AASHTO
Connected Vehicle
Field Infrastructure
Footprint Analysis

Preparing to Implement a Connected Vehicle Future
Part 1—Executive Summary

The fundamental premise of the Connected Vehicle Environment lies in the power of wireless connectivity among vehicles, the infrastructure, and mobile devices to bring about transformative changes in highway safety, mobility, and in the environmental impacts of the transportation system. Over the past decade, wireless technologies and wireless data communications have fundamentally changed the way we live our lives. Instant access to information and the proliferation of “apps” through which we are able to perform almost limitless functions have dramatically recast the ways in which we work, play, and socialize. The transportation system has not been immune to these changes.

The development of the Connected Vehicle Environment is envisioned to leverage several types of wireless connectivity (cellular, Wi-Fi, dedicated short range communications) to serve the public good in a number of ways:

- Highway crashes will be dramatically reduced when vehicles can sense and communicate the events and hazards around them;
- Mobility will be improved when drivers, transit riders, and freight managers have access to substantially more up-to-date, accurate, and comprehensive information on travel conditions and options; and when system operators, including roadway agencies, public transportation providers, and port and terminal operators, have actionable information and the tools to affect the performance of the transportation system in real-time;
- Environmental impacts of vehicles and travel can be reduced when travelers can make informed decisions about modes and routes and when vehicles can communicate with the infrastructure to enhance fuel efficiency by avoiding unnecessary stops.

AASHTO has been a partner in the Connected Vehicle initiative since 2004, working collaboratively with U.S. DOT and the automobile industry. Originally, the Connected Vehicle initiative was based on dedicated short range communications or DSRC. DSRC is a fast, dedicated network that is particularly well suited to safety applications. Today, the Connected Vehicle initiative’s strategy is to leverage any appropriate and cost-effective wireless network. Over the last eight years, substantial progress has been made in understanding the opportunities and demonstrating that the known challenges can be met through research and technology development.

Today, vehicles are increasingly connected wirelessly through cellular technology. ABI Research predicts that 80 percent of the cars operating on North American roads will be connected by 2015. General Motors announced at the Mobile World Congress that it plans to install high-speed wireless connections on all of its vehicles beginning with the 2015 model year. There is great potential in this type of connected vehicle for mobility and environmental applications. However, Connected Vehicle safety applications that prevent crashes present more challenges. They require fast and secure communications—faster than currently available with traditional cellular. DSRC is uniquely suited to this type of safety application. AASHTO, U.S. DOT, and automotive manufacturers have been specifically focused on this complex research. Due to the potential to positively transform highway safety, NHTSA is considering requiring this communication technology on new cars in the future.

Three key federal policy milestones lay on the immediate horizon that may advance the program from research to implementation. See [Figure 1].

![Figure 1—Key Federal Policy Milestones](image)

The 2013 NHTSA decision will determine the future of Connected Vehicle technology for safety. If NHTSA pursues a Rulemaking on safety applications, vehicles equipped with DSRC may begin rolling off the production line in late 2019. These vehicles would broadcast information such as their location, speeds, and direction of travel through the high-speed communication of DSRC.

Vehicles contain a wealth of information. Under a NHTSA regulatory decision, only information needed for safety applications would be broadcast. In the future, it may be possible to share additional information such as crash notifications and location, pavement condition, or slippery road surfaces. This type of information could be shared across any available wireless network. At its most robust, Connected Vehicle information such as travel times, border crossing wait times, work zone speed limits, curve speed warnings, intersection signal phases, and in-vehicle signing could also be transmitted from the roadside to vehicles.

As the key federal policy decisions for safety approach, the state and local transportation agencies need to understand what this will mean to them, what they need to know to prepare for the Connected Vehicle environment, and what investments may
need to be made. To provide guidance to agency decision-makers, AASHTO, with the support of U.S. DOT and Transport Canada, is undertaking a Connected Vehicle Field Infrastructure Footprint Analysis. The goal of this analysis is to describe the applications and infrastructure needed to realize the significant transportation benefits of Connected Vehicle systems no matter the type of wireless technology used.

Part 2—The Benefits of Connected Vehicle Infrastructure Deployment

The vision of a national, multimodal transportation system in which there is connectivity among all types of vehicles, the infrastructure, and other mobile devices requires the participation of a broad community of stakeholders. Federal, state, and local transportation agencies; car, truck, and bus manufacturers; telecommunications providers and consumer electronics manufacturers; and researchers must come together to design, develop, build, and deploy the technologies, applications, systems, and policy frameworks that will foster the Connected Vehicle environment. This presents a unique approach and challenge in the history of the nation’s transportation system. However, significant potential benefits are expected to accrue through this effort:

- **Highway Safety**—According to the National Highway Traffic Safety Administration (NHTSA), motor vehicle crashes accounted for 32,367 deaths in 2011. Crashes are the leading cause of death for Americans between the ages of five and 44 years, according to the Centers for Disease Control. The application of Connected Vehicle technologies is expected to offer some of the most promising opportunities for crash reductions. Research conducted by the Volpe National Transportation Systems Center for NHTSA found that deployment of Connected Vehicle systems and the combined use of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) applications have the potential to address 81 percent of unimpaired crash scenarios involving all light and heavy vehicles.

