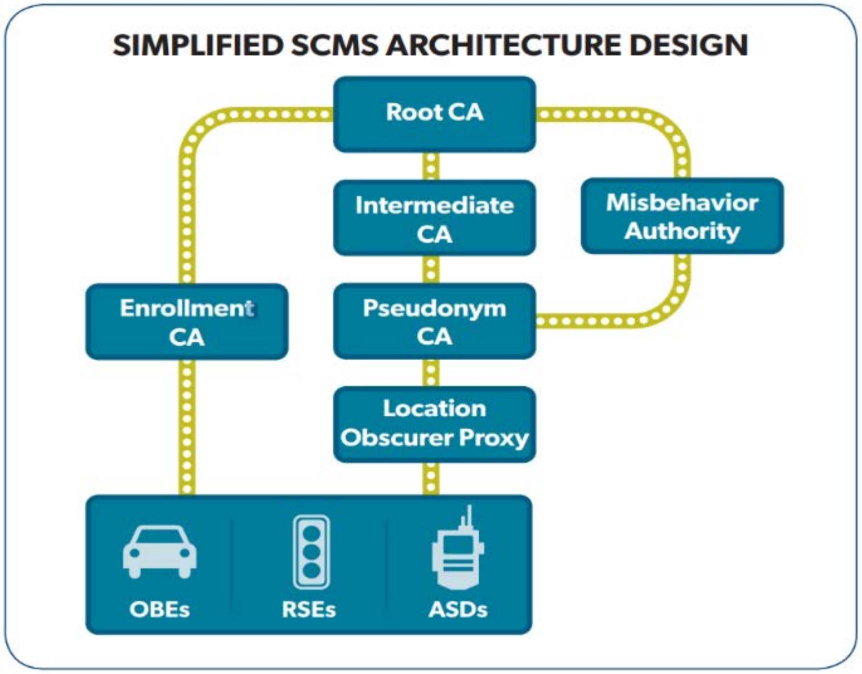
In 2015 the NHTSA began developing the SCMS with input from various interested parties from public, private, and academic entities. In more recent years, USDOT has partnered with CAMP[31] to implement SCMS proof of concepts with the goal of creating public documents for the public to use to establish a national SCMS. Much of the insight is currently being generated by the three USDOT-led connected vehicle pilot locations—New York City, Tampa, and Wyoming—which are required to implement an SCMS and have well documented their deployments.[32]

SCMS provides the security infrastructure to issue and manage security certificates, which are the basis of trust in connected vehicle communications by using PKI. Each OBU or RSU or broadcasting/receiving device in the system needs to have credentials to participate in the

[31] https://wiki.campllc.org/#all-updates.
[32] https://www.its.dot.gov/pilots/phase2_technical.htm.

system. OBU and RSU hardware can be loaded with a certain number of certificates, and therefore require reloading over time.

Figure 30 provides a high-level look at the architecture of an SCMS. The diagram introduces the concept of Certification Authority (CA). The CA is present in multiple parts of the process to continuously detect, identify, and remove misbehaving devices from the system.[33] Table 7 provides an overview of the companies providing SCMS nationally and abroad.



Source: USDOT

Figure 30. SCMS Architecture as Illustrated by USDOT

[33] https://rosap.ntl.bts.gov/view/dot/36397/dot_36397_DS1.pdf?

Table 7. SCMS Companies

Company	Website
Green Hills	https://www.ghs.com/products/auto_secure_connect.html
Blackberry (Certicom)	https://blackberry.certicom.com/en/products/certicom-scms
Escrypt	https://www.escrypt.com/en/products/cycurv2x-scms
PentaSecurity	https://www.pentasecurity.com/solutions/iot-security/car-security-autocrypt/

The main goal of an SCMS is to detect, identify, and remove misbehaving devices and to protect the privacy of system users (drivers). Misbehaving devices are OBUs in vehicles that may have been tampered with or are malfunctioning. Each OBU will have a large number of certificates that it will need to load periodically (every 2 to 3 years depending on rate of use) that other OBUs or RSUs can verify as safe devices to communicate with. If a driver's OBU were to be identified as misbehaving, then the driver receives an alert to have the OBU examined by a technician.

Schematic Diagrams of Applications

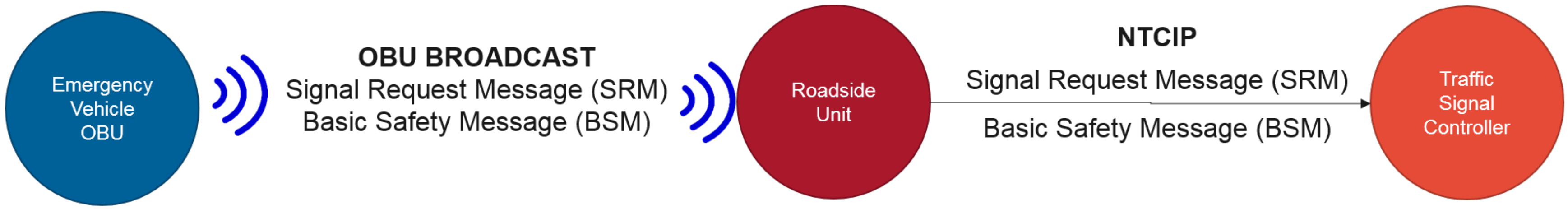
To illustrate how information is sent and received by each application, Figure 31 through Figure 36 were developed. A summary of the message content is also provided in the schematic diagrams.

Figure 31 and Figure 32 provide an overview of the communications process between vehicles and roadway infrastructure for preemption and/or priority applications. The process begins with the OBU in a vehicle sending a signal request message (SRM) to the RSU. The RSU parses the message and passes it on to the traffic signal controller with the appropriate request for service. The traffic signal controller evaluates the request for service and responds based on the operational parameters that are programmed in the traffic signal controller.

A BSM is sent at the same time as the SRM. The SRM includes information about the request as well as vehicle credential information. The BSM includes information about the vehicle such as speed, travel lane, direction, and detailed car status information.[34]

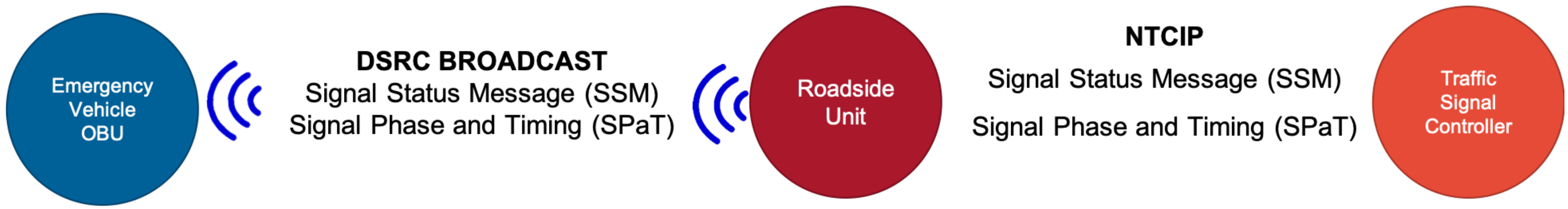
The traffic signal controller sends the appropriate command to the RSU to communicate with the OBU if a request has been granted as well as the appropriate SPaT message. Figure 32 details the composition of SSM and SPaT messages.

[34] Basic Safety Message Sample Visualization. ITS JPO USDOT. https://www.its.dot.gov/data/visualizations/element6/.



SRM	BSM	SSM	SPaT
• Preemption or priority request • Optional BSM information • Vehicle ID and credentials	• Lat/Long • Elevation • Speed • Heading • X/Y/Z Acceleration	• Intersection ID • Signal status • Priority status • Preempt status • Transit status	• Current state of the intersection • Active lane • Remaining time for current state

Figure 31. V2I Priority or Preemption



SRM	BSM	SSM	SPaT
• Preemption or priority request • Optional BSM information • Vehicle ID and credentials	• Lat/Long • Elevation • Speed • Heading • X/Y/Z Acceleration	• Intersection ID • Signal status • Priority status • Preempt status • Transit status	• Current state of the intersection • Active lane • Remaining time for current state

Figure 32. Infrastructure-to-Vehicle Preemption or Priority

The rail intersection blocked alert application is intended to provide information to motorists while a train occupies an at-grade crossing and blocks passage. This application is illustrated in Figure 33. The train detection can occur by two methods: a track relay can initially be used, and in the future a passive detection device located outside of the railroad right-of-way could be used to supplement the track relay information to improve the accuracy of tracking the train movement at a railroad crossing.

The first generation of this application may include the status of the railroad crossing (clear or blocked) delivered to a web application. Later phases will likely allow the application to mature and include communication to the driver with predictive (estimated) capabilities such as the time until the next train arrives, the time for the train to clear the railroad crossing, and the estimated duration of the railroad crossing blockage.

This application will particularly benefit emergency vehicle response times and prevent vehicles from blocking nearby intersections. An example of such an intersection can be seen on Figure 34 where an at-grade crossing alert could help reroute an emergency vehicle to a grade-separated crossing if needed.

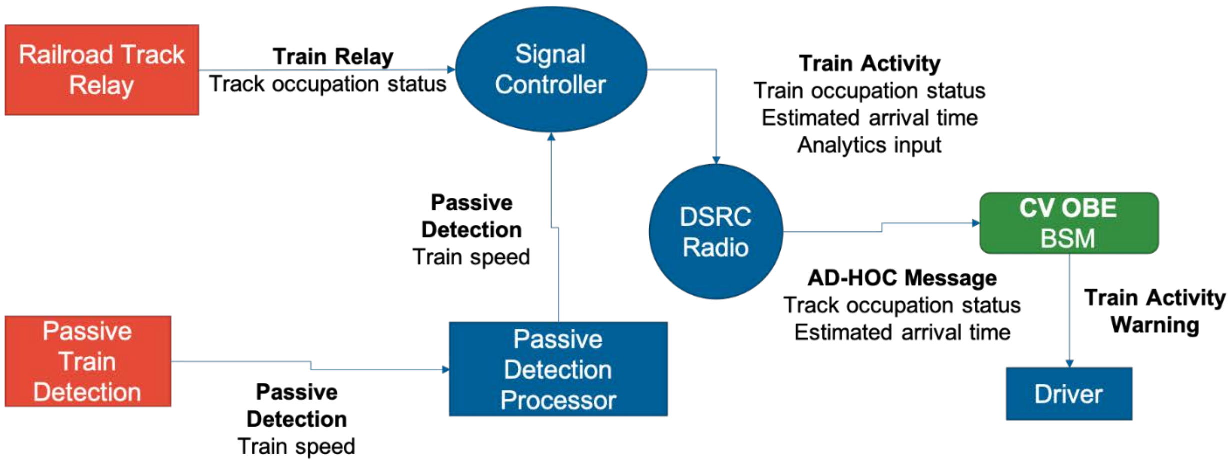


Figure 33. Railroad at At-grade Crossing Alert

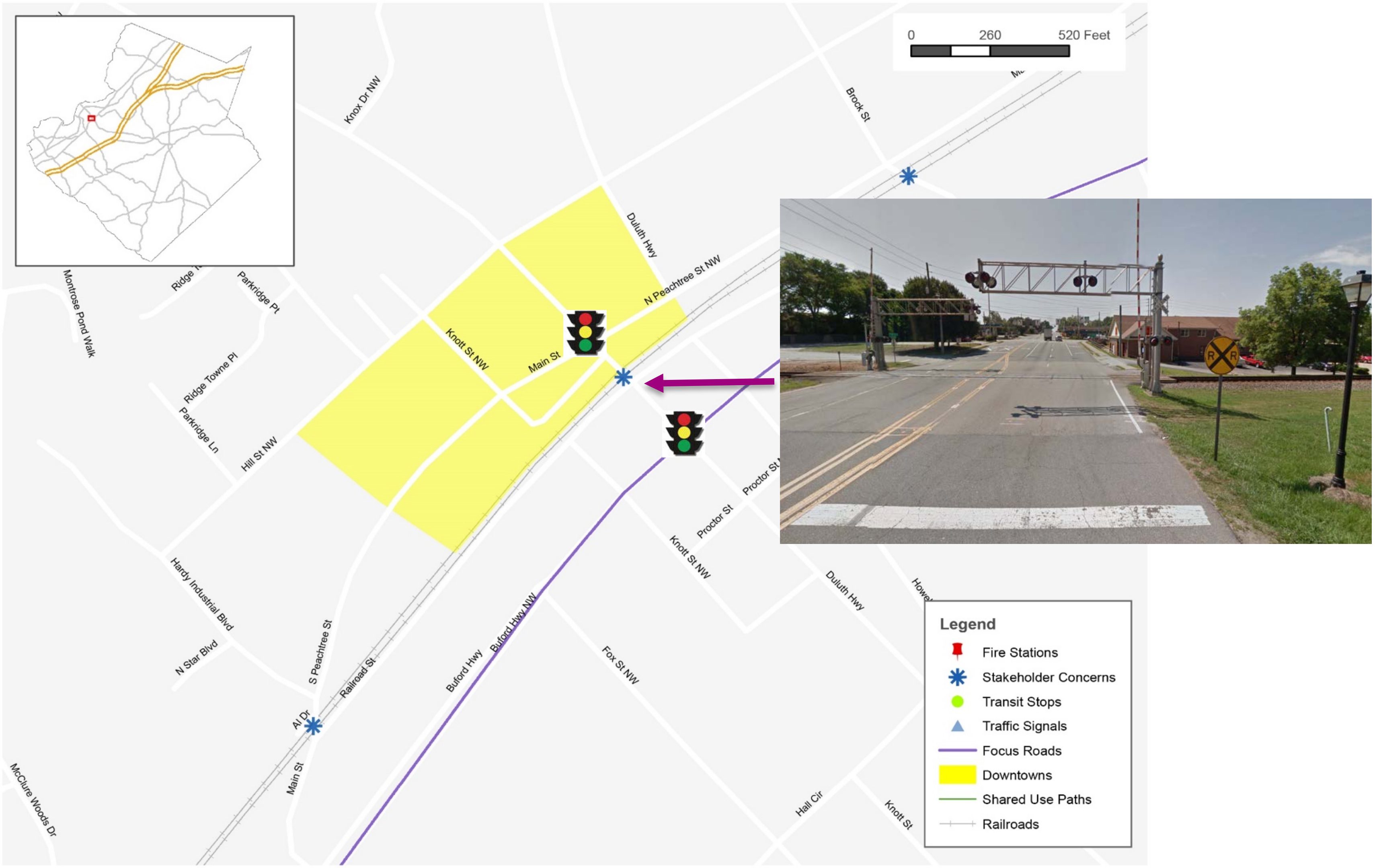


Figure 34. At-grade Crossings in Downtown Duluth

Figure 35 and Figure 36 illustrate the Mobile Accessible PPA application, which provides drivers with an alert about nearby pedestrian activity. In the near-term, an alert can be sent to nearby vehicles that a pedestrian is in the area based on when a pedestrian activated the push button to provide a safe crossing. This approach is technically simple to deploy but limited in its accuracy. For example, it is dependent on a pedestrian activating the push button and may not provide detailed insight about the direction of travel, speed, or location of the pedestrian.

