AASHTO ITS AMERICA ite

V2I Deployment Coalition

Technical Memorandum 4: Phase 1 Final Report

January 2017

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1. Executive Summary

Early Need for a Unified Approach to V2I Deployment

Since approximately 2011, the United States Department of Transportation (USDOT) has been proactive in leading discussions about the need for a unified approach to the deployment of Vehicle to Infrastructure (V2I) applications and technologies. There was industry-wide early recognition of the need for a coalition involving public and private sector individuals to represent infrastructure (transportation system) owners and operators, automobile manufacturers, trade and industry associations, academia and other entities likely to be involved in connected vehicle deployments. As illustrated in Figure 1, these groups, together with USDOT and the AASHTO Connected Vehicle Executive Leadership Team (ELT), represented the initial concept for a unified coalition.

Figure 1 - Initial Entities Envisioned for V2I Deployment Coalition

In September 2014, the Federal Highway Administration (FHWA) released the 2015 FHWA Vehicle to Infrastructure Deployment Guidance and Products to help ensure interoperability, as well as efficient and effective planning, procurement, and operations of V2I technology. The intended audience for the V2I Deployment Guidance includes the entities that are illustrated in Figure 1 and that were considered during the early discussions of a unified V2I approach. It was also understood that considerable feedback and input from these groups on the initial draft guidance documents would be needed to ensure that the later versions could be finalized and used routinely throughout the industry.

Creation of the V2I Deployment Coalition

In order to meet the needs and requests expressed by the public and private sectors, academia, and industry representatives, USDOT advised AASHTO, ITE and ITS America to develop a framework that would enable the collaboration needed to overcome V2I deployment obstacles. As such, these three associations organized and managing the Vehicle to Infrastructure Deployment Coalition (V2I DC). The V2I DC Project Team (consisting of members from AASHTO, ITE, and ITS America) then created a vision, mission, and set of objectives that would guide the Coalition.

The **vision** of the V2I DC is defined as:

> *An integrated national infrastructure that provides the country a connected, safe and secure transportation system taking full advantage of the progress being made in the Connected and Autonomous Vehicle arenas.*

The **mission** of the V2I DC is:

> *To work collaboratively with industry, state and local governments, academia and USDOT to achieve the goal of deploying and operating a functioning V2I infrastructure.*

Adhering to the original concept for a unified stakeholder group, USDOT, AASHTO, ITE, and ITS America created a structure that promoted collaboration among and between members, rather than segregating individuals by entity type. As illustrated in Figure 2, the V2I DC was organized into a set of Technical Working Groups (TWGs), each consisting of members representing Federal, State, and local governments, as well as private entities – all working side by side.

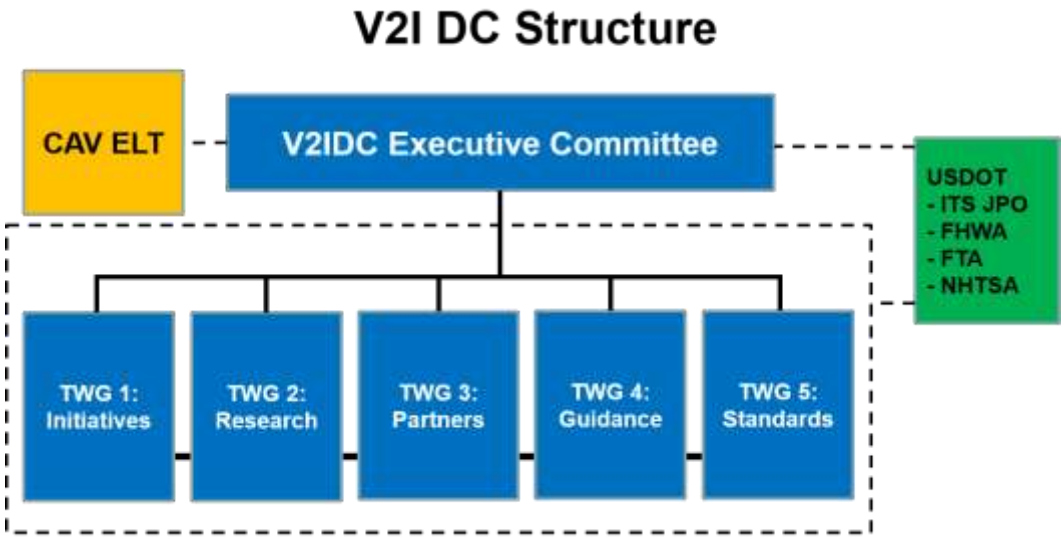

Figure 2 - V2I DC Structure

Accomplishments of the V2I DC

Once the V2I DC structure was established, the TWGs were presented with a set of prioritized issues that had been identified through outreach to members. After an initial V2I DC webinar in May 2015, the Coalition met in person in June 2015, with breakout meetings for each TWG. Each group identified the role they could play in addressing several of the issues being addressed by the V2I DC and created work plans. The TWGS then met regularly by webinar for approximately 16 months.

During this Phase 1 period of the V2I DC, the TWGs collectively helped define and clarify the V2I issues identified at the onset of the Coalition, and in many instances, helped advance towards some resolution of the issues. Details of Coalition actions and advances toward each issue are described in the body of this report as issue specific summaries. Additionally, six key outcomes have been identified as overarching accomplishments of the V2I DC, including:

- Engaging a unified coalition with common messages and discussion;
- Narrowing of the initial focus of V2I deployments to four key areas;
- Defining seven of the highest priority research areas to advance V2I deployment;
- Creating a V2I standards context diagram and supporting description;
- Creation of the SPaT Challenge and related AASHTO Resolution; and
- Creating a forum for collaboration between Infrastructure Owners/Operators and OEMs.

Future of the V2I DC

As Phase 1 of the V2IDC concludes, there is considerable momentum from the initial 18 months of activity. The individual TWG Chairs have agreed that some restructuring of the TWGs is appropriate considering the new focus areas and the current status of V2I deployments. Nonetheless, looking to the future, the V2I DC will continue to:

- Provide input to USDOT on V2I Deployment Guidance and Products,
- Support the SPaT Challenge,
- Engage the automobile manufacturers, and
- Serve as a mechanism for peer exchange, information sharing, and public outreach to the more than 200 members of the V2I DC.

Recognizing the long-term need for this unified coalition, the V2I DC will approach sponsors and seek a tapered approach to becoming as self-sustaining as possible while remaining consistent with the overall mission of the V2I DC.

Contents of this Document

This document is the fourth Technical Memorandum of the V2I DC. Following this Executive Summary, the remainder of the document presents an update on activities since Technical Memorandum 3 was presented, describes the overall outcomes of the V2I DC, and describes detailed progress on each of the V2I related issues as issue specific summaries. Finally, the document describes the likely Phase 2 scenario for the V2I DC.

2. Synthesis of the Technical Memorandum

Three technical memoranda have been developed by the Vehicle to Infrastructure Deployment Coalition (V2I DC) since it was established in early 2015. The first memo focused on establishment of the V2I DC and identification of the initial deployment issues for the Coalition to address. This provided the basis for how the V2I DC would be structured and what it would address in its first phase of work. The second memo summarized the findings of Workshop 1 of the V2I DC, highlighted the work plans of the four individual Technical Working Groups (TWGs), reviewed the status of deployment issues, and summarized establishment of the V2I DC Executive Committee. The third memo summarized proceedings from Webinar 2 of the full V2I DC, shared work progress of the Coalition, and outlined next steps for the Coalition leading up to Workshop 2 of the V2I DC in April 2016.

The primary **purpose of this fourth technical memorandum** is to describe the overall progress towards wide scale V2I deployment that the V2I DC has accomplished to date, summarize proceedings from Workshop 2 of the V2I DC, present "issue specific summaries" describing the results of the technical working groups' efforts since June 2015 on the initial deployment issues, summarize the September 2016 workshop involving infrastructure owners and operators (IOOs) and Original Equipment Manufacturers (OEMs), and highlight work proposed for the Coalition during its second phase.

Phase 1 of the V2I DC has helped advance towards wide scale deployment of V2I applications and technologies. **Section 3 of this document presents a summary of the key outcomes and progress that the V2I DC has achieved towards V2I deployment since its inception**, including:

- Engaging a coalition with common messages and discussion;
- Narrowing of the initial focus for V2I deployment;
- Defining research definitions describing seven areas of research to advance V2I deployment;
- Defining a standards context diagram and supporting information about V2I standards;
- Creating the SPaT Challenge; and
- Creating a forum for collaboration between automobile manufacturers and DOTs.

Workshop 2, held in April 2016 in Michigan, for the Coalition was coordinated with V2I application demonstrations provided by the Crash Avoidance Metrics Partnership (CAMP). The workshop focused on allowing time for the TWGs to continue their work and, as needed, collaborate on issues that were being mutually addressed. In addition, reports back to the full audience from each TWG were provided to support awareness of the broader Coalition activities. Immediately following the workshop, the V2I DC Executive Committee met to review progress and discuss potential plans for another phase of the Coalition. Section 4 of this document presents complete details of Workshop 2.

Section 5 of this document includes issue specific summaries that describe **the V2I DC activities performed during Phase 1.** The activities are presented in relation to each of the deployment issues that were identified when the Coalition was established. For each issue, the original intent as well as the results of the Coalition work over the past year and half are presented. Also included are recommended actions for further consideration, either as part of Phase 2 of the V2I DC or by other entities or organizations.

Section 6 of this document summarizes the proceedings of the workshop between OEMs and IOOs. This workshop represented a significant achievement for the Coalition and their ability to support collaboration among key stakeholders participating in the V2I DC.

Finally, Section 7 of this document highlights work proposed for the V2I DC during Phase 2. The V2I DC Executive Committee is scheduled to meet in December 2016 to further discuss work planned for Phase 2 of the Coalition. As the work on Phase 1 concludes, the V2I DC will work with USDOT to confirm a direction and develop a high-level work plan for Phase 2.

3. Overall Progress Advancing V2I Deployments

While each of the five individual TWGs have defined work plans and reached milestones within each work plan, the overall V2I DC has also made broad level strides towards encouraging wide scale deployment of V2I applications and technologies. Six key outcomes of the V2I DC are summarized below, together with a perspective on how the accomplishments have supported future V2I deployments.

3.1. Key Outcome: Engaging a Unified Coalition with Common Messages and Discussion

The V2I DC has grown to over 200 members, representing transportation and technical professionals from both the public and private sectors. A roster of the V2I DC membership is included in Appendix A. This has accomplished something unique in this industry by facilitating an opportunity for the different communities that must work together under the umbrella of "V2I" to meet face to face, by webinar, and through email exchanges to discuss the issues that are most pressing to each stakeholder group. Each V2I DC member typically belongs to one or multiple TWGs, and participates in Coalition-wide meetings and webinars. Maintaining such a coalition has contributed towards current and future deployments in several ways, including the following:

- ***Organizing a unified message regarding Dedicated Short Range Communications (DSRC) bandwidth needs and issues.*** In 2016, the Federal Communications Commission (FCC) invited comments on proposed approaches for sharing the 5.9 GHz bandwidth that is currently dedicated to DSRC to support Connected Vehicle applications. The V2I DC community was assembled for a webinar in which experts described the current status, proposed sharing options and associated technical challenges, and industry perspectives. Assembling this large representation of public and private sector individuals to provide technical context to assist AASHTO member agencies and the broader transportation community in preparing comments to the FCC would likely not have been possible without the V2I DC.

- ***Commenting and responding to USDOT deployment guidance documents.*** While TWG 4 has a specific charge of providing guidance feedback, the structure of the V2I DC has enabled TWG 4 to engage public and private sector individuals from other TWGs to represent comprehensive feedback and input to the very critical activity of finalizing V2I deployment guidance.

- ***Learning about outcomes and findings of V2I research and demonstrations.*** Over the course of Phase 1 of the V2I DC, there have been several webinars that invited speakers to share the results of research (e.g. USDOT research into costs and benefits of V2I deployments), the experiences of V2I deployments, and the progress of the Connected Vehicle Pilot Deployment sites. Some of the speakers presented during TWGs meetings, and some during the overall V2I DC meetings.

3.2. Key Outcome: Narrowing of Initial Focus for V2I Deployments

In September 2015, the V2I DC Executive Committee Identified the initial four focus areas of the V2I DC to include: ***Intersections, Work Zones, Queue Warnings, and Curve Warnings***. While this direction in no way limits public or private sector entities from pursuing deployments in other areas, this focus allowed the individual TWGs of the V2I DC to focus their research and activities around a narrow group of V2I applications.

It also provided a focus for initial discussions between infrastructure owners and operators and the OEMs. The four focus areas identified by the V2I DC Executive Committee were validated by a V2I DC survey of state and local DOTs asking about the V2I applications they believed would be most effective and that they were planning or proposing to deploy. As Figure 3 illustrates, the top 11 applications selected by survey responders relate to three of the four focus areas defined by the V2I DC Executive Committee.

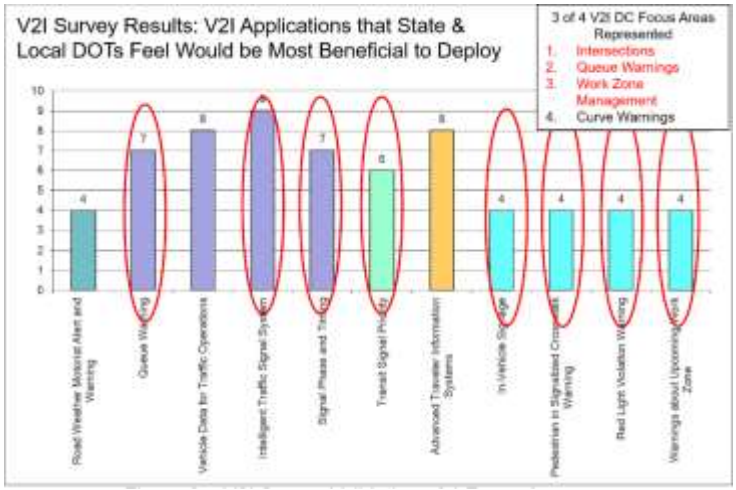

Figure 3 - V2I DC Survey Validation of Application Focus Areas

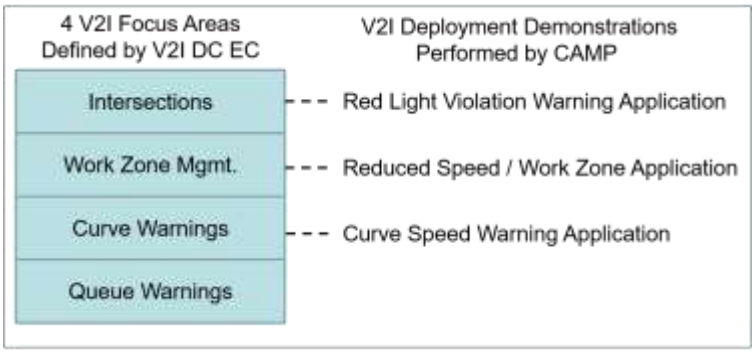

Figure 4 - Relationships of V2I Focus Areas to CAMP Demonstration

A second validation of the four focus areas was that the Crash Avoidance Metrics Partnership (CAMP) had been developing four V2I applications that ultimately were demonstrated in conjunction with the April 2016 V2I DC meeting. The V2I applications demonstrated by CAMP include Red Light Violation Warning, Reduced Speed / Work Zone, and Curve Speed Warning. The overlap of the CAMP V2I pilot demonstrations and the V2I DC focus areas is illustrated in Figure 4.

