Connected Vehicle Impacts on Transportation Planning

Technical Memorandum #2: Connected Vehicle Planning Processes and Products and Stakeholder Roles and Responsibilities

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16. Abstract

The objective of this project, "Connected Vehicle Impacts on Transportation Planning," is to comprehensively assess how connected vehicles should be considered across the range of transportation planning processes and products developed by States, Metropolitan Planning Organizations (MPO), and local agencies throughout the country. While the focus is primarily on Connected Vehicle (CV) technology Automated Vehicle technology is considered as well. As a result, the subject of this effort is referred to as Connected/Automated Vehicle (C/AV) technology. The overall research objective of Task 2 are to develop a typology matrix that cross-references transportation planning processes and products to facilitate the advancement and deployment of C/AV. Transportation planning involves a wide range of projects, activities, tools, products, stakeholders, and timeframes. In addition, these elements vary depending on the size, location, and political context in which they exist. These factors generate a high level of complexity in identifying and evaluating C/AV impacts. The purpose of this Technical Memorandum is to help document and organize these factors to provide a framework for both the typology to be developed in Task 2 and the overall project. This Technical Memorandum further documents the range of planning activities and products that may be impacted by CV technology using the results of both a C/AV literature review and stakeholder feedback to catalog the impacts of C/AV technology on different transportation planning activities.

The typology matrix covers a range of other planning agency characteristics and activities including type of agency, goal area, category of agency product, type of project, tools and processes required (data processing, modeling, etc.) and new or improved skills required. The report identifies how C/AV-related planning processes and products may be accommodated in a coordinated fashion in the next few years as agencies begin to incorporate these technologies into their planning and programming functions and identifies how C/AV technology can support and enhance performance-based planning and programming and reporting requirements imposed by the Moving Ahead for Progress in the 21st Century Act (MAP-21). The report also identifies elements and activities required to support the integration of C/AV technology into planning, including how C/AV should be considered, roles and responsibilities of stakeholders, both existing and new, and existing DOT planning guidance and tools that can provide support.

17. Key Words Connected vehicles, automated vehicles, transportation planning products and processes	**18. Distribution Statement** No restrictions

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Table of Contents

List of Tables

1.0 Introduction

The objective of this project, "Connected Vehicle Impacts on Transportation Planning," is to comprehensively assess how connected vehicles should be considered across the range of transportation planning processes and products developed by States, Metropolitan Planning Organizations (MPO), and local agencies throughout the country. While the focus is primarily on Connected Vehicle (CV) technology, it is clear that to incorporate the full range of planning products and activities, Automated Vehicle technology must be considered as well. As a result, the subject of this effort is referred to as Connected/Automated Vehicle (C/AV) technology. To meet the objective, the U.S. Department of Transportation (DOT) has identified four types of analyses, listed below:

1. Identifying how C/AV technology should be considered in transportation planning processes and products under a variety of circumstances (Task 2);
2. Identifying the need for new or enhanced tools, techniques, and data to support various C/AV planning activities and approaches to meeting those needs (Task 3);
3. Developing a number of illustrative scenarios of C/AV planning, based on real-world planning environments, that highlight the various ways that C/AVs can be addressed, including how new or enhanced tools, techniques, and data can be applied to address a number of specific connected vehicle issues (Task 4); and
4. Identifying the roles and responsibilities of stakeholders and organizational and workforce skills, expertise, and capabilities needed to carry out C/AV planning (Task 5).

The results of these tasks will be summarized in a Final Report that will document the findings of the project and actions that planning agencies can take to address C/AV impacts.

This report is the second of two reports to be prepared under Task 2. The overall research objective of Task 2 is as follows:

- Develop a typology matrix that cross-references transportation planning processes and products to facilitate the advancement and deployment of C/AV. While the primary focus is on CV technology that is being implemented in the vehicle fleet today, CV technology serves as the basic building block for automated, or self-driving, vehicles; therefore, automation must realistically be considered when addressing long-range planning projects. The typology matrix will also cover a range of other planning agency characteristics and activities, including the following:
    - Type of agency;
    - Goal area;
    - Category of agency product (long-range plan, congestion management plan, etc.);
    - Type of project (freeway capacity expansion, transit corridor improvement, etc.);
    - Tools and processes required (data processing, modeling, etc.); and
    - New or improved skills required.

- Identify how C/AV-related planning processes and products may be accommodated in a coordinated fashion in the next few years as agencies begin to incorporate these technologies into their planning and programming functions.
- Identify how C/AV technology can support and enhance performance-based planning and programming and reporting requirements imposed by the Moving Ahead for Progress in the 21st Century Act (MAP-21).
- Develop a better understanding of what information about C/AV technology and deployment is useful and how best can it be disseminated to the planning community.
- Identify elements and activities required to support the integration of C/AV technology into planning, including the following:
  - How C/AV should be considered;
  - Roles and responsibilities of stakeholders, both existing and new; and
  - Existing DOT planning guidance and tools that can provide support.

Transportation planning involves a wide range of projects, activities, tools, products, stakeholders, and timeframes. In addition, these elements vary depending on the size, location, and political context in which they exist. The latter may include the number and size of governmental units served by the agency, agency financing structure, and degree of centralization in the provision of public services. These factors generate a high level of complexity in identifying and evaluating C/AV impacts. The purpose of this Technical Memorandum is to help document and organize these factors to provide a framework for both the typology to be developed in Task 2 and the overall project.

This Technical Memorandum further documents the range of planning activities and products that may be impacted by CV technology using the results of both a C/AV literature review and stakeholder feedback to catalog the impacts of C/AV technology on different transportation planning activities.

The remainder of this report includes:

- Elements of Typology (Section 2.0);
- Summary of Planning Products and Processes (Section 3.0);
- Literature Review (Section 4.0);
- Stakeholder Input Summary (Section 5.0);
- Universal Impacts (Section 6.0);
- Product-Specific Impacts (Section 7.0);
- Proposed Case Studies (Section 8.0); and
- Summary (Section 9.0).

2.0 Elements of Typology

The typology developed in this task will address changes to different planning processes and products, roles and responsibilities, and planning contexts. How and when changes occur will be a function of the nature of technologies, their rate of adoption, and the level of transformation that occurs in both the private and public transportation sectors. The newness of C/AV technology and the rapid pace of change provide significant challenges in identifying what impacts will occur and in developing a structure to look at those impacts. A number of elements can be included in a typology matrix related to C/AV technology. Any of these elements could also serve as the starting point for categorizing C/AV information. The key elements that have been identified for this effort are the following:

- **Products –** Planning agencies produce a range of products that vary in purpose, timing, and content. These range from short-term studies that focus on an area as small as a single intersection to those that investigate a major regional or statewide transportation corridor. Standard documents produced by planning agencies include Transportation Improvement Plans (TIP) at the Metropolitan Planning Organization (MPO) or State level, long-range plans, State highway safety plans and Intelligent Transportation Systems (ITS) Architecture documents. Other products depend on requirements that may affect the region (Congestion Management Plans for all Transportation Management Areas) or transportation priorities of the region (Freight Plans). Certain categories of work may result in multiple outputs such as corridor studies or subarea transportation plans.
- **Goal Areas –** Goal areas can be a useful way to categorize impacts since planning agencies generally have similar goals. Common goals are generally related to mobility, safety, environmental protection, economic development, system preservation, and equity. More specific goals may be related to freight movement or promotion of specific modes. These more specific items may be expressed as objectives that provide ways to measure progress toward goals. As C/AV technology can be expected to impact most of the broader goals identified above, these goal areas can provide an organizing structure to assess impacts.
- **Demographic/Economic Characteristics –** Impacts of C/AV technology may vary, particularly in the short- and medium-term, by type of area. Some methods of stratifying geographic areas include region of the country, metropolitan area population, population density, and characteristics of transportation network (multimodal, highway oriented).
- **Projects –** Planning agencies conduct specific projects within a category of product. Many projects revolve around specific subregions, corridors, or intersections and focus on capital or operational improvements. Projects may focus on specific modes, including studies of specific transit lines or non-motorized facilities.
- **Processes, Tools, and Methods –** Planning agencies use a variety of tools, methods, and processes in their development of projects and products. Forecasting models, traffic analysis software, and various databases fall into this category. Planning agencies also must understand the new and emerging requirements of these processes and tools in the context of advancing C/AV technology.

Any or all of these elements could be used as the basis for the typology; for example, products, goal areas, and projects were all options for categorizing the impacts. The analyses and case studies that will be developed for this project in later tasks require that a range of options be considered under each element. After some discussion, it was agreed that focusing initially on products and processes would be the best way to provide a typology matrix that reflects the way planning agencies approach their work.

Table 2-1, which combines the elements described above, provides an overview of the elements required in the typology. The table also documents the process for categorizing impacts and building case studies. The second column identifies the geographic scope of the planning agency, which may be a State DOT, an MPO, a non-MPO Regional Planning Organization, or a municipal agency. These are distinguished below as either State or regional (includes municipal). Finer breakdowns may be made as the project progresses. Primary agency goal areas are also included and, as shown in the table, most transportation planning products address multiple goals. Projects may focus on a single goal but frequently address related goals as well. For example, projects designed to improve mobility often have positive impacts on environmental and economic development goals. The fourth column lists specific projects that planning agencies address. These projects are generally incorporated into some of the comprehensive products listed, such as the Long-Range Plan or Congestion Management Plan, while others may be “one-off” studies. The fifth column lists the agency tools and processes that are used to conduct business and develop their products. Connected and automated vehicle technologies will have impacts on the full range of activities identified below, and these will serve as the building blocks for the case studies developed and evaluated in Task 4 of the project.

Table 2-1. Typology Structure for Development of Case Studies

Typical Transportation Planning Products	State or Regional Scope	Primary Agency Goal Areas in Product	Project Types	Common Agency Tools and Processes
Long-Range Visioning	State, Regional	Mobility, Safety, Economic Development, Environment	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Statewide Long-Range Transportation Plan	State	Mobility, Safety, Economic Development, Environment Preservation	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Regional Long-Range Transportation Plan	Regional	Mobility, Safety, Economic Development, Environment, Preservation	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Transportation Improvement Program	State, Regional	Mobility, Safety, Economic Development, Environment	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.

Typical Transportation Planning Products	State or Regional Scope	Primary Agency Goal Areas in Product	Project Types	Common Agency Tools and Processes
Short-Range Transportation Plan	State, Regional	Mobility, Safety, Economic Development, Environment, Preservation	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Congestion Management Plan	Regional	Mobility	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Asset Management Plan	State, Regional	Mobility, Safety, Preservation	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
ITS and Operations Plan	State, Regional	Mobility, Safety, Environment	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
ITS Architecture	State, Regional	Mobility, Safety	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Strategic Highway Safety Plan	State	Safety	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Highway Safety Improvement Program	State	Safety	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
State Implementation Plan	State	Environment	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Transit Development Plan	Regional	Mobility, Environment, Economic Development	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Transportation Demand Management Plan	Regional	Mobility, Safety , Environment, Economic Development	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Nonmotorized (bicycle and pedestrian) Plan			Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.

Typical Transportation Planning Products	State or Regional Scope	Primary Agency Goal Areas in Product	Project Types	Common Agency Tools and Processes
Corridor Studies (Modal or Multimodal)	State, Regional	Mobility, Safety, Economic Development, Environment	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Public Involvement Plan	Regional	Mobility, Safety, Economic Development, Environment	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Freight Plans	State, Regional	Mobility, Safety, Economic Development, Environment, Preservation	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Financing Plans	State, Regional	Mobility, Economic Development, Preservation	Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.
Unified Planning Work Program			Refer to a complete list of common project types following this table.	Refer to a complete list of common agency tools and processes following this table.

Source: Cambridge Systematics, Inc.

Project Types (Items identified are common project types but are not directly related or aligned with all planning products.)

- New roadway corridor
- Roadway capacity expansion
- Corridor upgrade
- Corridor operational improvements
- New interchange(s)
- Major operational changes (high-occupancy vehicle (HOV), managed lane, etc.)
- New transit lines
- Transit line extension
- Transit capacity expansion
- Ride share services
- Spot physical improvements (capacity and/or safety)
- Intelligent Transportation Systems (ITS) deployments
- Signal timing

- Bicycle and pedestrian improvements
- Freight rail improvements
- Truck facilities
- Border crossing facilities and improvements

Common Agency Tools and Processes (Items identified are common agency tools and processes but are not directly related or aligned with all planning products).

- Public involvement program
- Customer surveys
- Historical data analysis
- Economic forecast
- Traffic and travel time data collection
- System condition data collection
- Travel demand forecast
- Micro- and meso-simulation
- Asset management analysis tools
- Investment tools
- Benefit-cost tools
- Data Security Plans
- Air quality modeling

3.0 Summary of Planning Products and Processes

This section provides brief descriptions of the planning products and processes that are summarized in Table 2.1. These represent the most common products developed by planning agencies, and while it is not an exhaustive list, it covers most of the major products that planning agencies or divisions provide. This list will form the basis of the proposed typology matrix.