To this end, a more detailed alert could be created by using passive detection and/or information from transit status messages. Passive detection such as intersection cameras, radar, etc., can provide more detailed information such as crosswalk occupancy, direction of travel, speed, and whether the crosswalk is clear of pedestrians. For situations when a pedestrian is not at a crosswalk, alerts can be crafted by parsing information about who is disembarking the bus, including the number of people, if there is a person with a disability disembarking, or if the person is removing a bicycle from the bus rack.

The diagrams serve to provide insight on what is currently possible and what could be possible. The exact functionality will be refined or improved via partnerships with vehicle and bus OEMs, combining information from cellular and DSRC sources, and leveraging insights from ITS devices at the intersection.

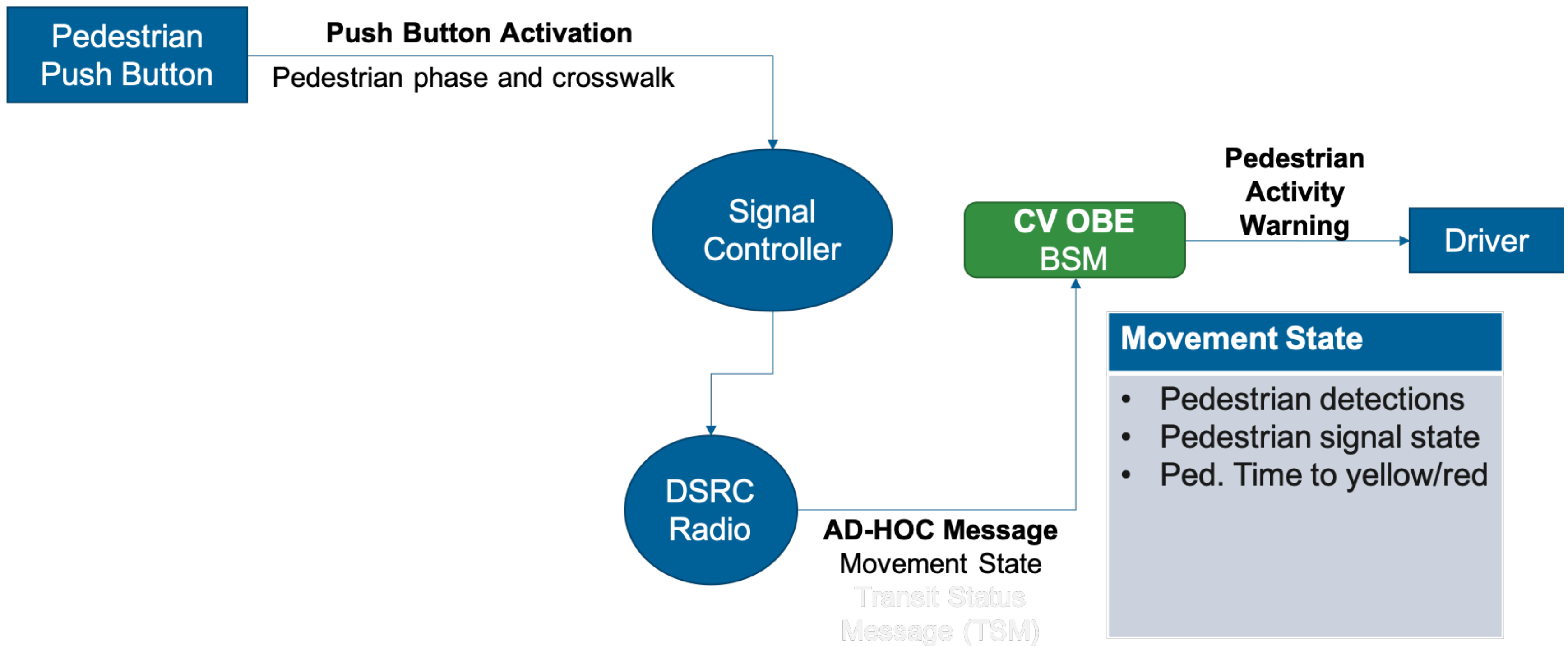


Figure 35. Pedestrian Alert – Near-term

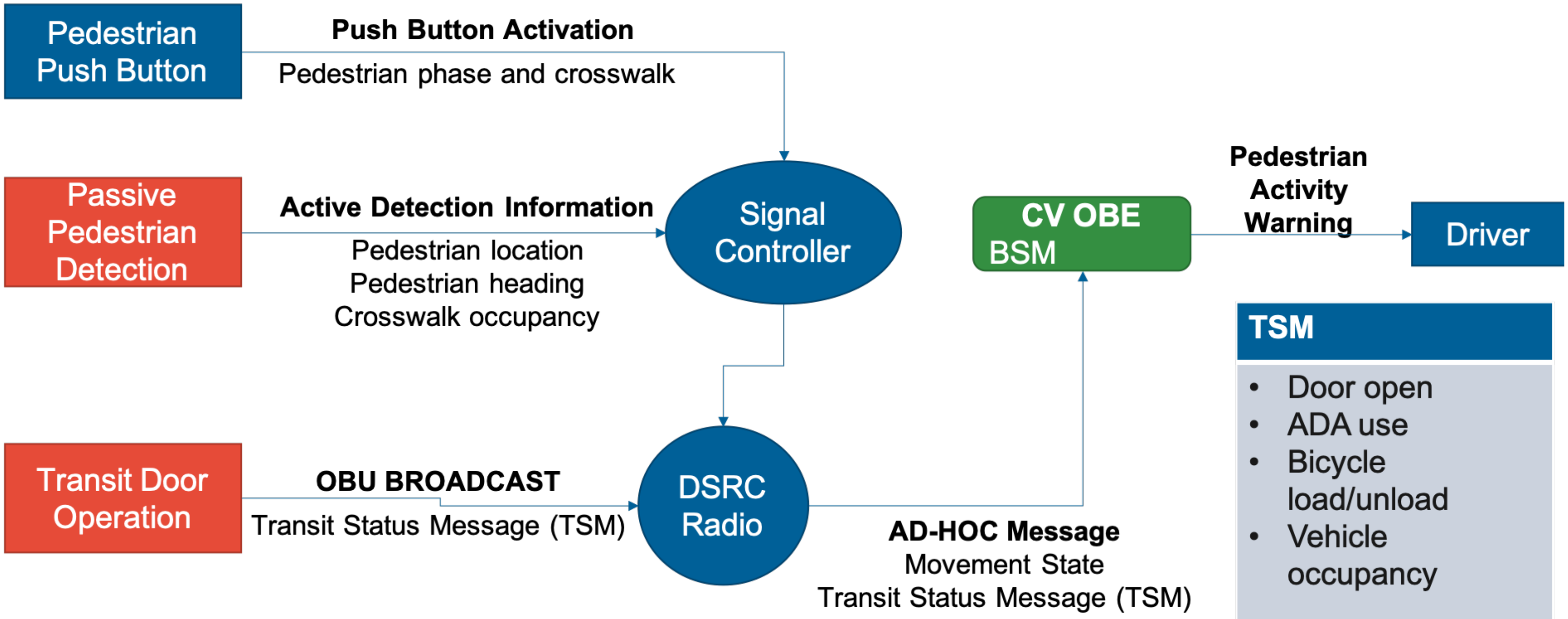


Figure 36. Pedestrian Alert – Future

CHAPTER 4 STAKEHOLDER PROCESS

Approach

To assess the mobility needs and goals of the county and how to apply connected and automated vehicle solutions, insight was gathered by interviewing local jurisdictions who have deployed connected and automated vehicle solutions. Additionally, two stakeholder meetings were conducted to share information and solicit feedback.

Interviews were held with staff from Renew Atlanta (RenewATL), Cobb County Department of Transportation (CCDOT), and the City of Marietta Fire Department. Detailed insights from each interview are provided in Appendix A.

RenewATL is the department at the City of Atlanta tasked with deploying connected vehicle technology. CCDOT has remained at the forefront of deploying various technologies to better manage traffic on their roadways. CCDOT works closely with local transit agency CobbLinc to improve the transit system and transit options for Cobb County residents and visitors. The City of Marietta was one of the first in the Metro Atlanta area to deploy cellular-based connected vehicle solutions including EVP. The City of Marietta Fire Department provided useful insight on how the system serves the needs of the Fire Department.

A summary of the local agency feedback is included in Table 8. Insight provided by each agency was found to be helpful and has been incorporated in the Smart Corridor considerations and the 5-year timeline.

Table 8. Aggregated Feedback from Local Jurisdictions

#	Question	Guiding Feedback
1	Does your agency have a smart mobility vision or problem statement(s)? If so, what is the overall vision and/or problem statement?	Most began with solving for an immediate need and are developing a process for project evaluation. For some, existing planning documents did not provide smart mobility vision.
2	Did you develop any criteria to help with narrowing down mobility technology solutions to test?	
3	What was the underlying need/focus/priority for your deployment?	Prioritization was sometimes set by a leadership council. Prioritization was sometimes dictated by which corridors were under local control.
4	Did interoperability with legacy and/or future systems concern you during the selection process?	Yes, the intention in some cases was to ease data sharing across departments and jurisdictions. Data storage and management quickly becomes a challenge. Entering data-sharing agreements can be difficult.
5	Did you already have funding secured for the solution(s)?	Yes. SPLOST programs may have a category for smart mobility. CIDs can also be supportive.
6	Describe the process for selecting the connected vehicle system?	Focus on EVP, TSP, SPaT messaging, and deployment ubiquity. Deployments relying on cell phones vs OBUs were found to be more appealing. Another appealing motivator was that it was already deployed in other Metro Atlanta communities.
7	Are there policies currently in place hindering or supporting the ability to adopt new technologies? What types of new policies do you think should be explored to prepare for or respond to these technology trends?	A project prioritization framework is needed.
8	How do you foresee the use of the existing and future technology solutions over the next five years? Do you foresee needing to expand the existing system(s) or to pursue new technologies?	Yes. Funding strategies are needed. Evaluation strategies are needed.
9	Is your agency/jurisdiction collaborating with other agencies/jurisdictions regarding smart mobility solutions?	Yes, at varied levels of engagement. A coordination mechanism is missing.
10	Did you have to upgrade communications capabilities prior to technology deployments?	Fiber upgrades were needed.

#	Question	Guiding Feedback
11	Are there any additional capabilities you wish for in the near-term? Long-term?	Network insights rather than intersection by intersection priority/preemption would be helpful for emergency vehicles.
12	Were there any unforeseen positive or negative impacts post deployment?	Training of the system for varying staff members is critical.
13	Did you establish specific KPI's ahead of the connected vehicle deployment? If so, what were they?	Not currently. Some are working on developing measures.
14	What have the measured outcomes indicated this far?	Anecdotally, improvements were noted in the EVP deployments.

Stakeholder Input

In addition to insight from agencies that have deployed connected vehicle technologies in their communities, local knowledge has been invaluable. Stakeholder meetings were held on October 26, 2018, and April 17, 2019. Table 9 and Figure 37 list the stakeholders present at each of the stakeholder meetings.

At the October 26, 2018, stakeholder meeting, the CVTMP team provided an overview of connected vehicle technology – the opportunities offered, what is occurring on the national stage, and how it could help move forward issues the Gwinnett County community identified through previous planning processes. The greatest amount of time was spent discussing questions from the stakeholders, which are outlined in Table 10, and engaging in a mapping exercise to help identify areas that connected vehicle technology could help mitigate.

