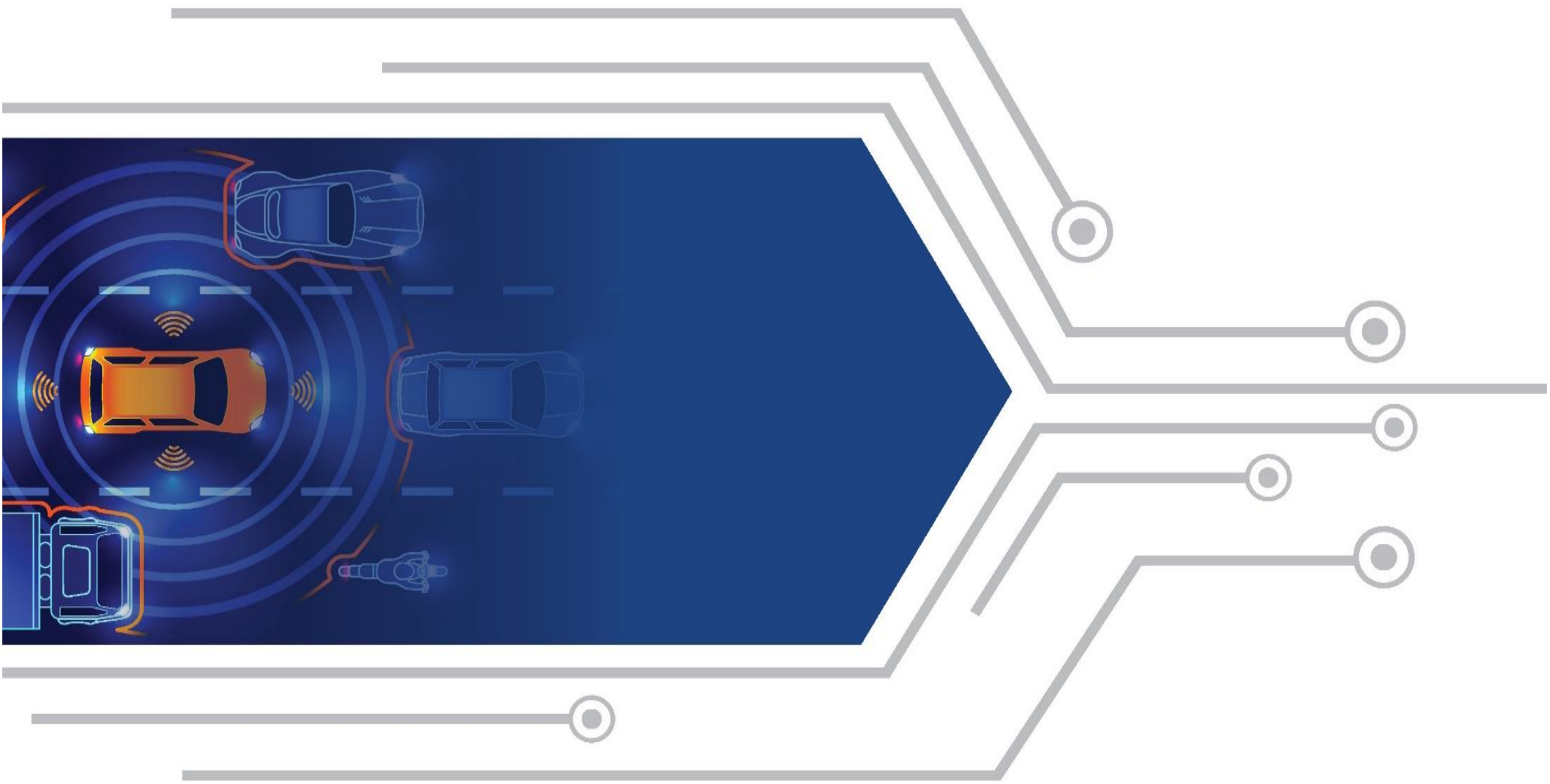
Considerations and Applications for Integrating CAV into Complete Streets

Technical Memo



FDOT

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Executive Summary

A complete street prioritizes travel and safety for all users of the right of way (ROW), regardless of mode. Within a complete street, additional priority and space of the ROW is often reserved for pedestrians, cyclists, transit to operate safely. To support these modes, complete streets will often have dedicated zones for different modes to operate, intersections and crossings that manage and prioritize all users, and a de-prioritization of vehicular traffic to ensure safety among other users.