3.3. Key Outcome: Definitions of Research Activities to Support V2I Deployment

The V2I DC developed research definitions (most including a description of the research needed, suggested work plan, estimated costs, and target outcomes) for seven topic areas that would help support V2I deployment. These research definitions are now ready for consideration by research entities and organizations, and once funded could proceed to active research. The topic areas include:

- *Research Definition for Cooperative Vehicle-Infrastructure Situational Awareness System* – a research concept to merge advanced detection techniques with Connected Vehicle technology to demonstrate advanced vulnerable road user detection.
- *Research Definition for Readiness Assessment of Connected Vehicle (CV) Applications in the OSADP* – a research concept to provide agencies with guidance on the readiness of V2I Applications available in the Open Source Applications Development Portal (OSADP) applications for re-use.
- *Research Definition for How to Prepare TIM Responders for a Connected Vehicle / Automated Vehicle World.*

- *Research Definition for I2V for Automated Vehicle Navigation* – a research concept to study the benefits of using connected vehicle technology to improve automated vehicle navigation in areas where the expected road structure has temporarily changed.
- *V2I Outreach (One-Stop Shop for Research)* – a concept for establishing a One-Stop Shop to house V2I research.
- *Research Definition for Cost-Effectiveness Assessment of Vehicle to Infrastructure Applications* – a concept to provide agencies with tools for large-scale assessment regarding the cost effectiveness of V2I applications.
- *Research Definition for Planning Analysis Methods for Assessing the Mobility and Reliability Impacts of Connected and Autonomous Vehicles.*

Note that the context of each research definition is described in the issue specific summaries included in Section 4, and the research definitions are included in the appendices.

3.4. Key Outcome: V2I Standards Context Diagram and Supporting Description

Standards will play a critical role in ensuring interoperability, vendor independence, and scalability of V2I systems and applications. The V2I DC has developed a standards context diagram and supporting documentation to illustrate and describe the different components of a connected vehicle environment, the relationships among them, and the standards that exist or are needed. The V2I DC is expected to continue to maintain this diagram as situations change over the coming years of the V2I DC. The context behind the diagram is described in Section 5 – Issue 8, and the diagram and supporting description is included as Appendix P. The V2I DC has also recommended a series of additional actions to address needs and gaps related to V2I standards. The actions are described in Section 5 – Issue 8 and in Appendix Q.

3.5. Key Outcome: Creation of the SPaT Challenge

After viewing the V2I demonstrations conducted by CAMP just prior to the April 2016 V2I DC meeting, discussions at the V2I DC meeting created what would later be known as the "SPaT Challenge." The SPaT Challenge was created to help address the "chicken and egg" issue regarding V2I deployments where vehicle manufacturers are hesitant to deploy vehicle based V2I communications until the roadside infrastructure is in place, while infrastructure owners and operators are also hesitant to invest in widespread roadside communications until enough of the vehicle fleet is equipped. The goal is to achieve DSRC infrastructure deployment of SPaT broadcast in approximately 20 signalized intersections in each of the 50 states by January 2020, and to commit to operating the SPaT broadcasts for a minimum of 10 years.

The primary purpose of the AASHTO SPaT Challenge is to:

- ***Provide state and local departments of transportation with a tangible first step for deploying V2I technology and operations***. The benefits of this will be valuable experience and lessons learned regarding procurement, licensing, installation, and operations of DSRC infrastructure.

- ***Promote future, more advanced, V2I applications***. As state and local transportation agencies select subsequent V2I applications to deploy, they will understand and feel more comfortable committing to these deployments having been through the process. To show a commitment to DSRC-based V2I deployments that the automobile OEMs need to enable them to commit to deploying in-vehicle V2I technologies.

- ***Enable some level of testing and validation of DSRC broadcasts using the RLVW V2I Application***, therefore expanding the understanding of the interoperability of V2I Applications as vehicles travel between states and interact with intersections operated by different DOTs.
- ***Bring the V2I community together to foster cooperation and coordination in deployment of an initial level of DSRC-based V2I infrastructure***.

Initiated during discussions within TWG 1: Deployment Initiatives during the April V2I DC meetings, the SPaT Challenge was quickly embraced by the other TWGs and the V2I DC Executive Committee. AASHTO developed the challenge into an AASHTO Resolution, and in October, 2016 the AASHTO SPaT Challenge Resolution was approved by majority vote of both the Subcommittee on Transportation Systems Management and Operations (STSMO) and the Subcommittee on Traffic Engineering (SCOTE) with results as follows:

- STSMO members approved the SPaT Challenge resolution with 36 votes positive, 2 votes negative, and 10 no votes;
- SCOTE members approved the SPaT Challenge resolution with 38 votes positive, 3 votes negative, and 11 no votes.

After approval by STSMO and SCOTE subcommittees, the AASHTO Standing Committee on Highways (SCOH) and Board of Directors unanimously supported the SPaT Challenge Resolution and it was officially passed at the November 2016 AASHTO Annual Meeting.

Outside AASHTO, ITE and ITS America have confirmed they will support outreach of the SPaT Challenge at the upcoming annual events. Additionally, both TRB and individual members representing OEMs have supported the SPaT Challenge through their participation in the Connected and Automated Vehicle Executive Leadership Team (CAV-ELT). The V2I DC continues to develop resources that will support agencies accepting the SPaT Challenge. A series of SPaT Challenge web pages on the National Operations Center of Excellence website will track progress on the challenge and house related resources.

The network of TWGs and outreach channels within the V2I DC were instrumental to advancing the SPat Challenge from the genesis of a concept in April 2016 to a voter approved AASHTO Resolution by October 2016.

3.6. Key Outcome: Creating a Forum for Collaboration between Infrastructure Owners/Operators and Original Equipment Manufacturers (IOOs and OEMs)

The activities of the V2I DC leading up to and including the April, 2016 coalition-wide meeting led to consensus that a workshop should be arranged to allow state and local IOOs and OEMs to meet in-person to discuss common issues and challenges, primarily surrounding the data exchanges between the vehicle and the infrastructure. This workshop occurred in September 2016, and is summarized in Section 6.

The outcome of the workshop was the creation of a “Forum for Collaboration” that will enable IOOs and OEMs to collaborate and coordinate much closer in the coming months and years as V2I deployment matures. This Forum has not created a new entity, but rather is an agreement for the OEMs and CAMP representatives and the IOOs to continue to conduct their own projects and deployments, but with an organized mechanism to collaborate across projects and work together. The immediate benefits already recognized include the following:

- ***Input to the SPaT Challenge.*** An ad-hoc group consisting of IOOs and OEMs/CAMP members is discussing and sharing results of CAMP demonstrations to define performance requirements for the SPaT Challenge. These performance requirements (which include validation strategies) will ensure that agencies accepting the SPaT Challenge and deploying SPaT broadcasts do so in a way that will ensure that Red Light Violation Warning applications on vehicles are functional.
- ***Discussing V2I Data Exchanges.*** The vision for potential bi-directional data exchanges between the vehicle and infrastructure are well known and thought out. However, the final decisions of what data are actually available, can be exchanged, and can usefully be used are still being defined. Another ad-hoc group has formed to take discussions about data exchanges beyond what is possible to discuss what the vehicle manufacturers and IOOs are capable and comfortable sending as the early V2I applications deploy.

4. V2I DC Workshop 2 Summary

The V2I DC Spring 2016 Meeting was held April 20-21, 2016 in Detroit, Michigan. This was the second workshop held for the Coalition and it focused on sharing progress towards the work planned during Phase 1. In conjunction with the workshop, CAMP conducted demonstrations of V2I applications at the CAMP facility in Fowlerville, MI on April 19 for the V2I DC. These demonstrations included passenger vehicle and commercial truck demonstrations of the following V2I applications:

- Curve speed warning
- Red light violation warning (RLVW)
- Reduced speed zone/reduced speed
- Reduced speed zone/lane closure

All TWGs met in full-day breakout sessions on April 20 and reported back to the full Coalition in the morning of April 21, following opening remarks from USDOT and association representatives. A summary of the discussions during each TWG breakouts session is included below.

4.1. TWG 1: Deployment Initiatives

Bill Legg, Washington DOT, explained that TWG 1 has focused on the following issues:

- Issue 1: V2X Applications
- Issue 7: Understanding the Benefits and Costs of V2I Deployment and Operation
- Issue 13: Infrastructure Processes as V2I Obstacles
- Issue 14: Federal V2I Policy Statement
- Issue 15: Maintaining V2I Infrastructure

The group initially focused on wanting to understand what was being deployed and how to use that information to support the Coalition. This led to a desire to explore costs, obstacles and a strong federal policy. For Issue 1, TWG 1 surveyed infrastructure owners and operators to better understand agency interests in V2I deployment. The survey was coordinated with the Connected and Automated Vehicle (CAV) Working Group within the Subcommittee on Transportation Systems Management and Operations (STSMO). There were 25 survey responses and Bill highlighted those responses to question 3 regarding planned, most beneficial, and already deployed applications. These survey responses were compared to the four priorities applications identified by the Coalition to show strong consistency. The survey further informed Issue 13. Responses confirmed many items already identified as obstacles including, for example, DSRC, security, patents, app readiness, and documentation of app details.

Bill explained that Issues 7 and 15 were closely linked by cost factors. TWG 1 conducted two webinars to highlight products from USDOT that will be released with the V2I Deployment Guidance to support agencies with assessing benefits and costs, particularly those associated with operating and maintaining V2I infrastructure. Bill also acknowledged that many of the new products coming from USDOT will address a variety of deployment issues. Issue 14 is focused on developing a strong statement from USDOT encouraging deployment. TWG 1 has coordinated with TWG 4 on this issue and the groups have chosen to first review the new V2I Deployment Guidance to understand if and how such a statement may be addressed.

Bill concluded the TWG 1 report by describing the direction of potential future work for TWG 1. In line with the Coalition's overall desire to accelerate deployment, TWG 1 would like to build or gather a set of

tools to support rapid deployment. Bill also briefly described the concept of deploying SPaT as a simple application that will allow agencies to practice using new tools and develop a framework for broader deployment – one that reduces fear and increases learning to set the stage for other application deployment.

4.2. TWG 2: Deployment Research

Greg Larson, Caltrans, reported that TWG 2 has been working on the following issues:

- Issue 1: V2X Applications
- Issue 3: V2I Data
- Issue 6: V2I Outreach
- Issue 7: Understanding the Benefits and Costs of V2I Deployment and Operation

Greg explained that although Issue 4: Patents-Intellectual Property and Issue 9: Understanding V2I Liability Assignment were also originally assigned to TWG 2 the group did not address them due to a lack of legal knowledge. TWG 2 has focused more on Issues 1 and 3. Regarding Issue 1, Greg noted that V2X applications have been identified in many places – CVRIA has a list of over 70 applications, FHWA has a list of more than 50 applications. This has caused some confusion and TWG 2 suggests that one definitive list be established to focus deployment and other efforts. Greg added there could be some filtering around application readiness. Regarding Issue 3, the identification of clear data needs from the OEMs should be further researched. TWG 2 will develop a problem statement to research and resolve as many of the prioritized data issues as possible over the coming 2-5 years.

Greg noted that the one-stop-shop for research in relation to Issue 6 will continue to be an important area for TWG 2 going forward. TWG 2 will describe the one-stop-shop to the point where entities could estimate the costs and resources required to create and operate it. Regarding Issue 7, TWG 2 has reviewed webinar summaries from TWG 1 and the case studies developed by TWG 3 to identify gaps that may require additional research. A problem statement will be created to define additional research needed to supplement both the current and completed benefit/cost studies. Greg concluded his remarks for TWG 2 by emphasizing the need create opportunities for OEMs and infrastructure owners/operators to work together.

4.3. TWG 3: Partners

Matt Smith, Michigan DOT, provided an overview of TWG 3 work on the following issues:

- Issue 1: V2X Applications
- Issue 3: V2I Data
- Issue 7: Understanding the Benefits and Costs of V2I Deployment and Operation
- Issue 16: Operator and OEM Goals for V2I

Matt shared that TWG 3 focused much of their work on Issues 1, 3 and 7. Regarding Issues 1 and 3, the group has noted that infrastructure owners/operators need data from vehicles just as OEMs need data from the infrastructure for certain applications. TWG 3 would like to further explore data needs with OEMs and infrastructure owners/operators by identifying what data is needed for each application, what may be common across applications and what could potentially be low-hanging fruit for continued deployment. Matt further explained that as TWG 3 has addressed Issue 7, they could only make assumptions based on research in many cases. Having results from the CV Pilots will be important for

improving benefit/cost information, particularly for application development, maintenance and security. He also noted that benefit/cost information will need to be consistently updated to be useful to agencies.

Matt explained that while TWG 3 discussed Issue 16, it was clear that safety is a common goal for all partners. Private industry is providing solutions and services that are in line with agencies' overall mission and goals, and they are providing new technological solutions for infrastructure owners/operators that will lead to new business opportunities. He proposed hosting a workshop for OEMs and infrastructure owners/operators to further discuss goals as well as data needs.