Table 9. Stakeholders from Meeting on October 26, 2018

Organization Type	# of Participants	Agencies
City Staff	10	Braselton, Buford, Dacula, Duluth, Lawrenceville, Snellville, Suwanee
State DOT Staff	2	GDOT Office of Traffic Operations
CID Staff	6	Evermore, Gateway 85, Gwinnett Place, Lilburn, Sugarloaf
Fire	3	Gwinnett County
Police	2	Gwinnett County
Neighbor	1	Chamblee
Academic	1	Georgia Institute of Technology

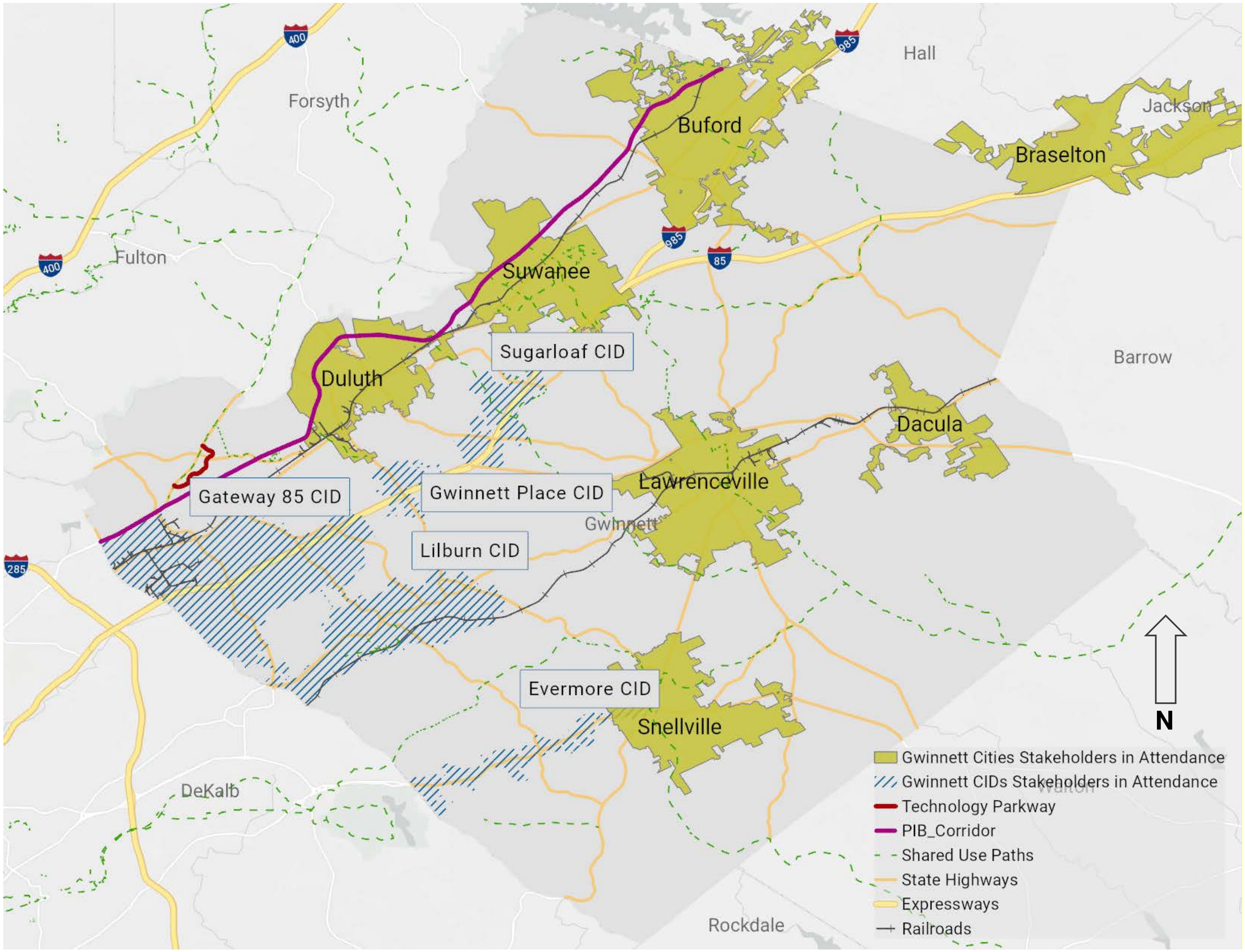


Figure 37. Spatial Representation of Stakeholder Participation

Table 10. Summary of Discussion with Stakeholders

	Questions	Discussion answer
1	When will connected vehicle, solutions become readily available in all vehicles?	One automaker has started adding devices to vehicles to enable connected vehicle solutions, and more automakers are expressing intent to add devices within the next few years. However, it will be many years before the vehicle fleet has a significant number of vehicles outfitted.
2	What is the cost of Dedicated Short-Range Communications (DSRC) unit?	The current cost is a few thousand dollars for the DSRC unit. Other costs related to the DSRC unit may include a cabinet, communications, and power for the unit.
3	As we upgrade roads now, what can we do to prepare for new technology?	The most significant need while upgrading roadways is to provide a robust communications system, such as fiber-optic communications, to provide a way to move the data generated by the connected vehicle system.
4	What is the plan for retrofitting existing vehicles since on-board units (OBUs) can be costly?	The cost of an on-board unit will drop over time. There is currently no plan to require retrofit units.
5	How does V2V/V2I communications connect to 5G?	5G cellular communications would provide a much higher communications capacity, and if applied to connected vehicle applications, those applications would benefit.
6	How much more data is needed since cell phone-based data is already available?	Connected vehicle applications would provide a richer data set, in real-time and as archived data. The data would support more applications than the data currently collected by transportation systems.

Appendix B documents the issues raised by the stakeholders. The insight found in the appendix is divided into three zones as shown on Figure 38. Zone 1 in blue covers the southern portion of Gwinnett County south of Duluth and Lawrenceville. Zone 2 in green includes an area west of I-85 and north of Zone 1. Zone 3 in red includes most of the county east of I-85 and north of Zone 1. Crossing through zones 1 and 2 is the Smart Corridor project area with Peachtree Industrial Boulevard as the spine.

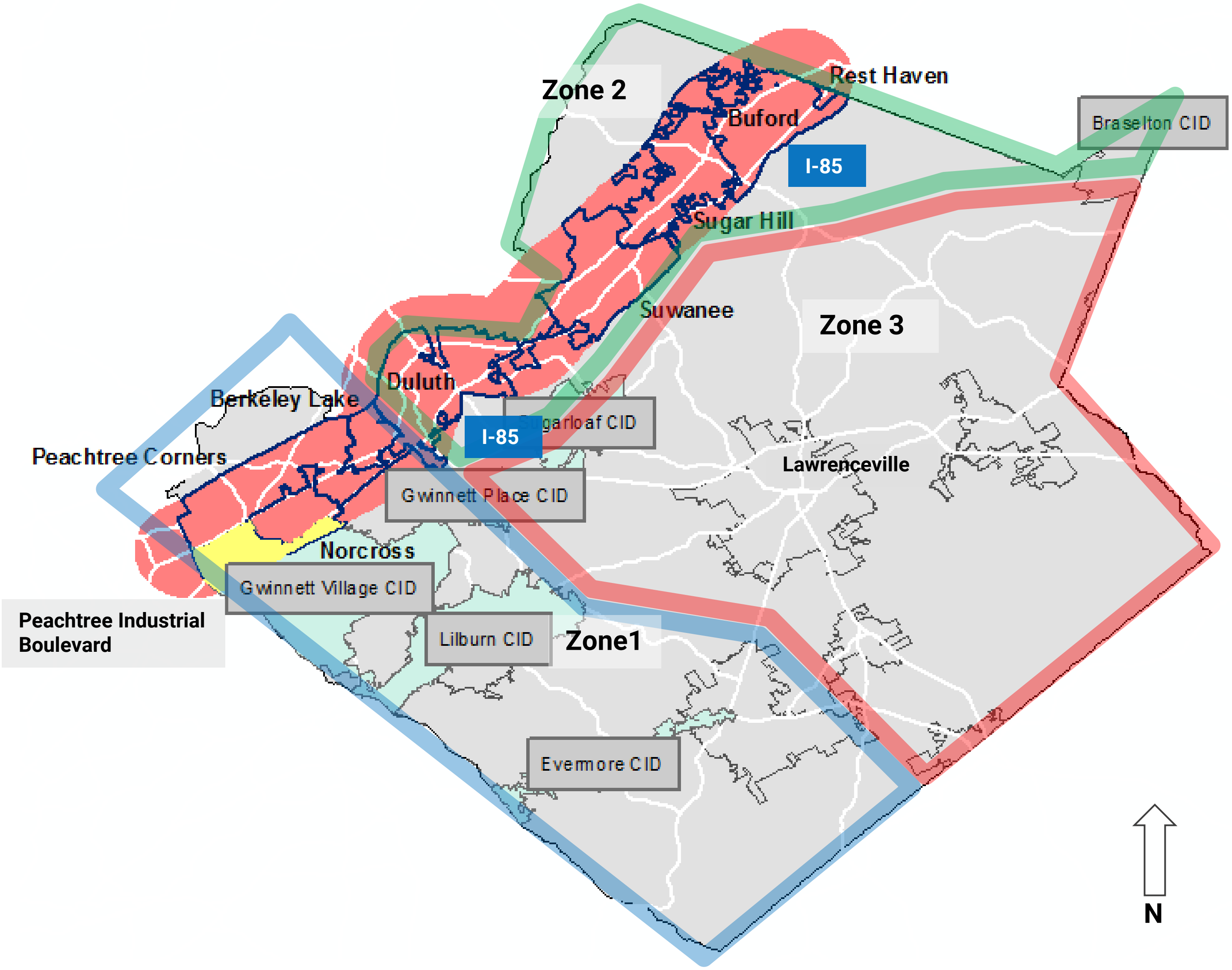


Figure 38. Map of Three Zones in Gwinnett County

Across all the zones stakeholders most frequently identified locations in need of congestion relief, emergency vehicle travel improvements, and pedestrian safety improvements. These issues are reflective of the growing development patterns identified in parts of the county. Also identified but with slightly less frequency are locations where transit buses could receive priority during times of congestion, alerts of bottlenecks, incentivized priority for freight, and improving incident response and clearance times. All the identified issues were further included in the evaluation process as discussed in Chapter 5.

As a result of the insight provided, the CVTMP has been tailored to address the issues raised by the stakeholders. The zones were also modified to better fit the connected vehicle deployment plan (Chapter 6). The stakeholder insight will need to be continuously updated as technology evolves and opportunities arise for the county.

Project Priority Based on Stakeholder Input

At the stakeholder meeting held on October 26, 2018, the stakeholders filled out small surveys so that the transportation challenges throughout Gwinnett County could be documented. The result of the survey is provided by category in Table 11.

Table 11. Stakeholder Meeting Transportation Challenges Summary

Focus Areas Identified by Stakeholders	Comment Frequency
Congestion relief	12
Emergency vehicles	8
Pedestrian safety	8
Transit buses	3
Bottleneck alerts	3
Freight	3
Incident response and clearance times	3

The survey results provide the CVTMP with a clear direction of priority with respect to application selection, including congestion relief, emergency vehicles, and pedestrian safety as the top areas of focus.

Project Coordination Opportunities with Agency Partners

As part of discussions with GDOT and local agencies, opportunities to coordinate with other technology projects in the Atlanta Metro area were examined. The opportunities include hardware and software deployments for a range of purposes, including network communication, school beacon management, and traffic signal operation data. These opportunities were examined to determine how Gwinnett County could leverage these assets for further deployment opportunities. A summary of the opportunities is provided in Table 12.

Table 12. Applications Deployed in Metro Atlanta

Device/Software	Deployed?	Description	Status/Details
Traffic Signal Software Capability for EVP and TSP (Intelight)	Summer 2019 (target)	State-wide license and capability, licensed to GDOT	Testing underway
Connected Vehicle Software Applications (Intelight MaxView CV)	Yes	State-wide license and capability, licensed to GDOT	Tested with GDOT DSRC roll out
Traffic Signal System Software (Intelight MaxView)	Yes	State-wide license and capability, licensed to GDOT	Operating in Gwinnett County and most other counties throughout the state of Georgia
State-wide Data Aggregation tool (Connected Data Platform)	Phase 2 target: fall/winter 2019	Phase 1: aggregates crash, incident, and ITS device data, owned by GDOT	State-wide data aggregation platform
Cellular-Based Applications (Applied Information, TravelSafely App + Glance)	Yes	School flashing beacon system management	Operating in Gwinnett County
Cellular-Based Applications (Applied Information, TravelSafely App + Glance)	Yes	Transit signal priority, emergency vehicle preemption	Operating in Marietta (Cobb County)
Cellular-Based Applications (Applied Information, TravelSafely App + Glance)	Yes	Pedestrian and vehicle alert applications	Operating in Marietta (Cobb County)

CHAPTER 5 EVALUATION OF APPLICATIONS

Prioritizing Applications for Gwinnett County

The stakeholder engagement process and interviews with local partners served to fine tune the selection and prioritization of connected vehicle applications. The details of how the applications will be deployed in the future are discussed in Chapter 6. A comprehensive list of applications that have been or are currently being tested across the nation by other agencies is provided in Appendix C. This section focuses on the types of applications available and the process to evaluate and prioritize application development.

In the interest of public safety, connected vehicle applications must be rigorously tested before being deployed for public consumption. DSRC systems and C-V2X systems are fundamentally different with respect to the fact that the testing should include conformance to existing protocols and messaging. DSRC-based systems use standard protocols and messaging associated with specific applications.[35] At this time, C-V2X-based systems are typically proprietary in nature, since standard protocols and messaging are not currently available.