3.1 Planning Product: MPO Long-Range Visioning Plan[1]

- **Decision Making Level:** Metropolitan Planning Organization
- **Timeframe:** 20 years or more into future
- **Update Cycle:** 5 years

Essential Components of an MPO Long-Range Visioning Plan

MPOs will sometimes produce a long-range visioning plan to support a major Long-Range Transportation Plan (LRTP) update to ensure the LRTP is guided by a uniform vision that is supported by the public. The long-range visioning plan will account for the same timeframe as the related LRTP (often looking 20 years or more into the future) and is heavily influenced by public input from an in-depth public involvement process. Based on public opinion, the long-range visioning plan will establish the major themes and sometimes overarching goals that are present in the related LRTP.

3.2 Planning Product: MPO Long-Range Plan

- **Decision Making Level:** Metropolitan Planning Organization
- **Timeframe:** 20 years or more into future
- **Update Cycle:** 5 years

Essential Components of an MPO Long-Range Plan

Long-Range Transportation Planning is the phase of the transportation planning process that typically includes setting strategic priorities for the transportation system, identifying and understanding needs and deficiencies, and in some cases identifying solutions, including specific projects. This "Planning Product" focuses specifically on MPO LRTPs. According to federal requirements, MPO LRTPs are

[1] States have conducted Long-Range Visioning Projects as well; the process is similar to that undertaken by MPOs.

required to identify transportation facilities, identify performance measures and targets, identify environmental considerations, and develop a cost-feasible plan.

3.3 Planning Product: State DOT Long-Range Plan

- **Decision Making Level:** State
- **Timeframe:** 20 years or more into the future
- **Update Cycle:** 5 years

Essential Components of a State DOT Long-Range Plan

Each State must prepare a long-range statewide transportation plan, in accordance with 49 U.S.C. 5304(f), that provides for the development and implementation of the multimodal transportation system (including transit, highway, bicycle, pedestrian, and accessible transportation). This plan must identify how the transportation system will meet the State's economic, transportation, development, and sustainability goals.

3.4 Planning Product: Statewide Transportation Improvement Program

- **Decision Making Level:** State
- **Timeframe:** At least 4 years into the future
- **Update Cycle:** 4 years

Essential Components of a Statewide Transportation Improvement Program (STIP)

Each State is required, under 49 U.S.C. 5304(g), to develop a statewide transportation improvement program for all areas of the State, covering a period of at least four years. The STIP is a staged, multi-year, statewide intermodal program of transportation projects, consistent with the statewide transportation plan and planning processes as well as metropolitan plans, TIPs, and planning processes. The STIP must be developed in cooperation with MPOs, public transit providers, and any Regional Transportation Planning Organizations (RTPO) in the State and must be compatible with the TIPs for the metropolitan areas in the State.

3.5 Planning Product: MPO Transportation Improvement Program

- **Decision Making Level:** Metropolitan Planning Organization
- **Timeframe:** At least 4 years into the future
- **Update Cycle:** 4 years

Essential Components of an MPO Transportation Improvement Program (TIP)

49 U.S.C. 5303(j) requires MPOs to develop a Transportation Improvement Program—a list of upcoming transportation projects—covering a period of at least four years. The TIP must be developed in cooperation with the State and public transit providers. The TIP should include capital and non-capital surface transportation projects, bicycle and pedestrian facilities and other transportation enhancements, Federal Lands Highway projects, and safety projects included in the State's Strategic Highway Safety Plan. The TIP should include all regionally significant projects receiving FHWA or Federal Transit Administration (FTA) funds or for which FHWA or FTA approval is required, in addition to non-federally funded projects that are consistent with the Metropolitan Transportation Plan. Furthermore, the TIP must be fiscally constrained.

3.6 Planning Product: MPO 5-Year Plan

- **Decision Making Level:** Metropolitan Planning Organization
- **Timeframe:** 5 years into the future
- **Update Cycle:** Annually

Essential Components of an MPO 5-Year Plan

An MPO 5-year plan is meant to reflect immediate planning activities and projects that will occur over the next five years. These plans involve allocating funding to various projects and activities that are either currently underway or will begin during the five-year period. This plan, which is updated annually, reports which projects and activities have been completed and introduces new projects and activities to be funded. An MPO 5-year plan will generally consist of a prioritized list of projects/activities, a cost-feasibility section, and a section describing funding.

3.7 Planning Product: MPO Congestion Management Plan

- **Decision Making Level:** Metropolitan Planning Organization
- **Timeframe:** Short term
- **Update Cycle:** As needed

Essential Components of an MPO Congestion Management Plan (CMP)

A Congestion Management Plan provides guidance for the application of strategies to improve transportation system performance and reliability by reducing adverse impacts of congestion on the movement of people and freight. The CMP identifies congestion management objectives, multimodal performance measures, causes of congestion and management strategies, and the effectiveness of management strategies.

3.8 Planning Product: State DOT Asset Management Plan

- **Decision Making Level:** State
- **Timeframe:** 10 Years
- **Update Cycle:** 4 Years

Essential Components of a Transportation Asset Management Plan (TAMP)

Each State is required to develop a risk-based asset management plan for the National Highway System (NHS) to improve or preserve the condition of the assets and the performance of the system. (23 U.S.C. 119(e)(1), MAP-21 § 1106). A TAMP requires documentation of a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the lifecycle of the assets at minimum practicable cost. At a minimum, a TAMP must include an inventory of pavement and bridge assets and their condition, asset management objectives and measures, performance gap identification, lifecycle cost and risk assessment analysis, a financial plan, and investment strategies.

3.9 Planning Product: ITS Architecture and Operations/ITS Plan

- **Decision Making Level:** State and MPO
- **Timeframe:** 5-10 Years
- **Update Cycle:** 5-7 Years

Essential Components of an ITS Architecture and Operations Plan

As part of the Transportation Equity Act for the 21st Century (TEA-21) passed in 1997, Congress addressed the need to begin to work toward regionally integrated transportation systems. In January 2001, the FHWA published a Final Rule, and the FTA published a companion Policy, to implement section 5206(e) of TEA-21. The Final Rule/Policy supports regional integration by requiring that all ITS projects funded by the Highway Trust Fund conform with the National ITS Architecture and appropriate standards by April 2005. Conformance with the National ITS Architecture is defined in the Final Rule as using the National ITS Architecture to develop a regional ITS Architecture tailored to address the local situation and ITS investment needs and the subsequent adherence of ITS projects to the regional ITS Architecture. Development of the regional ITS Architecture should also be consistent with the transportation planning process for Statewide and Metropolitan Transportation Planning.

While not required, a number of States have developed a statewide architecture. The statewide architectures have been used to provide consistent frameworks for MPO architectures as well as to cover non-urban areas that are not served by MPOs. While not required, many States and MPOs develop Operations and ITS plans that detail specific projects and timelines for implementation. These plans may be coordinated with TIPs and STIPs to promote the incorporation of ITS into capital projects.

3.10 Planning Product: State DOT Highway Safety Improvement Program

- **Decision Making Level:** State
- **Timeframe:** 1 year
- **Update Cycle:** Annually

Essential Components of a State DOT Highway Safety Improvement Program

The Highway Safety Improvement Program (HSIP) is established in 23 U.S.C. 148 and regulated under 23 CFR 924. This program was created to significantly reduce the number of transportation related injuries and fatalities on a national scale. The HSIP should address all projects implemented using HSIP funds, including local projects and non-infrastructure projects. The HSIP contains four sections: program structure, progress in implementation of projects, assessment of the effectiveness of improvements, and the High-Risk Rural Roads Program (HRRRP).

3.11 Planning Product: MPO Transit Development Plan

- **Decision Making Level:** Metropolitan Planning Organization, often in coordination with the transit provider
- **Timeframe:** At least 10 years into the future
- **Update Cycle:** Typically every 5 years

Essential Components of an MPO Transit Development Plan

A transit development plan (TDP) is meant to guide improvements to the efficiency and effectiveness of the transit system. A TDP typically contains an overview of the existing transit system; an identification of goals, objectives, and policies; a situation appraisal; a section describing proposed projects and improvements, capital improvements, and a financial plan; and a plan monitoring and evaluation section.

3.12 Planning Product: MPO Transportation Demand Management Plan

- **Decision Making Level:** Metropolitan Planning Organization
- **Timeframe:** Short term

- **Update Cycle:** As needed

Essential Components of an MPO Transportation Demand Management Plan

A transportation demand management (TDM) plan establishes strategies aimed at reducing the demand for roadway travel, particularly via single occupancy vehicles. These strategies address a wide range of externalities associated with driving, including congestion, poor air quality, less livable communities, reduced public health, dependence on oil, reduced environmental health, and climate change and greenhouse gas emissions. Some TDM strategies are designed to reduce total travel demand, while others are designed to reduce peak period demand that may disproportionately contribute to these externalities.

3.13 Planning Product: MPO Nonmotorized Plan

- **Decision Making Level:** Metropolitan Planning Organization
- **Timeframe:** 3-10 years
- **Update Cycle:** Variable

Essential Components of a MPO Nonmotorized (Bicycle/Pedestrian) Plan

A nonmotorized plan, often called a bicycle/pedestrian plan, is meant to guide the development of an effective and efficient nonmotorized network. While typically these plans are most focused on bicycle users and pedestrians, they are also meant to be coordinated with all modes of transportation, especially transit, and their corresponding plans to promote an integrated multimodal environment. Nonmotorized plans typically provide an inventory of the existing network; describe the potential future network; provide an overview of design guidelines; establish goals, objectives, and policies; and note funding opportunities.

3.14 Planning Product: State DOT Corridor Study[2]

- **Decision Making Level:** State
- **Timeframe:** Variable and Project Dependent
- **Update Cycle:** As needed

Essential Components of a State DOT Corridor Study

A Department of Transportation will perform a corridor study on a major transportation corridor when improvements are under consideration. The corridor study begins with a planning, development, and environment (PD&E) process that evaluates the consequences corridor improvements have on the environment. Following completion of the PD&E, the corridor study will illustrate various alternatives

[2] MPOs frequently conduct corridor studies as well, with similar scopes of work.

for the transportation corridor, evaluating each one and ultimately recommending the preferred alternative.

3.15 Planning Product: MPO Public Involvement Plan

- **Decision Making Level:** Metropolitan Planning Organization
- **Timeframe:** Short to medium term
- **Update Cycle:** 5 years

Essential Components of an MPO Public Involvement Plan

A public involvement plan is meant to guide the public involvement process to ensure there are opportunities for public review and comment at important decision points in the planning process. The public involvement plan should establish a process that emphasizes early and continuous public involvement opportunities; reasonable public access to technical policy information used in the planning process; adequate public notice of public involvement activities; convenient and accessible public meeting locations and times; and consideration and response to public input during the planning process. This plan should be reviewed at least once every five years to ensure its continued effectiveness.

3.16 Planning Product: Statewide Freight Plan[3]

- **Decision Making Level:** State DOT
- **Timeframe:** Short to medium term
- **Update Cycle:** As needed

Essential Components of a Statewide Freight Plan

Section 1118 of MAP-21 directs the Secretary of Transportation to encourage States to develop freight plans that are comprehensive and that include both immediate and long-term freight planning activities and investments. Freight plans identify freight transportation facilities that are critical to each State's economic growth and give appropriate priority to investments in such facilities. Freight plans include an identification of significant freight system trends, needs, and issues; a description of freight policies, strategies, and performance measures that guide freight investments; consideration of innovative technologies and operational strategies; and an inventory of facilities with freight mobility issues.

3.17 Planning Product: Statewide Financing Plan

- **Decision Making Level:** State DOT/Toll Road Authorities

[3] Larger MPOs are beginning to develop regional freight plans more frequently, often within the framework of a Statewide Plan. MPOs also conduct studies that may focus on a freight-oriented location such as an intermodal terminal.

- **Timeframe:** Medium to Long Term
- **Update Cycle:** As needed

Essential Components of a Statewide Financing Plan

Financing plans required in the STIPs and TIPs are generally a component of long-range plans; however, States may develop separate financing plans. These may involve an analysis of new or modified sources of funding. Options may include dedicated taxes and fees (sales tax increments), tolling, privatization of specific facilities, or emerging sources such as the Vehicle Miles Traveled (VMT) fee. In States with toll authorities, those authorities will generally participate in the study or even lead it. Similar plans may be developed at a regional level, particularly when regional expressway authorities or other agencies have revenue-raising authority (i.e., sales tax dedicated to transportation).

3.18 Unified Planning Work Program

- **Decision Making Level:** Metropolitan Planning Organization
- **Timeframe:** 2+ years
- **Update Cycle:** 2 years

Essential Components of a Unified Planning Work Program

The Unified Planning Work Program (UPWP) for MPOs is updated every two years to permit citizens and stakeholders to see how federal and State transportation planning dollars are expended by the MPO, local governments and transit agencies, and the State DOT in order to meet federal metropolitan planning requirements. Federal requirements include 23 CFR 450.30 (planning factors to be considered), 23 CFR 450.308 (c) (description of work and how it will be performed), and 23 CFR 420.117 (annual performance and expenditure report). Additional requirements at the State level may apply. The UPWP is developed by MPO staff in consultation with partner agencies and input from local citizens and stakeholders. It may be amended to account for changes in funding or project needs.