The group's future work will continue to focus on these issues as well as security and international harmonization. Security is relevant at multiple levels in V2I and it was suggested that establishing higher level principles for security may be a good starting point.

4.4. TWG 4: Deployment Guidance

Faisal Saleem provided an overview of the issues that TWG 4 has been working on:

- Issue 1: V2X Applications
- Issue 6: V2I Outreach
- Issue 7: Understanding the Benefits and Costs of V2I Deployment and Operation
- Issue 9: Understanding V2I Liability Assignment
- Issue 11: V2I Consumer Messaging
- Issue 13: Infrastructure Processes as V2I Obstacles
- Issue 14: Federal V2I Policy Statement

Faisal explained that TWG 4 has been predominantly focused on Issue 6 which has included reviewing and commenting on the V2I Deployment Guidance and several supporting products, as well as providing feedback to USDOT on their V2I outreach activities. The group has also reviewed and provided feedback to USDOT on messaging that is being used with consumers to help them understand CAV. Faisal added that work by the other TWGs on the other deployment issues will be reviewed by TWG 4 in relation to the new V2I Deployment Guidance once it is issued.

He also shared the process for further developing Issue 14 with TWG 1. Faisal explained that the groups have agreed to wait until the new Guidance is issued to determine what specifically an additional Federal policy statement could address. He explained that feedback would be then presented to the Executive Committee for review and feedback, and then it would be further presented to the CAV ELT to determine how the feedback should be presented to USDOT. It was noted that although the Coalition cannot make formal recommendations, the resulting discussion on this issue can still be provided as feedback to USDOT regarding the current policy position.

Faisal concluded his remarks by reiterating the need to find a supplemental path for issuing guidance to the agencies in a timelier fashion. He added the need to continuously support outreach on V2I especially since it involves so many audiences, messages, etc. and TWG 4 would like to see outreach be sustained and continuous – especially as information changes. It was also noted that outreach should include a scenario describing how local agencies in particular can fit CAV in with all the other transportation priorities (e.g. walkable communities, increased transit, etc.).

4.5. TWG 5: Deployment Standards

Ed Seymour, TTI, provided an update on the progress that TWG 5 has made with the following issues:

- Issue 1: V2X Applications
- Issue 3: V2I Data
- Issue 6: V2I Outreach
- Issue 8: V2I Standards

Ed noted that broader input goes beyond OEMs to include standards development organizations, other associations, freight, transit, vulnerable road users, etc. TWG 5 would also like to have input on standards from the deployment sites – both those selected and those proposed. Ed added that waiting for deployment findings to be published is not an efficient model to encourage further standards deployment. Finding a way to get interim feedback is needed. TWG 5 has discussed the potential for reviewing recent grant funding applications to extract information related to standards and other deployments proposed. USDOT explained that although the Smart Cities applications may be available eventually this won't likely be the case with the CV Pilot applications. It was suggested that the group contact those who submitted CV Pilot applications to request from their proposals. USDOT noted that they could potentially issue a request to the submitters to voluntarily share their information with the V2I DC.

Ed further explained that TWG 5 has primarily focused on identifying standards gaps during their work to address Issue 8 and they will suggest potential actions for filling the gaps. For potential future standards-related work of the Coalition, TWG 3 suggested several items for further consideration, including:

- Maintain the standards context drawing
- Engage Smart Cities and Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) grant applicants in standards discussions
- Engage telecommunications providers
- Gauge conformance with appropriate standards
- Monitor certification standards – currently limited to and focused on CV Pilots
- Monitor security needs and engage experts as the issue comes forward
- Consider standard specification for an after-market system design, subject to the contents of the NHTSA V2V ruling
- Focus on and look for gaps in fleet-related standards if a ruling for heavy vehicles is released
- Consider broader engagement with commercial vehicle fleets
- Stay involved with the SAE I2V/V2I Task Force and other standards development organizations

4.6. V2I DC Executive Committee Meeting

All the TWG chairs then reported progress to the Executive Committee in the afternoon of April 21. Chairs highlighted progress from current work plans and presented potential future work. From the discussion, the following activities were identified for further consideration by the V2I DC:

- Host a workshop for OEMs and infrastructure owners/operators
- Develop the national SPaT deployment concept
- Explore additional methods for providing deployment guidance
- Build understanding of and identify how to address security issues
- Develop a roadmap or deeper guidance for the four priority apps identified by the Coalition
- Maintain ongoing, broad-based outreach

- Mine CAV projects and proposals for deployment experiences

The V2I DC is awaiting feedback from USDOT on the proposed business plan for continuation and further development of a work plan to support these and other activities in the next phase of work.

5. Issue Specific Summaries of V2I DC Work on Deployment Issues

Following Workshop 2, the TWGs continued their work – individually and collectively – on the 16 issues the V2I DC identified initially when it was established. This section presents a summary of the work accomplished by the Coalition on all 16 issues. Table 1 summarizes the 16 issues and which TWGs worked on them. The table also identifies the role each TWG provided for each issue such as Primary Role, Supporting Role or No Role. Following the table, the intent and results associated with each issue are summarized, along with references to numerous supporting products developed by the TWGs since June 2015. Also included for each issue – even those not directly addressed during Phase 1 – are recommended actions that could be further considered by the V2I DC for Phase 2.

Table 1: TWG Roles by Issue

Issue	TWG 1 Initiatives	TWG 2 Research	TWG 3 Partners	TWG 4 Guidance	TWG 5 Standards
Issue 1: V2X Applications	P	S	P	S	S
Issue 2: Complementary Communications to DSRC	No action was taken on this issue during Phase 1				
Issue 3: V2I Data	N	S	P	N	S
Issue 4: Patents-Intellectual Property	No action was taken on this issue during Phase 1				
Issue 5: Security	No action was taken on this issue during Phase 1				
Issue 6: V2I Outreach	N	S	N	P	S
Issue 7: Understanding the Benefits and Costs of V2I Deployment and Operation	S	S	P	S	N
Issue 8: V2I Standards	N	N	N	N	P
Issue 9: Understanding V2I Liability Assignment	No action was taken on this issue during Phase 1				
Issue 10: V2I Synergies with Other Emerging Technologies	No action was taken on this issue during Phase 1				
Issue 11: V2I Consumer Messaging	N	N	N	P	N
Issue 12: V2I Multimodal Applications	No action was taken on this issue during Phase 1				
Issue 13: Infrastructure Processes as V2I Obstacles	P	N	N	S	N

Issue 14: Federal V2I Policy Statement	P	N	N	S	N
Issue 15: Maintaining V2I Infrastructure	P	N	N	N	N
Issue 16: Operator and OEM Goals for V2I	N	N	P	N	N

Note: P-Primary Role; S-Supporting Role; N-No role planned

5.1. Issue 1: V2X Applications

Intent: There are numerous CAV safety and mobility applications identified in the Connected Vehicle Reference Implementation Architecture (CVRIA). USDOT has led the development of concepts of operations and requirements for many applications. In addition, the auto industry is in the process of developing applications for their customers. There has also been some limited pilot testing done at the state and local levels of selected applications (e.g. signal priority, wrong way driving).

Recognizing the current state of practice as described in the previous paragraph, the intent of V2I DC work around this issue is to **prioritize V2X applications and develop common understanding of how OEM and infrastructure applications will work together**.

Results: The Coalition conducted and summarized a **survey of infrastructure owners/operators regarding V2X applications.** The survey asked respondents to identify the V2I application that they were planning or proposing to deploy, that they feel would be most beneficial to deploy, and that they had already deployed. A total of 25 responses were received and compiled in a summary report which is included in Appendix B. Survey results indicated strong consistency between the responses regarding planned/proposed and most beneficial applications and the priority applications identified by the Coalition. Below are the six V2I applications that received high priority responses for both planned/proposed and most beneficial. Survey results were also shared with other TWGs for their use in further addressing other issues.

- Road Weather Motorist Alert and Warning
- Queue Warning
- Vehicle Data for Traffic Operations
- Intelligent Traffic Signal System
- Signal Phase and Timing[1]
- Warnings About Upcoming Work Zones

[1] It is recognized that Signal Phase and Timing (SPaT) is not a V2I application but rather a technology that supports other applications. At the time the survey was conducted, the Connected Vehicle Reference Implementation Architecture (CVRIA) identified SPaT as a support application, and therefore it was included in the survey.

The Coalition **developed three research definitions** to be considered by USDOT and other research entities to advance the understanding of V2X application priorities. The topics of the research definitions include:

1. How V2I applications will address situational awareness at intersections and in other highly dynamic environments (Appendix C);
2. How to provide agencies with guidance on the readiness of open source application development portal (OSADP) applications for reuse (Appendix D); and
3. How to prepare traffic incident management (TIM) responders for CAV (Appendix E).

Finally, the Coalition **developed the concept for a SPaT Challenge**. SPaT Challenge will provide a bold and measurable goal that allows the V2I community to join and collectively work towards a near-term milestone for V2I deployment. To the automobile equipment manufacturers, the AASHTO SPaT Challenge will demonstrate a commitment to DSRC-based V2I infrastructure deployment, and enable individual application developments to occur in upcoming vehicle releases. The goal is to achieve DSRC infrastructure deployment of SPaT broadcast in approximately 20 signalized intersections in each of the 50 states by January, 2020, and to commit to operating the SPaT broadcasts for a minimum of 10 years. As part of the AASHTO process to create the SPaT Challenge Resolution, a background document summarizing the SPaT Challenge was created and is included in Appendix F.

Further Considerations:

This issue is expected to remain an open topic over the next several years as application development continues and as stakeholder like those represented by the Coalition gain experience with the applications. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Review V2I Deployment Guidance and supporting products for how they address applications identified as priority by the Coalition and survey respondents.
- Develop a roadmap for priority applications. A roadmap could, among other things, identify the finer details of and more specific guidance for each application. For example, the “intersections” priority application could consist of several applications (e.g. red light violation warning, pedestrian in signalized crosswalk warning, transit signal priority, etc.). A roadmap for this application could identify all the intersection related V2I applications, applicable pre-deployment guidance, supporting systems engineering material, operation and management considerations, etc.

5.2. Issue 2: Complementary Communications to DSRC

Intent: Most discussion around V2I deployment has assumed the use of DSRC as the communications medium. However, other communication methods, such as cellular, may present viable alternatives to DSRC for some V2I applications. There is a need to document the benefits and limitations of communication various technologies with emphasis on implementation challenges, operational challenges, infrastructure requirements, and cost implications. NCHRP Project 03-101 proposed research to investigate some of these questions and was extended allow for implementation strategies to be explored with various stakeholder groups. Additional work is also being done to coordinate the report with NCHRP Project 20-24(98) and to explore the use of mobile cellular technologies.

The intent of V2I DC work around this issue was to **understand the potentially competitive roles of communication technologies, such as cellular and DSRC, and in particular to explore how DSRC may work in conjunction with other technologies for select V2I applications**. Consideration should be given to protocols, interfaces on messaging, and engagement of system and equipment providers, and work should include discussions with the Department of Commerce on the broadband cellular network and FirstNet.

Results: No action was taken on this issue during Phase 1.

Further Considerations: This issue is expected to remain an open topic as early deployments are completed and stakeholders gain experience with licensing, implementation and operational aspects of DSRC. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Review key findings from NCHRP Projects 03-101 and 20-24(98), and deployment experiences, to understand if and how each address questions regarding how communication technologies could compete with and complement DSRC.
- Review V2I Deployment Guidance and supporting products to determine if and how they address competing and complementary communication alternatives to DSRC.
- Work with the IOO/OEM Forum for Collaboration to maintain discussions between state and local DOTs and the OEM and CAMP representatives. For example, one priority identified by the IOO/OEM Forum is to discuss whether DSRC is the most appropriate communication medium for “end of queue warning” applications.

5.3. Issue 3: Data Strategies

Intent: Discussions surrounding V2I data have advanced in recent years, but there remain unanswered questions regarding data needs of transportation agencies; availability of data (particularly the Basic Safety Message Parts 1 and 2 (BSM 1 and BSM 2); accessibility of V2I data; security of V2I data; ownership of data; and, business models for data access, management and storage.

Recognizing the current state of practice, and the questions that remain, the V2I DC **intends to develop a succinct business model that addresses the data needs, availability, security and ownership of data**.

Results: The V2I DC **gathered input about data issues to be addressed from infrastructure owners/operators** through interviews with members of the state DOT pooled fund, as well as from OEM members of the Coalition. Information needed for all three focus areas included roadway geometry and road condition information. Therefore, these two data element categories should be prioritized for V2I deployment activities in the four priority applications identified for this exercise. There appears to be a gap in the data needs and availability for a variety of different applications. These gaps and needs can only be addressed through further cooperative work between the infrastructure owners/operators and the automobile OEMs. Full details from this effort are included in Appendix G.

OEMs and infrastructure owners/operators also briefly **discussed data needs in conjunction with an OEM workshop** that was held in September 2016, and created an ad-hoc group that began meeting in November, 2016 to continue discussing the data to be exchanged to support the initial four priority focus areas defined by the V2I DC.

The Coalition also developed a **research definition** to be considered by USDOT and other research entities to understand how unanticipated changes to map data may be problematic for the vehicles that rely on them for navigation. This specific research definition proposes work with a representative digital map structure and experimental automated vehicle to study the benefits of using Connected Vehicle technology to improve Automated Vehicle navigation in areas where the expected road structure has temporarily changed. The complete research definition is included in Appendix H.

Further Considerations: This issue is expected to remain an open topic as OEMs and infrastructure owners/operators gain experience with exchanging data in pilot deployments. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Continue supporting the ad-hoc group that has formed consisting of OEMs and infrastructure owners/operators to discuss data to be exchanged between the vehicle and the infrastructure.

5.4. Issue 4: Patents-Intellectual Property

Intent: Questions about patent ownership and intellectual property have been raised with regard to the development of V2I applications and systems. V2I DC work related to this issue was **intended to develop a frame of reference and best practice regarding patents and intellectual property to assist public agencies with managing both** during projects designed to support application development and testing.

Results: No action was taken on this issue during Phase 1.