For the Smart Corridor Request for Proposals, there is an opportunity to evaluate the expectations, capabilities, and delivery of DSRC and C-V2X-based systems. This opportunity may be useful to regional infrastructure and policy leaders, since both system types can provide viable applications. The Smart Corridor project will focus on a pilot deployment in one portion of Gwinnett County, with the possibility of scaling applications that are of particular benefit to the rest of Gwinnett County in future deployments.

The insights gained from all parties will help to refine a list that pushes innovation while maintaining a realistic set of expectations for capabilities and deliverability. The applications recommended in Chapter 6 are focused on Gwinnett County's needs while understanding the significance of scalability across other communities within and outside of Gwinnett County. The remainder of this chapter focuses on application types and scalability.

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

Types of Applications

Stand-alone Applications

Stand-alone applications are those that apply to a unique geographical area and are not intended to be applicable to an area the size of a county or larger. The applications are appropriate to solve local issues, so the application may need to be customized or scaled to a specific intersection, roadway, or roadway network. Stand-alone applications are typically developed by aggregating input data to automatically generate the system output, preferably in a manner that allows the application to be self-contained at the edge devices and/or the vehicles that have an OBU. Examples of stand-alone applications include:

- Incident management for freeways
- Microclimate applications (fog, etc.)
- Specific movements associated with intersection congestion mitigation

Wide Area Applications

Wide area applications are those that are appropriate for county-wide or state-wide application. The applications are sufficiently generic in nature to apply to most any location. Wide area applications aggregate input data from standard sources to generate the system output. The source of the input data may include data generated at the edge devices and/or vehicles that have an OBU; however, in some cases the data source may be located elsewhere. Examples of wide area applications include:

- Traffic signal SPaT data transmission to vehicles
- Pedestrian presence alert via push button activation to approaching vehicles
- Construction and maintenance vehicle alert to approaching vehicles

Flexibility and Scalability Considerations

The flexibility and scalability of connected vehicles is different for stand-alone and wide area applications. A stand-alone application does not require consistency across the state to provide the core functionality of the application, while a wide area application does require consistency across the state to provide the core functionality of the application. How these differences impact the development of the connected vehicle system is described below.

Stand-alone applications collect inputs and send outputs on a local, small area scale, with the primary limitation being the number of vehicles that have OBUs to send and receive data and messages. Stand-alone applications may include preemption and/or priority functions at traffic signals, if the emergency and/or transit vehicles are outfitted with equipment that is capable of triggering a call to the traffic signal for service. While a consistent approach with respect to the technology used and/or software behind the application is desirable, it is not necessary to achieve the core functionality of the application.

Wide area applications require the same protocol, message sets, and software to achieve the core functionality of the application. Although multiple systems could be employed across the state, this limits the ability of the system to provide a single point of system management and associated parameters, performance measures, and standard reports. The goal of any system as complex as a connected vehicle system is to reduce the barriers and complexity related to system operation and maintenance.

As the connected vehicle system grows in size and complexity, the need for tools that enable the operator to perform critical functions efficiently and effectively should be considered an objective. With each additional application, the stakeholders should consider whether the functionality can or should be considered as a stand-alone or wide area application.

Applicability to the State of Georgia

Connected vehicle applications with potential for wide area application should be considered eligible for state-wide use. Figure 39 shows how Gwinnett County is one of 159 counties in the State of Georgia, and highlights that the connected vehicle system will require inter-county interoperability.

A goal of any wide area application should be interoperability. Interoperability allows any jurisdiction or agency in the State of Georgia to apply a wide area application to their connected vehicle deployment with minimal modification to the application. As wide area applications are developed, Gwinnett County will coordinate with GDOT to determine the best way for the application to be added to the connected vehicle system.

In most cases, a pilot project would be useful to demonstrate the proof of concept before the application advances to state-wide use. The Smart Corridor project will be managed and designed to achieve applicability for use throughout the State of Georgia.

Figure 39. Gwinnett County in Context of the State of Georgia

CHAPTER 6 CONNECTED VEHICLE DEPLOYMENT PLAN

Overview

The deployment plan focuses on a 5-year approach as detailed in Table 13. By 2024, the expectation is that a significant number of vehicles will be manufactured with connected vehicle-enabled capability. The 5-year plan is intended to provide a period of testing connected vehicle applications as Gwinnett County expands to a county-wide deployment, anticipating that the market saturation level in private vehicles will remain relatively low until 2024

Workflow and Timeline

The approach begins with limited connected vehicle applications as part of the Smart Corridor project, which shows how connected vehicle applications can benefit a variety of users by improving safety and mobility and enhancing traveler information. Then, Gwinnett County will coordinate with other agencies with respect to applications that have state-wide potential so that staff and financial resources are utilized efficiently. After testing and evaluating connected vehicle applications, an application can be expanded county-wide with applications that have proven benefits.

The 5-year plan is intended to provide a timeframe (2020 to 2024) during which innovation can be tested and evaluated. During this period, connected vehicle applications that apply to a range of users will be tested. Testing applications for a range of users on a small scale is desirable to demonstrate the feasibility and value of the connected vehicle application.

Table 13. 5-Year Deployment Plan

Application	Near-Term (2020) Smart Corridor project	Short-Term (2020-2022) In Coordination with ARC, GDOT	Long-Term (2020-2024) In Coordination with GDOT
1. All Solutions	• Deploy RSUs in the Smart Corridor area • Test connected vehicle data collection, analytics, and archiving	• State-wide; dashboard for intersection traffic signal operations (RR + EVP + TSP + FSP transition times) • State-wide; manage RR + EVP + TSP + FSP conditional requirements • Test connected vehicle-generated safety data alerts • Cybersecurity; deploy SCMS or similar system	• Deploy RSUs county-wide • Test county-wide connected vehicle data, analytics, and archiving • Deploy mission-critical connected vehicle-generated safety data alerts
2. Signal Phase and Timing (SPaT) Information	• Enable red light warning, phase termination/next signal phase, and green band speed applications	• Monitor benefits of safety applications related to fleet penetration of RSUs and cellular OBUs	• Monitor benefits of safety applications related to fleet penetration of DSRC/cellular OBUs
3. Emergency Vehicle Preemption (EVP)	• Enable EVP • Install OBUs on fire trucks	• State-wide; manage EVP conditional priority requirements	• Alerts for excessive transition time
4. Transit Signal Priority (TSP)	• Enable TSP • Install OBUs on transit vehicles	• Manage TSP conditional priority • Test schedule adherence conditional priority • Test bus occupancy conditional priority	• County-wide system development • Alerts for excessive transition time
5. Freight Signal Priority (FSP)		• Enable FSP • State-wide; manage FSP conditional priority • Develop commercial freight outreach program	• County-wide system development • Alerts for excessive transition time
6. Construction and Maintenance Vehicle Alert	• Enable alerts • Install OBUs and HMIs on select GCDOT vehicles	• State-wide; manage alert conditional requirements	• County-wide system development
7. Rail Intersection Blocked Alert	• Test railroad intersection blocked alert	• State-wide; evaluate railroad crossing safety applications • Evaluate railroad crossing prediction accuracy	• County-wide system development • Develop additional railroad crossing safety applications • **Enable predictive railroad crossing delay**
8. Mobile Accessible Pedestrian Presence Alert (PPA)	• Test alert from pedestrian push button activation at intersections	• Test transit and bus door open events • County-wide system development • Test applications for the visually impaired	• Test alert from pedestrian push button activation for mid-block pedestrians • County-wide system development

Phase 1: Smart Corridor Project (Near-term)

The first deployment is a pilot project that is intended to demonstrate connected vehicle applications that are deployed elsewhere and to demonstrate new connected vehicle applications within the state of Georgia. The Smart Corridor project lies in the western portion of Gwinnett County, between the western county line and the I-85/I-985 corridor. It includes the cities of Norcross, Peachtree Corners, Berkeley Lake, Duluth, Suwanee, Sugar Hill, and Buford. Figure 40 provides context on the project extents.

The connected vehicle applications identified for the Smart Corridor project will primarily benefit emergency vehicles and transit vehicles through the functions of traffic signal preemption and priority. These benefits will provide enhanced safety and mobility operations for first responders and improved on-time performance for public transportation by providing preemption and priority along a route.

Additional applications include SPaT information, Construction and Maintenance Vehicle Alert, Rail Intersection Blocked Alert, and PPA. Safety-oriented messages associated with these applications could be delivered to vehicles equipped with HMIs.

During the near-term, the intention is to deploy the applications that will be tested and evaluated, with a focus on improving their capability and verifying scalability. All but 94 signals will be outfitted with connected vehicle devices. The remaining 94 were not deemed to be critical for the success of the applications to be deployed but will need to be integrated over time.

The Smart Corridor project will include an "innovation solution" component, which is intended for the technology industry to showcase the broadest or most effective ways in which to apply connected vehicle technology. Following the Smart Corridor Request for Proposals, the contractor teams will be challenged to provide solutions that provide short-term public benefit, additional value, mobility benefits, and safety benefits. The outcome of the innovation solution is that Gwinnett County will improve the project value to the transportation users in Gwinnett County.

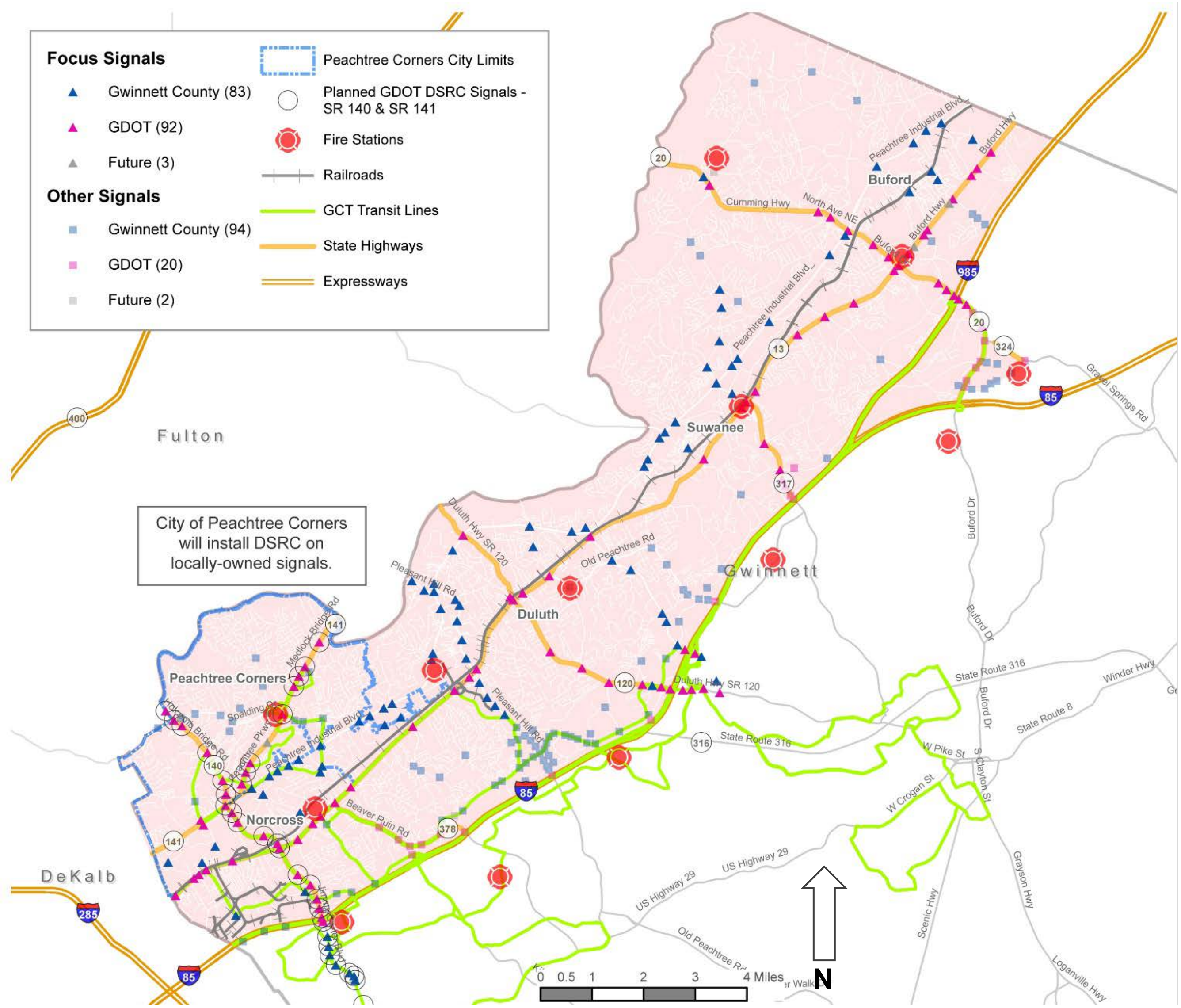


Figure 40. Smart Corridor Project Limits

The contractor will need to include sufficient software licenses for the Smart Corridor applications at all traffic signals in the Smart Corridor area. Expansion of software to traffic signals outside of the Smart Corridor may be deployed as part of a separate project during any portion of the 3-year service period. In addition, the contractor will provide a license unit cost for Smart Corridor applications per traffic signal located outside of Gwinnett County, if other agencies elect to participate during the 3-year service period.

The license per traffic signal, at a minimum, will include:

- State-wide access with login for various users with varying access levels (administration, local agency, etc.)
- The hardware on which the software is to be distributed must be free of defects
- License per traffic signal must include updates to ensure quality and accuracy of system logic and outputs.

Before completing the Smart Corridor project, Gwinnett County will want to increase the level of technical staffing to support the needs from deploying a new and evolving technology. The technical staffing level changes should occur for engineering and IT.