4.0 Lessons Learned from Review of CV-Related Literature

This section includes a summary of the bibliography presented in Appendix A of this document along with more detailed document summaries. A variety of documents and projects were reviewed, including the following:

- **Operations Planning Documents –** FHWA has produced a number of documents that are designed to help agencies integrate Operations and ITS into the planning process. There are clearly parallels between this work and the current effort to integrate C/AV technology into transportation operations. More recent documents focus on Performance Management, with a goal of helping agencies measure performance and use those measures to improve the efficiency and effectiveness of their operations. Important documents include the following:
  - U.S. DOT, Performance-Based Planning and Programming Guidebook, FHWA-HEP-13-041, September 2013;
  - U.S. DOT, Model Long-Range Transportation Plans: A Guide for Incorporating Performance-Based Planning, FHWA-HEP-14-046, August 2014;
  - U.S. DOT, Best Practices of Rural and Statewide ITS Strategic Planning, FHWA-OP-02-037, July 2012; and
  - U.S. DOT, Real-Time Data Capture and Management (DCM) Program Update on Program Status, Winter Webinar Series, February 27, 2013.

- **Connected/Automated Vehicle Guidance Documents –** The American Association of State Highway and Transportation Officials (AASHTO) and U.S. DOT are collaborating on efforts to identify and define a Vehicle to Infrastructure (V2I) program and provide guidelines to State, regional, and local transportation agencies for implementation. The Footprint report and current efforts to provide deployment guidance are included in the review. Documents were also reviewed that apply directly to Vehicle to Vehicle (V2V) deployment, including the 2013 Government Accountability Office report on V2V Safety Benefits and Deployment Challenges.
  - AASHTO, National Connected Vehicle Field Infrastructure Footprint Analysis, Applications Analysis, Contract No. DTFH61-11-D-00008, Version 3, submitted to the U.S. Department of Transportation, Federal Highway Administration, July 31, 2013;
  - AASHTO, National Connected Vehicle Field Infrastructure Footprint Analysis, Deployment Analysis, Contract No. DTFH61-11-D-00008, Final, Version 2, submitted to the U.S. Department of Transportation, Federal Highway Administration, September 20, 2013;
  - AASHTO, National Connected Vehicle Field Infrastructure Footprint Analysis, Final Report Executive Summary;
  - Draft 2015 FHWA Vehicle to Infrastructure Deployment Guidance and Products, http://www.its.dot.gov/meetings/pdf/V2I_DeploymentGuidanceDraftv9.pdf;
  - U.S. DOT, National Connected Vehicle Field Infrastructure Footprint Analysis, Deployment Scenarios, Final Report, www.its.dot.gov/index.htm, December 27, 2013;

   - U.S. DOT, 2015 FHWA Vehicle to Infrastructure Deployment Guidance and Products, Handout, Revision 1, September 12, 2014;
   - FHWA National Highway Traffic Safety Administration Research and Innovative Technology Administration, Principles for a Connected Vehicle Environment, Discussion Document, www.its.dot.gov/index.htm, FHWA-JPO-12-018, April 18, 2012;
   - U.S. DOT Intelligent Transportation Systems (ITS) – Joint Program Office (JPO), Connected Vehicle Reference, Implementation Architecture, Stakeholder Workshop – Standards Plan, February 2014;
   - U.S. DOT, Vehicle-to-Infrastructure (V2I) Safety Applications, Concept of Operations Document, Final Report, www.its.dot.gov/index.htm, FHWA-JPO-13-060, March 8, 2013;
   - 2015 FHWA Vehicle to Infrastructure Deployment Guidance and Products, V2I Guidance Draft Version 9, September 9, 2014;
   - Connected Vehicle Reference Implementation Architecture (CVRIA) http://www.iteris.com/cvria/;
   - Cost Overview for Planning Ideas and Logical Organization Tool (CO-PILOT) https://co-pilot.noblis.org/CVP_CET/; and
   - NCHRP 03-101 "Costs and Benefits of Public-Sector Deployment of Vehicle to Infrastructure Technologies" (Project in Progress) http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2951.

- **V2V Documents –** Most of the activity regarding V2V technology within U.S. DOT has been undertaken by the National Highway Traffic Safety Agency (NHTSA). Two important documents that look at V2V deployment are reviewed with respect to safety benefits and deployment issues.

   - U.S. DOT – NHTSA "Vehicle-to-vehicle communications: Readiness of V2V technology for application" (Report No. DOT HS 812 014)", August 2014;
   - U.S. GAO – "Intelligent Transportation Systems – Vehicle-to-Vehicle Technologies Expected to Offer Safety Benefits, but a Variety of Deployment Challenges Exist (Report No. GAO-14-13)", November 2013;
   - U.S. DOT, U.S. DOT Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) Technology Test Bed and Affiliated Interoperable Test Beds; and
   - U.S. DOT Intelligent Transportation Systems (ITS) – Joint Program Office (JPO) Connected Vehicle Test Bed, Testing Connected Vehicle Technologies in a Real-World Environment.

- **State and Regional Efforts –** Through partnerships with the auto industry, the University of Michigan and FHWA, Michigan DOT has established itself as a public sector leader in C/AV promotion. Ongoing projects such as the Data Use Analysis Processing (DUAP) and other testbed activities are documented along with the Safety Pilot field test being conducted by University of Michigan Transportation Research Institute (UMTRI), FHWA, and Michigan DOT. While there have been limited deployments outside of the Safety Pilot and other demonstration projects in Southeast Michigan, significant planning work has been conducted for other projects around the U.S. For example, the Gateway Cities Strategic Plan includes incorporation of C/AV technology into a proposed new truck-only highway serving the Ports of Los Angeles and Long Beach; a pilot program is underway in Maricopa County, Arizona. Several other documents are identified in the bibliography but not summarized since they had limited applicability to planning. Key documents include the following:

- Michigan DOT, Vehicle Infrastructure Integration (VII), Data Use Analysis and Processing, Project Summary Report, Final, prepared by Mixon/Hill, Inc., March 2012;
- Michigan Department of Transportation and the Center for Automotive Research, Connected Vehicle Infrastructure Plan, Parsons Brinckerhoff, October 2012;
- Michigan Department of Transportation and the Center for Automotive Research, MDOT ITS Investment Plan, September 2013;
- Gateway Cities Technology Plan for Goods Movement, I-710 Technology and Autonomous Vehicle Research Summary, prepared by Cambridge Systematics, Inc., December 2012;
- Gateway Cities Strategic Transportation Plan, Truck Autonomous Connected Commercial Vehicle, Draft, prepared by Cambridge Systematics, Inc., October 9, 2013;
- Gateway Cities Strategic Transportation Plan, Initial Concept of Operations for the I-710 Zero Emissions Freight ITS Corridor, prepared by Cambridge Systematics, Inc., September 30, 2013;
- Maricopa County DOT, Arizona E-IntelliDrive[SM] Program, Scoping Study: E-IntelliDrive[SM] Field Test Emergency Vehicle and Transit Priority, December 2010;
- San Diego FORWARD The Regional Plan, Draft Emerging Technologies White Paper; and
- Maricopa County DOT, MCDOT SMARTDrive Handout, April 2012.

The remainder of this section summarizes relevant findings for planning agencies that have been derived from the literature review. Findings are summarized in the following categories:

- Strategy;
- Performance measurement and evaluation;
- Infrastructure investment;
- Planning products;
- Data collection, processing and analysis; and
- Education and training.

While impacts are listed in a single category below, it is important to note that there is significant overlap between categories and many of the impacts identified apply to multiple categories. Some of the key documents and projects that will help planners obtain an understanding of C/AV technology are summarized in text boxes throughout this section.

4.1 Strategy

- With the mass production of C/AVs on the horizon, transportation agencies should understand how C/AVs affect strategy identification, investment priorities, monitoring, and reporting.
- The FHWA Performance-Based Planning and Programming Guidebook referenced above provides instruction regarding developing goals and objectives, with an emphasis on outcomes. Transportation agencies should establish goals and objectives informed by careful thought regarding C/A vehicles.

- ITS strategic plans serve as roadmaps for implementing ITS projects system-wide over a period of time. An ITS strategic plan, developed by a State transportation agency or an MPO, should give consideration to CV infrastructure to address mobility needs.
- DOTs and other agencies recognize liability concerns in managing transportation operations; thus, they can use their expertise to help guide the process of officially determining who or what entity owns the data transmitted between vehicles by V2V technologies. In the event of a crash, officially recognized practices make it easier to determine liability.
- Through its experience in CV deployment Michigan DOT has identified the following as important strategic factors for successful CV programs:
    - **Encourage regulation –** Only government has the ability and obligation to establish CV mandates and ensure infrastructure necessary to realize safety benefits.
    - **Form coalitions –** Public-private partnerships are instrumental to successful tests and deployment.
    - **Create industry competition –** Set standards, create infrastructure test deployments, then invite manufacturers to participate.
    - **Develop programmatic themes and bold goals –** Emphasize themes such as safety, and use bold goals to motivate achievements.
    - **Generate agency expertise –** Nurture CV/ITS skill development to create future opportunities and demonstrate ability to contribute to competitive bids for Federal projects.
    - **Standardize data architectures –** Implementing common CV technology standards is necessary to support inter-region connectivity as well as decrease equipment costs (via increased production volumes).
    - **Leadership by regional and State governments is crucial for CV success.** Strong leadership must support sensible regulation to create catalysts for adopting and incentives for improving safety applications.

AASHTO Footprint

The Footprint was developed by AASHTO in partnership with U.S. DOT and Transport Canada to set a policy foundation for the CV environment and guide the process towards the following set of "Desired" outcomes. Planners can use these outcomes as benchmarks in the planning and implementation of C/AV technology:

- Clear description of the value of and justification for deployment for the benefit of the public and important State and local planners and transportation decision-makers;
- Compilation of possible needs of priority applications (data, communications, infrastructure, etc.);
- Generic development concepts that connect potential applications and operating conditions to required infrastructure;
- State and local funding strategies and implementation scenarios that are harmonized with national policy;
- Timelines and activities for deploying infrastructure across State and local agencies;
- Cost estimates for development, operations, and maintenance;
- Estimated requirements for workforce training and the development of policy and guidance; and
- Implementation challenges and institutional issues that may impede successful implementation.

- Agencies must think about autonomous vehicles and their impact on operations. The concept of operations for a network of fully automated vehicles will be significantly different than that for routine operations, will likely be more complex, and will impact planning for all modes that use roads. DOTs should note that all rollouts of CV will be incremental due to resource scarcity at the State level. In particular, CV/ITS projects require significant operations and maintenance expenditures.

> **Connected Vehicle Testbeds**
>
> To evaluate connected vehicle technology, U.S. DOT created six "test beds" to analyze vehicle and infrastructure communication and automation. Test bed sites are equipped with instrumentation giving the testers access to V2V, V2I, and probe data, as well as signal phase and timing services. C/AV technology will provide data to analyze the effectiveness of the V2I connection.

- ITS planning is a necessary part of the system's adaptation to automated vehicle networks. Vehicle automation is not an isolated technology; it will benefit from the information systems that support efficiency and safety. The Transportation Systems Management and Operation (TSM&O) initiatives promoted by U.S. DOT and adopted by many State DOTs provide a good platform for this communication.
- Management responsibilities for new technologies are complex and require broad coordination.
- Agencies must work with the private sector. Private sector entities play a role in the technology arena and can share information about emerging technologies and support development of mutually beneficial standards.
- Emergency response applications can serve as effective early deployments of C/AV technology. They can also provide some of the infrastructure that will later help to support applications that can be used by a broader audience, such as traveler information data and signal timing and phasing information. In addition, working with first responders is a way to engage a wider audience beyond transportation agencies and build public support for broader deployments.
- Agencies with limited resources can focus on smaller demonstrations covering an intersection or limited corridor to demonstrate CV concepts. These can then be expanded incrementally over time.

4.2 Performance Measurement and Evaluation

- Deployment of C/AV technology, particularly near-term V2I deployments, must be justified based on benefits and costs. The impacts of these deployments must be evaluated so that data generated from them can be used to measure the performance of other improvements and the overall system itself.
- DOTs must develop a clear business case for external audiences regarding the costs and benefits of ITS and CV projects. The audience should include politicians, local agencies, agency board members, and the general public.
- It is difficult to express the costs and benefits of CV/ITS systems in a way that is both accurate and precise; thus, a rigorous benefit/cost analysis would also compare technical solutions to low-tech and no-tech solutions.
- Measures are important to implementing a performance-based planning process. Guidance in the Performance-Based Planning and Programming Guidebook can be used to determine what performance measures matter most in a C/A vehicles environment.