Further Considerations: This issue is expected to remain an open topic as public and private entities gain experience with developing and testing V2I applications. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Review V2I Deployment Guidance and supporting products to determine if and how patents and intellectual property issues are addressed.
- Engage stakeholders with legal expertise to provide a context for patent and intellectual property law, to identify applicable precedence, and to support the development of a framework that could support public agencies with managing patent and intellectual property issues when conducting research and development projects.

5.5. Issue 5: Security

Intent: Security for Connected Vehicle continues to be a concern even though substantial work has been done by USDOT and others attempting to define an effective approach for managing security. In 2014, NHTSA released a request for information soliciting input from the private sector about how to approach and operate a secure CAV network. In the summer of 2015, media coverage of the hack into a Chrysler Jeep generated even more concerns about security for CAV and V2I applications.

The V2I DC recognizes the value of having a robust security framework that extends beyond specific individual solutions, and recognizes the need to develop a framework within the transportation industry. The V2I DC **intended to collaborate with security stakeholders to leverage and apply frameworks developed by other domains**, such as the Industry Council for Emergency Response Technologies (ICERT) within the Department of Homeland Security (DHS).

Results: No specific TWG action was taken on this issue during Phase 1. However, V2I DC representatives identified and explained this issue to the Connected Automated Vehicle – Executive Leadership Team (CAV-ELT) at the April, 2016 meeting. The CAV-ELT identified security related issues as two of the seven highest priority policy issues. At the November, 2016 CAV-ELT meeting the CAV-ELT members agreed to submit a white paper that combines the two security related issues titled "Security Management for AV Operations" to TRB for inclusion in the TRB plans for security research.

Further Considerations: This issue is expected to remain an open topic as OEMs and infrastructure owners/operators gain experience with V2I applications and deployments. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Review V2I Deployment Guidance and supporting products to determine if and how security is addressed.
- Watch for NCHRP Project 20-102(10) which is anticipated in 2017. The objective of this project is to develop a primer on cybersecurity and related privacy issues in state DOT and local agency environments, based on experience gained in other domains (such as financial services) where security and privacy issues are currently being managed.
- Engage stakeholders with security expertise to support the Coalition with reviewing existing CAV-related resources on this subject and identifying additional guidance as may be needed.
- Continue discussions between OEMs and infrastructure owners/operators to determine how security can be effectively and consistently applied to V2I applications.
- Continue to support the CAV-ELT, as needed, to provide input on security needs for V2I applications.

5.6. Issue 6: V2I Outreach

Intent: Since the state and local transportation agencies will be directly involved with operating a CAV system there is a sense that they should be more prominently and directly involved with the OEMs and USDOT in developing the system. It is essential for the USDOT to have broad stakeholder input into V2I Deployment Guidance and the overall CAV program.

Additional outreach and education is needed regarding CAV in general and V2I issues in particular for transportation agencies. Coalition work related to this issue was **intended to identify topics that should be included in V2I outreach activities, including but not limited to the V2I Deployment Guidance and supporting products**. Such topics may include planning and investing for V2I deployments; control, operations and maintenance of V2I applications; adding DSRC devices to roadside ITS devices; and other issues that surround a transition to supporting large scale roadside infrastructure that will be required for V2I applications.

Results: Early after its formation, the Coalition **provided extensive review and feedback on version 14 of the V2I Deployment Guidance**. Comments included, for example, clarifications on the definition of a Connected Vehicle environment and suggestions for additional detail on topics such as federal-aid programs for V2I activities. A complete list the over 100 comments submitted by the V2I DC is included in Appendix I.

While awaiting release of the revised V2I Deployment Guidance, the Coalition **continued offering feedback to USDOT by reviewing the additional products that have been developed to support the guidance**. The following products have been reviewed by the V2I DC to-date:

- Near-Term Transition and Phasing
- Connected Vehicles and the Planning Process
- Pre-Deployment Guidance
- V2I Message Lexicon

The Coalition has also **discussed and offered feedback to USDOT regarding additional products that may be developed** to support the more technical aspects of V2I application installation and operation.

In addition to offering feedback guidance, the V2I DC has also **offered USDOT feedback on outreach activities associated with V2I**. Initially, the Coalition identified outreach that may be needed to increase awareness and support of V2I among transportation agencies and service providers. They reviewed a sampling of existing and developing outreach materials and discussed outreach needs which were summarized and shared with USDOT as they began developing their V2I outreach plan. The outreach summary is included in Appendix J. The Coalition also **participated in focus groups** during Workshop 2 that were led by USDOT contractors to gather information about the most effective messaging and methods of outreach to the diverse V2I stakeholder audiences. Following the focus groups, the V2I DC **reviewed**

and commented on the draft V2I outreach plan created by USDOT and then **reviewed the beta website, www.v2ideploy.com that** has been designed as a broad point of information to educate and support stakeholders in the deployment of V2I applications.

In addition to offered feedback on general outreach activities, the V2I DC has also **developed the concept of a one-stop-shop for CAV research oriented outreach**. The details of the concept and steps to coordinate with the National Operations Center of Excellence are included in Appendix K.

Further Considerations:

This issue is expected to remain a pressing issue as V2I deployment increases and practices surrounding deployment evolve based on experiences gained. Outreach will need to remain a continuous activity to ensure growth in awareness, understanding and acceptance of V2I deployment. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Review and comment on revised V2I Deployment Guidance when it is issued.
- Continue to review and comment on V2I Deployment Guidance supporting products and tools such as the V2I Hub, training resources, the Systems Engineering Guide, etc.
- Discuss how the Manual on Uniform Traffic Control Devices and other traditional guidance may need to be modified to address V2I applications.

5.7. Issue 7: Understanding the Benefits and Costs of V2I Deployments

Intent: The potential benefits of V2I applications have been researched and identified through early deployment initiatives. Potential benefits include increased safety, improved mobility, and cost savings to transportation agencies. As transportation agencies begin to plan for long-term sustained deployment of V2I applications, it is inevitable that the need will arise for a business model to facilitate decision-making. Analyses of the benefits and costs, and prioritization of specific applications are just some of the elements that would fold into an eventual business model. As one example, V2I applications may enable agencies to eliminate existing infrastructure and systems that are costly to maintain. These cost savings will result in financial benefits to help offset V2I costs.

Each transportation agency will face the challenge of prioritizing V2I application deployments and weighing the benefits to the costs. If no additional funding sources are available, V2I application deployments may compete with other infrastructure deployments and operations. The **intent of V2I DC work related to this issue is to discuss and offer feedback regarding an overall approach for how agencies can approach benefit/costs analysis in their eventual business models to assist with V2I deployment**.

Results: The V2I DC **facilitated two webinars that highlighted ongoing research projects related to CAV benefit/cost analyses**. The intent of the webinars was to share project information with all TWGs who were working on V2I benefit/cost efforts. The first webinar featured the desk reference and tools for estimating the local, regional, and statewide economic development of benefits of Connected Vehicles to infrastructure. The second webinar featured the Near-Term V2I Transition and Phasing Analysis, and the Connected Vehicle Life Cycle Cost Model (LCCM) products developed by USDOT to support V2I Deployment Guidance. A summary of both webinars is included in Appendix L.

The Coalition **initiated dialog among OEMs and infrastructure owners/operators to identify elements of benefits and costs** that ought to be considered for the Reduced Speed Zone Warning/Lane Closure and Red Light Violation Warning applications. The summary explains basic functionality, potential benefits and deployment cost estimates for each application and it is included in Appendix M.

In addition to the planning oriented tools featured in the webinars sponsored by the V2I DC, the Coalition also **reviewed and offered feedback to USDOT on Connected Vehicles Pre-Deployment Guidance**. For the Pre-Deployment Guidance, the Coalition reviewed preliminary guidance for the Reduced Speed Zone Warning (Work Zone Management) and Curve Warning applications. The group also discussed preliminary content for the Queue Warning and Red Light Violation Warning (Intersections) applications that will be used to guide further pre-deployment guidance for these and other V2I applications in the coming year.

Finally, The V2I DC **developed two research definitions** to further support the refinement of benefit/cost analysis for V2I applications. The topics of the research definitions include:

1. How to provide agencies with tools for large-scale assessment regarding the cost effectiveness of V2I applications (Appendix N); and
2. How to ascertain the likely capacity and operational effects of CAV at a planning level decision making (Appendix O).

Further Considerations: This issue is expected to remain open as deployment continues and interest grows. Agencies will need to better understand the benefits and costs associated with deployment so that they may compare V2I deployments in relation to other alternatives for addressing transportation mobility and safety challenges. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Review V2I Deployment Guidance and supporting products to further understand how the assessment of benefits and costs is addressed particularly in relation to developing a business model for V2I deployment.
- Provide feedback on the continued development of Pre-Deployment Guidance.

5.8. Issue 8: V2I Standards

Intent: As transportation agencies begin the process of deploying V2I equipment and supporting systems, they may begin to deploy V2I infrastructure during their normal life cycle replacement period. This poses a challenge with understanding how an agency can confidently procure and deploy infrastructure that will be compatible with future V2I applications. Similarly, from the vendor perspective, vendors will inevitably want to begin to design, develop and manufacture devices and systems that they are confident will be compatible with future V2I applications.

Standards are perhaps the most logical solution to ensure interoperability, vendor independence, and scalability of V2I systems and applications. The **intent of V2I DC work on this issue is to review the scope of V2I standards** to understand the migration of current ITS and vehicle standards to the V2I environment, as well as developing new standards as needed to enable consistent development, procurement, and deployment of the infrastructure and devices that will eventually comprise the nation's V2I network.

Results: The Coalition has **developed a V2I Standards Context Diagram** illustrating the various standards that exist to support the vehicle, the infrastructure, and the roadside units. The diagram has been critical towards understanding the spectrum of V2I standards. It serves as a framework showing the relationship of V2I standards, both current and needed, and how they relate to the vehicles, roadside units, and infrastructure; and can be used to facilitate discussions about current and needed standards, and to discuss gaps and needs for new standards. The diagram is available in Appendix P.

Further Considerations: This issue is expected to evolve as V2I application experience grows. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2. Additional detail regarding these actions is also available in Appendix Q.

- Maintain the Standards Context Diagram as a tool for framing V2I standards activities.
- Representatives from the V2I DC should interact with the SAE DSRC Technical Committee.
- Once the DSRC Roadside Unit (RSU) "specification" is stabilized it should be transferred to an appropriate standards development organization (SDO) and updated to a consensus driven standard.
- Explore development of automated testing tools for roadside units (RSUs) to ensure they meet applicable standards.
- Support standardization and expansion of the Security Credential Management System (SCMS).
- Monitor RSU certification activities as actual deployments occur and look for opportunities to incentivize a comprehensive certification process for RSUs that can be performed on a national scale.
- Explore the move from best practices to "enforceable" or "gradable" performance that helps ensure acceptable reliability.

- Encourage and work with AASHTO, ITE, ITS America and their partners to support efforts to update the Manual on Uniform Traffic Control Devices (MUTCD) and other guidance documents.
- Conduct a webinar based workshop to review the USDOT Data Capture Management (DCM) document with all V2I Deployment Coalition working groups.
- Engage with Smart Cities and Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) projects to identify lessons learned especially with regard to standards and other needed guidelines.
- Engage the telecommunications and information technology (IT) industries to ensure that standards and guidelines for connectivity in the V2I ecosystem are robust and reflect current technologies. This would also relate to further considerations suggested for Issue 2: Complementary Communications to DSRC.
- Focus on and look for gaps in fleet-related standards if an NPRM for heavy vehicles is released.

5.9. Issue 9: Understanding V2I Liability Assignment

Intent: While V2I research and pilot deployments have been ongoing for several years, there are limited examples of full scale live deployments involving large numbers of participants from the traveling public. For this and other reasons, the V2I industry lacks a history of legal proceedings that can serve as precedence to understand how liability is typically assigned. Transportation agencies, drivers, manufacturers and third party data providers would benefit from guidance on how to interpret, understand, and quantify liability and risk exposure related to V2I applications. The V2I DC effort related to this issue is **intended to formulate guidance for how transportation agencies can begin to prepare to interpret and manage liability assignment.**

Results: No action was taken on this issue during Phase 1.

Further Considerations: This issue is expected to remain open as more permanent deployments are completed and applications become more widely available for vehicles. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Review V2I Deployment Guidance and supporting products to further understand if and how liability is addressed.
- Engage stakeholders with legal expertise to provide context for how transportation agencies can begin to prepare to interpret and manage liability assignment.
- Review any precedent established by other ITS-relate deployments. For example, in 2010 the National Conference of State Legislatures released the report, "Weather or Not? State Liability and Road Weather Information Systems (RWIS)," in collaboration with the FHWA Road Weather Management Program. The report was intended to help state legislators and DOTs understand liability concerns related to the use of RWIS and provide a menu of strategic options for addressing those concerns, illustrated by real-life examples from the states.

5.10. Issue 10: V2I Synergies with Other Emerging Technologies

Intent: Outside of the V2I industry, there are examples of other emerging technologies that could soon become a part of everyday life. These may include Smart Cities, the Internet of Things (IoT), and other similar emerging technologies. If approached in a collaborated fashion, a scenario could easily be imagined where V2I equipment, communications, and infrastructure can co-exist and integrate with other technologies. V2I DC work associated with this issue was **intended to explore the extent to which it is possible to collaborate with other sectors, and the timing and technology ramifications of this collaboration** to enable the industry to make long term decisions.

Results: No action was taken on this issue during Phase 1.

Further Considerations: This issue could become more prevalent as state and local governments struggle with broader wireless technology deployments to support public infrastructure. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Monitor the SmartCities experience in Columbus, Ohio to understand if there are potential synergies between V2I related deployment and other wireless communication deployments necessary for other public services.
- Explore what other wireless communication deployments state and local governments are facing – outside of transportation – over the next 10 years to understand if there are potential deployment synergies among them.

5.11. Issue 11: V2I Consumer Messaging

Intent: As V2I applications spread throughout the United States, public education and marketing will become increasingly important. There are potentially several issues associated with common marketing messages between public and private marketing campaigns. For example, consumers may not understand the role the public sector plays in the product or service they have purchased. The approach that transportation agencies and vendors take towards marketing could play a large role in managing expectations while generating enthusiasm for new products and services.

The V2I DC work regarding this issue is **intended to explore common messaging to end consumers that may be used by both public and private sector organizations involved in V2I deployment**.