As connected and automated vehicle (CAV) technologies and emerging travel modes continue to increase in maturity, the planning and implementation of complete streets will change. CAV technologies may lead to an evolution for how people travel, offering challenges to how we currently plan for complete streets, but the technology may also offer additional tools to promote safety and equal prioritization of travelers in the ROW. This document explores the high-level impacts that CAV technologies could bring to complete streets, as well as the potential to incorporate CAV technologies to strengthen and promote complete streets programs, both of which are described below:

- **Planning Considerations** – An overview of how CAV technologies and emerging travel modes will affect the context, decisions, and implementation of complete streets projects. Several changes beyond transportation may accompany a shift toward CAV, including land use, development densification and sprawl. The form of vehicles themselves may change, creating challenges in how these vehicles and technologies fit within a complete street.

- **Implementation –** An overview of how CAV technology can be deployed to support the desired goals, outcomes, and implementation strategies for a complete streets program. Strategies in this section are categorized into infrastructure-based strategies, vehicle-based strategies, and bicycle/pedestrian/micromobility-based strategies.

This document is intended to provide an introduction to the potential impacts of CAV technologies and emerging travel modes in planning for complete streets and to identify key strategies where CAV technology can be used to strengthen complete streets programs. As CAV technology continues to evolve, this relationship may change, potentially adding additional considerations and opportunities for integration.

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1.0 Introduction

1.1 Purpose

The intent of this document is to provide a summary description of how connected and automated vehicle (CAV) technologies and emerging travel modes may affect the planning and implementation of complete streets infrastructure and programs. Additionally, it is intended to provide several strategies in which CAV technologies may be used to support the goals and implementation of complete streets.

While the complete streets concept has been developed and implemented for decades, CAV technologies and emerging travel modes are new and currently evolving. Some technologies and modes may not yet be mature, but this document considers a spectrum of technologies and modes regardless of maturity.

1.2 Complete Streets Concept

Complete streets concepts and policies have been developed and implemented at all levels of government. Definitions of what constitutes a complete street may differ between organizations, regions, and by context (urban, suburban, rural). However, most definitions have the following characteristics:

- Designed and operated to enable safe use and support mobility for all users
- Includes people of all ages and abilities
- Varies by context
- Components can include sidewalks, bike lanes, bus lanes, transit stops, frequent and safe crossings, median islands, pedestrian signals, curb extensions narrow travel lanes, and more.

Figure 1: City of Casselberry Complete Street

<u>Additional complete streets resources</u>
USDOT Complete Streets Homepage Link
FDOT Complete Streets Homepage Link
FDOT Complete Streets Implementation Plan 2015 Download Link
Metroplan Orlando Complete Streets Link
Central Florida Complete Streets Report Download Link

2.0 Complete Streets Planning Considerations for CAV

The planning considerations outlined in this section include the high-level impacts that CAV technologies and emerging travel modes could have on a complete streets program. These include the potential proliferation of modes, the importance of curb management, the changing considerations for parking, and the potential impacts on land use.

2.1 Proliferation of Modes

The automation of mobility could spur an evolution of mobility modes beyond what is normally seen on Florida streets. Not only the vehicles themselves, but the ways in which they operate could have consequences for how complete streets are planned and implemented. The current approach to planning complete streets segregates travel mode into specific zones of the right-of-way (ROW); however, the addition of new modes could pose challenges for geometrically constrained ROWs. The following outlines how CAV technologies are being applied to different forms of mobility.