- C/AV data could be used in monitoring and reporting to assist implementation and evaluation of planning strategies. Transportation staff must consider the feasibility and practicality of collecting, storing, and analyzing C/AV data.
- Operations data are often used to identify and investigate congested locations. Collected C/AV operational data can be used as part of a Congestion Management Process, as well as in mapping congestion bottlenecks and in needs identification.
- The U.S. DOT's Real Time Data Capture and Management Program is potentially useful to planning agencies in the following respects:
    - This program generates important information and guidance for planning agencies on the data that might be made available and the applications for which they can be used.
    - Planning agencies should participate in or least monitor closely the progress of demonstration projects conducted under this program.
- The AASHTO Footprint assumes that by 2040, the majority of vehicles on the nation's roads and highways will be connected vehicles. Planners should recognize that there might still be infrastructure users that will not necessarily be in "CV compliant" vehicles, or in vehicles at all (such as pedestrians, wheelchair users, bicyclists, motorcyclists, etc.). Planners should consider the impacts of projects on the full public, not just those who are able (or who choose) to use CV technologies. This is a major challenge in the transition period between now and when full market penetration of CV compliant vehicles occurs.

Arizona SMART Drive Field Test

Arizona DOT and Maricopa County are conducting a field test that has equipped several intersections and vehicles to demonstrate the different capabilities that CV technology can provide for transit and emergency vehicle priority. An interface to a mobile device will show participants when priority has been granted and for which vehicles (transit and emergency response).

Key components of this demonstration (SMART Drive) include the following:

- Six signalized intersections equipped with DSRC radios, Wi-Fi, and Bluetooth readers;
- Traffic signal priority application installed;
- Representative emergency vehicle and transit vehicle used to test application priority logic;
- Field test for emergency and transit applications;
- Pedestrian crosswalk application using smartphones (developed by Savari using U.S. DOT funding) to display crossing status; and
- Collection of detailed vehicle and traffic operations data for post-operational analysis.

US DOT V2I Communications and Safety Applications

The FHWA previously developed multiple tracks in a Vehicle to Infrastructure Safety Applications Roadmap to assist in infrastructure planning. Specific tracks developed were:

- Track 1 – Applications Analysis;
- Track 2 – Prototype Development;
- Track 3 – Enabling Technologies;
- Track 4 – Field Operation Tests; and
- Track 5 – Infrastructure Planning.

During 2015 the products to support infrastructure planning will be delivered as intended in Track 5. Public agency staff and other transportation practitioners will identify their program requirements through a stakeholder involvement process. Their input will mold the development of a practitioner toolbox.

- C/AV technology will generate safety related data that can be helpful in measuring potential impacts of the technology on crash rates and thus in planning future safety improvements. As C/AV market penetration increases over time and the fleet mix evolves, safety policies and investments will change.
- In combination with V2V, V2I technologies offer additional safety features, such as providing drivers with additional warnings when traffic signals are about to change – warnings that could help reduce collisions at intersections. V2I technologies also offer potential mobility and environmental benefits: they can collect, analyze, and provide drivers with data about upcoming roadway and traffic conditions and suggest alternate routes when roadways are congested. V2I systems require significantly higher public investments, however. In the context of government resource scarcity, enabling V2V systems is gaining ground as a valued strategy for DOTs wishing to improve public health via road safety.
  - When developing CV systems, DOTs must address important agency needs (improving cost efficiency, enhancing the effectiveness of agency operations, incorporating quantifiable performance measures, etc.).

4.3 Infrastructure Investment

- Over the last decade ITS systems and technologies have been increasingly incorporated into transportation infrastructure. As these plans gain importance it becomes more obvious that they should address C/AV infrastructure deployment. DOTs and other deploying agencies must phase in infrastructure and recognize that earlier phases can yield much public benefit without requiring a mature CV environment. Deployment of CV systems will create challenges for State DOTs in terms of delivering durable infrastructure that can allow the collection and processing of vast amounts of potential data.
- Some potential impacts on V2I deployment that planners need to be aware of are as follows:
  - **Backhaul communications –** Investment in the arterial network is critical for transmission of CV data (backhaul) to the traffic operations centers. This must be phased in before CV deployment.
  - **Advanced Signal Controllers –** All controllers require replacement. When they are upgraded, new models should include Internet protocol (IP)-ready ports and National Transportation Communications for Intelligent Transportation System Protocol (NTCIP) compliance for a full scale CV deployment while achieving integration into the Advanced Traffic Management System (ATMS).
  - **Conduit Installation –** Conduit must be considered an essential component of any arterial roadway upgrade.
  - **Data Management Planning –** Detailed technical requirements and a concept of data management operations must be developed that are harmonized with (or within) a statewide data warehouse strategic plan.
- Traditional roadway technologies presume maintenance and a gentle slope for lifetime utility. In the beginning CV infrastructure may increase the level of uncertainty over the cost of constructing and maintaining roadways. It is important that DOTs track operations and maintenance costs so that the life cycle costs of future deployments can be projected with greater confidence.

4.4 Planning Products

- Development of the ITS architecture should be consistent with the statewide and MPO transportation planning process and with any existing or planned ITS strategic planning efforts; therefore, an ITS strategic plan should be implemented to better facilitate coordination of separate C/AV ITS efforts. The ITS strategic plan can often provide the mechanism for bringing stakeholders together to address transportation operations and management issues that may affect multiple agencies or organizations. The ITS strategic plan can then be used to initiate C/AV infrastructure deployments for a broad cross-section of organizations.
- The planning community should participate in the development of the toolbox that will provide guidance on procuring connected vehicle ITS equipment, identify installation specifications, and summarize all the benefits of vehicle to infrastructure communication and safety applications. This will be important reference material for planners.
- There are many competing system needs, so CV/ITS deployments must be harmonized with STIPs and long-range transportation plans.
- Agencies must identify constraints to technology in the planning process so steps can be taken to proactively mitigate them.
- Specific planning products that are likely to be affected by an autonomous vehicle focused infrastructure project such as this include the following:
    - **Long-range transportation plans –** Agencies must identify how and where corridors are planned for specific upgrades to accommodate autonomous vehicles.
    - **Corridor plans –** The plans for specific corridors must reflect changes resulting from the deployment of autonomous vehicles and related technologies. Specifically, corridor plans should reflect the anticipated impact on capacity and congestion and the necessary infrastructure to support autonomous vehicles.
    - **ITS plans –** ITS Plans should reflect the

Michigan Data Use Analysis and Processing (DUAP)

This project was developed to support MDOT and partners in evaluating uses and benefits of CV data in transportation agency management and operations. DUAP goals included the following: identify uses for data, develop algorithms to use and process data, develop prototype applications and data management software, and evaluate the utility of the processed data for MDOT and partners.

- The DUAP project presumed that data would be available from the efforts of other connected vehicle projects, but research was significantly constrained by the relative unavailability of CV data. DUAP experienced challenges with scale and diversity of data sources – the best data sources proved to be those developed by MDOT for deployment on its own fleet of vehicles.
- Relying only on MDOT data sources, the project focused on three tasks: traffic condition monitoring, pavement condition monitoring, and origin/destination studies. DUAP data was collected from vehicles and shared via smartphone (3G) and Wi-Fi download spots at MDOT facilities.
- DUAP utilized some available OEM data (Chrysler Fleet/MTS Technologies); however, the data were anonymized in such a way that there were no associations between particular vehicles and data points, so O/D analysis was not possible.

technologies necessary to support autonomous vehicle technology and fully realize the benefits.

- **Project Environmental Impact Assessments –** Agencies must capture the anticipated benefits of autonomous vehicle operation in terms of emissions reductions and fuel savings.

4.5 Data Collection, Processing, and Analysis

- The U.S. DOT is working to provide a data environment in which real-time data are captured, managed, and disseminated to mobility applications (including those within vehicles). Fully connected vehicles can transmit data on latitude, longitude, time, speed, lateral acceleration, longitudinal acceleration, throttle position, brake status, steering angle, headlight status, wiper status, external temperature, turn signal status, vehicle length, vehicle width, vehicle mass, and bumper height. ITS infrastructure can send messages on cross street speeds, weather, e.g., fog, oncoming trains, available parking, and signal phasing and timing.
- From the DOT planner's perspective almost any information about vehicle travel paths might be useful; however, data regarding an individual vehicle's origin, path, time history, and destination(s) are inherent to probe data collection, subject to limitations for owner/operator privacy. Once CV-equipped vehicles start communicating with the system, new data will be generated that can be used for system analysis and operational planning – for example, calibrating micro-simulation models. Ongoing analysis of capacity impacts will help to make larger investment decisions in the future.
- When DOTs are assembling data from multiple sources, collection practices and data security/privacy measures must be consistently implemented so that data are useful for achieving multiple agency goals.
- Interface requirements for gathering and inputting data into existing DOT systems should be developed and standardized in collaboration with companies and agencies that are likely data partners.
- CV and ITS deployments should be aligned with agency performance standards and holistic data requirements so that DOTs can leverage data sources across the organization.
- Meeting agency goals requires different types of data collection:
  - Safety applications such as intersection collision avoidance with very short latency needs require the application to run at the roadside.
  - Asset management applications where data about pavement conditions are aggregated over a period of months or even years can use data that are aggregated and analyzed on remote servers.
- Operational planning to utilize CV deployments to capture travel time and origin-destination (O/D) data must start early and include outreach to and awareness by major stakeholders.

4.6 Education and Training

- The AASHTO Footprint proposes infrastructure augmentation for all DOT public assets. Improvements of that scale and scope will require a greater number of, and more and differently trained, DOT analysts, planners, and engineers.
- The importance of communicating basic instructions to users of these new systems is especially high. Planners must be aware of the burden placed on the user to learn new systems and should by default strive to develop user interactions that are consistent and intuitive.
- CV applications will provide a significant amount of system performance data. These data are potentially helpful to planners in many areas (traffic data, counts, infrastructure condition, weather management, etc.). Processing such large volumes of data and making them useful requires highly skilled information technology (IT) professionals and data scientists who DOTs or other agencies simply do not have on staff at present. Without sufficient dedicated resources to evaluate data validity and analyze actual performance, the advantages that these “improvements” offer will be limited. Thus, DOTs must coordinate with educational institutions to adapt curricula, develop new job classifications, create many new jobs, and improve the capacity of a large number of existing staff to begin to meet the requirements of successful CV application and infrastructure deployment. DOTs may choose to contract out much of the IT work associated with C/AV technology functions. DOTs will still have to plan for IT infrastructure and will need to be knowledgeable about it, but the day-to-day logistics may be handled, to various degrees, by IT contractors.

Safety Pilot Model Deployment

Safety Pilot is designed to determine the effectiveness of safety applications in reducing crashes and to show how real-world drivers will respond to these safety applications in their vehicles. Specific devices tested include vehicle awareness devices (VAD) both integrated into the vehicle and installed as aftermarket devices. The U.S. DOT Joint Program Office (JPO) is leading the Safety Pilot effort but is supported by several other DOT departments, including FHWA, NHTSA, the Federal Motor Carrier safety Administration (FMCSA), and the Federal Transit Authority (FTA).

The largest component of the Safety Pilot Program is being led by the University of Michigan Transportation Institute (UMTRI) in conjunction with Michigan DOT, U.S. DOT and numerous partners in industry and academia. Nearly 3,000 vehicles have been equipped with wireless connected vehicle devices to test safety applications using DSRC. Safety applications tested include the following:

- **The Basic Safety Message (BSM)** that contains vehicle-safety-related information such as speed and location, which is broadcast 10 times per second to surrounding vehicles.
- **Forward Collision Warning (FCW) –** Warns the driver if he/she fails to brake when a vehicle in the driver's path is stopped or traveling slower and there is a potential risk of collision.
- **Lane Change Warning/Blind Spot Warning (LCW/BSW) –** Warns the driver when he/she tries to change lanes if there is a car in the blind spot or an overtaking vehicle
- **Emergency Electric Brake Light Warning (EEBL) –** Notifies the driver that there is a vehicle ahead (or several vehicles ahead) that the driver can't see but which is braking hard for some reason.
- **Intersection Movement Assist (IMA) –** Warns the driver when it is not safe to enter an intersection – for example, when something is blocking the driver's view of opposing or crossing traffic.

The results of this effort, which are still ongoing, contributed to NHTSA's recent Notice of Proposed Rulemaking (NPRM) to require DSRC technology in all new vehicles. Evaluation of the large datasets generated by this project is still underway.

- Public acceptance drives V2V effectiveness and yields public safety benefits; therefore, far in advance of V2V deployment, DOTs may find it beneficial to partner with automobile manufacturers to develop an effective public outreach strategy to communicate potential safety benefits of V2V technologies.
- DOTs often operate in a legacy system where the ITS planning and operations positions are staffed by civil engineers who are provided skills training through State agencies. Going forward, this method of training will be insufficient. Planning for CV/ITS implementation requires a hybrid skillset that combines an understanding of transportation with skills in the areas of electronics, programming, and computer science, placing professionals with this skillset in high demand. State salaries and legacy job descriptions create challenges to attracting and keeping valuable staff onboard.
- Agencies must monitor technology advancements. They may not be the lead testing agency, but they still need to learn from active research programs. Agencies also must implement change management to keep up with and adapt to new technologies.