Results: The Coalition **reviewed samples of public and private sector materials targeted at consumers to identify those messages regarding V2I deployment** that are:

- Common: Used by all or most
- Supportive: Clear, factual
- Questionable: Confusing, potentially misleading

The materials reviewed by the V2I DC included those currently being directed to consumers by private industry (e.g. automobile manufacturers, technology companies), as well as messages coming from public agencies like USDOT. The group also reviewed examples of media interpretations of the messaging being directed to the public. A full summary of the materials reviewed and the discussion about common, support and questionable messages is included in Appendix R.

Further Considerations: This issue will remain open as agencies share information about experiences with pilot deployments and as private industry continues to market V2X features. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Continue to review and offer feedback on consumer messaging to public agencies and private industry stakeholders participating in the V2I DC.

5.12. Issue 12: V2I Multimodal Applications

Intent: Many of the V2I applications identified to-date have focused on safety and mobility for passenger and commercial fleet vehicles. These applications will generate broader and deeper data regarding current conditions of the transportation system and that, in turn, offers the potential to make traveler information more robust. Such data could create greater information for travelers to choose multimodal options in real-time as an alternative or as a daily transportation choice. There are also opportunities to develop V2I applications that will make multimodal options more appealing and feasible to travelers. For example, knowing the current and forecasted availability of space at park and ride facilities could encourage travelers to explore mass transit alternatives for daily transportation.

The V2I DC is **intended to explore how V2I applications could be assessed for their potential to support multimodal travel** and identify what types of V2I applications could be specifically developed to support various modes.

Results: No action was taken on this issue during Phase 1.

Further Considerations: This issue will become more prevalent as V2I deployment experience grows among applications with passenger vehicles, particularly those that relate to other modes (e.g. red light violation warning and pedestrian in signalized crosswalk warning). Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Encourage stakeholder participation from organizations (e.g. transit agencies) that represent other modes of transportation.
- Identify current V2I applications in the CVRIA that directly relate to transportation modes other than passenger vehicles (e.g. dynamic transit operations, smart park and ride system), and discuss how they may evolve in relation to other V2I applications.

5.13. Issue 13: Infrastructure Processes as V2I Obstacles

Intent: The next iteration V2I technologies and systems are being invented quickly. There are existing processes, procedures, and/or regulations (e.g. the environmental review process, the MUTCD and established process to add or edit infrastructure uses in the MUTCD) that could be obstacles for a DOT wishing to implement V2I. The V2I DC will address this issue with the **intent to understand the extent to which existing processes (e.g. MUTCD, environmental reviews) are obstacles to V2I**.

Results: The V2I DC developed, administered, and summarized the results of a survey of infrastructure owners/operators (consisting of state and local level DOTs) to ask questions regarding recent V2I proposals, deployments and plans. As part of this survey, a question was included that asked responders to share their actual or planned challenges related to this issue. It was decided to phrase the question in an open-ended style and invite expressions of any concerns. Respondents were asked if they had identified any current infrastructure processes (e.g. environmental reviews, MUTCD compliance, etc.) or other challenges (e.g. lack of backhaul, technical capability, lack of developed applications, security concerns, etc.) that will prevent or hinder deployment of the Connected Vehicle infrastructure.

The response to the survey did not identify any infrastructure processes to be considered obstacles to V2I deployment, however the individuals working on this specific issue identified a series of additional potential obstacles. The Coalition further **discussed the responses to this question and developed a position paper**, which is included in Appendix S, summarizing their conclusions.

Further Considerations: This issue will become more prevalent as grant funding to support deployment decreases, as operational costs are experienced, and as pressure increases to continue deployment. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Review V2I Deployment Guidance and supporting products to understand if and how traditional infrastructure processes (e.g. federal-aid program) are addressed or modified to minimize obstacles to V2I deployment.
- Continue discussions with agencies that have deployed V2I applications to further clarify existing or identify any additional infrastructure processes that have created obstacles to deployment.

5.14. Issue 14: Federal V2I Policy Statement

Intent: The recent NHTSA resolution regarding vehicle-to-vehicle communications has helped the V2V industry. Similar strong encouragement from a federal agency to give infrastructure owners and operators a push to deploy V2I would also help V2I. It is recognized that a rulemaking is likely not possible, but perhaps another strong encouragement from a federal agency (e.g. something similar to an "Every Day Counts" EDC model) could be released. The intent of V2I DC work related to this issues was to explore the potential for a strong message from a federal agency encouraging V2I deployment.

Results: The V2I DC **discussed and prepared a briefing to describe the focus of Issue 14; highlight initial policy topics of interest identified by the Coalition; and, recommend a process for moving forward**. The initial topics of interest identified for consideration in a potential federal V2I policy statement were highlighted in the briefing as an indication of current thinking and awareness among V2I DC stakeholders. Some of the initial topics included, for example, an explanation of why agencies should deploy V2I and sample legislative language for agency consideration. The full briefing is included in Appendix T.

Further Considerations: This issue could become less critical depending on reactions to the anticipated V2I Deployment Guidance, NHTSA ruling on V2V regulation and the SPaT Challenge. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Review V2I Deployment Guidance and supporting products for statements regarding the national direction and expectations for V2I deployment.
- Monitor response to the SPaT Challenge as an indication of interest and ability to proceed with broader V2I deployment.
- Monitor automotive industry response to the anticipated NHTSA ruling on V2V regulation as an indication of how they will proceed with broader deployment of CAV applications in vehicles.

5.15. Issue 15: Maintaining V2I Infrastructure

Intent: Infrastructure owners & operators considering V2I infrastructure investments need to consider long term infrastructure maintenance costs (outside deployment and operating costs). With relatively little actual experience in maintaining the types of infrastructure that will be required for V2I, these costs are largely unknown.

The V2I industry needs to begin a process to learn as much as possible about anticipated V2I infrastructure maintenance costs.

Results: The V2I DC **hosted a webinar featuring three deployment experiences and their insight into maintenance**. UMTRU, NYCDOT and Caltrans all shared their experiences to-date with maintaining V2I infrastructure associated with their deployments. The presenters noted many new maintenance responsibilities, including requirements for maintaining both field and fleet devices, database and security management processes, operations monitoring procedures, radio frequency measurement and network monitoring. The webinar was recorded, and the summary document (including a link to the recording) is available as Appendix U.

Further Considerations: This issue will expand as deployment increases and it will be necessary to prepare agencies for the new maintenance responsibilities that will be required for V2I deployment. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Continue dialog with V2I deployment sites, especially those that may become involved with the SPaT Challenge, to further clarify maintenance responsibilities and understand how agencies have addressed them.

5.16. Issue 16: Operator and OEM Goals for V2I

Intent: As the Vehicle-to-Infrastructure "concept" is quickly moving to "reality", potential opportunities and benefits will quickly become apparent. While infrastructure owners and operators, automobile OEMs, and suppliers will cooperate on deploying these systems, they may be doing so with different end goals in mind. It is important that those involved with deployment understand not only what these different goals and hopeful outcomes are, but also the fact that there may be varying goals and expectations amongst entities. Focusing on areas where there is commonality between goals and expected outcomes is likely to result in the highest chance of success for initial V2I deployments.

For V2I deployment, there are likely varying goals and expected outcomes for all partners involved. V2I DC work related to this issue was **intended to identify commonality in these goals and expected outcomes will improve the chances for success in initial V2I deployments**.

Results: During Workshop 2 breakout sessions, the V2I DC spent time identifying common goals for V2I deployment among infrastructure owners/operators and automobile OEMs. A summary of the results from this preliminary exercise is included in Appendix V.

To further expand upon the discussion regarding common goals, the Coalition worked with USDOT to host a workshop between OEMs and infrastructure owners/operators. The purpose of the workshop was to provide an opportunity for participants to develop a process by which the two groups can work together to identify data elements that will enable applications they envision for a vibrant connected vehicle environment. Details regarding the workshop findings are included in Section 6.

Further Considerations: This issue will remain open as OEMs and infrastructure owners/operators continue discussions regarding V2I deployment. Below are suggested actions for further consideration by the Coalition as work is planned for Phase 2.

- Participate in future workshops between OEMs and infrastructure owners/operators.
- Monitor activities sponsored by USDOT through CAMP, VIIC and other OEM-oriented groups working on V2X development.

6. IOO/OEM Workshop Findings

Considerable efforts were spent planning the September, 2016 two-day workshop involving representatives from state and local IOOs and representatives from OEMs and CAMP. Multiple conference calls and a pre-workshop in-person meeting helped to refine the overall agenda. This was not the first time that the IOOs and OEMs had met, a similar workshop occurred just prior to the start of the V2I DC Phase 1 activities. The group however agreed that it was imperative at this stage of the V2I deployment process that this group meet more regularly and determine a mechanism for accomplishing the common actions agreed by the group. Therefore, the agenda for the September meeting was primarily focused on establishing a long-term framework that could enable these meetings and collaboration to occur. USDOT supported the workshop by facilitating and documenting the discussions as well as key participation from a number of USDOT staff and supporting contractors. Members of the AASHTO support team were also in attendance, however the structure of the workshop was aligned such that the interactions between IOOs and OEMs was the primary emphasis.

The two and a half days of workshop discussion resulted in several outcomes that will (and already have) support V2I deployments. Highlights of these are summarized as follows:

- ***Proceeding with a "Forum for Collaboration".*** It was agreed that the IOOs and OEMs will cooperate to implement and evaluate V2I applications, but that a new entity or group is not needed at this time. Rather, attendees agreed that a "Forum for Collaboration" describes the approach where both the IOOs and OEMs will collaborate without any cross-funding of projects. The IOOs and OEMs would work together using the administrative and technical support and structure provided by the V2I DC to collaborate when needed, with the intent performing ***action focused activities***.

- ***Two Levels of Cooperation.*** The overall "Forum for Collaboration" would consist of the IOO and OEM members who participated in the September workshop, who would provide strategic discussion and direction. Detailed and technical work and collaboration would be performed by ad-hoc groups that form around specific technical topics. These ad-hoc groups would be limited to those IOO/OEM partners identified by the Forum (as well as invited guests as needed) and would exist until the topic is addressed and reported to the Forum.

- ***Defined Goals for Initial 90 Days.*** The Forum agreed that two topic areas required urgent actions and agreed to short-term 90 days goals to establish the ad-hoc groups and initial activities. These groups include:

    - *SPaT Challenge discussions related to Red Light Violation Warning (RLVW) Applications*. In order to encourage that SPaT deployments performed as part of the challenge are compatible with current and future V2I Applications deployed by automobile manufacturers, an ad-hoc group will discuss the findings and lessons learned by CAMP in deploying RLVW Applications, with an emphasis on the performance requirements and validation needed. This group conducted their initial meeting in October, 2016 and agreed to a schedule that will result in documentation prepared in time for the SPaT Challenge formal kickoff in early 2017.

- *Discussion of the data exchanges required to support the various V2I Applications.* As preparation for the workshop, both IOOs and OEMs prepared requests for data for selected V2I Applications representing the initial four focus areas (Curve Speed Warning, Road Weather, Work Zone Warning). Both sides will now present the extent to which they can meet the requests for data delivery, and discuss details surrounding data exchanges. Actions were initiated through email exchanges of follow-up written requests, and an initial phone call discuss responses to the requests was conducted in early November.

- ***Defined Longer-Term 12 Month Goals.*** The Forum agreed to three topic areas to be addressed over the initial 12 month period (less time critical than the initial 90 days). These included:

  - *Queue Warning.* Both IOOs and OEMs have decided to have a conceptual discussion about the queue warning application and to determine if DSRC based V2I data exchanges to support queue warnings are the most appropriate communication mechanism

  - *MMITSS (Advanced Traffic Signal).* Multi-modal Intelligent Traffic Signal Systems (MMITSS) have been deployed and demonstrated in Arizona and California through a Connected Vehicle Pooled Fund initiative. IOOs and OEMs are interested in building relationships and assessing the best approach toward expanding deployment of MMITSS Applications.

  - *Cooperative Adaptive Cruise Control (CACC).* The IOOs and OEMs agreed to continue to build relationships and increase communications surrounding deployment of CACC systems over the coming 12 months.

- Identified Issues and Topics for the Forum to Address in to Coming Years. Both the IOOs and OEMs agreed that several topics would be key to the successful collaboration and to the rollout of V2I deployments, including:

  - *Defining who the lead is, and where the intelligence resides* for each V2I Application. Some will be led by IIOs and intelligence will reside on the infrastructure side, with alerts sent to vehicles, while others will be vehicle based.

  - Agreeing on Measures of Effectiveness, Validation, and Evaluation parameters.

  - Steps that can be followed to ensure that the IOO/OEM collaboration is sustained, regardless of project funding, or other issues that might prevent the group from meeting.

  - Pushing beyond the “chicken and egg” challenge facing V2I deployment.

The IOO/OEM Workshop concluded with the Forum agreeing to meet again (either by webinar or in person) in approximately 90 days (near the end of 2016). The ad-hoc groups will report on progress addressing the “90 day” topics.

7. V2I DC Work Planned for Phase 2

The V2I DC Executive Committee is scheduled to meet in early December 2016 to further discuss work planned for Phase 2 of the Coalition. As the work on Phase 1 also concludes in December, the V2I DC will work with USDOT to confirm a direction and develop a high-level work plan for Phase 2.

During Phase 1, the primary activities of the V2I DC were dedicated to addressing deployment issues identified by the Coalition members. These issues were complex and spanned multiple stakeholder groups, and not all were resolved in the initial 18 months of the Coalition. The issues are discussed and better defined and, when appropriate, action plans were created to resolve the issues over subsequent years and primarily with resources outside of the V2I DC.

Table 2 summarizes the general activities envisioned for the Coalition during Phase 2. V2I Deployment support continues to be a work in progress. The outcomes described in this report and the discussions at the December 2016 V2I DC Executive Committee meeting will continue to shape the direction of Phase 2 of the V2I DC. In light of the outcomes of Phase 1, the V2I DC will restructure the Phase 2 working group structure. Some of the original structure will be maintained, but some changes will be implemented to better address the focus areas, support the SPaT Challenge, and continue the data and information exchange with the OEMs.