At minimum, one full-time engineer position would be needed to perform the following tasks:

- Monitor the activity of the Smart Corridor contractor during the 3-year service period
- Monitor the activity of the innovative solution during the 3-year service period
- Manage connected vehicle infrastructure operations, maintenance, and warranty work
- Iterate and innovate connective vehicle applications
- Provide guidance for the subsequent phases of connected vehicle deployment
- Educate others on the capabilities of the connected vehicle system
- Coordinate with other connected vehicle system operators in the Atlanta metro area and beyond

At minimum, one full-time technology manager would be needed to perform the following tasks:

- Manage and monitor the connected vehicle system and support the needs of other departments such as but not limited to GCT.
- Manage and monitor the Gwinnett County communications network with respect to the connected vehicle devices, protocols, data flows, applications, and bandwidth requirements
- Manage the network security requirements related to connected vehicle devices, including RSUs, OBUs, and HMIs
- Follow industry developments with respect to network security, connected vehicle device security, physical security, hack threats, and hack outcomes in similar environments
- Provide network security guidance for the subsequent phases of connected vehicle deployment

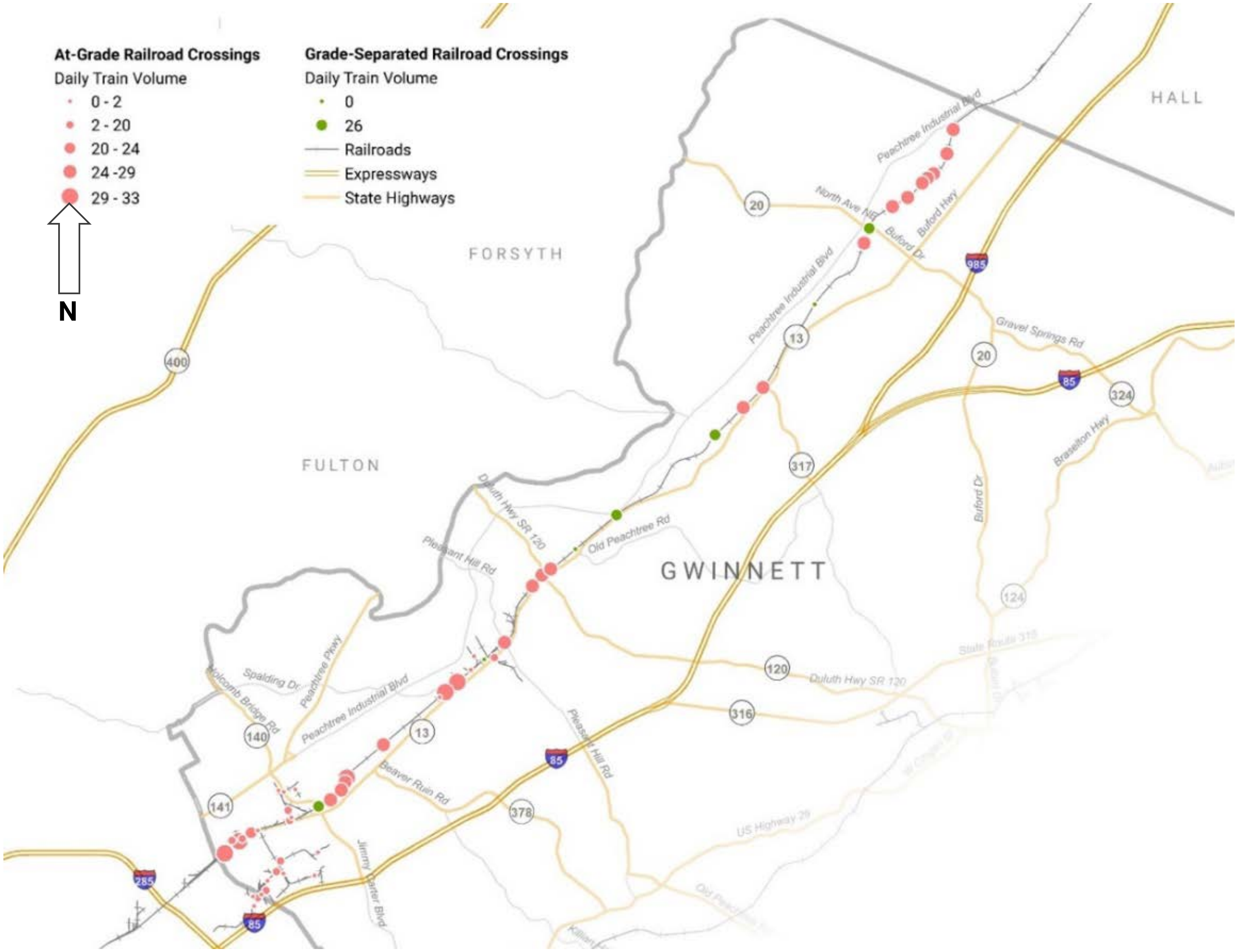
The 2017 ITS Master Plan identified the following projects, which have relevance to the success of the connected vehicle deployment:

Table 14. Short-term ITS Projects

Project Number	Project Title
ST-2	ITS Expansion on SR 13 (Buford Hwy)
ST-3	ITS Expansion on Peachtree Industrial Blvd (Phase 1)
ST-5	ITS Communications and Asset Management Program
ST-6	ITS Communications Upgrades 1
ST-7	Network Upgrades and Operational Enhancements

Figure 41 provides insight on railroad activity at highway-rail at-grade railroad crossings in the Smart Corridor area. The size of the red dot indicates a greater volume of train activity, which translates to the greater likelihood an emergency vehicle (and other vehicles) may be delayed by the train event. For example, a railroad intersection blocked alert application in the future will have the potential to reduce the time it takes to get a patient to the care they need, or to reduce the severity of the fire for the purposes of saving lives and property.

The first generation of this application may include the status of the railroad crossing (clear or blocked) delivered to a web application. In addition, initially very few vehicles will be outfitted by OEMs to accept messages regarding the status of the railroad crossing. Later phases will likely allow the application to mature and include communication to the driver with predictive (estimated) capabilities such as the time until the next train arrives, the time for the train to clear the railroad crossing, and the estimated duration of the railroad crossing blockage.



Source: GDOT OTD

Figure 41. At-grade Crossings within the Limits of the Smart Corridor

Connected Vehicle System Sample Project

Table 15 and Table 16 provide an overview of a sample project with rough estimates for a system with 20 intersections outfitted with connected vehicle technology.

Table 15. Sample Project Field Installations

Field Installation	# of Units + Install + Programming	Unit Cost	Total Cost
Roadside Unit	20	$5,000.00	$100,000.00
MAP Message Development	20	$1,500.00	$30,000.00
Edge processing	20	$350.00	$7,000.00
Software (units = intersections)	20	$7,000.00	$140,000.00
Service (units = years)	3	$ 10,000.00	$ 30,000.00
Cyber Security (SCMS)	20	$ 100.00	$ 2,000.00
		TOTAL	**$ 309,000.00**

Table 16. Sample Project Vehicle Installations

Vehicle Installation	# of Units + Install + Programming	Unit Cost	Total Cost
OBU	20	$5,000.00	$100,000.00
HMI	20	$3,000.00	$60,000.00
Cybersecurity (SCMS)	20	$100.00	$2,000.00
		TOTAL	**$ 162,000.00**

Phase 2: Short-Term (2-3 years)

Following the Smart Corridor project, Gwinnett County will have the opportunity to test and evaluate the connected vehicle applications, and to demonstrate new connected vehicle applications as they become available. Collaboration with GDOT and ARC will improve the value of the connected vehicle testing and refinement process for all agencies that seek to provide connected vehicle applications within the State of Georgia.

During this phase, the number of vehicles manufactured with connected vehicle-enabled capability will grow. Gwinnett County will experience first-hand learning about how drivers respond to messages generated by connected vehicle applications, as the market penetration of OBUs occurs over time.

New connected vehicle applications that will be evaluated during Phase 2 are as follows:

- Freight signal priority, including conditional requirements
- Transit signal conditional priority based on bus schedule adherence and bus occupancy level
- Railroad intersection blocked alert application enhancements
- Safety alerts generated by vehicle-derived data, such as hard braking events
- Pedestrian presence alerts based on transit bus door open events
- Pedestrian applications to support visually impaired users

Testing and evaluation opportunities include:

- A dashboard for evaluating the impact of preemption and priority on traffic signal operations, to apply conditional requirements that may be appropriate
- Next steps towards implementing the rail intersection blocked alerts application to drivers
- Understanding the communications network and ATMS network impacts as the number of vehicles with an OBU grows

Supportive infrastructure was identified in the 2017 *Intelligent Transportation System Master Plan* as mid-term and long-term projects. There are 11 mid-term projects identified and 6 long-term projects, some of which will be critical to support a connected vehicle system. Two such ITS expansion projects are the Peachtree Industrial Boulevard (phase 2) and the SR 120 Duluth Highway (phase 1). Additionally, DSRC and C-V2X devices will need to be deployed and programmed in coordination with local agencies.

Scaling Connected Vehicle Infrastructure County-wide

Following the Smart Corridor project deployment, much of Gwinnett County will remain in need of connected vehicle technology deployment. A recommended strategy is to identify where and when to expand the connected vehicle system. This includes:

- Coordinate with GDOT to outfit additional intersections with RSUs
- Deploy connected vehicle infrastructure in batches of 75 to 175 traffic signals per phase
- Focus on outfitting signals that serve FSP and TSP

Figure 42 illustrates how Gwinnett County can be divided into three zones. The deployment of traffic signals could be divided in a similar manner, should project funding be available in amounts that support wide-scale deployment.

If funding is available in smaller increments, then deployments can be targeted at

- Area surrounding the Mall of Georgia and Coolray Field
- Area surrounding Gwinnett Place Mall
- Major commuter corridors, such as Sugarloaf Parkway
- Downtown areas, such as Lawrenceville, Lilburn and Snellville

Deployments will need to be cognizant of Fire District boundaries

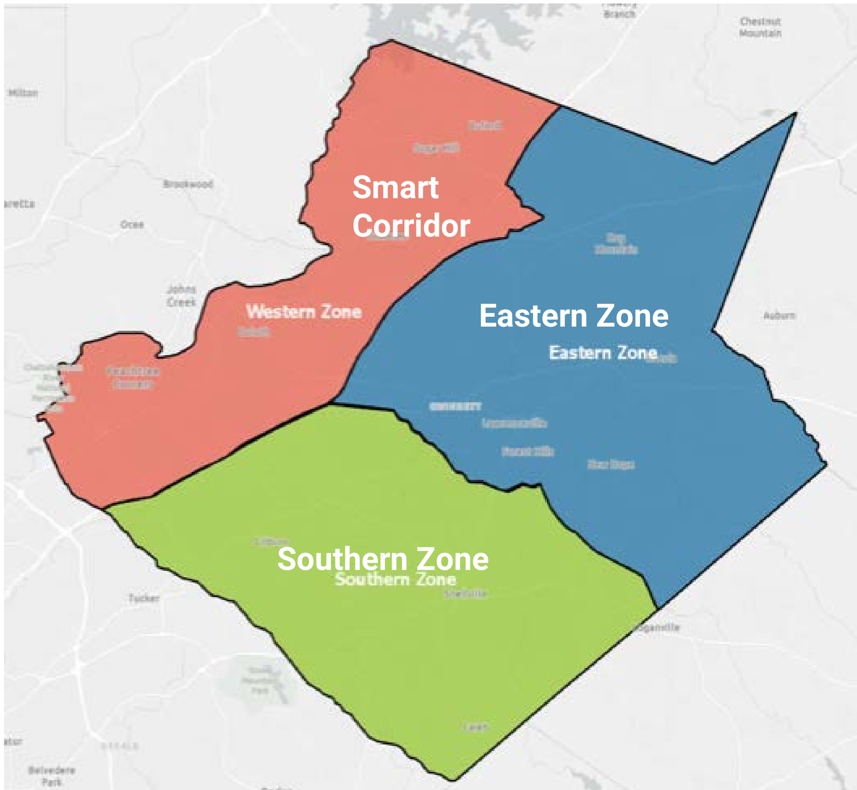


Figure 42. Map of Deployment Zones

For reference, Table 17 provides selected assets related to the connected vehicle applications by deployment zone. This data will be helpful as the connected vehicle projects are developed and will be further verified by coordinating with GDOT and Gwinnett County Transit if information changes over time.

Table 17. Gwinnett County Selected Assets by Zone

	Western Zone	Eastern Zone	Southern Zone	Total
Total Traffic Signals	269	249	231	740
Smart Corridor Traffic Signals	76	2	0	78
GDOT Traffic Signals	102	121	83	306
Local Traffic Signals	162	115	147	424
Future Traffic Signals	5	4	1	10
Fire Stations	7	13	12	32
Fiber Hubs	15	10	9	34
Traffic Signals near Transit Stops (900 feet)	90	63	66	219
Traffic Signals along Transit Routes (900 feet)	117	99	94	310

Phase 3: Long-Term (4-5 years)

By 2024, a significant number of new vehicles will be manufactured with connected vehicle capabilities. The applications that are appropriate and ready for county-wide deployment will be deployed, including an expansion of the connected vehicle system components, including connected vehicle devices and fiber communications.

While all connected vehicle applications may not yet be fully mature, Gwinnett County will continue to select and prioritize applications based on the results of the testing and evaluation phase. The anticipated safety and mobility benefits, number of users, cost, staffing, and amount of hardware and software will be considered for making decisions regarding county-wide deployment.