4.7 Equity and Legal Compliance

- Planners should expect that CV infrastructure will be incrementally (organically) brought online; therefore, the system's benefits will be unequally distributed among potential users. Ample research must be completed to justify and transparently document how pilot locations are prioritized. Care should be taken to ensure that CV infrastructure projects are compliant with Title VI of the Civil Rights Act.
- As the role of State DOTs will henceforth include planning for IT and IT systems customer service, it is especially important that CV projects be compliant with Section 508 of the Rehabilitation Act as well as the Americans with Disabilities Act. This is an especially important issue because C/AV technology and infrastructure will offer significant mobility advantages to people with disabilities who are currently unable to drive. Many operating agencies and divisions are already trying to incorporate dedicated short-range communications (DSRC) capability into intersection and arterial corridor upgrade projects. These investments must be incorporated into TIPs, STIPs, and short-range plans. Planners will need basic knowledge of capital and operating costs and will play a central role in educating decision makers on the benefits of these projects.

5.0 Stakeholder Input: Best Practices and Recommendations

The consultant team interviewed approximately 20 stakeholders[4] from State DOTs, MPOS, and academia. A summary of stakeholder input is provided in this section. The interviews were relatively open-ended in nature. While gathering information on specific projects and initiatives was an important goal, most organizations were not likely to have actual C/AV projects in place or even underway. Open-ended discussions were considered the best way to determine respondents' levels of knowledge and interest, their views of potential impacts on their agencies, and their thoughts about the future of the transportation system. For that reason, the interviews were focused on five (5) specific questions:

- Is your agency now active in any Connected/Automated Vehicle initiatives, and if so, what are they and what is the agency's role?
- How do you and your agency obtain information on C/AV technology and have you used information provided by U.S. DOT, such as websites, newsletters, webinars, and conferences?
- What products and processes do you see being impacted by C/AV technologies, in the short-, medium-, and long-term periods?
- What changes do you see in the area of skill and technical requirements as a result of C/AV technologies?
- What specific impacts do you envision on the transportation network?

A summary of responses to each are is provided below.

5.1 Best Practices

Some of the current best practices identified through the interviews are summarized below:

- Michigan DOT has a number of C/AV initiatives underway that involve partnerships with the automobile industry. A number of major freeways and arterials will be outfitted with DSRC equipment in anticipation of the launch of DSRC-equipped vehicles in the next two years. The State's DUAP program has expanded over the years to incorporate numerous sources of mobile data. There are opportunities for planners to use this information in a variety of applications, particularly those involving operational resources. MDOT V2I arterial testbeds are providing an opportunity to test communication between vehicles and signals that will provide information regarding both safety messages and recommended driving speeds. This technology will likely have an influence on future investment decisions in these corridors.

[4] Additional interviews are underway and will be documented in the final version of TM#2.

- Michigan DOT noted that it is working with both universities and technical colleges to develop programs that will provide the engineers and the technicians who can design, manage, and maintain the C/AV infrastructure and provide communication with in-vehicle systems.
- Oregon DOT noted two initiatives. One is a leadership team initiative that is looking broadly at the impacts of technology, including C/AV, on all parts of the agency; the other is a joint effort between planning and operations to add a TSM&O chapter to the Planning Analysis Manual as it is updated. This would address methods for operational, ITS, and C/AV technologies.
- The Texas DOT (TxDOT) created a Connected Vehicle Task Force to identify C/AV opportunities and plan future direction that was led by Texas Transportation Institute and included MPOs. TxDOT and North Central Texas COG have identified a State-owned managed lane on I-30 between Dallas and Arlington as a potential C/AV testbed.
- Florida DOT (FDOT) has ongoing statewide initiatives, including hosting stakeholder workshops and forums in both 2013 and 2014. Florida has two connected vehicle test beds, one in Orlando and one recently designated in Tampa. FDOT Districts also have engaged in public outreach efforts to raise awareness and prepare for future coordinated efforts; for example, a major bridge design includes additional conduit space and lane designs.
- Wisconsin DOT (WisDOT) has been active in multistate pooled funds and in regional traffic operations coalitions principally focused on TSM&O, including efforts to share best practice information between States through peer exchanges.
- LA Metro leveraged a standing ITS Working Group formed by a related project to help share information and progress on C/AV commercial vehicles. The reconstruction of the I-710 corridor provides an opportunity to ensure a newly designed facility takes into consideration the impacts of commercial C/AV.
- Houston-Galveston Area Council (H-GAC) noted that a wireless communications system will soon cover all signals in the City of Houston, providing a backbone that could be used in the future to collect and transmit data from C/AV equipped vehicles.
- Chittenden County MPO in Burlington, Vermont, is working with the Vermont Agency of Transportation and local municipalities to implement adaptive signal control in two corridors and include DSRC installation as part of the project.
- The Capital District Transportation Agency (CDTA) in the Albany, New York region is developing a white paper that will review the impacts of technology, including C/AV, on the region in general and planning activity specifically.
- The Genesee Transportation Council (Rochester, New York) has been identifying how to best integrate C/AV considerations into its LRTP.
- In the Tampa Bay region, the Tampa Hillsborough Expressway Authority (THEA) has launched research studies and pursued designation as a connected vehicle test bed. The research study, completed by the Center for Urban Transportation Research at the University of South Florida, focused on developing white papers and launching regional working groups to see how the Tampa Bay region could use C/AV as an economic development opportunity. In addition to workshops and working group activities, THEA hosted live demonstrations of vehicle manufacturers' technology and is exploring partnerships with other agencies, including the public transportation provider in the region. THEA produces a regular newsletter on the subject and is engaging in its own community focused strategic planning process.

5.2 Key Findings for Planners

Developing Knowledge of C/AV Technology

- The U.S. DOT website and webinars are currently being used by many in the planning community. Some respondents noted that travel is difficult and that it would be helpful for FHWA to bring training sessions or workshops to the States.
- A number of respondents attended the ITS World Congress or previous ITS America meetings and found these very helpful in learning about the latest developments. Those who attend the Transportation Research Board (TRB) annual meeting noted recent growth in C/AV sessions there. They noted that while some of the more planning-oriented conferences are beginning to address the topic, it does not yet have high visibility.
- The ITS America Newsbrief was cited as a common source of information, as was Bernie Wagenblast's daily email letter. TRB email summaries were also identified as good sources.
- The TSM&O initiatives and Capability Maturity Model workshops were considered very timely in educating both operations and planning personnel and were helping to forge better ties between planning and operations personnel. Benefits of this initiative apply to ITS and operational projects as well as C/AV.
- Los Angeles Metro did task a consultant to develop monthly C/AV news summaries to help track the ongoing developments in this arena
- Other frequently cited sources that can be of use to planners were Dr. Alain Kornhauser (Princeton University), information from IBM's Smart Cities initiative, articles included in Atlantic Cities/City Lab, and policy studies prepared by the Eno Foundation and RAND.

Incorporating C/AV into Products and Processes

- There are opportunities to incorporate DSRC technology and safety-oriented infrastructure investments into specific projects that are in the planning and development stage. These projects, which are part of the STIPs and TIPs, include arterial coordination, freeway upgrades, and spot safety improvements.
- Agencies attempting to incorporate DSRC should investigate Federal grant programs such as the upcoming CV Pilot program awards or the FHWA Accelerated Innovation Deployment (AID) program. The CV Pilot program is expected to greatly increase insight into the issues related to CV deployment in different environments. Independent evaluations will also provide useful information on costs and benefits that can be used by agencies to assess future deployments. See http://www.itsdocs.fhwa.dot.gov/factsheets/pdf/JPO_CVPilot_v3.pdf.
- There is a need to educate a wide variety of stakeholders on the benefits of incorporating C/AV technology at this time, especially since benefits may not be realized until vehicle market penetration increases several years from now.
- Crash reduction technology, much of which is vehicle-based, is likely to increase in the short term and could have a significant impact on both operational and capital investment strategies.
  - Fewer resources may be needed for incident management purposes, freeing them for use elsewhere.

  - Safety plans may change significantly with less need for infrastructure investments in such items as rumble strips and guardrails. It is likely that these changes will occur more in the medium-term but they must be considered in short-range safety planning activities.

- Agencies may see a major change in the way the industry itself understands and gives guidance through the Highway Capacity Manual as regards both the concept of capacity and the analytics behind it. These changes will cascade down to influence the ways in which funding decisions are made for both system expansion and maintenance.
- Planning agencies should fill a role as essential leaders in education efforts directed toward policy committees, elected officials, and the general public. These efforts will be critical to obtaining funding for the infrastructure needs of C/AV.
- Planners can also provide higher-level analyses, such as those relating to benefit/cost and safety impacts, to help support funding and deployment. Respondents see MPOs as potentially having more direct contact with the public as an educational resource regarding C/AV technology. This could include hosting clinics and educational events to help the public learn how to best take advantage of the technology. This might be in done in partnership with consumer organizations such as AAA or the manufacturers and suppliers of the technology.
- Respondents saw the growing prominence of “big data” as a major opportunity resulting from C/AV technology but a major challenge as well. Planners need to consider ways to link “big data” to “big insights”—specifically using the information to change conventional thinking. C/AV data generated by both vehicles and related infrastructure will be extremely valuable and possibly provide cost-effective replacements for many current data collection programs. Information on weather, travel times, and signal operations can be used not only to monitor and regulate real-time operations but also can be archived and analyzed for planning purposes.
- Asset management is an area where planners can use mobile data from vehicles already on the road to eliminate some expensive field data collection activities. Important outstanding questions involve availability of the data for public sector use and the level of market penetration required to obtain a reasonable data sample for operations and analysis. This will vary by application.
- Significant long-term impacts are likely to result from a high level of C/AV penetration in the market. The potential for major reductions in crashes and closer headways could result in increased throughput on existing facilities and reduce the need for new lanes or entirely new facilities. This will have a major impact on long-range visioning and planning activities. Given the difficulty of predicting what these emerging technologies will look like and the adoption rate, future planning necessarily must include a higher and more sophisticated level of risk analysis.
- Current long-range forecasting models, which have assumed a continuation of today’s technologies and travel patterns, might not be useful in the future. Long-range planning activities may shift to development of “alternative futures” that make different assumptions about technologies, market adoption, and impacts on the transportation system. These assumptions would then be reviewed on a regular basis and the long-range plan modified based on actual developments. A similar scenario is that current models will evolve into “mobility optimization” tools that will use real-time data to inform both operational changes and future planning.
- For micro-simulation and more operational models, calibration may not be necessary as a full picture of the traffic flow may be gained directly from the field. Analysts can then focus on

testing of alternative scenarios and operational strategies. The likelihood that totally unforeseen technological changes will occur within short timeframes greatly increases the challenges involved. The technology potentially enables a more fundamental conversation about what the right combination of public sector and private sector involvement should be. This tension between public service (transit, open highways, etc.) and private innovation (automated taxis, private toll facilities, new vehicle ownership models) creates new paradigms for transportation planners. Engaging the business community and economic development leaders becomes critical for big picture thinking.

5.3 Impact on Skills and Technical Requirements

- Significant changes in skill needs are inevitable and are being considered by planning agencies. Planning agencies will require some knowledge of C/AV technology, as they will play an essential role in educating decision makers and the general public about the technology and why infrastructure investments are necessary to support it. Under current funding systems, these investments will have to compete with other needs, and without an educational component they will not be able to do so.
- The technology will require a high level of skill on the operational side, yet current DOT pay scales and job requirements are not well suited to recruiting the highly trained specialists that will be needed in this area. There also was a concern that the high turnover that these skilled positions would have could impact implementation timelines. At the highest level some knowledge of communications system hardware and software will be required, and workers with that expertise are more likely to be attracted to technology companies and areas such as robotics. Depending on the ability of agencies to obtain this expertise, it may need to be contracted shifting DOT, and possibly some MPO personnel into a contract management role. These contract management responsibilities will also will require training and a new set of skills.
- After more than 20 years of ITS deployment, many agencies have not revised job requirements and pay scales to bring in adequate personnel with electrical and communications backgrounds. With the deployment of C/AV technology, the challenge will become much greater. The increasing sophistication of signal operations may lead to a similar outcome: contracting of real-time operations and maintenance (including with respect to C/AV infrastructure components) to private contractors. MPOs may need to plan to obtain outside expertise, as budgets and project activities in most smaller planning organizations could not support such specialization. FHWA has developed training courses on Public-Private Partnerships (P3) that could be useful in helping both planners and operations personnel work effectively with the private sector.
- The availability of C/AV data will lead to the further development and of and demand for the “data scientist.” There is both great opportunity and significant challenge in boiling down the large amounts of data that may come from C/AV technology and turning it into useful, actionable information. This is true for both operational data and planning data. While many agencies have personnel who can manage and use existing databases, data science is a much more challenging field that will require more sophisticated capabilities. There is a need to reduce and manage a potentially enormous stream of data, as well as increase the capability to analyze it and provide guidance in decision making to the agencies. At least some of this work will also have to be contracted to private parties, with agency personnel managing the effort and implementing resulting recommendations.

- Planning agencies must closely cooperate with the entire regional community this consensus builder or consolidator of information role would be very valuable at the regional level. Some type of “single point of contact” for industry partners and agencies alike would be useful.