- **Traffic Congestion**—The Urban Mobility Report prepared by the Texas A&M Transportation Institute indicates that congestion in 498 urban areas during 2011 accounts for 5.5 billion hours of extra time and 2.9 billion gallons of wasted fuel at a cost of $121 billion annually. The cost to the average commuter was $818 in 2011. While there is no comprehensive analysis of the potential impacts of Connected Vehicle systems on urban congestion, the focus of certain applications on reducing travel delays should ensure that benefits will accrue in this area. Much is happening today through wireless apps in the vehicle and through personal devices.

- **Vehicle Emissions**—Vehicle internal combustion engines produce emissions that include pollutants and greenhouse gases (GHGs). GHGs are not as directly harmful as pollutants but could contribute significantly to climate change. Reduction of pollutants and GHGs produced by surface transportation through reductions in fuel consumption, idling, and vehicle miles of travel is a major goal of some Connected Vehicle applications.

Sidebar 1—A National Partnership: Working Together toward Successful Deployment

AASHTO, Transport Canada, and the state DOTs provide unique perspective, insight, and understanding of the needs and challenges associated with the deployment, operations, and maintenance of the roadway and transportation system infrastructure across the nation and across international borders. This knowledge and experience is critical to the success of the Connected Vehicle initiative.

“Connected Vehicle technology has the potential to transform how we preserve our environment and improve safety and mobility. This technology can significantly reduce the number and severity of vehicle crashes and improve traffic flow on all roadways. As state DOTs, we should consider how it might change the way we do business and plan for its arrival. We will also work closely with our key stakeholders and regional and local partners so we can all take advantage of the benefits that this technology offers.”

—Malcolm Dougherty
Director, California DOT (CalTrans)

“This is a major undertaking for AASHTO, Transport Canada, and the United States as we prepare for a safer and more productive transportation environment.”

—Mike Lewis
AASHTO President and Director, Rhode Island DOT

“We can stay here, stuck in traffic, or we can invest in transportation and ITS technology that has the potential to transform how we travel. This technology can lower business costs, improve quality of life, ease traffic congestion and make us safer.”

—Kirk Steudle
Director, Michigan DOT

“We are proud to invest in innovation and new opportunities to improve transportation safety and efficiency. By working together now we can lay the groundwork to align standards and regulations in North America and prevent barriers to cross-border travel and trade.”

—Susan Spencer
Director of ITS Programs, Transport Canada
Research on the applications, technologies, policy and institutional issues, and implementation strategies will ultimately shape the Connected Vehicle environment. Evaluating the potential benefits of the Connected Vehicle system and driver acceptance of vehicle-based safety systems is central among the research that is being undertaken. This work will provide factual evidence needed to support NHTSA’s decisions on the deployment of core technologies for light and heavy vehicles.

The Connected Vehicle Safety Pilot comprises a real-world implementation of the safety technologies, applications, and systems using everyday drivers. A Model Deployment underway in Ann Arbor, Michigan from fall 2012 to fall 2013 is collecting data from approximately 3,000 equipped vehicles. Using a mix of cars, trucks, and transit vehicles, the Safety Pilot will test performance, evaluate human factors and usability, observe policies and processes, and collect the empirical data needed to present a more accurate, detailed understanding of the potential safety benefits.

**Sidebar 3—AASHTO’s Connected Vehicle Activities**

2009—Connected Vehicle Strategic Plan
Articulated the commitment and role of AASHTO and its members in the national program.
Described areas of leadership for AASHTO, as well as activities best accomplished through collaboration and partnership with the federal government and the automakers.

2011—Connected Vehicle Deployment Analysis
Described the state of development and deployment efforts; the readiness of technologies and markets to support deployment; the applications of greatest significance to state and local agencies; a phased deployment scenario for the agencies; and a set of potential strategies and actions to be undertaken by AASHTO and its members.

2012–13—Footprint Analysis
To be completed in October 2013, this will provide a concept for a national Connected Vehicle field infrastructure footprint that includes:

- prioritized applications for state and local agencies including the data, communications, security, roadside equipment, and information service needs of each agency
- a set of design concepts and deployment gaps for approximately ten of the highest priority applications, with sufficient engineering detail to describe an operational system
- a range of scenarios that illustrate how different government entities—state, county, or municipal—would approach deployment
- a preliminary national footprint for Connected Vehicle field infrastructure created by expanding the deployment scenarios
- an initial strategy for coordinated, phased deployment based on the scenarios and national footprint, highlighting interoperability and institutional challenges and opportunities
- a set of deployment cost estimates including equipment, operations and maintenance, and training and staff development

**Part 3—Deploying a Connected Vehicle Infrastructure**

The AASHTO Footprint Analysis will provide greater insight into the Connected Vehicle field infrastructure that may be deployed through the development of approximately ten engineering design concepts. These concepts will likely include illustrations of typical deployments at signalized intersections, urban freeways, rural roadways, international border crossings, and other locations intended to provide agencies with a better understanding of the type of systems and equipment that may be implemented. The design concepts will not serve as the plans and specifications that agencies will ultimately require as they begin actual deployment.