Collaboration with GDOT and ARC will remain critical as technology and connected vehicle applications change. For instance, some applications may be better served by applications that can be displayed via an HMI installed in a vehicle, and some applications may be adequately served by a mobile device.

The mission-critical nature of providing first-line safety applications requires the connected vehicle system to be robust, redundant, and secure to the extent practical. To reduce pressure on the network communications system, applications that can be served at the "edge," such as by a local intersection, will be deployed first. Applications that require external triggers to be sent to the intersection through the network communications system will be considered supplementary.

As with any technology-oriented plan, there is a significant likelihood that the plan will become obsolete before the horizon year occurs. As a result, the recommendations for long-term will be considered advisory in nature. As Gwinnett County experiences the Smart Corridor project, the applications and communications approach will be reviewed to take advantage of the most beneficial methods of delivering connected vehicle benefits.

APPENDIX A INTERVIEW GUIDING QUESTIONS REGARDING RECENT SMART MOBILITY DEPLOYMENTS

Questions for Municipalities

1. Does your agency have a smart mobility vision or problem statement(s)? If so, what is the overall vision and/or problem statement?
2. Did you develop any criteria to help with narrowing down mobility technology solutions to test?
3. What was the underlying need/focus/priority for your deployment?
4. Did interoperability with legacy and/or future systems concern you during the selection process?
5. Did you already have funding secured for the solution(s)?
6. Describe the process for selecting the connected vehicle system?
7. Are there policies currently in place hindering or supporting the ability to adopt new technologies? What types of new policies do you think should be explored to prepare for or respond to these technology trends?
8. How do you foresee the use of the existing and future technology solutions over the next five years? Do you foresee needing to expand the existing system(s) or to pursue new technologies?
9. Is your agency/jurisdiction collaborating with other agencies/jurisdictions regarding smart mobility solutions?
10. Did you have to upgrade communications capabilities prior to technology deployments?
11. Are there any additional capabilities you wish for in the near-term? Long-term?
12. Where there any unforeseen positive or negative impacts post deployment?
13. How many vehicles in your fleet are outfitted to receive signal pre-emption?
14. Did you establish specific KPI’s ahead of the connected vehicle deployment? If so, what were they?
15. What have the measured outcomes indicated this far?

Insight from the City of Atlanta

Subject	Insight
Vision/Project Selection Process	• Needs based. Prioritized roads under City control, underserved communities, areas in need of complete streets projects. • City Council and Public Engagement directed projects • Updating process to work closer with planning department using the Atlanta Transportation Plan (ATP) as a foundation for adding technical rigor
Funding	• All local dollars. April will be year 3 of 5 of SPLOST. • Funding strategy for project delivery could be a full-time job • Too often money is left on the table
Interoperability	• A consultant was hired to upgrade all city fiber. Goal is to move all City departments to the same network. • Growing from 5 miles of fiber to 50 miles of 144/288 fiber when all projects are built. • Would connect 100 of 950 traffic signals. • AIM has new leadership and is currently working on an IT master plan • Concerned about maintenance of fiber system
Data Sharing	• Has been a challenge navigating data storage needs, solidifying data agreements • GDOT via TTS has been successful in providing analytics of car movements to CoA • At this time, companies do a better job of managing data than the City
Transit	• Glance has been deployed at 5 intersections along Campbellton Rd • MARTA needs to add receivers to buses – currently delayed • Chose Glance over Opticom because of multi-solution option Glance provides
Standards	• CV standards need to be set. Similar to how GDOT set up Cabinet standards; company agnostic, performance-based, product must do x, y, z.
Traffic Signal Operations Software	• For North Avenue, the Surtrac adaptive system was installed, but is currently turned off. Surtrac was used instead of Intelight because SPaT module was not available at the time. Surtrac will be moving from North Ave to DeKalb Ave when corridor is reconfigured • Not ideal in a grid setting
Collaboration	• This is a great need internally at the City of Atlanta for project delivery • This is also a great need regionally to develop many necessary standards crucial for interoperability

Insight from Marietta Fire Department

Subject	Insight
Vision/Project Selection Process	• Opportunity based decision making • Deployment was traffic solution driven with the added benefit of EVP
Funding	• City funded • Test bed for Glance
Findings	• Travel time is being reduced by not having to slow down as much at intersections • Reduced secondary crashes • There has been a culture shift since switching from Opticom • There was an issue of triggering signal preemption at a nearby signal when turning into a fire department. Company was responsive to fix the issue.
Data/KPIs	• Fire Department has not analyzed any of the perceived benefits
Future	• Would like to have a system that predicts a route from station to call location and clears the entire route • Would like to see notifications inside the car stating the type of emergency vehicle approaching, what side it's approaching from, and when it is arriving • For notifying the public, would like a better solution than the current mobile app

Insight from Cobb County Department of Transportation

Subject	Insight
Vision/Project Selection Process	• Comprehensive Transportation Plan is the most mature vision. • Device selection process was opportunity based. Interoperability with neighbors was key.
Funding	• SPLOST funds often used to match federal. CIDs help with cost-sharing • Most cost concerns for County are operational
Interoperability	• Key driver for TSP project
Data-Sharing	• For CV, the plan is to provide data access to TTS with local data and have them make it available to others with goal of improving safety and reducing congestion • Have an agreement with Smyrna for SCATs system • Smart city data platform will focus on incident-based congestion - what is needed to arrive at and clear an incident and, for ambulance, arriving to the hospital quickly
Transit	• Testing on the table TSP – working to set up business rules to match how we track on-time performance (0-5 mins) and passenger load
Future	• Anything that helps to reduce crashes • Last-mile improvements • Looking forward to creating data streams of mobility options and putting them all on one platform

APPENDIX B STAKEHOLDER INSIGHTS BY ZONE

Stakeholders

Name	Title	Organization
Jennifer Scott	City Manager	City of Braselton
Dan Branch	Public Safety Director	City of Buford
Rebecca Keefer	Consultant / Special Projects Manager	City of Chamblee
Joey Murphy	City Administrator	City of Dacula
Brittni Nix	City Planner	City of Dacula
Jimmy Wilbanks	Mayor	City of Dacula
Margie Pozin	City Engineer	City of Duluth
Bill Aiken	Planning and Development Director	City of Duluth
Judy Jordan Johnson	Mayor	City of Lawrenceville
Eric Van Otteren	Economic Development	City of Snellville
Marty Allen	City Manager	City of Suwanee
Jim Brooks	Executive Director	Evermore CID
Masha Anderson Bomar	Executive Director	Gateway 85 CID
Matt Gore	Project Manager	Gateway 85 CID
Sam Harris	Traffic Engineer	Georgia Department of Transportation
Laura Olle	Intern	Georgia Department of Transportation
Jesse Jones	GCPD Assistant Chief	Gwinnett County Police Department
Butch Ayers	GCPD Chief of Police	Gwinnett County Police Department
Stoney Polite	Chief of Logistics	Gwinnett County Fire Department
Russell Knick	Fire Chief	Gwinnett County Fire Department
Ronnie Ezell	FF/LT	Gwinnett County Fire Department
Karen Winger	Transit Division Director	Gwinnett County Department of Transportation
Alex Hofelich	Division Director for Traffic Engineering	Gwinnett County Department of Transportation

Name	Title	Organization
Tom Sever	Deputy Director for Traffic Engineering, Operations, and Maintenance	Gwinnett County Department of Transportation
Vince Edwards	Section Manager – Infrastructure Analysis	Gwinnett County Department of Transportation
Ken Keena	Engineer IV	Gwinnett County Department of Transportation
Joe Allen	Executive Director	Gwinnett Place CID
Emory Morsberger	Executive Director	Lilburn CID
Alyssa Davis	Executive Director	Sugarloaf CID

Map of Gwinnett County in Three Area Zones

This map was later updated to better represent the county and stakeholder's input.

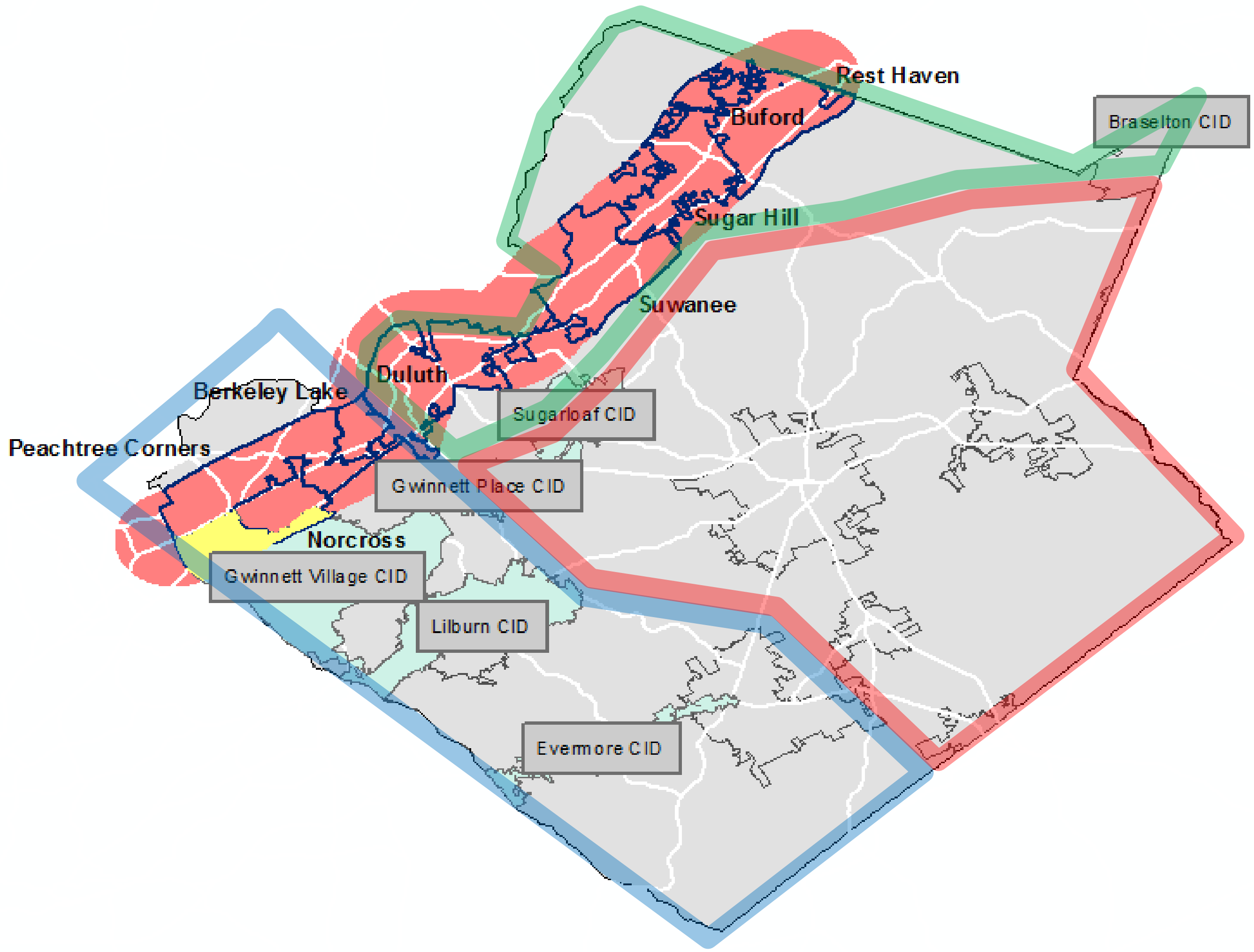


Table 18. Zone 1

Location	Goal/Action	Reason	Priority
Jimmy Carter Blvd @ Buford Hwy	Enhance/create electronic wayfinding for freight carriers and consider preference/preemption for freight	Freight can move more efficiently through the area and vehicular traffic will be less impacted by freight	High
Various	Consider adding technology to pedestrian signals (RRFB/PHB, etc.) to warn drivers that they are nearing an activated signal for a crossing ahead	Pedestrians have an additional layer of protection at pedestrian crossings	Medium
Everywhere	V2V – Driver awareness of approaching emergency vehicles	Drivers to clear route for emergency vehicles. Driver distraction and vehicle noise limitation have reduced the effectiveness of emergency sirens on police and fire vehicles	High
Everywhere	V2I – Emergency vehicle – traffic light preemption	Quick emergency response to incidents	High
Everywhere	Alert authorities of traffic flow issue or driver/vehicle initiated a notice of accident, etc.	Quick response to the situation to mitigate and get traffic moving again.	Medium
Parkview High School and Trickum Middle School	Reset nearby lights to allow better flow in and out		
US-29 and Jimmy Carter Blvd	Worsening backups during rush hour	Reduce bottlenecks	
US-29 @ Rockbridge Rd NW	Worsening backups during rush hour	Reduce bottlenecks	
Jimmy Carter Blvd @ Lawrenceville Hwy	Rush hour drivers traveling in the turn lane and switching into through lane at the light	Delineators or plastic curbs to stop turn lane abuse	
Jimmy Carter Blvd, Beaver Ruin Rd, Indian Trail Rd	Instrument signals with pedestrian detection	Make walking safer	Medium
Zone 1	Instrument JCB between McDonough Dr. and Buford Hwy, as well as Buford Hwy	Trucks can have signal prioritization	High