Terrestrial drones or Personal delivery devices (PDD): Several companies are currently developing the autonomous devices and deploying devices in pilot programs to explore how CAV technology and emerging travel modes can be used to deliver goods. These devices have been developed in a variety of sizes and operate at lower speed on sidewalks, exclusive paths, or within the ROW. Current ROW distribution does not typically have an area best suited for the operation of these devices, potentially posing a safety issue with other users of the ROW due to lower visibility, travel conflicts, or issues arising when devices cross streets and make deliveries.

Automated transit: The potential to lower operations and maintenance costs through connectivity and automation could spur an evolution in transit. Automated transit may take the form of smaller vehicles operating at higher frequency to provide less wait time and lower travel time to passengers. For complete streets, this may require a revaluation of how vehicles operate on streets, how they access the curb, how they interact with other users, and how they may impact overall network traffic with higher frequency service.

Mobility as a Service (MaaS): The concept of buying mobility instead of machines may not change the form of the vehicle, but may have an impact on traffic, congestion, and curb access. Automated MaaS holds the potential to significantly reduce the cost of a trip which could induce additional demand. Automated vehicles may also add network traffic through "deadheading" vehicles that operate without any passengers or drivers. The need for these vehicles to access curb space could also pose issues in areas where curb space is at a premium, where development density is high, or where a high number of trips are originating to or from (such as events).

Micromobility: The introduction of shared micromobility such as scooters and e-bikes have increased their deployments throughout the country, providing access and availability to many travelers nationwide. Autonomous technology is beginning to be applied to these vehicles, in particular scooters, to allow the vehicles to operate without riders. These system allows riders to “hail” a scooter to a location where the rider prefers, then reposition the scooter for charging. Our current ROW orientation does not accommodate smaller vehicles without a rider or driver, and the low visibility of vehicles could be an issue for complete streets planning.

Aerial drones: While not surface transportation, these drones are currently being tested for goods delivery throughout the country. Aerial drones may need to be addressed in complete streets concepts, as they may require landing and delivery pads within the ROW.

2.2 Curb Management

Management of curb space has become an important topic, particularly in urbanized areas. These effects can be seen today with the growth of ride hailing/transportation network companies (TNCs), and the increase in e-commerce that leads to an increase in delivery and an increased need for curb space. Context is a key element, and dense areas with a larger number of vehicles needing access to a limited amount of curb space will be the areas needing robust curb management strategies. If automation leads a movement towards MaaS, the need to manage the curb will continue to be an important element of any complete street policy.

An example of a curb management program was developed in the City of Seattle. The policy for each curb within the city’s downtown was codified into a GIS format, which included the allowable uses of curbs throughout different times of the day. The GIS data is interpolated by an API that allows delivery companies and TNCs to automatically determine where deliveries or pick-ups can be made when fulfilling a request. Other concepts have explored dynamic or electronic curb management signage that dynamically communicates the curb policy to drivers.

Within the concept of a complete street, curb management will become an important component to ensure the safety of all road users, and to ensure the modes and services requiring curb space are managed to ensure equal access between users.

2.3 Impacts on Parking

Parking demand is likely to change as CAV use increases due to the movement toward MaaS and the adoption of autonomous (and self-parking) vehicles, both of which may shift the quantity of parking needed and its location. These impacts apply to both public and private parking areas and could potentially allow a more efficient use of both developable land and public right of way that is currently prioritized for parking.

MaaS effect on parking: Like the TNCs of today, the need for parking decreases when conventional vehicle trips are reduced. If automated MaaS becomes a widely adopted means of travel, then the need for parking will likely decrease. Parking comes at a steep cost, in terms of land, structure, and the decline of development density. If systems exist that can functionally replace the conventional automobile (which requires parking) then developers will likely reduce the amount of parking provided on-site, further reinforcing MaaS as a preferred mobility choice for travelers.