Overall, the Connected Vehicle environment has the potential to exchange data among all types of vehicles and the infrastructure supporting all surface transportation modes, as illustrated in Figure 2. Data communications will occur among vehicles, personal wireless devices, and transportation infrastructure components, as well as to local and back-office services running applications and other systems responsible for a variety of services such as Connected Vehicle security.

Figure 2—Connected Vehicle Concept (U.S. Department of Transportation)

A Connected Vehicle infrastructure deployment will generally include several elements such as:

- Roadside communications equipment (for DSRC or other wireless services) together with enclosures, mountings, power, and network backhaul.
• Traffic signal controller interfaces for applications that require signal phase and timing (SPaT) data.
• Systems and processes required to support management of security credentials and ensure a trusted network.
• Mapping services that provide highly detailed roadway geometries, signage, and asset locations for the various Connected Vehicle applications.
• Positioning services for resolving vehicle locations to high accuracy and precision.
• Data servers for collecting and processing data provided by vehicles and for distributing information, advisories, and alerts to users.

Some elements are specific and unique to state and local DOT interests. These elements may include traffic signal interfaces or roadside equipment to send infrastructure information or to receive DSRC messages broadcast from vehicles. Agencies may choose to deploy these elements themselves or may consider a variety partnership or outsourcing approaches for deployment. Some elements of the overall Connected Vehicle system, particularly those necessary for vehicle-based safety applications, may be provided by the automotive industry if regulated by NHTSA, and the elements associated with security management could be provided by a third-party entity. These specifics are still evolving.

Sidebar 4—Wireless Communications for V2I Applications

Connected Vehicle V2I applications have varying communications needs and are not necessarily limited to a particular communications solution.

DSRC refers to a form of wireless communications intended for transportation applications. In the U.S., DSRC operates over 75 MHz of spectrum in the 5.9 GHz band. This spectrum was allocated by the FCC in 2004 to be used for the purpose of protecting the safety of the traveling public. DSRC works as a fast (low latency) broadcast over a limited range. It is not currently widely implemented.

4G (and older 3G) cellular mobile communications provide high-bandwidth data communications for mobile data terminals including smart phones, tablets and laptop computers and, increasingly, in cars. Commercial networks are widely deployed across most of the US. Existing vehicle telematics systems use these networks to exchange data between vehicles and their remote information services but they are not suitable for active safety applications that require low latency. Other wireless technologies, such as Wi-Fi, satellite communications, and HD radio, may also have roles to play in the overall Connected Vehicle environment.

Part 4—Funding Connected Vehicle Infrastructure Deployment

State and local DOTs will decide the extent to which they will take advantage of Connected Vehicle technology and applications. In making that decision, state and local DOTs will need to assess several factors. For example, benefits may be substantial, providing new opportunities to address safety, mobility, and environmental challenges. Connected Vehicle deployment may be particularly beneficial at signalized intersections with a crash history, on congested arterial corridors where extensive data may be useful, or in areas where communicating information about the roadway (e.g., work zones, bridge clearances, speed limits, lane control, icy pavement) may have a safety, operational, or environmental benefit. The AASHTO Footprint Analysis will develop cost estimates to support this assessment.

Costs too must be considered, including the costs of installing, operating, and maintaining the Connected Vehicle infrastructure. Among the key tasks facing state and local DOTs that intend to deploy a Connected Vehicle infrastructure is the need to identify a funding mechanism for the capital and ongoing operations and maintenance costs. Depending on the type of Connected Vehicle infrastructure and the applications it supports, agencies can consider various funding categories to support deployment. For example, Connected Vehicle systems are a form of ITS technology, so an agency might use an ITS budget or any category of federal or state funds for which ITS is eligible. Connected Vehicle systems are expected to have significant impacts on vehicle and highway safety, so deployment with funds intended for safety systems might be appropriate. Mobility impacts of Connected Vehicle technologies and consequent emission reductions could warrant funding some deployments with funds set aside for congestion mitigation or air quality improvement projects.

There will be ongoing day-to-day operations costs (e.g., staffing; power and backhaul communications from Connected Vehicle field sites), maintenance costs (both scheduled and unscheduled), and the costs of replacement of field and back-office equipment at the end of its life. For Connected Vehicle systems, agencies may wish to explore public–private partnerships or asset and revenue sharing mechanisms to acquire the desired Connected Vehicle infrastructure.
As illustrated in Figure 3, several state and local DOTs are already engaged in the deployment of a Connected Vehicle infrastructure in support of research, development, and testing activities; many more are active participants in the AASHTO Connected Vehicle Deployment Coalition that is providing oversight to the current Footprint Analysis. The more Connected Vehicle infrastructure is deployed nationwide using common standards, the more likely applications will be developed to take advantage of new safety, mobility, and environmental opportunities. Particularly for Connected Vehicle infrastructure, deploying on a broad scale improves the benefits for all.

For further information on the Connected Vehicle program, the Footprint Analysis, or getting involved in the AASHTO Connected Vehicle Deployment Coalition, contact James L. Wright, P.E., at jwright@aashto.org.