Location	Goal/Action	Reason	Priority
Brook Hollow Parkway	Expedite transit and future BRT		High
Zone 1	Reduce traffic congestion on US 78	Improvements to US 78 at 285	High
Snellville Town Center. 124, 78, Wisteria Dr	Town Center Development	Begin construction fall 2019	High
Scenic HWY 124 from 78 To Web Gin	Traffic and emergency vehicle		Medium
Hwy 78 east to west	Emergency vehicles		Low
Everywhere	Identify "hard-driving" so it can be addressed and reduce wear and tear on vehicles	Identify specific vehicles and drivers that are in need of retraining	Medium
County-wide	Ensure that Public Safety is able to view cameras throughout the county because we often get bad information about where the incident is located	So we can respond promptly to the correct location	Medium
County-wide	Traffic congestion – trying to get emergency response trucks around all congestion	We can get to emergency scenes faster	High
Mall of GA Blvd west of fire station 24	Improve the ability of station 24 to get through traffic Heading towards Buford Dr	Station 24 can respond promptly to emergencies in that direction	Medium
Particularly in areas with large buildings like malls, schools, where it may be harder to "radio out" from inside	Improve portable radio communication/eliminate dead spots	So we always have good radio communication during emergency incidents	High

Table 19. Zone 2

Location	Goal/Action	Reason	Priority
Braselton	Connect traffic signals to Gwinnett System		Low
Braselton	Improve pedestrian safety	Crossing SR 211 is safer	High
Duluth	Know how many trains will clog up the at-grade crossings and for how long as multiple trains in a row tend to clog up all crossings and it takes a long time to recover. Ideally, road users have access to this info long before I approach the crossings		
SR 120 WB heading into Duluth	Relieve congestion. Can traffic be diverted This is RR related		
PIB and SR 120	Alleviate bottleneck @ PIB and SR 120. Widening project assumed to help	Traffic congestion decrease. Level of Service Increase	
Pleasant Hill Rd at Satellite Blvd	Intersection needs mobility and safety enhancements	Intersection needs to be improved to better move vehicle and move make more pedestrian friendly	High
Satellite Blvd – Old Norcross to Old Norcross NW	Move employees entering/exiting office buildings during AM/PM peak into office parks	Backups do not occur on roadways new office buildings crossings.	Medium
Entering Gwinnett Place Dr	Adjust Traffic signalization during special events or accidents clog Steve Reynolds, Pleasant Hill, and Satellite Blvd	Drivers alerted to alternative or signals adjusted until “event” has passed	Medium
Pleasant Hill At Major intersections from Pleasant Hill @ Club to Pleasant Hill @ Old Norcross	Pedestrian crossings between intersections and not at crosswalks. Due to larger blocks	Not cross. Mid-block.	High
Venture Pkwy/Dr at Day Dr	Improve safety at the intersection	Project underway	Medium
Steve Reynolds Blvd at I-85	Backups to enter and exit interstate	Relieve backups on Steve Reynolds in AM	Medium

Location	Goal/Action	Reason	Priority
Pleasant Hill at I-85	Trucks blocking lanes	Remove vehicles from blocking DDI and allow easier flow of vehicles	High
Peachtree Corners – St. 4			
Norcross – 1, 11, 23, 25, 3, 22, 6, 28, 19			
Lilburn, Duluth, Snellville, Loganville	Reduce travel time	Better respond to emergencies	High
5885 Live Oak Pkwy – Fire Station 11	Reduce travel time to emergencies	Mitigate more quickly	
Snellville – Fire Station 12 – 2815 Lenora Church Rd	Reduce travel time through heavy travel time	Fire responds in a timely manner. EMS in emergencies	High
Sugarloaf Pkwy @ Satellite Blvd	Figure out how to coordinate pedestrian and vehicle movements during big events	We can help pedestrians move more efficiently and safely (and can help cars look out for pedestrians)	High
Buford Hwy @ Buford Drive Buford Hwy @ Hamilton Mill Rd Hamilton Mill Rd @ South Coon Rd Buford Dr @ Gravel Springs Rd	Heavy congestion at all four intersections during peak traffic hours	Communication which would or could alert drivers to seek an alternate route	High
Buford Hwy @ George Pierce Park	During sporting events, traffic backs up inside the park enormously	Have more dynamic signalization. 90% of the time not a problem but when it's a problem, it is significant	Medium
Town Center Ave @ Buford Hwy	Pedestrian safety, existing HAWK needs to be replaced	Ped safety	High
PIB and Suwanee Dam Drive	Peak hour congestion		High
PIB @ McGinnis Ferry	Peak congestion relief		Medium
Lawrenceville-Suwannee + Satellite Blvd	Peak congestion		Medium

Location	Goal/Action	Reason	Priority
SR20 @ Old Peachtree Rd NE	SR20 increased traffic due to development	Find ways to use technology to make traffic flow smoothly	
All areas	Use the technology to be able to determine a vehicles exact location	Find crash sites faster	
Horizon Dr @ Lawrenceville-Suwanee	Peak hour congestion		High

Table 20. Zone 3

Location	Goal/Action	Reason	Priority
Dacula Rd @ Winder Hwy	need for better driver decision-making to choose between SR 316 and US 29 routes; Dacula at Fence is a key point on the US 29 corridor		
Duluth Hwy @ University Pkwy		this intersection has significant left turn crashes	
SR 316 at Harbins Rd	history of fatal crashes		
Duluth HWY at Professional Drive, Lawrenceville, GA 30046	these locations need transit signal priority, due to significant bus delays		
Sugarloaf Mills Park/Ride	perhaps provide motorists with I-85 traffic conditions and parking space availability		
Near Braselton		this area near Braselton is impacted when there is a crash on SR 316, and impacts traffic around Dacula as well (Dacula is growing quickly)	
US-29 @ Jimmy Carter Blvd	this area has significant congestion 3-5 PM, particularly when there is a crash on US-29		
Fire Station #3	it takes a significant amount of time for the fire truck to leave the station, due to congestion on the two-lane roadway. The nearest signals that could be used to flush the roadway congestion would be at Lucerne and Killian		

APPENDIX C APPLICATIONS BEING TESTED NATIONWIDE

Near-term Applications (1-3 years)

Curve Speed Warning

Description: An application where alerts are provided to the driver who is approaching a curve at a speed that may be too high for safe travel through that curve. The curve speed warning system is a cooperative vehicle and infrastructure system that assists drivers in avoiding crashes. The application provides a warning to the driver that the vehicle's current speed may be too high to safely traverse one or more upcoming curves. Alerts are classified by the location of the vehicle within the curve and the vehicle speed at the time of the alert.

Potential Benefits: Safety benefits for driver on arterial and non-arterial road

Deployment: New York (testing), Florida (testing), Michigan (planning), and Minnesota (researching)

Emergency Vehicle Preemption (PREEMPT)

Description: An application that provides signal preemption to emergency vehicles and accommodates multiple emergency requests.

The EVP application is a very high level of priority for emergency first responder vehicles. Historically, priority for emergency vehicles has been provided by special traffic signal timing strategies called preemption. The goal of EVP is to facilitate safe and efficient movement through intersections. As such, clearing queues and holding conflicting phases can facilitate emergency vehicle movement. For congested conditions, it may take additional time to clear a standing queue, so the ability to provide information in a timely manner is important. In addition, transitioning back to normal traffic signal operations after providing EVP is an important consideration since the control objectives are significantly different.

Potential Benefits: Mobility benefits for driver on non-arterial road

Deployment: Maricopa County, Arizona (deployment), Pennsylvania (planning), and Virginia (planning)

Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)

Description: An application that provides input to responder vehicle routing, staging, and secondary dispatch decisions.

The Incident Scene Pre-Arrival Staging Guidance for Emergency Responders application will provide situational awareness to and coordination among emergency responders - upon dispatch, while en route to establish incident scene work zones, upon initial arrival and staging of assets, and afterward if circumstances require additional dispatch and staging. The application collects a variety of data from emergency, traffic, and maintenance centers. The application includes a vehicle and equipment staging function that supplies the en-route responders with additional information about the scene of an incident that they can use to determine where to stage personnel and equipment prior to their arrival on-scene. The application also includes a dynamic routing function that provides emergency responders with real-time navigation instructions to travel from their base to the incident scene, accounting for traffic conditions, road closures, and snowplow reports if needed. In addition, the application includes an emergency responder status reporting function that continuously monitors the location of the en-route responder vehicles as well as the vehicles already on-scene. The function develops and maintains the current position of the responder's vehicles and provides updates for estimated time of arrival to other applications.

Intelligent Traffic Signal System (I-SIG)

Description: An overarching system optimization application accommodating signal priority, preemption, and pedestrian movement requirements.

The Intelligent Traffic Signal System (I-SIG) application uses both vehicle location and movement information from connected vehicles as well as infrastructure measurement of non-equipped vehicles to improve the operations of traffic signal control systems. The application utilizes the vehicle information to adjust signal timing for an intersection or group of intersections to improve traffic flow, including allowing vehicle flow through the intersection. The application serves as an overarching system optimization application, accommodating other mobility applications such as TSP, FSP, EVP, and Pedestrian Mobility to maximize overall arterial network performance. The application may consider additional inputs such as environmental situation information or the interface (i.e., traffic flow) between arterial signals and ramp meters.

Potential Benefits: Mobility benefits for driver on non-arterial road

Deployment: Maricopa County, Arizona (deployment), Florida (testing), New York (testing), and Virginia (planning)

Mobile Accessible Pedestrian Signal System (PED-SIG)

Description: An application that allows for an automated call from the smart phone of a visually impaired pedestrian to the traffic signal, as well as audio cues to safely navigate the crosswalk.

Potential Benefits: Mobility benefits for drivers and pedestrians on non-arterial road

Deployment: Maricopa County, Arizona (deployment), Florida (testing), and New York (testing)

Multimodal Intelligent Traffic Signal System (MMITSS)

Description: The MMITSS application bundle seeks to develop a comprehensive traffic signal system that services all modes of transportation. MMITSS is composed of the following applications:

- Intelligent Traffic Signal System (I-SIG)
- Transit Signal Priority (TSP)
- Freight Signal Priority (FSP)
- Mobile Accessible Pedestrian Signal System (PED-SIG)
- Emergency Vehicle Preemption (PREEMPT)

Potential Benefits: Mobility benefits for agencies on arterial and non-arterial road

Deployment: Maricopa County, Arizona (deployment), California (deployment), Colorado (planning), Pennsylvania (planning), and Utah (testing)

Pedestrian in Signalized Crosswalk Warning (Transit)

Description: An application that warns transit bus operators when pedestrians within the crosswalk of a signalized intersection are in the intended path of the bus. This application utilizes RSE to warn bus drivers of a pedestrian's presence using pedestrian detection equipment set up to recognize pedestrians in delineated crosswalks.

Potential Benefits: Safety benefits for driver on non-arterial road

Deployment: Florida (testing), New York (testing), Minnesota (planning), and Texas (planning)

Red Light Violation Warning

Description: An application that broadcasts SPaT information and other data to connected vehicles, to provide a warning to the driver if they may violate an upcoming red light, based on the driver's approach speed and distance to the intersection. The application in the vehicle cross references the vehicle's speed and acceleration profile, along with the signal timing and geometry information, to determine whether it appears likely that the vehicle will enter the intersection in violation of a traffic signal. If the violation seems likely to occur, a warning can be provided to the driver.

Potential Benefits: Safety benefits for driver on non-arterial road

Deployment: Michigan (testing) and Virginia (planning)

Reduced Speed/Work Zone Warning

Description: An application that utilizes RSE to broadcast alerts to drivers warning them to reduce speed, change lanes, or come to a stop within work zones.

Potential Benefits: Safety benefits for driver on arterial and non-arterial road

Deployment: Maricopa County, Arizona (deployment), New York (planning), and Virginia (planning)

Transit Signal Priority (TSP) and Freight Signal Priority (FSP)

Description: An application that provides signal priority to transit at intersections and along arterial corridors as well as signal priority to freight vehicles along an arterial corridor near a freight facility.

The TSP application uses transit V2I communications to allow a transit vehicle to request a priority at one or a series of intersection. The application includes feedback to the transit driver indicating whether the signal priority has been granted or not. This application can contribute to improved operating performance of the transit vehicles by reducing the time spent stopped at a red light.

Potential Benefits: Mobility benefits for driver on non-arterial road

Deployment: Maricopa County, Arizona (deployment), Colorado (planning), Florida (planning), Michigan, (testing), Minnesota (planning), Pennsylvania (planning), Tennessee (planning), Utah (deployment), and Virginia (planning)

Short-term Applications (3-5 years)

Advanced Traveler Information System

Description: The Advanced Traveler Information System application provides for the collection, aggregation, and dissemination of a range of transportation information. The collection of information includes traffic, transit, road weather, work zone, and connected vehicle-related data. All the sources of data are aggregated into data environments that can be used to drive data portals, allowing dissemination of the spectrum of transportation information to travelers via mobile devices, in-vehicle displays, web portals, 511 systems, and roadside signage.

Potential Benefits: Environmental benefits for driver on arterial and non-arterial road

Deployment: Tennessee (planning) and Virginia (planning)

Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)

Description: An application that warns on-scene workers of vehicles with trajectories or speeds that pose a high risk to their safety. It also warns drivers passing an incident zone if they need to slow down, stop, or change lanes.

The Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) application employs communications technologies to provide warnings and alerts relating to incident zone operations. One aspect of the application is an in-vehicle messaging system that provides drivers with merging and speed guidance around an incident. Another aspect is providing in-vehicle incident scene alerts to drivers, both for the protection of the drivers and incident zone personnel. A third aspect is an infrastructure-based warning system for on-scene workers when a vehicle approaching or in the incident zone is being operated outside of safe parameters for the conditions. Additional information such as arriving and staging of additional responders is provided to assist in staging decisions and response to the incident.