Self-parking functionality: The location of parking is often within a quarter-mile radius of the land use it is intended to serve. The development of autonomous vehicles that can self-park may effectively eliminate the connection between parking and land use and allow parking to be consolidated and located further from its use. It would not eliminate the need for parking, but it would change how parking is allocated and prioritized within an area. Self-parking autonomous vehicles may also require less circulation space than human drivers, which could improve the operation and capacity of existing parking lots and garages.

2.4 Land Use Considerations

Autonomous and connected vehicles may have significant impacts on land use and the built environment, caused by the potential reduction in parking and the potential reduction in cost (both monetary and time) of travel. For land use and the built environment, reduced parking and reduced travel cost may have two distinct outcomes: increased density and increased sprawl.

2.4.1 Density

Parking remains one of the largest impediments to development density in our current development system. Parking requirements are usually required by local jurisdictions and stipulate the minimum (or sometimes maximum) number of parking spaces required for a quantity of a certain land use. For example, retail is often parked at one space for every 300 square feet of building area. Given a defined area of land, only a portion of the land can be developed into usable building area if parking is required on-site. The more parking is required, the less building area can be developed on a site.

Automated mobility in the form of MaaS can lower the need for parking, which can allow a higher level of density and development in a given site. This holds the promise to densify areas where land value is higher, which can increase the amount of developable land within an area.

2.4.2 Sprawl

Lowering cost in terms of time and money per trip can lead to sprawl. Each urbanized area is limited in its extent usually due to the time and cost of travel from employment. If automated vehicles lower the cost, provide faster travel, or can recapture time spent in the car toward other productive means, then the potential for development to spread outward may increase. Sprawl is often induced by lower land prices and lower travel costs that allow a buyer to maximize their purchase of acreage and building square footage. Lowering the time and monetary cost of transportation can increase this trend and cause urbanized areas to expand outward at a faster pace than today.

3.0 Applications of CAV technology to enhance complete streets

The technologies used to enable CAV operation can also be used to support the desired goals and outcomes of a complete streets program. These technologies can provide a greater awareness of users within the ROW, the ability to dynamically manage traffic flows, and the potential to improve the travel experience for all users. High-level strategies were developed that use CAV technologies and emerging travel modes to support the outcomes of a complete streets program, categorized as infrastructure-based, vehicle-based, and pedestrian/cyclist/micromobility-based strategies.

3.1 Infrastructure-based strategies

3.1.1 Cyclist/pedestrian detection

Infrastructure that can actively monitor and detect the presence of cyclists, pedestrians and micromobility users, coordinate their travel with traffic signals at crossings, and alert drivers of their presence.

Benefits to complete streets: Understanding who is using the ROW will increase safety for all travelers and allow the management of vehicles and travelers within the ROW. This strategy will leverage other key CAV functions, such as ROW management, ROW allocation, and coordination with CV-enabled vehicles.

Current state of practice: Pedestrian and cyclist detection systems are being deployed today, including radar-based systems to detect the presence of objects within a specified area, and optical-based systems that utilize machine vision to detect the presence, position, and classification of objects in the ROW.

FDOT role: Funding, implementation (on appropriate FDOT facilities), standards, and guidance.

Requirements: System that can detect and classify ROW users by mode, placement, speed, and communication infrastructure between signals and/or other vehicles.

3.1.2 Dynamic/adaptive signal management technologies

This strategy would introduce a system to dynamically manage the signal phase and timing (SPaT) in response to the current and forecasted traffic conditions and user profiles (e.g., general purpose, freight, vulnerable roadway users, etc.). Ultimately, the system should recognize and prioritize different modes (including non-vehicular travelers), optimize travel for all modes through an area, and improve safety for all users in the ROW.

Benefits to complete streets: Signals would have the ability to adjust to real-world traffic conditions and prioritize different modes or traffic flows within the intersection. This could also enable the ability to better allocate ROW and intersection use efficiently.

Current state of practice: Dynamic/adaptive signals have been implemented in signal systems throughout the country.

FDOT role: Funding, implementation (on appropriate FDOT facilities), coordination, standards, and guidance.