5.4 Impact on Transportation System

- Impacts on the transportation system mentioned by stakeholders included reduction in crashes with corresponding changes in operational focus, ability to implement advanced signal timing strategies, and improved information for targeting of spot safety improvements. Another impact of safety improvements may be lighter vehicles that require less fuel, a factor that will have implications for both energy and environmental analyses.
- Communication directly with the vehicle provides a number of opportunities to improve system efficiency. Drivers can be provided with information about the proper speed to optimize their green light times on arterial corridors or can be provided with an alarm that notes they are traveling too fast to take an upcoming curve under wet road conditions. Note that these are initial steps toward more advanced automation, where the vehicle will respond to such messages on its own. Initially there may be C/AV-only highways or lanes, with some level of automation or platooning provided. In the medium term C/AV could support Integrated Corridor Management strategies by automatically balancing traffic between freeways and arterials. Small groups of drivers could be diverted with targeted messages, for example, a more effective to maintain overall flow than a Dynamic Message Sign.
- There are requirements imposed on both the vehicle and the infrastructure to achieve the benefits of C/AV technology. Planning-related impacts might go well beyond the transportation system, impacting land use, development strategies, and economic activity. With increased automation, car sharing may evolve into a service-on-demand industry that would shift car ownership from individuals to fleets. This would allow greater urban densities since parking requirements could be relaxed. Automated vehicles could replace existing inefficient transit feeder services and some line-haul services as well. On the other hand, these developments may result in reduced land use density, since commuting time can be used more productively.

5.5 Summary

The introduction of C/AV technology will accelerate a general trend in transportation agencies focusing more on operations and less on large capital investments. Over the past few years, planning agencies and departments have become more aware and more involved in operations and ITS. Through webinars, tool development, and workshops, U.S. DOT has provided support to agencies that have recognized the importance of bridging the gap between planning and operations. As a result of these efforts, planners at both the State and MPO levels seem to have a strong awareness of C/AV technology and an understanding that it will have a major impact on how their business is conducted.

Stakeholders are aware of opportunities to keep up with industry developments and are taking advantage of them. They envision changes in many areas ranging from short-term deployment of DSRC on arterial corridors to investments required in the long term to support the deployment of large numbers of automated vehicles. Changes in the medium term include new and much more robust sources of data that will change methods of data collection and result in new tools and products related to operational planning. Rapid changes in technology mean that for long-range planning, major capital investments will be subject to a much more rigorous type of risk analysis.

Many of the assumptions that have long been built into planning models must change, as must the techniques themselves. Skills needed to address C/AV technology will be different as well, and at least in the short to medium term it will be difficult for transportation agencies to obtain and keep employees with those skills. As a result, there are likely to be more public-private partnerships and contracting arrangements, which will in turn require more employees with more sophisticated project and contract management skills in public agencies.

6.0 Universal Impacts

C/AV will, in the long run, fundamentally change travel behavior, but it will also have impacts on planning over the next five to ten years. Planners must account for, and be encouraged to consider, a host of new and emerging characteristics. Many impacts of connected vehicle on the planning process are relatively universal to all products and projects, regardless of the end outcome or planning product. These universal observations are found in all categories of the framework documented in Technical Memorandum #1: system impacts, planning processes or tools impacts, and agency skills and abilities. To help planners address C/AV technology, it is important to provide an overview of impacts that apply to most activities, then guidance that relates to smaller sets of products, or even individual products or project activities. Also, new products are likely to emerge—for example, performance management reporting that utilizes C/AV data—as new data becomes available and business models evolve. In identifying these universal impacts, it is important to discuss the overall impacts on the transportation system that may occur.

6.1 Societal Impacts

- C/AV technology has the potential to bring improvements in mobility, including decreased congestion. V2V and V2I technologies will result in more efficient vehicle interactions, reducing unnecessary braking, poor merging, and other congestion-causing activity. This could result in reduced need for new capacity projects, although the outcome will in part be determined by how much additional driving results.[5] Crash reduction benefits may be realized in the medium term as more vehicles are introduced into the fleet with a suite of safety-related applications; however, a relatively large market penetration may be needed to obtain a level of safety and mobility benefit that will reduce or eliminate the need to expand capacity. These impacts will materialize more slowly. Any assessment or quantification of C/AV crash reduction benefits must focus on measuring the incremental benefits over and above those already achieved through ongoing progress in non-CV active safety systems, many of which are already available.
- Infrastructure investment strategies driven by V2I and V2V operational requirements, like growth in industries such as infotainment/, targeted advertising/, and connected mobile offices, are new developments that must be considered in the planning process. Long-range planning activities will be affected as long-term capacity projects are reassessed and funding and planning programs restructured.
- Growth in car-sharing and ride-sharing services, mostly smartphone based, already is changing economic patterns in ways that are influencing transportation regulation in the short term and will almost certainly influence transportation planning over time. New technologies are allowing automobile travel to evolve into more of a service industry, with the ability to track

[5] Increases in self-driving vehicles without commensurate deployment of V2V technology could bring more vehicles on the road and increase congestion.

vehicles and price according to demand. Ultimately, the evolution from connected vehicle technology to self-driving vehicles may shift the industry entirely over to service.

- There could be significant reduction in the need for on-site parking; the potential for greater development density with reduced vehicle parking and storage requirements; and allowance for new vehicle storage, staging, and service areas. New zoning and land use policies will be needed to accommodate changes as car-sharing and ride-sharing services play a larger overall role in the transportation system. Planning models and investment decision tools must improve to better incorporate these services.

Reduced energy consumption and environmental factors also are potential impacts of C/AV technology. Improvements in operational efficiency, along with reduced fuel consumption, will lead to reduced emissions and improved air quality. Reduction in fuel consumption has been affecting transportation funding for some time, and these effects will increase as efficiency continues to improve. The size and number of Clean Air Act attainment areas may be reduced.

6.2 Planning System Impacts

These observations are not intended to be an exhaustive summary of impacts that will apply across a wide range of planning products; they may be more or less applicable to any given individual planning use case and process. For example, a transportation planner will be required to simultaneously weigh costs and benefits of large V2I installations while also recognizing the efficiency and safety gains from V2V deployments. Short-term impacts (0-10 years) should be addressed first, followed by medium- to long-term impacts (10 years and beyond).

Short-Term Impacts

- For C/AV planning, there are lessons to be learned from more than 20 years of experience in development of ITS plans. ITS plans include strategic plans, pre-deployment plans, and program plans. Many of the original plans were developed within Operations and Traffic Divisions of DOTs and had minimal, if any, ties to the planning process. Over time several factors have led to closer links between ITS/Operations and Planning. U.S. DOT and FHWA have made significant efforts to incorporate Operations and ITS into the general planning process and provide training and materials on Planning for Operations. Operations and ITS staff have realized the value of incorporating ITS and Operations projects into their STIPs, TIPs and Long Range Plans. Mainstreaming of ITS projects into larger capital projects has enabled more projects to be deployed while requiring greater cooperation between Planning, Operations and Design personnel. Planning staff have recognized the ability of Operations and ITS projects to cost-effectively address needs in an era of limited capital funds. These efforts provide a good platform for incorporating C/AV technology into the planning process early on, avoiding the isolated approach that was so common during the early years of ITS planning and deployment.
- There is growing interest in operational and ITS strategies related to arterial management. Recent advances in software technology have reduced the cost of implementing adaptive signal control, and many agencies are expanding their communications networks along arterials to support these efforts and other programs such as Integrated Corridor Management (ICM). More agencies are gathering probe data from arterial corridors, using Bluetooth and/or private sector sources. Some agencies are now considering installing DSRC on major arterial corridors to be used in operational strategies as the penetration of DSRC in

the vehicle fleet increases. Similar proposals are being developed for implementing V2I on freeway systems and at safety hotspots on the arterial system. These proposals must be incorporated into short-term plans such as Transportation Improvement Programs (TIP) and State Transportation Improvement Programs (STIP), as well as operational plans and corridor studies focused on short-term improvements.

- Incorporating DSRC into short-term programs will require some familiarity by planning personnel with the technology and associated costs and benefits. Stakeholders interviewed for this project noted that without new sources of funding these deployments must compete with other system needs; thus, education of technical and policy committee members, elected officials, and the general public will be necessary. Stakeholders also noted that without additional funding these deployments must compete with other needs, including many capital projects that have been in the pipeline for years. Planning agencies and departments are well suited to this effort as they have regular contact with a wide range of stakeholders.
- New stakeholders, many of whom are private-sector entities as yet unknown (e.g., national phone carriers such as Verizon or AT&T who deploy new and different wireless networks), must be included in the planning process. These information and services providers typically have not been engaged in traditional transportation planning activities. Their engagement will be required in order to understand how C/AV technology will operate and what ongoing relationships are required between the public and private sectors. The ability to involve private-sector stakeholders, including technology suppliers and emerging service providers, and help them communicate effectively with traditional stakeholders and the public will be in high demand. These skills typically are not taught in planning programs, but they will be important as additional ITS and communications technologies are added to the infrastructure network. These relationships are critical to the evolution of the transportation system over time and should be established as soon as possible. Another group of potential stakeholders include new technology-based providers of direct transportation services (Uber, Lyft) and private sector providers of traveler information and telematics (Google, Waze, HERE, Inrix, TomTom, Qualcomm).
- Existing stakeholders will be faced with new challenges and options as a result of C/AV technology deployment and will likely seek guidance from planning agencies and stakeholder groups such as Technical Advisory Committees. Issues may revolve around incorporating DSRC technology into locally funded arterial corridor improvements or evaluating opportunities to incorporate C/AV technology into emergency response vehicles or systems.
- Planning agencies must assess the use of C/AV technology, including both roadside- and vehicle-based units, for collecting data, including information such as parking availability, travel speeds, weather conditions, and other operational conditions. Pavement conditions, air quality monitoring, or additional traveler information can be presented through V2I. These uses will inform understanding of baseline operating characteristics of the network and impacts of events, changes to the infrastructure, or other factors. Some applications will benefit from C/AV technology in the short term, particularly applications where a relatively small sample of equipped vehicles is needed to obtain useful data. Travel time and weather data are two possible examples. Other applications such as operational strategies will require larger samples and thus be relevant more in the medium- and longer-term periods. It should be noted that agencies will probably continue to meet these goals with technology other than V2I, particularly with continuing growth in crowd sourced data from mobile sources. Much of this data is already widely available.

Medium- to Long-Term Impacts

- From the system perspective, it appears that V2V and V2I deployments will likely alter physical infrastructure in both the near and long term. As safety improves and as the impacts of human factors associated with driving are mitigated due to deployment of connected vehicles, it follows that reduced lane widths, operational changes, and new infrastructure components will change the transportation facility owners' context for work products.
- A planner may need to consider hardware installations to support equipment or design sufficient signage to communicate time-sensitive information. Due to the expected safety improvements from C/AV technologies, we would expect reductions in requirements for safety-related physical infrastructure in the long term. As a result, planners could focus physical safety improvements on infrastructure projects with short- to medium-term life cycles.
- Planners must prepare for more rapid technology upgrades and changes in V2I involved deployments. Not only must basic safety messages and other information be secure, but the security of the software and hardware products that are broadcasting or receiving such information most likely must be updated. The expected rapid improvements in communications technology and information processing generated by C/AV technologies should lead to ultimate retirement and/or technological shifts of current transportation technologies. The hardware placed in early deployments will likely become obsolete more quickly than other transportation infrastructure. Given this likelihood, the planner's dictionary should be updated to include the phrase "planning for obsolescence". It is also important to note that there will be both long-term "legacy" hardware at the roadside and legacy in-vehicle systems in the fleet as turnover occurs over time. Roadside units will need to be backward compatible so that they work with all vehicles.
- To prepare for these changes, planning agencies must develop additional workforce skills and abilities. Adequate knowledge of C/AV technology will be mandatory to identify and mitigate potential impacts of various market penetration rates on condition, safety, mobility, and data quality. Different C/AV technologies rely on different communications spectrums and are capable of a variety of service functions. Understanding these technologies will enable providers and users alike to better prepare and ultimately manage the transportation network.
- New modeling tools and travel projections must reflect C/AV deployment horizons. The ability to evaluate the costs and benefits of alternative C/AV technology deployment in a corridor, including incorporation of these concepts into safety evaluations and modeling tools, will be a priority for planning agencies. Models that account for the changing nature of travel patterns based on V2I and V2V driver assistance must be developed and calibrated.
- The management of fleet integration over time is a significant policy issue that will require the input and participation of planning agencies. Integration of C/AVs into the fleet will happen gradually; while at some point they will comprise a majority of the fleet, there will continue to be significant numbers of non-C/AVs in the fleet for some time after that. Policies regarding both investment and operational strategies will be affected. The tools discussed elsewhere in this document will be needed to address these issues.

7.0 Product and Process-Specific Impacts

Table 7-1, below, further guides the development of the typology that will be used to illustrate the impacts of C/AV technology. An initial set of impacts on planning products and processes is shown in Table 7-1. Additional information, to be determined through the case studies in Task 4, include assessments of the following:

- What is the role of C/AV technology on both general activities and specific projects; for example, does C/AV technology reduce the amount of additional capacity required or reduce crashes to a point where physical safety projects can be eliminated or reduced in cost?
- What are the locations, costs, and impacts of incorporating CV infrastructure requirements into a specific project?
- What are the impacts on the specific tools and processes that are used by the agency, including such elements as demand models, traffic simulation, and safety analysis?
- What new stakeholders should be involved in the planning process and what role will planners play in developing new public-private partnerships and innovative financing plans?