Table 2 General V2I DC Phase 2 Activities

Activity Name	Description
Stakeholder Workshops / Peer Exchanges / Training and Education	- The V2I DC will organize and operate overall stakeholder workshops. - Peer exchanges will be conducted to allow 'early adopter' agencies share lessons learned with 'late adopters'. - V2I DC will help align and support training and education that may be performed by any number of established technology transfer groups.
Webinars	The V2I DC will continue to execute four levels of webinars: - Coalition-wide webinars are used to engage stakeholders more frequently than in-person travel budgets allow. - TWGs organize smaller group specific webinars where the dialog and technical work of the Coalition is performed. - TWG Chairs meet by webinar to discuss collaboration and coordination - The V2I DC EC will meet by webinars in between in-person meetings
Activities of the TWGs	In between the webinars, TWG members and V2I DC Project Team liaisons perform the activities outlined in each TWG work plan. These are expected to include: - Helping to find funding opportunities to resolve the issues defined in the initial 18 months; tracking and supporting issue resolution - Identifying and defining additional issues relevant to V2I - Providing feedback to V2I Pilot Sites - Providing support and input to IOO collaboration with OEMs/CAMP

Activity Name	Description
Technical Memorandums and White Papers	The V2I DC will prepare technical memorandums, as needed, to: - Document issues, - Describe findings of the coalition, and - Report on other technical or institutions topics.
Project Team support to V2I DC	The V2I DC Project Team will perform a series of activities to maintain the V2I DC, including: - provides liaisons offering technical a support to each TWG; - Supporting the V2I DC Executive Committee - Overall planning and management of activities of the coalition - Help coordinate activities between TWGs. - Seek out funding options, prepare proposals, help form agreements - Seek alternate funding through sponsorship and/or partnerships - Encourage mainstreaming of activities (e.g. standards development, research) into existing, funded operations to the extent possible

Restructuring the working groups is suggested as follows to best accommodate the activities and Phase 2 focus of the V2I DC. Following is a brief overview of the suggested restructuring.

Guidance Working Group will continue the activities of the V2I DC Phase 1 TWG 4: Guidance. The Guidance Working Group will continue to meet regularly by webinar, and remain a forum for members to review and offer feedback to USDOT on Connected Vehicle guidance and tools. Members in the current TWG 4 should consider participation in this group.

Strategic Initiatives Working Group will carry on the actions of the V2I DC Phase 1 TWG 1: Initiatives, and some of the activities of TWG 3: Partners. The Strategic Initiatives Working Group's activities will:

- Continue to advance the SPaT Challenge and related resources,
- Continue to work towards solving issues defined in Phase 1, and
- Continue to seek opportunities to develop initiatives similar to the SPaT Challenge to help encourage deployment.

The Strategic Initiatives Working Group will continue to be a forum for public and private sector members to discuss the issues and seek initiatives to develop. The focus areas will be expanded to include connected vehicle applications deployed for Fleet vehicles (e.g. maintenance, transit). The Phase I focus did not exclude this, but there will be a dedicated push to recruit members representing these areas and to facilitate their input.

Peer Review/Outreach Working Group will be a forum for attendees to receive and share information on Connected Vehicle advances towards deployment. Regular webinars (frequency to be determined) will be organized with advanced planning to identify the best presenters and topics. Each webinar will touch on a series of topic areas that are identified as the focus of this working group, including (but not limited to):

- Pilot Deployment Sites updates and lessons learned;
- Smart Cities updates and lessons learned;
- Connected Vehicle Standards, including summaries of which Standards Development Organization is working on CV standards, and how attendees could get involved, as well as discussions about gaps in standards (note: the intent is not that this would be detailed standards discussions, but if need be a Task Force could form as needed to resolve technical issues);
- Connected Vehicle Research, including summaries of the current and planned CV research, with presentations from research teams when appropriate. This would also be a forum for attendees to bring up suggested new research (needs or approaches);
- Deployment status;
- Autonomous Vehicle Policy updates; and
- Sharing outcomes of IOO/OEM Forum discussions.

The Peer Exchange / Outreach Working Group is envisioned to be a group that all Coalition members would subscribe to. Webinar agendas will be circulated in advance with sufficient detail to determine attendance. It is anticipated that Phase I TWG 2, TWG 3, and TWG 4 members would find this working group useful.

Appendix A: V2I DC Roster

1.	Thomas Huie	3M
2.	John Conrad	AASHTO
3.	Patrick Zelinski	AASHTO
4.	Daniel Worke	AECOM
5.	Ken Yang	AECOM
6.	Bob Murphy	AECOM
7.	Saravana Suthanthira	Alameda County
8.	Praveen Singh	Arada Systems
9.	Reza Karimvand	Arizona DOT
10.	Allison Klein	ARTBA
11.	Dean Deeter	Athey Creek Consultants
12.	Ginny Crowson	Athey Creek Consultants
13.	Suzanne Murtha	Atkins
14.	Brian Watson	ATSSA
15.	Roger Wentz	ATSSA
16.	Brent Cain	AZDOT
17.	Dominie Garcia	BAH
18.	Denise Manzelmann	BAH
19.	Chris Stanley	Battelle
20.	Markus Bauer	BMW
21.	Amir Bushehri	Cal Amp
22.	Thomas West	California PATH/UC Berkeley
23.	Greg Larson	Caltrans
24.	Erin Flanigan	Cambridge Systematics, Inc
25.	Stan Caldwell	Carnegie Mellon University
26.	Zachary Rubinstein	Carnegie Mellon University
27.	Jack Hall	CCTA
28.	Randy Iwasaki	CCTA
29.	Alvin Stamp	CDOT
30.	Austin Gilbert	CDOT
31.	Tamara Hunter-Maurer	CDOT
32.	Barry Einsig	Cisco
33.	Kyle Connor	Cisco
34.	Azeem Shaik	Cisco
35.	Paul Carlson	City of Columbus
36.	Hsu-Chieh Hu	CMU
37.	Patrick Brunett	Cohda Wireless America LLC
38.	Richard Mudge	Compass Transportation and Technology
39.	Patrick Chan	Consystec
40.	Patrick Chan	Consystec
41.	Randell Iwasaki	Contra Costa Transportation Authority

42.	Roger Berg	DENSO International America, Inc.
43.	Jim Peters	DKS & Associates
44.	Adrian Pearmine	DKS Associates
45.	Jeffrey Holabaugh	Dye Management
46.	Jeff Holabaugh	Dye Management Group
47.	Gary Duncan	Econolite
48.	Gary Duncan	Econolite
49.	John Estrada	eTransSystems
50.	Paul Steinman	FDOT
51.	Jonathan Walker	FHWA
52.	Ben McKeever	FHWA
53.	Steven Siko	Fiat Chrysler Automobiles
54.	Paul Steinman	Florida Department of Transportation
55.	Ed Hutchinson	Florida DOT
56.	Elizabeth Birriel	Florida DOT
57.	Mohammed Hadi	Florida international university
58.	Mike Shulman	Ford
59.	Scott Geisler	General Motors
60.	Matt Hamill	Global-5 Communications
61.	Naveen Lamba	Grant Thornton
62.	Jim Frazer	Gridaptive Technologies
63.	Jim Frazier	Gridaptive Technologies
64.	Mike Tourville	Gridsmart
65.	Jeff Price	Gridsmart
66.	Robert Dingess	GTMA
67.	Matt Volz	HDR
68.	Joey Yang	HDR
69.	Joey Yang	HDR Inc.
70.	Jennifer Carter	HERE
71.	Weimin Huang	HERE
72.	Monali Shah	HERE
73.	Harry Voccola	HERE
74.	Ben Walker	HNTB
75.	Martha Morecock Eddy	HNTB
76.	Frank Perry	HNTB
77.	Sue Bai	Honda
78.	John Robb	Hyundai
79.	Oubada Abuchaar	Hyundai America Technical Center
80.	Frank Fickel	IAV Automotive
81.	Daniel Hermann	IAV Automotive
82.	Bob Koeberlein	Idaho Transportation Dept
83.	Saad Bedros	Image Sensing Systems
84.	Craig Gardner	Intelight

85.	Samian Kaur	InterDigital
86.	Scott Marler	Iowa DOT
87.	Siva Narla	ITE
88.	Cliff Heise	Iteris
89.	Alan Clelland	Iteris
90.	Cliff Heise	Iteris
91.	David Binkley	Iteris
92.	John Lower	Iteris
93.	Adrian Guan	ITS America
94.	Carlos Alban	ITS America
95.	Darryl Dawson	ITS Engineering Ltd.
96.	Brian Burkhard	Jacobs Engineering
97.	Brian DePan	Jacobs Engineering
98.	Oliver Brandl	Kapsch
99.	Nu Rosenbohm	Kapsch
100.	Chuck Mraz	Kapsch
101.	Dennis Motiani	KHA
102.	Douglas Gettman	Kimley-Horn
103.	Jonathan Moore	Kimley-Horn
104.	Ed Alegre	LA Metro
105.	Reinland Jones	LA Metro
106.	John Abraham	Macomb Co. DOR
107.	Devang Naik	Marben Products
108.	Nishil Naik	Marben Products
109.	Faisal Saleem	Maricopa Co., AZ
110.	Masashi Yamamoto	Mazda North American Operations
111.	Donald Mass	McCain
112.	Alan Korn	Meritor WABCO
113.	Jim Katsafanas	Michael Baker
114.	Matt Smith	Michigan DOT
115.	Ray Starr	MnDOT
116.	Emil Wolanin	Montgomery Co., MD
117.	Linda Lee	MTC
118.	Rob Rich	MTC
119.	Nisar Ahmed	MTC
120.	William Mahoney	National Center for Atmospheric Research
121.	Stanley Young	National Renewable Energy Laboratory
122.	John Bassett	New York State DOT
123.	Roy Goudy	Nissan Technical Center North America
124.	Kelly McVeigh	NJDOT
125.	Wasif Mirza	NJDOT
126.	Frank Prezioso	NJDOT
127.	Jeevanjot Singh	NJDOT

128.	Jeffrey Rockower	NJDOT
129.	Jonathan Martinez	NJDOT
130.	Ann Diephaus	Noblis
131.	Leland Key	NXP
132.	Steve Galgano	NYC
133.	Mohammad Talas	NYCDOT
134.	Richard McDonough	NYDOT
135.	Owais Memon	NYDOT
136.	Eryca McCartin Dinsdale	Oregon DOT
137.	Jan-Mou Li	ORNL
138.	George Webb	Palm Beach Co., FL
139.	Micheal Stelts	Panasonic
140.	Mark Kopko	PennDOT
141.	Robert Taylor	Pennsylvania Turnpike Commission
142.	Shel Leader	Private Consultant-Telecom
143.	Darcy Bullock	Purdue University
144.	Jeff Adler	Q-Free
145.	Jeff Adler	Q-Free
146.	Jim Misener	Qualcomm
147.	Gary Piotrowicz	RCOC
148.	Mary Doyle	SAE International
149.	S. William Gouse	SAE International
150.	Mary Doyle	SAE International
151.	Peter Thompson	SANDAG
152.	Ravi Puvvala	Savari
153.	Faroog Ibrahim	Savari
154.	Navin Katta	Savari
155.	Mike Schagrin	Schagrin Consulting
156.	William Whyte	Security Innovation
157.	Dave Miller	Siemens
158.	Dave Miller	Siemens
159.	Gary Wallace	SiriusXM Connected Vehicles
160.	Gary Strack	SKW Inc.
161.	Purser Sturgeon	Southwest Research Institute
162.	Koorosh Olyai	Stantec
163.	Rod Schebesch	Stantec
164.	Steve Lockwood	Steve Lockwood LLC
165.	Michael Baril	STV Incorporated
166.	Hiroto Nakajima	Subaru R&D
167.	Kyle Garrett	Synesis Partners
168.	Ed Seymour	TAMU
169.	Susan Wilson	Technology Planning
170.	Kevin Comstock	TNDOT

171.	Hideki Hada	Toyota
172.	Hongcheng Lu	Toyota
173.	Ed Bradley	Toyota Motor North America
174.	Kevin Ro	Toyota Motor North America, Inc.
175.	Kiel Ova	Traffic Technology Services, Inc.
176.	Jeff Spinazze	Trafficware.com
177.	Bob Rausch	Transcore
178.	Daniel Lai	Transpo Group
179.	Barry Pekilis	Transport Canada
180.	Ray Derr	Transportation Research Board
181.	Dean Erickson	Triunity
182.	Melissa Tooley	TTI
183.	Jianming Ma	TXDOT
184.	Andy Mao	TXDOT
185.	Andrew Harding	UL
186.	Debra Bezzina	UMTRI
187.	Debby Bezzina	UMTRI
188.	John Maddox	UMTRI
189.	Larry Head	University of Arizona
190.	Mohammed Hadi	University of Florida
191.	Carrie Morton	University of Michigan
192.	Jerome Lynch	University of Michigan
193.	Bezzina Debby	University of Michigan
194.	Robert Bertini	University of South Florida
195.	Hyungjun Park	University of Virginia
196.	Chen Danjue	University of Wisconsin
197.	Yang Cheng	University of Wisconsin
198.	John Riehl	University of Wisconsin
199.	Madhav Chitturi	University of Wisconsin
200.	Ken Leonard	USDOT
201.	Brian Cronin	USDOT
202.	Deb Curtis	USDOT
203.	Jon Obenberger	USDOT
204.	Leisa Moniz	USDOT
205.	Bob Arnold	USDOT
206.	Bob Rupert	USDOT
207.	Caitlin Bettisworth	USDOT
208.	Josh Hassol	USDOT
209.	Robert Sheehan	USDOT
210.	Suzanne Sloan	USDOT
211.	Dale Thompson	USDOT
212.	Karen Timpone	USDOT
213.	Mike Pina	USDOT

214.	Steve Sill	USDOT
215.	Kingsley Azubike	USDOT
216.	Carl Andersen	USDOT
217.	Robert Arnold	USDOT
218.	Robert Rupert	USDOT
219.	Bob Sheehan	USDOT
220.	Deborah Curtis	USDOT
221.	Gregory Davis	USDOT
222.	Blaine Leonard	Utah DOT
223.	Melissa Lance	VDOT
224.	Virginia Lingham	VDOT
225.	Andrew Cunningham	Volkswagen Group
226.	Stephanie Fischer	Volpe Center-USDOT
227.	Sean Peirce	Volpe Center-USDOT
228.	Skip Yeakel	Volvo Group North America
229.	Ray Resendes	VTTI
230.	Shaun Quayle	Washington Co., OR
231.	Michael Jensen	Wavetronix
232.	Geoff Smith	WMC
233.	Bill Legg	WSDOT
234.	Steve Kuciemba	WSP | Parsons Brinckerhoff
235.	Scott Shogan	WSP | Parsons Brinckerhoff
236.	Tom Timcho	WSP | Parsons Brinckerhoff
237.	Thomas Timcho	WSP | Parsons Brinckerhoff
238.	Joe Averkamp	Xerox
239.	Bryan Nace	
240.	John Thai	
241.	Raman Patel	

Appendix B: Connected Vehicle Applications Survey Results

Vehicle to Infrastructure Deployment Coalition (V2I DC) and AASHTO CAV TWG

Connected Vehicle Applications Survey Results
February, 2016

1.0 Introduction

The Vehicle to Infrastructure Deployment Coalition (V2I DC) is organized through AASHTO, ITS and ITS America. The first meeting of the V2I DC and technical working groups (TWGs) was held in June 2015, where the top V2I deployment issues were presented and discussed by five technical working groups.