Requirements: Upgraded traffic controller and hardware (where not already in place), cyclists and pedestrian detection or call boxes.

3.1.3 Vehicle-to-Infrastructure (V2I) applications

V2I infrastructure communication can support complete streets by supporting safe operation of a variety of travel modes, prioritizing where demand is highest, and communicating the presence of vulnerable roadway users.

Benefits to complete streets: Communication of real-time location data between infrastructure, vehicles, cyclists, and pedestrians to improve travel, safety, and use of the ROW for all users. The technology could also allow a more efficient allocation of the ROW and signal priority among modes.

Current state of practice: USDOT has funded several pilots to explore the applicability and value of V2I infrastructure, including the Tampa Hillsborough Expressway Authority (THEA) Connected Vehicle Pilot. The standards and infrastructure are still being developed, and while the technology has proved functional, it has yet to be widely deployed.

FDOT role: Funding, piloting, implementation (on appropriate FDOT facilities), municipal/regional support, coordination, standards, and guidance.

Requirements: Infrastructure-based CV communications technologies, and the adoption of CV technology within vehicle fleet, personal mobile devices, and micromobility vehicles.

3.1.4 Multi-use slow travel lanes

As the number of travel modes increases, the need to re-evaluate how the ROW is allocated may be necessary. An emerging concept is the multi-use slow travel lane, which has the potential to combine several slower modes (such as cycles, scooters, terrestrial drones/PDDs) in a segregated portion of the ROW to ensure safety for users.

Benefits to complete streets: Lanes would accommodate vulnerable users into a dedicated area of the ROW and allow a greater flexibility to re-allocate portions of the ROW over time. The slow lane can be redefined or amended to potentially accommodate new modes as they emerge.

Current state of practice: Cities throughout the country have piloted "slow lane" concepts to test how different forms of mobility can be coordinated and prioritized within the existing roadway system.

FDOT role: Development of guidance and standards for use by regional and local agencies and compiling best practices from pilots and programs.

Requirements: Dynamic maintenance of traffic (MOT) signage and/or V2I communication infrastructure.

3.1.5 Dynamic/managed lane technologies

The ability to dynamically assign different portions of the ROW to different modes, speeds, or direction based on anticipated demand or real-world conditions. This is a key concept for incorporating CAV into complete streets, as it can dynamically change the capacity of each travel mode in response to demand.

Benefits to complete streets: The ability to reallocate ROW in response to demand, real-time or anticipated.

Current state of practice: Dynamic/managed lanes have been deployed within the context of corridors and arterials but are not typically used within the context of a complete street.

FDOT role: Implementation (on appropriate FDOT facilities) and development of guidance and standards for use by regional and local agencies.

Requirements: System to monitor traffic and demand by mode, dynamic signage and/or V2I communications infrastructure.

3.1.6 Smart work zone/temporary roadway and lane closure technologies

The use of a variety of sensor and active management technologies to promote safe and effective establishment of work zones and MOT within a complete street environment.

Benefits to complete streets: Enhanced safety for ROW users and work zone construction workers. Additionally, the ability to temporarily re-allocate ROW for business and community use.

Current state of practice: Technology is under development but has also been used in limited deployments. Some technologies, such as smart traffic cones use wireless technologies to detect incursions into the work zone and alert workers of an incident.

FDOT role: System development, funding, and deployment. Support for technology among other agencies in Florida.

Requirements: Vehicle intrusion detection system, and dynamic MOT signage and/or V2I communications.

3.1.7 Curb Management

A curb management strategy would include the ability to change access priority of curb space by use, time of day, and demand. This can potentially include dynamic pricing for curb access. Several approaches have been explored, including a GIS-based API to communicate with digitally deployed services, and dynamic signage that can react in real-time to demand.

Benefits to complete streets: Coordination of access among travelers, and prioritization of access by time of day, mode, and/or service model.

Current state of practice: Active dynamic curb management technologies have been proposed and are under development. The City of Seattle deployed a GIS-based curb policy that allows fleets to access curb policy in real-time to coordinate curb access.