These product- or process-specific impacts are supplemental to the universal impacts noted in Section 6.0.

Four of the products and processes below are combined into two pairs since the impacts would be similar. Combinations include:

- Operations Plans and ITS Architecture; and
- Strategic Highway Safety Plan and Highway Safety Improvement Program.

Table 7-1. Typology Framework

No.	Planning Agency Activity	Impacts on Planning Products and Processes
1	Long-Range Visioning	• Reduction in crashes and ability to operate at closer headways may reduce need for additional roadway capacity in the future. • Visioning must extend to evaluating alternate futures that involve different technology outcomes as well as different economic and land use scenarios. • Visioning must be updated frequently, taking into account changes in technology as they occur. • Information from the visioning process must feed more directly into investment decisions. • New tools will be needed that are better suited to alternative futures evaluation; current forecasting tools that have "locked in" technology assumptions will not be as useful.
2	Statewide Long-Range Transportation Plan	• The visioning process must be more closely tied to long-range planning. Long-range plans must include evaluation of alternative futures and their impacts on land use and economic activity. • Long-range plans must consider the impacts of reduced crashes and potential capacity improvements resulting from C/AV technology. New forecasting tools must be developed that can address alternative futures and provide risk assessments of different investment strategies. • Planning must evaluate alternatives for deployment of CV technology, such as roadside DSRC units, and how they are packaged with other improvements. In the long-range plan, agencies may consider programming these improvements into major capital projects that will be implemented a number of years in the future. • Funding State investments required to facilitate deployment of C/AV technology in rural areas will be a challenge to planners. Planners will need to identify opportunities to incorporate these investments into long-range plans.
3	Regional Long-Range Transportation Plan	• The visioning process must be more closely tied to long-range planning. Long-range plans must extend to evaluation of alternative futures and their impacts on land use and economic activity. • Long-range plans must consider the impacts of reduced crashes and potential capacity improvements resulting from C/AV technology. New forecasting tools must be developed to address alternative futures and provide risk assessments of different investment strategies. • Planning must evaluate alternatives for deployment of CV technology, such as roadside DSRC units, and how they are packaged with other improvements. In the long-range plan, agencies may consider programming these improvements into major capital projects that will be implemented a number of years in the future.

No.	Planning Agency Activity	Impacts on Planning Products and Processes
4	Transportation Improvement Program	• Planning agency personnel must provide cost estimates of deployment of C/AV technology. • The planning agency will need to educate committee members, decision-makers, and the general public about the need for C/AV-related investments. • The planning agency must incorporate C/AV-related investments into the TIP prioritization process. This will require analytical tools as well as educational materials. • Models and tools used to forecast demand and operational characteristics should be able to incorporate the impacts of increased wireless communication technology, such as DSRC market penetration, into the evaluation of project benefits. Short-term benefits that do not require a large vehicle market penetration of DSRC technology, such as improved signal timing, can be evaluated with these tools.
5	Short-Range Transportation Plan	• Models and tools used to forecast demand and operational characteristics should be able to incorporate the impacts of increased wireless communication technology, such as DSRC market penetration, into the evaluation of project benefits. • The planning agency must identify supporting technologies and services related to DSRC and V2I operation such as security, back-office processing capability, and maintenance. • The planning agency will need to educate committee members, decision-makers, and the general public about the need for C/AV-related investments. • Implementation of CV-related safety investments, particularly those involving security or V2I, will require a greater level of cooperation among different units within government (police, traffic engineering, parking management, maintenance).
6	Congestion Management Plan	• Planning agencies will need to incorporate C/AV technologies into the Congestion Management Planning process. • Appropriate evaluation criteria and performance measures related to congestion mitigation will need to be applied to C/AV alternatives. • Tools for evaluating the impacts of C/AV deployments on congestion will be needed, including tools that address both mobility and travel time. • Planners will need to develop processes for combining C/AV technology with other proposed CMP projects (signal timing, etc.).
7	Asset Management Plan	• Planning agency personnel will have access to a greater volume of infrastructure condition information, with an ability to update current conditions in real time. This may reduce the reliance on longer-term maintenance strategies as information is continuously updated. Planning agencies could take a greater role in managing this information and helping prioritize reconstruction and maintenance strategies. On the other hand, the ability to continually monitor conditions may raise the expectations of the traveling public as information is continuously broadcast. Heightened expectations may make it harder for agency personnel to respond and prioritize longer-term maintenance needs. The ability to process and analyze large amounts of data is critical to effective use of C/AV data for asset management. • The planning agency will assess the use of C/AV technology, including both roadside and vehicle-based units, for collecting operational and asset data in the corridor, including information such as travel speeds, weather conditions, and pavement condition. • Planners may need to engage the public to explain the technology, data transmitted, and other aspects of such data collection programs. Otherwise the traveling public may opt not to provide condition information or may expect to be compensated for providing such information.

No.	Planning Agency Activity	Impacts on Planning Products and Processes
8	ITS and Operations Plan	• ITS and Operations plans will need to identify a path from current deployments and technologies to those that are compatible with C/AV technology. This analysis will be incorporated into ITS and Operations programs as legacy system replacements are planned. • The planning agency must identify supporting technologies and services related to DSRC and V2I operation such as security, back-office processing capability, and maintenance. • Many planning agencies manage or play a crucial role in ITS architecture. Agencies must become familiar with new C/AV elements of the architecture and engage new stakeholders. • Operations planning priorities may change as a result of reductions in crashes, with fewer resources placed in incident management and more in system maintenance activities needed to support C/AV (striping, obstacle removal, etc.).
9	ITS Architecture	• ITS and Operations plans will need to identify a path from current deployments and technologies to those that are compatible with C/AV technology. This analysis will be incorporated into ITS and Operations programs as legacy system replacements are planned. • The planning agency must identify supporting technologies and services related to DSRC and V2I operation such as security, back-office processing capability, and maintenance. • Many planning agencies manage or play a crucial role in ITS architecture. Agencies must become familiar with new C/AV elements of the architecture and engage new stakeholders. • Operations planning priorities may change as a result of reductions in crashes, with fewer resources placed in incident management and more in system maintenance activities needed to support C/AV (striping, obstacle removal, etc.).
10	Strategic Highway Safety Plan	• Planning agency personnel will need more detailed simulation tools to estimate the safety impacts of C/AV deployments in this type of corridor. • Planning agency personnel will need to incorporate assessments of the safety impact of increasing levels of C/AV market penetration in the vehicle fleet, as well as advances in the technology. • Implementation of C/AV-related safety investments, particularly those involving security or V2I strategies, will require a greater level of cooperation between MPO member municipalities since consistency is critical to realizing safety benefits. • Implementation of CV-related safety investments, particularly those involving security or V2I, will require a greater level of cooperation among different units within government (police, traffic engineering, parking management, maintenance).
11	Highway Safety Improvement Program	• Planning agency personnel will need more detailed simulation tools to estimate the safety impacts of C/AV deployments in this type of corridor. • Planning agency personnel will need to incorporate assessments of the safety impact of increasing levels of C/AV market penetration in the vehicle fleet, as well as advances in the technology. • Implementation of C/AV-related safety investments, particularly those involving security or V2I strategies, will require a greater level of cooperation between MPO member municipalities since consistency is critical to realizing safety benefits. • Implementation of CV-related safety investments, particularly those involving security or V2I, will require a greater level of cooperation among different units within government (police, traffic engineering, parking management, maintenance).

No.	Planning Agency Activity	Impacts on Planning Products and Processes
12	State Implementation Plan	• Planners will need analytical tools to identify the impacts of V2I deployments on air quality—for example, Signal Phasing and Timing (Spat) projects or in-vehicle advisories and efficient driving speeds. • Incorporation of data and operating strategies from local implementation of U.S. DOTs "The Applications for the Environment: Real Time Information Synthesis" (AERIS)" Program has the potential to generate environmentally relevant real-time transportation data and use these data to create actionable information that supports and facilitates "green" transportation choices by transportation system users and operators.
13	Transit Development Plan	• The planning agency will be required to reevaluate ridership expectations based on potential impacts of C/AV technology. Ridership projections could be overstated if V2V and V2I and efficiencies gained through car sharing improve traffic flow to the point that personal vehicles become the preferred choice. Ridership could be understated if improved parking management creates seamless connections from parking to points of interest. • New modeling tools, possibly supported by new data sources, may be required to estimate the changes in demand. Models must be tied more closely to visioning activities and incorporate alternative futures. • The planning agency will need to evaluate alternatives for deployment of C/AV technology, such as roadside DSRC units, and how they are packaged with transit improvements such as BRT. Early deployment of C/AV technology may be accomplished through incorporation in new transit vehicles. Benefit/cost analysis of these deployments should be considered. Both physical locations for C/AV deployments and related operational strategies (i.e., managing buses in real-time along a route or implementing signal priority) will be considered by the planning agency. • The planning agency may assess the use of C/AV technology, including both roadside and vehicle-based units, for collecting operational and asset data in transit corridors, including information such as travel speeds, parking availability, weather conditions, bus capacity, and on-board condition.
14	Transportation Demand Management Plan	• The planning agency will evaluate the efficiency improvements and traffic demands associated with CV investments. New modeling and analysis tools will be required. • The planning agency must evaluate alternatives for deployment of CV technology, such as roadside DSRC units, for improving the performance of the existing system. C/AV deployment may generate data and information that can increase use of existing facilities and make them more efficient, including parking, transit availability, and travel time information.
15	Nonmotorized (bicycle and pedestrian) Plan	• The planning agency must consider specific V2I elements for non-motorized users, including travel times and other traveler information. This may include new infrastructure installations (dynamic signs, detectors, and warning indicators). • The planning agency will assess the use of CV technology, including both roadside and vehicle-based units, for collecting operational and asset data in the corridor, including information such as facility usage, travel speeds, weather conditions, and condition of non-motorized facilities (cycle track, bike lanes). • V2V and V2I technologies will result in an evolution from driver warnings, to vehicle-based actions designed to avoid crashes, to fully automated driving. There are estimates that this development could eliminate the majority of crashes that now occur involving bicyclists. Planners must evaluate and track crash rates and the impact of changes on infrastructure needs. Separation of motorized and non-motorized vehicles may not be as necessary if C/AV technology reduces the risk of crashes.

No.	Planning Agency Activity	Impacts on Planning Products and Processes
16	Corridor Studies (Modal or Multimodal)	• Planning agencies must assess the need for and feasibility of incorporating DSRC technology into corridor improvement projects. Depending on the proposed timeframe for implementation, planners will have to develop alternative scenarios for such deployments. • Planning agency personnel will need more detailed simulation tools to estimate the safety impacts of C/AV deployments in different types of corridors. • Planners will need a level of knowledge adequate to understand the physical and operational requirements of V2I technology in order to develop reasonable planning-level cost estimates for corridor deployment.
17	Public Involvement Plan	• The planning agency must educate committee members, decision-makers, and the general public about the need for C/AV-related investments. • New stakeholders, many of whom are private-sector entities as yet unknown (e.g., national phone carriers such as Verizon or AT&T who deploy new and different wireless networks), must be brought into the planning process in order to understand how the C/AV technology will operate and what ongoing relationships are required between the public and private sectors. • Implementation of C/AV-related safety investments, particularly those involving security or V2I strategies, will require a greater level of cooperation between MPO member municipalities since consistency is critical to realizing safety benefits. This may widen the range of municipal officials who are involved in the transportation planning process, such as IT personnel.
18	Freight Plans	• Planners will need tools to evaluate the impact of V2V and V2I technologies on operational efficiency and commercial vehicle safety. Models will be needed that can assess the impacts of truck platooning and partial automation on throughput and safety. • C/AV technology provides opportunities to improve air quality through reductions in truck delays and idling. Planners will need both analytical tools and new data collection efforts to evaluate these impacts and account for them in air quality improvement programs. • The planning agency must reevaluate future port-related infrastructure (e.g., freeway lanes) needed to service the ports; reductions in lane miles can potentially be realized by increased truck throughput due to C/AV technologies. New modeling is required to assess these factors. • Planning agencies will have an opportunity to work with commercial vehicle enforcement personnel to identify ways in which C/AV technology can be utilized for more cost-effective enforcement. This may impact various transportation plans.
19	Financing Plans	• C/AV technology may require new public-private partnerships in order to fund key elements of the system, especially in the areas of infrastructure elements and security are two. Planners must help identify funding options for these deployments. • In developing TIPs and short-range and long-range plans, planners will need to identify criteria and evaluation tools for assessing the costs and benefits of C/AV deployments. • Planning agency personnel will need to provide cost estimates for deployment of C/AV technology. • The planning agency will need to educate committee members, decision makers, and the general public about the need for C/AV-related investments and identify tradeoffs between C/AV and other investments.

Source: Cambridge Systematics, Inc.

The table above will be used to guide the development of case studies in Task 4 of this project.