Members of the V2I DC Technical Working Group 1: Deployment Initiatives (TWG 1) decided to survey infrastructure owners and operators (state and local DOTs) about several topics related to the issues being addressed by the coalition. In addition, input from the AASHTO Connected and Automated Vehicle TWG (CAV TWG) led to additional questions in the survey.

This document summarizes the results of the survey, and presents the input received from responders.

The survey was distributed by AASHTO to 48 individuals identified through collaboration of the V2I DC and AASHTO CAV TWG.

Section 2 below presents a summary of the survey results. Section 3 presents the actual responses received from survey participants.

2.0 Summary of Survey Results

The subsections below present a summary of the survey results.

2.1 Phone Survey Respondents and Results

Two agencies opted to participate in a phone conversation to provide input on CV applications rather than completing the online survey. The phone responses resulted in the following free responses.

- A local agency explained their primary short-term emphasis for Connected Vehicles would likely be traffic signal control.
- A state agency had multiple comments:
    - Success will be a measure of the penetration and the acceptance of the roadside deployments and vehicle applications.
    - Safety is their highest priority, but it needs to go beyond just delivering warnings to the vehicle to also interacting with the V2V control aspects.
    - Traffic Signals are low on their list because it requires most or all vehicles to be equipped to recognize the most value.
    - The agency described 3 levels of safety applications:
        - Static alerts of threats to drivers (e.g. “30 MPH” warning on curves)
        - Monitor vehicle performance and warn if needed (e.g. display “30 MPH if vehicles going above XX speed)

- Potential Automation has the highest potential for impact (external alert sent from the roadside work with on-board controls to adjust vehicle speed and with V2V to warn other vehicles)

2.2 Online Survey Respondents and Results

The online survey resulted in 21 full responses to the survey.

The questions asked in the online survey were as follows:

- Question 1: Please indicate the agency you are representing.
- Question 2: If you would like to discuss the responses to these questions by phone, instead of completing the survey, please provide a convenient way to contact you and we will do so.
- Question 3: Please identify the Connected Vehicle applications that are included in your agency's plan or proposal for Connected Vehicle deployment, or that you have already deployed. Please also indicate which 5 applications you feel are the most beneficial to deploy.
- Question 4: If there were additional applications that you seriously considered, but decided not to include in your proposed or planned deployment, please list those, together with an explanation of why you decided not to include the application(s).
- Question 5: What are the problems you are solving by deploying these applications?
- Question 6: What communication technology approaches are included in your plan/proposal?
- Question 7: If DSRC is a communication approach identified in #6 above, please provide the DSRC messages you used/plan to use for your DSRC communications?
- Question 8: If you have identified any current infrastructure processes (e.g. environmental reviews, MUTCD compliance, etc.) or other challenges (lack of backhaul, technical capability, lack of developed applications, security concerns, etc.) which will prevent or hinder your deployment of the Connected Vehicle infrastructure, please list those with a brief explanation.
- Question 9: As you have worked toward deployment (planning, pilot proposal preparation, early deployment experience, etc.), what are the two most important or surprising things you have discovered that you think would be useful for others to be aware of?

The following subsections include a summary of the responses received. A complete list of survey responses is included in Section 3.

2.2.1 Online Survey Responses Related to V2I Applications

Question 3 of the survey gathered feedback in three key areas:

- *Which CV applications are **included in the respondent's proposal or plans** for CV deployment?*
  The intent of this question was to capture the extensive consideration that infrastructure owners and operators dedicated to preparing Connected Vehicle pilot deployment proposals and/or other plans for connected vehicle deployment.
- *Which CV applications responding agencies felt **were most beneficial**.*
  The intent of asking this question was a recognition that applications included in proposals or plans might not be all the applications an agency feels are most beneficial. For example, proposals might focus on those applications that can be deployed in the very near-term or with the current level of in-vehicle devices. Note: for this portion of the question, each responder was asked only to indicate the top five most beneficial applications.
- *Which CV applications responding agencies **had already deployed.***
  The intent of this question was to understand which applications have already been deployed by agencies and how these are similar or different to the applications they feel would be most beneficial.

The survey presented 72 V2I applications contained in the Connected Vehicle Reference Implementation Architecture (CVRIA) and allowed responders to select the application(s) related to each of the questions asked in Question 3. Applications were presented and analyzed in 8 groupings based on the designated CVRIA group (e.g. AERIS/Sustainable Travel, Road Weather). Some groups were combined to reduce the size of the survey text. Twenty-one responses to this question were received.

2.2.1.1 Connected Vehicle Applications Included in Proposals or Plans for Deployments

Of the 72 connected vehicle applications presented, most were identified by at least one agency as being a CV application included in their plans or proposals for deployment as shown in Figure 1.

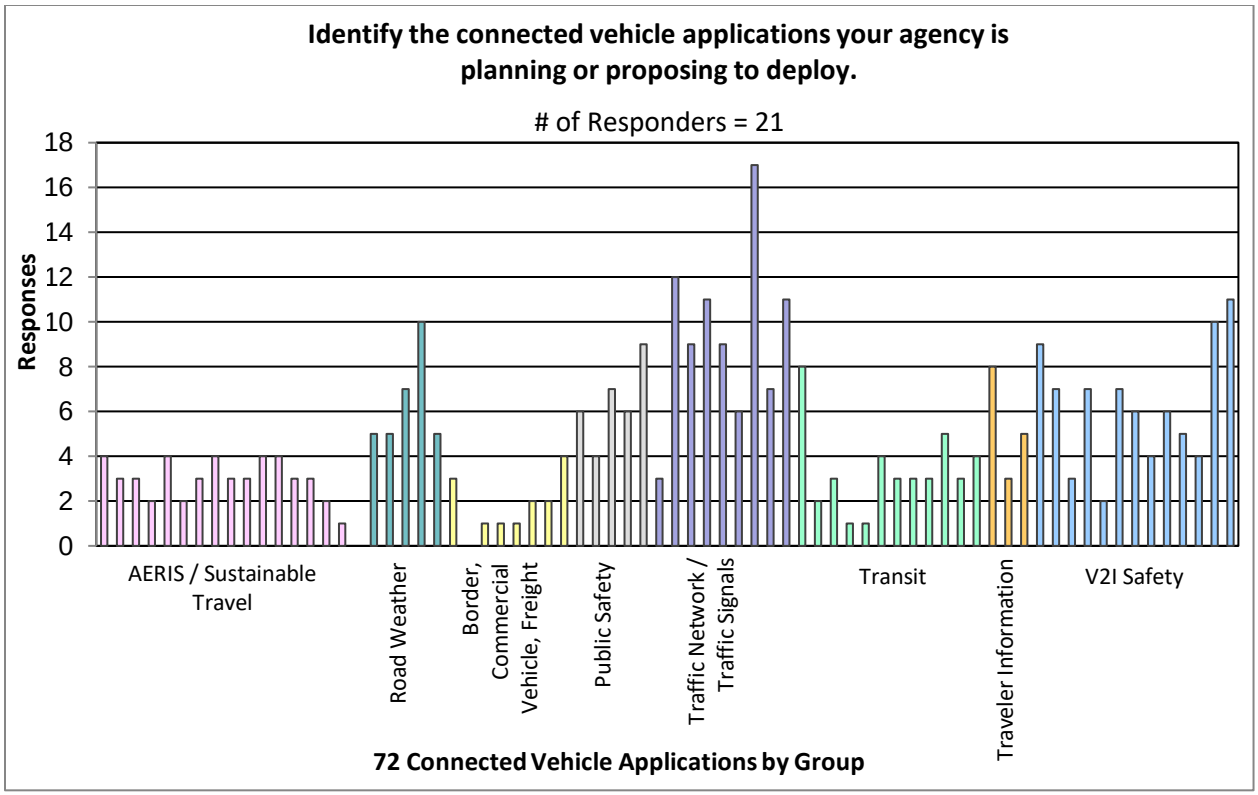

Figure 1: Connected Vehicle Applications Included in Agencies Plans or Proposals for Deployment by Application Group

The top 11 responses of connected vehicle applications from Figure 1 that are included in or proposed in agency plans are shown in Figure 2. These connected vehicle applications included 6 applications in the Traffic Network/Traffic Signals group, 3 applications in the V2I Safety group, 1 application in the Road Weather group, and 1 application in the Public Safety group. For example, 17 out of 21 survey responders indicated that the Intelligent Traffic Signal System application in the Traffic Network/Traffic Signals category has been included in their agency's plan or proposal for Connected Vehicle deployment.

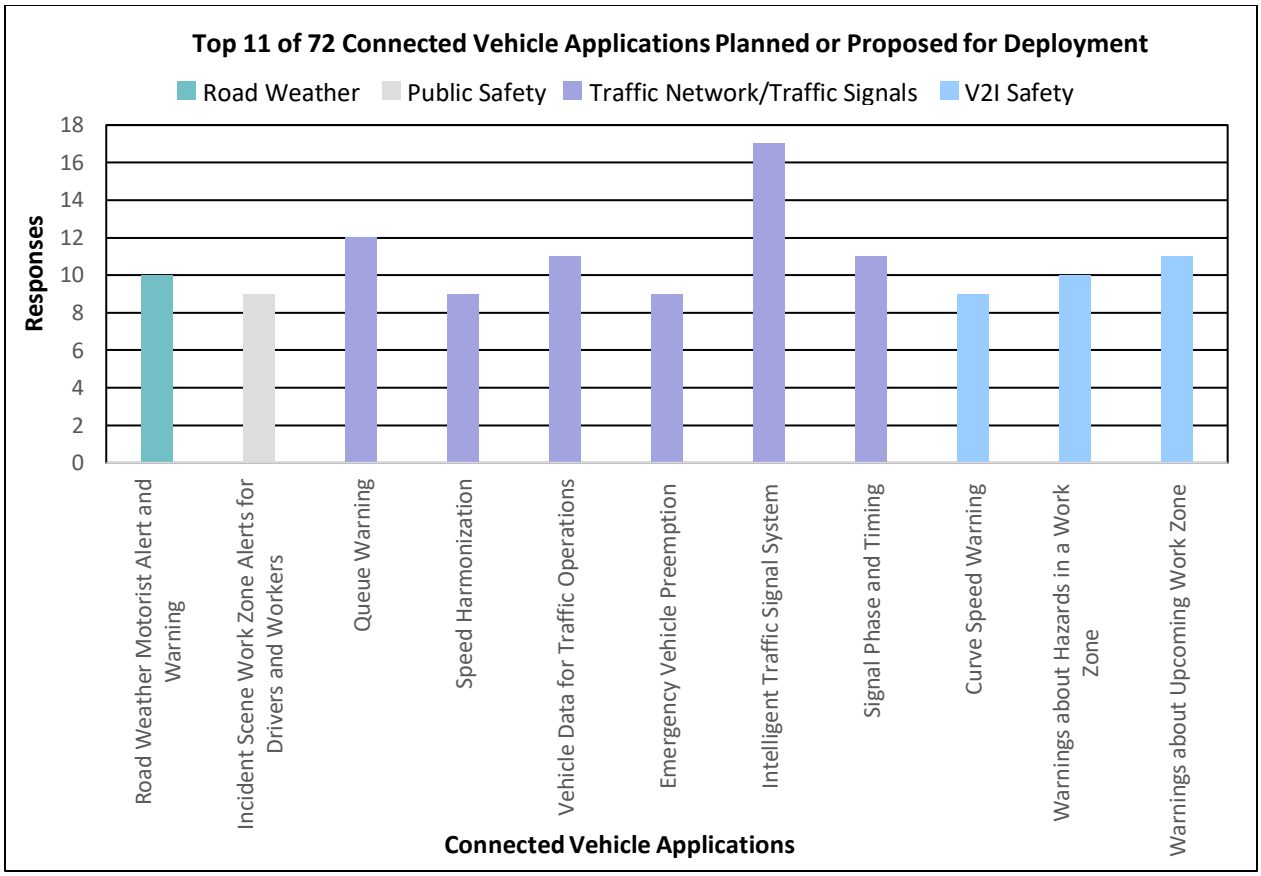

Figure 2: Top 11 of 72 Connected Vehicle Applications Planned or Proposed for Deployment

In September, 2015, the V2I DC Executive Committee met in Denver, Colorado. During this meeting, the V2I DC Executive Committee identified the following four focus areas for connected vehicle applications:

1. Intersections
2. Queue Warnings
3. Work Zone Management
4. Curve Warnings

Figure 3 maps the four focus areas to the top 11 applications included in agency plans or proposals.