FDOT role: Funding, standards, and guidance.

Requirements: Clear, machine-readable curb management policy (CV/GIS).

3.2 Vehicle-based strategies

3.2.1 CV applications

Wireless communications between vehicles and infrastructure can enable a better situational awareness of the activities and users in the ROW, providing increased safety and more efficient use of the ROW for all users. The use-cases identified below assume the presence of connected vehicle infrastructure, which includes communications equipment, power, and the sensors needed to enable functionality.

Wireless communication can be vehicle-to-everything (V2X) which includes vehicle-to-vehicle (V2V), vehicle-to-pedestrian (V2P), vehicle-to-infrastructure (V2I). The system would communicate the presence of a pedestrian detected by the infrastructure and relay that information to the vehicle. Alternatively, vehicles could identify the presence of pedestrians within the ROW and communicate their position back to the infrastructure and other vehicles, essentially using the vehicle as a sensor within a V2V or V2I mesh network. USDOT provides some CV applications which would be appropriate for consideration in a complete streets environment:

- Pedestrian in signalized crosswalk warning
- Red light violation warning, left turn assist, and intersection movement assist
- Cyclist and pedestrian detection warning
- AV and/or CV-based emergency braking
- Forward Collision Warning
- Transit, emergency, and freight vehicle signal priority and preemption

Benefits to complete streets: Situational awareness and ability to respond to events in real-time. The potential for additional machine vision to monitor ROW conditions, communicate with infrastructure, and manage traffic through infrastructure or vehicle operation.

Current state of practice: CV infrastructure and vehicle applications are under development.

FDOT role: Monitoring of deployment opportunities of CV applications as they are enabled within vehicles, development of long-term phasing, and coordination with infrastructure programs to develop applications that support complete streets programs.

Requirements: Connected vehicles with V2X capabilities such as V2V and V2I

3.2.2 AV Transit

The application of CAV technology to transit service holds several potential advantages, such as lower operations and maintenance costs, better levels of service for passengers through higher frequency operation, and additional service types that can more effectively move passengers to their destination. Transit is often a key component of a complete street concept, and the automation of transit may change the prioritization of transit in the ROW, mode-shift travelers toward transit, and alter how transit interfaces with the curb for pickup and drop-off. Additionally, each vehicle can utilize machine vision to provide additional situational awareness of conditions in the ROW and communicate those conditions to other vehicles and infrastructure.

Benefits to complete streets: Higher frequency service with the potential to carry more travelers within the ROW. The potential to for automated transit to function as "pace vehicles" for speed management.

Current state of practice: Technology is in development. Connecticut plans to deploy automated transit buses on an existing bus rapid transit (BRT) route. Autonomous microshuttles are deployed in pilots throughout the country, but the operational capabilities in mixed traffic are being developed.

FDOT role: Development of standards and guidance for transit agencies.

Requirements: Automated transit vehicles and system.

3.2.3 Speed Management

A fleet of automated vehicles operating at a maximum of the roadway speed limit has the potential to modulate and manage the speed of other vehicles on the roadway. Additionally, CV-equipped vehicles can alert drivers to excessive speeds when entering pedestrian zones, further increasing safety for all travelers.

Benefits to complete streets: Lower speeds will promote safety for all users of the ROW.

Current state of practice: Automated vehicles remain limited in deployment and are primarily deployed in select cities and operate within geofenced areas.

FDOT role: Development of guidance and standards for local jurisdictions and agencies.

Requirements: Connected vehicles with V2V, V2I capabilities, CV equipment, speed detection and alert systems.

3.3 Bicycle/pedestrian/micromobility-based strategies

3.3.1 CV communications

The ability for all travelers and vehicles, regardless of size, to be equipped with communications capability, allowing an awareness of their position, the number of ROW users, and the potential management and coordination of these travelers and vehicles with through smart infrastructure.

Benefits to complete streets: Situational awareness of smaller and more vulnerable ROW users.