Potential Benefits: Mobility and safety benefits for driver on arterial and non-arterial road

Deployment: Tennessee (planning) and Virginia (planning)

Vehicle Turning Right in Front of Bus Warning (Transit)

Description: An application that warns transit bus operators of the presence of vehicles attempting to go around the bus to make a right turn as the bus departs from a bus stop.

The Vehicle Turning Right in Front of a Transit Vehicle (VTRFTV) application determines the movement of vehicles near a transit vehicle stopped at a transit stop and provides an indication to the transit vehicle operator that a nearby vehicle is pulling in front of the transit vehicle to make a right turn. This application will help the transit vehicle determine whether the area in front of it will not be occupied as it begins to pull away from a transit stop.

Potential Benefits: Safety benefits for driver on arterial and non-arterial road

Deployment: Florida (planning) and New York (planning)

Work Zone Traveler Information

Description: An application that monitors and aggregates work zone traffic data.

Potential Benefits: Agency data benefits for agencies on arterial and non-arterial road

Deployment: Pennsylvania (planning) and Virginia (planning)

Long-term Applications (5+ years)

Eco-traffic Signal Timing

Description: An application that uses data collected wirelessly from vehicles (and other sources) to optimize the performance of traffic signals, thus reducing fuel consumption and emissions.

The Eco-Traffic Signal Timing application is similar to current adaptive traffic signal control systems; however, the application's objective is explicitly to optimize traffic signals for the environment rather than the current adaptive systems' objective, which is to enhance the intersection level of service or throughput, which might improve the intersection's environmental performance. The Eco-Traffic Signal Timing application processes real-time and historical connected vehicle data at signalized intersections to reduce fuel consumption and overall emissions at the intersection, along a corridor, or for a region. The application evaluates traffic and environmental parameters at each intersection in real time and adapts so that the traffic network is optimized using available green time to serve the actual traffic demands while minimizing the environmental impact.

Potential Benefits: Environmental benefits for driver on non-arterial road

Freight Advanced Traveler Information Systems (FRATIS)

Description: The FRATIS application bundle seeks to provide freight-specific route guidance and optimize drayage operations so that load movements are coordinated between freight facilities to reduce empty-load trips. FRATIS is composed of the following applications:

- Freight Specific Dynamic Travel Planning and Performance)
- Drayage Optimization (DR-OPT)

Potential Benefits: Mobility benefits for agencies on arterial and non-arterial road

Freight Drayage Optimization

Description: An application that optimizes truck/load movements between freight facilities, balancing early and late arrivals.

The Freight Drayage Optimization application covers the information exchanges between all intermodal parties to provide current drayage truck load matching and container availability and appointment scheduling at railroad and steamship line terminals. The application includes a link from drivers and freight management systems dispatchers to an intermodal terminal reservation system and integrates an appointment function with Terminal Queue Status and Load Matching. The application set provides information to the dispatcher and driver concerning the availability status for pickup of a container at an intermodal terminal. The application bundle also provides drivers and dispatchers with both intermodal terminal queue length, and estimated time from the back of the queue to the gate.

Potential Benefits: Mobility benefits for driver on arterial and non-arterial road

Freight-Specific Dynamic Travel Planning and Performance

Description: An application that enhances traveler information systems to address specific freight needs. Provides information such as wait times at ports, road closures, work zones, and route restrictions.

The Freight-Specific Dynamic Travel Planning application provides both pre-trip and en route travel planning, routing, and commercial vehicle-related traveler information, which includes information such as truck parking locations and current status. The information will be based on data collected from the commercial fleet as well as general traffic data collection capabilities. The information, both real time and static, can be provided directly to fleet managers, to mobile devices used by commercial vehicle operators, or directly to in-vehicle systems as commercial vehicles approach roadway exits with key facilities such as parking. The application can also provide oversize/overweight permit information to commercial managers.

Potential Benefits: Mobility benefits for driver on arterial and non-arterial road

In-Vehicle Signage

Description: The In-Vehicle Signage application augments regulatory, warning, and informational signs and signals by providing information directly to drivers through in-vehicle devices. The information provided includes static sign information (e.g., stop, curve warning, guide signs, service signs, and directional signs) and dynamic information (e.g., current signal states including highway intersection and highway-rail intersection status and local conditions warnings identified by local environmental sensors). This application also includes the capability for maintenance and construction and emergency vehicles to transmit sign information to vehicles in the vicinity so that in-vehicle signing can be used without fixed infrastructure in work zones and around incidents.

Potential Benefits: Safety benefits for driver on arterial and non-arterial road

Intermittent Bus Lanes (IBL)

Description: The Intermittent Bus Lane (IBL) application provides dedicated bus lanes during peak demand times to enhance transit operations mobility. IBL consists of a lane that can change its status from regular lane (accessible for all vehicles) to bus lane, for the time strictly necessary for a bus or set of buses to pass. The status of the IBL is communicated to drivers using roadside message signs and through in-vehicle signage. The creation and removal of dedicated bus lanes is managed through coordination between traffic and transit centers.

Potential Benefits: Mobility benefits for agencies on arterial and non-arterial road

Pedestrian in Signalized Crosswalk Warning

Description: A V2I system that assists drivers in avoiding crashes involving pedestrians at signalized intersections. The application provides a warning to the vehicle driver when, based on their movement and location of the pedestrian and crosswalk, a potential conflict exists.

Potential Benefits: Safety benefits for drivers and pedestrians on non-arterial road

Pedestrian Mobility

Description: The Pedestrian Mobility application will integrate traffic and pedestrian information from roadside or intersection detectors and new forms of data from wirelessly connected, pedestrian (or bicyclist) carried mobile devices (nomadic devices) to request dynamic pedestrian signals or to inform pedestrians when to cross and how to remain aligned with the crosswalk based on real-time SPaT and MAP information. In some cases, priority will be given to pedestrians, such as persons with disabilities who need additional crossing time, or in special conditions (e.g., weather) where pedestrians may warrant priority or additional crossing time. This application will enable a "pedestrian call" to be routed to the traffic controller from a nomadic device of a registered person with disabilities after confirming the direction and orientation of the roadway that this pedestrian is intending to cross. The application also provides warnings to the personal information device user of possible infringement of the crossing by approaching vehicles.

Potential Benefits: Mobility benefits for drivers and pedestrians on non-arterial road

Railroad Crossing Violation Warning (RCVW)

Description: The Railroad Crossing Violation Warning (RCVW) application will alert and/or warn drivers who are approaching an at-grade railroad crossing if they are on a crash-imminent trajectory to collide with a crossing or approaching train. This will be achieved through the integration of both vehicle-based and infrastructure-based technologies. The RSE sends to the vehicle detailed geometric information about the intersection, as well as information about whether a train is approaching or blocking the intersection. The geometric information could be obtained from an RSE at the intersection or obtained from an RSE at some earlier point in the vehicle’s trip. The information about the approach or presence of a train is obtained from the infrastructure via a connection between the rail infrastructure and the RSE. The information received from the RSE at the intersection could also be augmented with road surface information or other weather-related data. A more advanced version of the application could provide train arrival information or information about the amount of time the Highway Rail Intersection will be blocked by the train.

Potential Benefits: Safety benefits for driver on arterial and non-arterial road

Reduced Speed Zone Warning (RSZW)

Description: The Reduced Speed Zone Warning/Lane Closure (RSZW/LC) application provides connected vehicles that are approaching a reduced speed zone with information on the zone's posted speed limit and/or whether the configuration of the roadway is altered (e.g., lane closures, lane shifts). Reduced speed zones include (but are not be limited to) construction/work zones, school zones, pedestrian crossing areas, and incorporated zones (e.g., rural towns). The RSZW/LC application inside the connected vehicle uses the revised speed limit along with any applicable changed roadside configuration information to determine whether to provide an alert or warning to the driver. Additionally, to provide warnings to non-equipped vehicles, infrastructure equipment measures the speed of the approaching vehicles, and if greater than the reduced speed zone posted speed limit, will provide warning signage. The application will provide an alert to drivers in advance when aggressive braking is required to reduce to the posted speed limit.

Potential Benefits: Safety benefits for driver on arterial and non-arterial road

Restricted Lane Warning

Description: The Restricted Lane Warning application provides the connected vehicle with restriction information about the travel lanes, such as if the lane is restricted to high occupancy vehicles, transit, or public safety vehicles only or has defined eco-lane criteria. A connected vehicle can use this information to determine whether the vehicle is in a lane that has lane restrictions.

Potential Benefits: Safety benefits for driver on arterial and non-arterial road

Road Weather Information and Routing Support for Emergency Responders

Description: The Road Weather Information and Routing Support for Emergency Responders application provides the capability of collecting road weather data from connected vehicles and other sources and using that data to develop short-term warnings or advisories that can be provided to individual emergency response vehicles or to emergency response dispatchers. The information may come from vehicles operated by the general public and commercial entities (including passenger cars and trucks) or specialty vehicles and public fleet vehicles (such as snowplows, maintenance trucks, and other agency pool vehicles). The raw data will be processed in a controlling center to generate road segment-based data outputs. The processing will also include a road weather vehicle alerts algorithm to generate short time horizon alerts that will be pushed to user systems and available to emergency response dispatchers. The short time horizon alerts that are pushed to emergency vehicle drivers and dispatchers will include information on high winds, standing water, and flooding of roadways. This information will be acquired from other fixed and remote observation systems and will be provided with as much geographic precision as possible. In addition, the information collected can be combined with observations and forecasts from other sources to provide medium (next 2 to 12 hours) or long-term (more than 12 hours) advisories through a variety of interfaces, including web-based and connected vehicle-based interfaces.

Potential Benefits: Safety weather warnings for agencies on arterial and non-arterial road

Road Weather Information for Freight Carriers

Description: The Road Weather Information for Freight Carriers application is a special case of the Road Weather Advisories and Warnings for Motorists application focuses on Freight Carrier users. This application provides the capability of collecting road weather data from connected vehicles and using that data to develop short-term warnings or advisories that can be provided to individual commercial vehicles or to commercial vehicle dispatchers. The information may come from vehicles operated by the general public and commercial entities (including passenger cars and trucks) or specialty vehicles and public fleet vehicles (such as snowplows, maintenance trucks, and other agency pool vehicles). The raw data will be processed in a controlling center to generate road segment-based data outputs. The processing will also include a road weather commercial vehicle alerts algorithm to generate short time horizon alerts that will be pushed to user systems and available to commercial vehicle dispatchers. In addition, the information collected can be combined with observations and forecasts from other sources to provide medium (next 2 to 12 hours) or long-term (more than 12 hours) advisories through a variety of interfaces including web-based and connected vehicle-based interfaces.

Potential Benefits: Safety weather warnings for driver on arterial and non-arterial road

Road Weather Information for Maintenance and Fleet Management Systems

Description: The Road Weather Information for Maintenance and Fleet Management Systems Application can be viewed as a stand-alone application and as an adjunct to the Enhanced-MDSS. Vehicle data is collected both from vehicles used during winter maintenance and from other maintenance vehicles and equipment used year-round. The data collected is road weather data as well as specialized maintenance information such as status of vehicle systems, material distribution rate, and materials remaining. The data collected can be used by maintenance or fleet dispatchers to monitor the status of the maintenance operations, or the data can be used as an input to the Enhanced-MDSS application.

Potential Benefits: Safety weather warnings for agencies on arterial and non-arterial road

Transit Pedestrian Indication

Description: The Transit Pedestrian Indication application provides vehicle-to-device communications to inform pedestrians at a station or stop about the presence of a transit vehicle. In addition, this application informs the transit vehicle operator about the presence of pedestrians nearby and those waiting for the bus. It helps prevent collisions between transit vehicles and pedestrians.

Potential Benefits: Mobility benefits for driver on non-arterial road

Transit Stop Request

Description: The Transit Stop Request application allows a transit passenger to send a stop request to an approaching transit vehicle. This application allows a transit vehicle to know that a passenger has requested a transit stop from an infrastructure device.

Potential Benefits: Mobility benefits for pedestrian on non-arterial road

Transit Vehicle at Station/Stop Warnings

Description: The Transit Vehicle at Station/Stop Warnings application informs nearby vehicles of the presence of a transit vehicle at a station or stop. The application also indicates the intention of the transit vehicle when pulling into or out of a station/stop.

Potential Benefits: Mobility and safety benefits for driver on non-arterial road

Warnings about Hazards in a Work Zone (WHWZ)

Description: The Warnings about Hazards in a Work Zone (WHWZ) application provides warnings to maintenance personnel within a work zone about potential hazards within the work zone. This application enables vehicles or the infrastructure to provide warnings to workers in a work zone when a vehicle is moving in a manner that appears to create an unsafe condition (e.g., moving at high speed or entering the work zone).

Potential Benefits: Safety benefits for driver on arterial and non-arterial road

Warnings about Upcoming Work Zones (WUWZ)

Description: The Warnings about Upcoming Work Zone (WUWZ) application provides information about the conditions that exist in a work zone to vehicles that are approaching the work zone. This application provides approaching vehicles with information about work zone activities that may result in unsafe conditions to the vehicle, such as obstructions in the vehicle's travel lane, lane closures, lane shifts, speed reductions, or vehicles entering/exiting the work zone.

Potential Benefits: Safety benefits for driver on arterial and non-arterial road

APPENDIX D CVTMP PRESENTATION