8.0 Case Study Summaries

This section documents proposed case studies that will be developed under Task 4 of this project. This exercise will identify a specific set of activities for use by planning agencies in developing products that involve C/AV technology. For short-term products (TIP, STIP) a series of steps will be identified along with existing resources that can be used. Medium- to long-term products (Long Range Plans, major corridor studies) will be presented in a narrative format and focus on potential impacts that must be considered in connection with these activities and identify what techniques and analyses are appropriate for planning in an uncertain environment. The case studies listed below are essentially a starting point for Task 4; it is likely that some will be combined or modified once that work is underway. We anticipate that approximately 10 to 12 detailed case studies will be done; a final decision will be made at the beginning of work on Task 4.

Table 8-1. Case Study Summaries

No.	Planning Agency Activity	Case Studies
1	Long-Range Visioning	New fixed Route Transit Corridor of $1 billion or in 20+ year timeframe. Case study will look at how to evaluate potential impacts of C/AV technology on this investment. Incorporating risk analysis for this proposed investment will be the focus. Issues: • Impact of C/AV operations and economics on land use; • C/AV opportunities for feeder service; • More efficient mainline operations with C/AV on transit vehicles; and • Potential impact of proposed roadway capacity improvements on mode share.
2	Statewide Long-Range Transportation Plan	Upgrade of rural two-lane roads to four lanes with grade separation in some sections in the $50-$75 million range and the 15-20 year timeframe. Issues: • Impact of C/AV technology on need for safety-related infrastructure investments; • Infrastructure investment needed in safety hotspots to support V2I and V2V safety applications, including communications in remote areas of corridor; and • Ongoing operations and maintenance strategies to support C/AV safety applications.
3	Regional Long-Range Transportation Plan	Reconstruction of 10-mile suburban major arterial corridor, including safety improvements and spot capacity increases, in the $25-$30 million range and 10-15 year timeframes. Issues: • Timing of V2I investments to accommodate application of advanced signal timing and phasing applications as DSRC vehicle market penetration increases; • Impact of C/AV technology on need for safety-related infrastructure investments; and • Consideration of different risks, including security risks to communications systems and legal/privacy issues, related to the use of data from C/AV systems.

No.	Planning Agency Activity	Case Studies
4	Transportation Improvement Program	Operational and Bottleneck Improvements to Major Arterial Corridor in the $300,000 to $500,000 range over 0-2 years. Issues: • Incorporating up-front investment in DSRC technology across corridor to take advantage of short-term construction; • Over time, strategies for using data to allow more responsive signal timing and facilitate the implementation of strategies for specific circumstances such as weather and special events; and • Possible deferral of physical capacity improvements if additional throughput can be achieved with C/AV technology.
5	Short-Range Transportation Plan	Freeway Interchange Improvements in the $1-$1.2 million range over 3-5 years. Issues: • Consideration of DSRC investment in signal reconstruction; • Consideration of V2I and V2V support infrastructure in redesign of merges; • Consistent policy related to DSRC deployments on future improvements to both freeway and arterial corridor; and • Consideration of TSM&O priorities (i.e., ramp metering).
6	Congestion Management Plan	Upgrading criteria and tools for decisions about including projects in Congestion Management Plan, $100,000 study over 0-1 year. Issues: • Resources available for identifying opportunities to utilize C/AV technology for congestion management alternatives; • Methods for incorporating C/AV projects in CMP criteria and analytical tools and identifying potential impacts; and • Role of C/AV pilot and demonstration projects in CMP plan.
7	Asset Management Plan	Data Collection Program for Bridge and Pavement Condition, $4-$5 million range over 5-7 years. Issues: • Strategy for transitioning to mobile-based road condition information, broadcast from traveling vehicles, and alerting maintenance to issues more quickly than occurs in existing scheduled inspection cycles; • Managing expectations of traveling public who may expect more rapid repair of known issues, including minor issues, potentially changing the workflow of existing maintenance activities; and • Turning large amounts of data into beneficial information that provides better understanding of materials performance, rapid repair techniques, and associated maintenance activities, improving performance reporting.
8 and 9	ITS and Operations Plan, and ITS Architecture	Implement Truck Platooning and Limited Automation on a Truck-only C/AV Corridor, $10 million range over 10-12 years. Issues: • Develop infrastructure investment strategies that incorporate V2I and V2V strategies such as lane change warning and infrastructure needed to support platooning; signage could be outfitted with C/AV equipment that serves multiple purposes; • Incorporate technologies/techniques to achieve reductions in truck delays and idling; • Update ITS architecture to incorporate system and its components; and • Improve coordination with CV enforcement and permitting agencies to identify opportunities for combined infrastructure and operations.

No.	Planning Agency Activity	Case Studies
10	Strategic Highway Safety Plan	Highway Safety Improvement Program – Safety Improvements to High Crash 30-Mile Intercity Corridor, $2 million range over 3-5 years. Issues: • Plan for installing V2I infrastructure to provide roadside warnings at high-crash locations through various types of electronic signing; • Transition plan from V2I to V2V warnings as more vehicles have ability to receive tailored safety message directly; and • Evaluate impact of C/AV technology on need for physical safety investments, with possible shift from crash prevention investments (rumble strips, guard rail) to investments supporting C/AV (improved striping, security, etc.).
11	Highway Safety Improvement Program	Highway Safety Improvement Program – Safety Improvements to High Crash 30-Mile Intercity Corridor, $2 million range over 3-5 years. Issues: • Plan for installing V2I infrastructure to provide roadside warnings at high-crash locations through various types of electronic signing; • Transition plan from V2I to V2V warnings as more vehicles have ability to receive tailored safety message directly; and • Evaluate impact of C/AV technology on need for physical safety investments, with possible shift from crash prevention investments (rumble strips, guard rail) to investments supporting C/AV (improved striping, security, etc.).
12	State Implementation Plan	Implementation of AERIS program to help support air quality improvements and environmentally friendly programs. $250,000, 0-3 years. Issues: • Obtaining access to C/AV data for use in Applications for the Environment: Real-Time Information Systems program implementation; • New modeling and analytical tools to reduce large amounts of environmental data to actionable information; and • Tools and methods for evaluating the impact of C/AV investments on air quality.
13	Transit Development Plan	Implement circulator service in urban core, $2-3 million range over 2-3 years. Issues: • Incorporating V2I and V2V strategies; shelters, stops, and signage could be outfitted with CV equipment that serves multiple purposes; • Improved consistency of service for the circulator from implementation of C/AV technologies and how it may impact the typical target market for such services (e.g., tourists); • Evaluation of risks involved in selecting modes and commensurate investment levels with decisions including routing, vehicle size, operational strategies, and fare payment technologies; and • Incorporating safety improvements such as Vehicle to Anything (V2X), hand-held devices, and associated assistance technology (driver assist, Integrated Motor Assist (IMA), Left Turn Assist (LTA), etc.); evaluating the benefits and costs of incorporating these technologies.

No.	Planning Agency Activity	Case Studies
14	Transportation Demand Management Plan	Bicycle and Pedestrian Regional Study, $150,000 over 0-1 year. Issues: • Identify opportunities for reduced conflicts between pedestrians/cyclists in the urban core; • Identify impacts of potential reduced need for parking infrastructure as automated parking becomes more accepted and reliable; on-street parking can be converted to other uses including bicycle/pedestrian infrastructure; • Provide infrastructure to support V2I and V2V strategies such as bicycle and pedestrian warning systems; this investment also be used to support management of bus stops, delivery areas, and other applications; and • Evaluate migration strategy of V2V and V2I technologies, from driver warnings to vehicle-based actions designed to avoid crashes to fully automated driving.
15	Nonmotorized (bicycle and pedestrian) Plan	Develop Cycle Track facility in downtown, $300,000 to $400,000 range over 1-2 years. Issues: • Accommodate V2V and V2I technologies for safety applications; plan for evolution from driver warnings to vehicle-based actions designed to avoid crashes to fully automated driving; and • Evaluate impacts of technologies that could eliminate the majority of crashes that now occur involving bicyclists; this might reduce the need for separated infrastructure in the long term as technology improves, so physical safety improvements might be planned and designed for short- to medium-term life.
16	Corridor Studies (Modal or Multimodal)	See issues addressed in table items 3, 4, and 10; these can be combined into a multi-modal Integrated Corridor Management project that includes parallel freeway and arterial corridors.
17	Public Involvement Plan	Update agency Public Involvement Plan to incorporate C/AV stakeholders as part of agency work plan. Issues: • Identify new stakeholders who should be involved in supporting planning activities related to C/AV technology; these could include telecommunications companies, cybersecurity experts, C/AV equipment vendors and installers, and freight industry representatives; • Identify educational and public outreach efforts required to attract new stakeholders and identify their roles in the planning process; and • Develop materials and programs to educate the public and decision makers about C/AV technologies and investment strategies.
18	Freight Plans	Multimodal Freight Plan to Serve Proposed Industrial Zone, $1,000,000 range over 3-5 years. Issues: • Evaluate how V2V and V2I technology can be incorporated to assist freight traffic through identification of safe intersection and left-turn movements or dynamic signal timing; and • Evaluate potential short- and long-term impacts of C/AV technology on infrastructure requirements, particularly needs to widen or add lanes.

No.	Planning Agency Activity	Case Studies
19	Financing Plans	Financing plans will be incorporated primarily into products identified in table items 2 through 5 (TIP, Long-Range and Short-Range plans); however, innovative financing approaches for C/AV deployment may be developed as a separate task and incorporated into transportation plans. Issues include: • How to support formation of new public-private partnerships that may be required in order to fund key elements of C/AV systems, including communications; security and data analysis methodologies for estimating capital investments and ongoing operations and maintenance costs must be considered as well; • Financing strategies must be accompanied by criteria and evaluation tools for assessing the costs and benefits of C/AV deployments; and • Agencies must provide estimates of costs of deployment of C/AV technology.

Source: Cambridge Systematics, Inc.

9.0 Summary

Based on a literature review, interviews with stakeholders, and reviews of and feedback regarding Technical Memorandum #1, this memorandum addressed the following issues regarding the impact of C/AV technology on transportation planning products and processes and stakeholder responsibilities:

- Which activities will be most influenced and in what timeframe?
  - An initial hypothesis is that long-range plans, corridor plans, and ITS/operational plans will be most influenced.
  - There is significant progress occurring toward deployment of V2I infrastructure, specifically DSRC, in the short term. A number of agencies are attempting to incorporate DSRC into arterial and intersection improvement projects. They see opportunities in the next few years to begin to use this technology as probes for travel time data and for arterial operations.
  - Many agencies are thinking about the implications of C/AV on long-range planning and are aware of the potentially transformational changes that could impact transportation, land use, and the economy in general. There is awareness that long-range planning will involve more risk analysis of high-cost capital investments and a need to track technology advances and their impacts. Agencies see a need to develop these techniques and implement them in the near future.

- How will the data available from C/AV technology change agency work plans, data collection methods, and analysis tools and methods?
  - Planners see major changes in data collection methods and a need for new analytical tools that can address C/AV impacts. The uncertainty of the technology arc and the fact that it could greatly influence capital investment strategies has led some to think that current methods of long-term forecasting may be replaced by evaluation of "alternative futures" that would assess the likelihood of different outcomes.
  - Data collection methods in many areas, including traffic data and asset management, may change dramatically with higher penetration of C/AV technology. Some applications will need large market penetration while others will be effective with market penetration rates as low as 10 to 15%. In the latter category are physical condition data such as those relating to pavement or weather conditions; these are likely to arrive sooner.

- What new products and processes are likely to be needed, including new plans, tools/modeling/simulation, stakeholder outreach programs, and financial arrangements?
  - Agencies are aware that new skills will be needed on both the operational side and the planning side. As C/AV operations evolve, transportation agencies will be increasingly in need of personnel with communications, hardware, and software backgrounds. These skills are in demand in many fields, and it will be difficult to attract those personnel to transportation. It is unclear whether these highly technical skills will be needed on the planning side, but basic knowledge and understanding of the technology will be needed.

  - Analysts who can transform large amounts of data into useful information are clearly seen as necessary for planners to take full advantage of C/AV data streams. This “data scientist” role is seen as a requiring a higher level of skill than that required to manage and utilize existing databases. Using C/AV data effectively will require not only a different set of personnel skills but a new and more sophisticated suite of models and analytical tools, including those that provide a level of decision support to planners, policy makers, and operational personnel.
  - There are differing opinions on how technical challenges will be met. Some see a continuing shift of analytical responsibilities to the private sector with public sector planners and operating personnel serving as contract managers. Contract management itself, however, will require a higher level of skill and qualification. Others see planning agencies being able to adapt as personnel pick up the skills necessary to fulfill their roles in C/AV planning. There is general agreement that educational programs are needed in all phases of C/AV technology.

- With what new entities must planning agencies develop closer relationships?

  - In addition to educational institutions, closer ties are likely with communications companies, which will supply at least part of the infrastructure required for C/AV deployment. Other possible stakeholders include vendors of C/AV equipment and systems along with companies that will provide security. While planners may have less direct contact with these groups than operations and engineering personnel, their input may be needed in programming the needed infrastructure investments and operating budgets. Players in the emerging car sharing industry are also likely stakeholders and may become more important as the automobile economy shifts from an ownership to a service model. Vendors supplying data management and analytical services are another set of potential stakeholders, likely to include both existing technology companies and new niche organizations that have not yet emerged.

Appendix A. Literature Review – Document Descriptions

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