Current state of practice: Connected technologies are widely deployed in shared micromobility, but their potential to coordinate with V2I infrastructure is not known. Further development is likely and may continue to evolve.

FDOT role: Development of standards and guidance for CV micromobility applications within complete streets.

Requirements: CV-enabled micromobility vehicles, and compatible infrastructure.

3.3.2 Automated micromobility

Automated shared micromobility is beginning to be developed, allowing users to “hail” scooters for a trip and allowing scooters to return to a consolidated area for charging. These vehicles may be lower visibility to other ROW users, potentially causing issues if they are introduced into existing traffic. Lower visibility could be addressed through CV communications, machine vision, and infrastructure strategies such as dedicated and exclusive mobility lanes.

Benefits to complete streets: Increased safety for vulnerable roadway users, automatic repositioning of vehicles to keep sidewalks clear for other users, and the potential for AV goods movements.

Current state of practice: Pilot programs for automated scooters have been established in San Jose, CA, and the City of Boise, ID is planning a scaled-up deployment summer, 2021.

FDOT role: Development of standards and guidance for automated micromobility within complete streets.

Requirements: Automated micromobility vehicles.

Summary Table

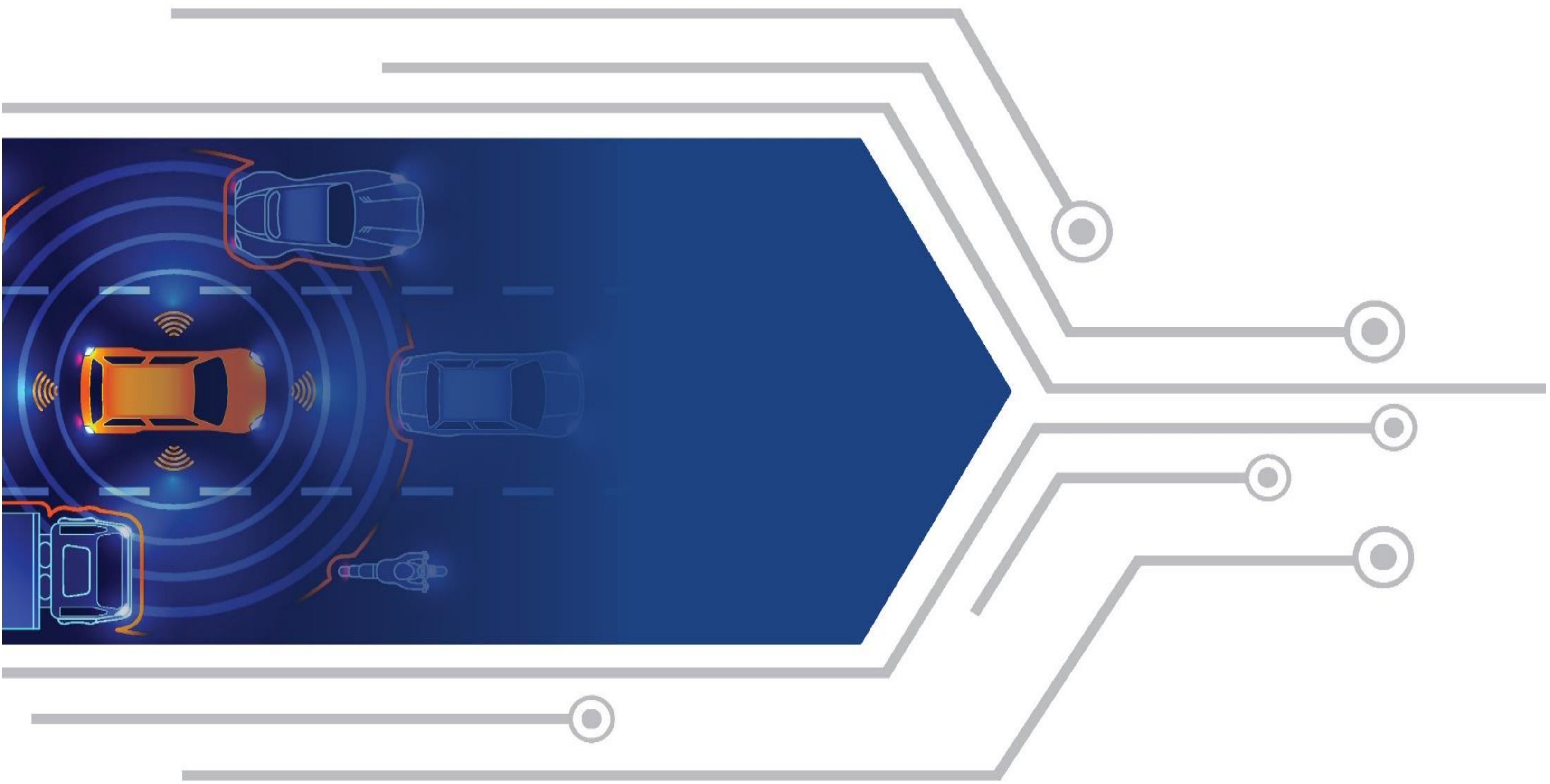
Strategies		FDOT Role	Requirements
Cyclist/pedestrian detection	Cyclist/pedestrian detection	• Funding • Implementation (on appropriate FDOT facilities) • Standards, and guidance.	System that can detect and classify ROW users by mode, placement, speed, and communication infrastructure between signals and/or other vehicles.
	Dynamic/adaptive signal management technologies	• Funding • Implementation (on appropriate FDOT facilities), • Standards, and guidance.	Upgraded traffic controller and hardware (where not already in place), cyclists and pedestrian detection or call boxes.
	V2I applications	• Funding • Piloting, implementation (on appropriate FDOT facilities) • Municipal/regional support and coordination • standards, and guidance.	Infrastructure-based CV communications technologies, and the adoption of CV technology within vehicle fleet, personal mobile devices, and micromobility vehicles.
	Multi-use slow travel lanes	• Development of guidance and standards for use by regional and local agencies and compiling best practices from pilots and programs.	Dynamic MOT signage and/or V2I communication infrastructure.
	Dynamic/managed lane technologies	• Implementation (on appropriate FDOT facilities and development of guidance and standards for use by regional and local agencies.	System to monitor traffic and demand by mode, dynamic signage and/or V2I communications infrastructure
	Smart work zone/temporary	• System development • Funding, and deployment	Vehicle intrusion detection, and dynamic MOT signage and/or V2I communications.

Strategies		FDOT Role	Requirements
	roadway and lane closure technologies	• Support for technology among other agencies in Florida.	
	Curb Management	• Funding • Standards, and guidance.	Clear, machine-readable curb management policy (CV/GIS).
Vehicle-based	CV applications	• Monitoring of deployment opportunities of CV applications as they are enabled within vehicles • Development of long-term phasing • coordination with infrastructure programs to develop applications that support complete streets programs.	Connected vehicles with V2V, V2I capabilities.
	AV Transit	• Development of standards and guidance for transit agencies.	Automated transit vehicles and system.
	Speed Management	• Development of guidance and standards for local jurisdictions and agencies.	Connected vehicles with V2V, V2I capabilities, CV equipment, speed detection and alert systems.
Bicycle/pedestrian/ micromobility-	CV communications	• Development of standards and guidance for CV micromobility applications within complete streets.	CV-enabled micromobility vehicles, and compatible infrastructure.
	Automated micromobility	• Development of standards and guidance for automated micromobility within complete streets.	Automated micromobility vehicles

4.0 Next Steps

This white paper has identified areas for further exploration, study, and implementation for CAV technology and complete streets. In particular, the following next steps could be taken to continue the development, coordination, and integration of CAV technologies into complete streets programs:

- Identify crossovers between CAV and complete streets programs
- Develop CAV/complete streets toolbox for practitioners
- Conduct CAV/complete streets training webinar for department staff and consultants
- Identify opportunities for pilot project(s)



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