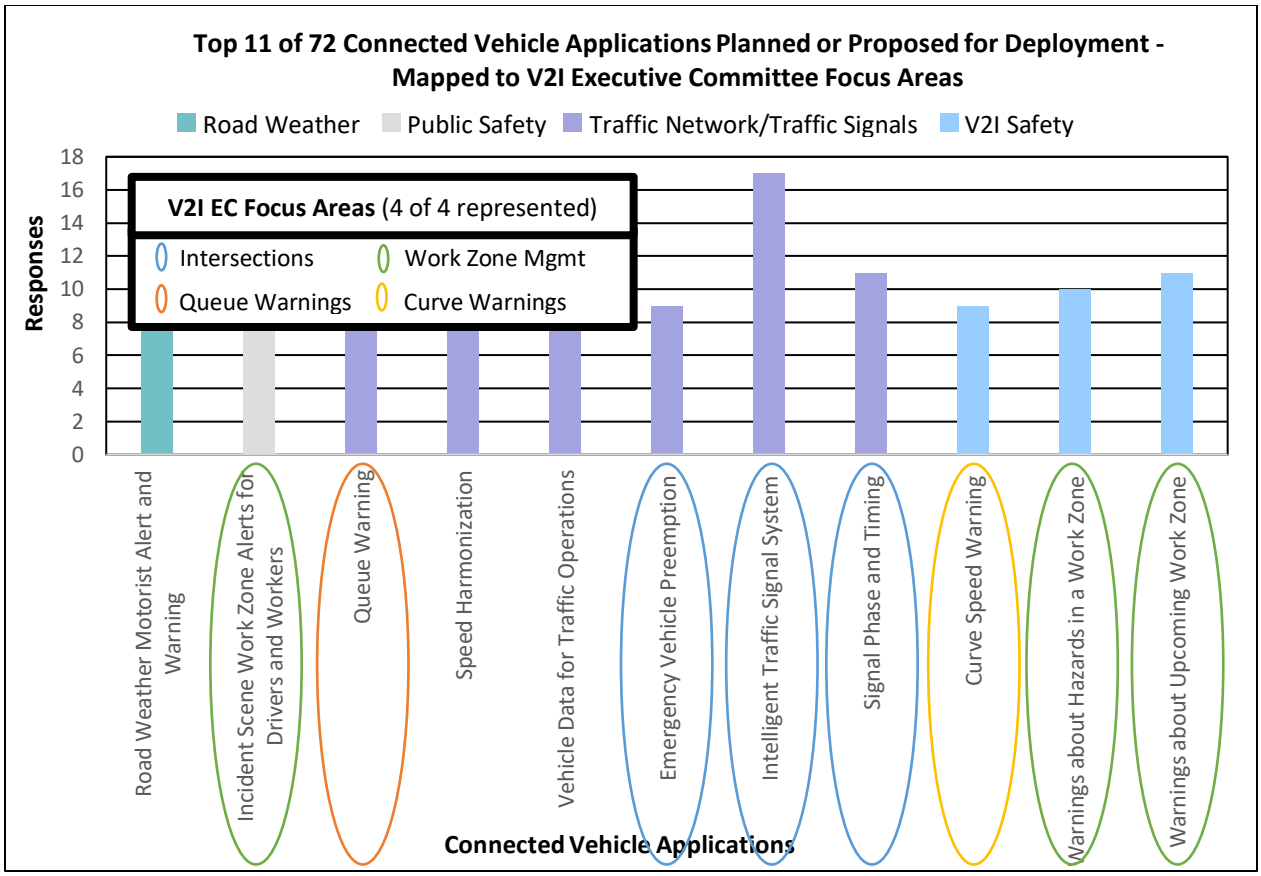

Figure 3: Top 11 of 72 Connected Vehicle Applications Planned or Proposed for Deployment – Mapped to V2I Executive Committee Focus Areas

2.2.1.2 Connected Vehicle Applications Most Beneficial to Deploy

Survey responders also reviewed the 72 connected vehicle applications presented in the survey and selected the 5 applications they felt were most beneficial to deploy. Figure 4 shows that though several applications were selected, not all applications were selected.

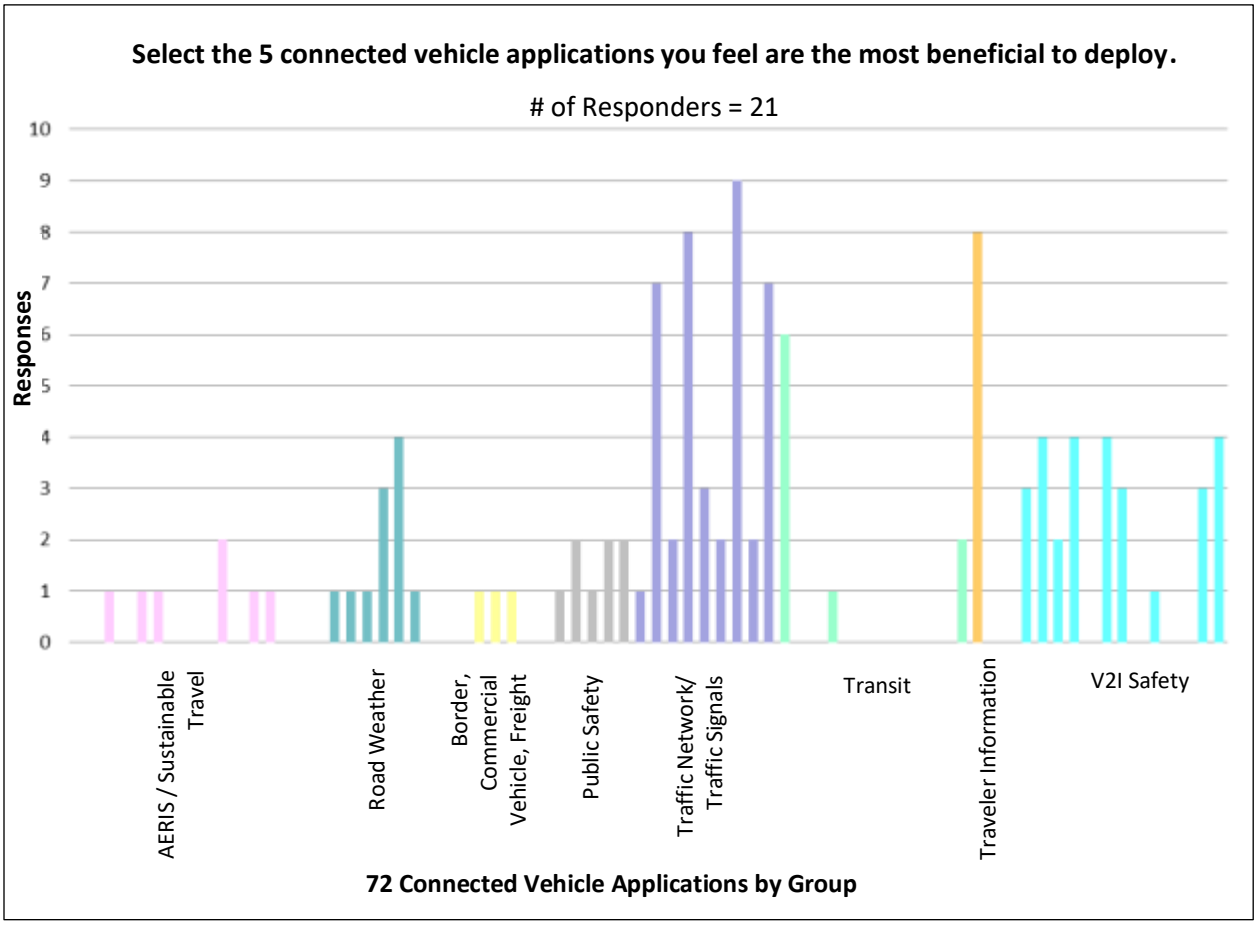

Figure 4: Connected Vehicle Applications Most Beneficial to Deploy

The top 11 CV applications that were viewed as most beneficial to deploy are shown in Figure 5. Of these top 11 applications, 4 applications were from the Traffic Network/Traffic Signals group and 4 applications were from the V2I Safety group. The Road Weather, Transit, and Traveler Information groups each had 1 CV application viewed as most beneficial to deploy.

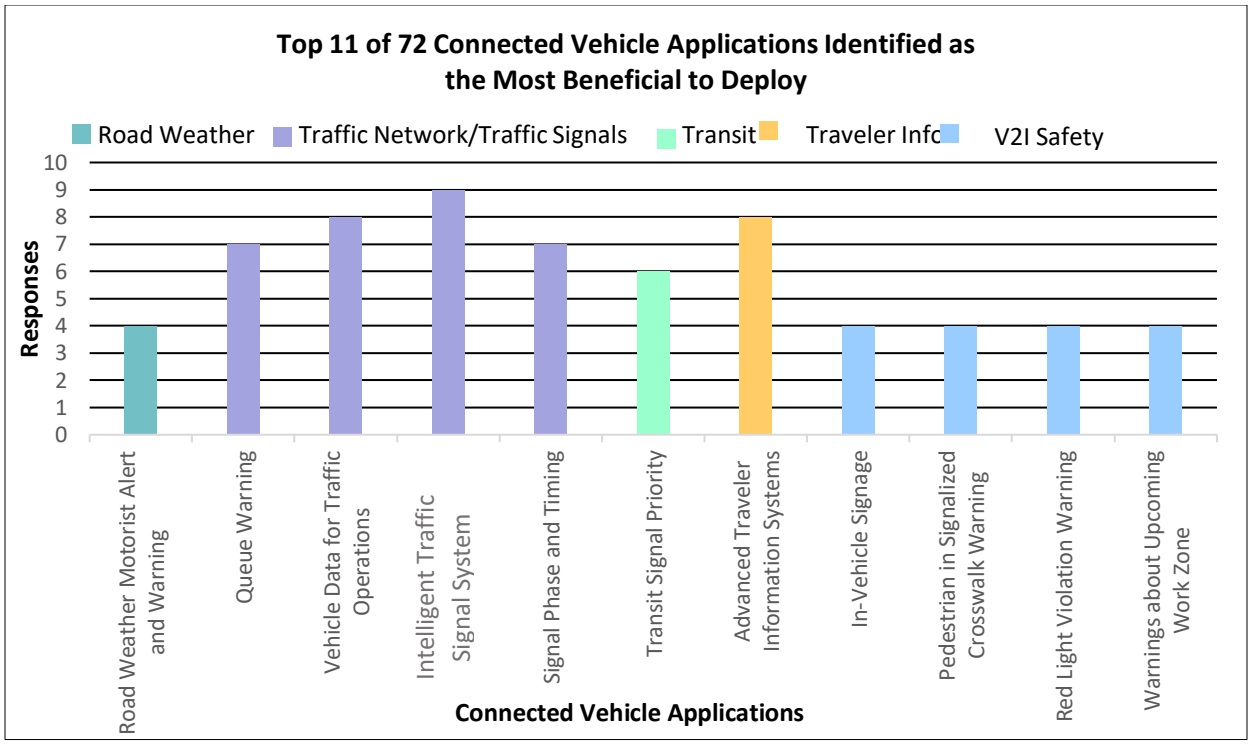

Figure 5: Top 11 Connected Vehicle Applications Most Beneficial to Deploy

Figure 6 maps the top 11 applications identified by 21 responders as being the most beneficial to deploy against the four focus areas defined for the V2I DC.

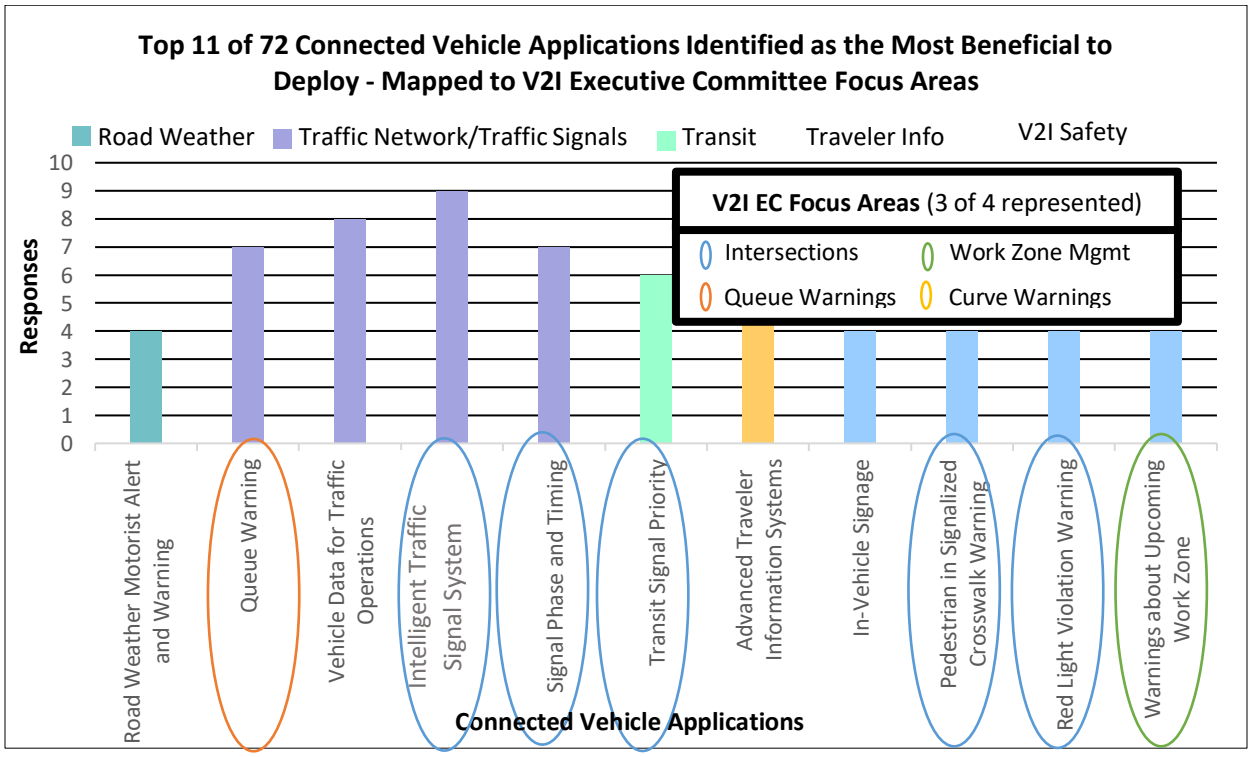

Figure 6: Top 11 Connected Vehicle Applications Most Beneficial to Deploy – Mapped to V2I EC Focus Areas

2.2.1.3 Comparison of the Most Beneficial CV Applications with the Proposed/Planned CV Applications

Comparing the top 11 most selected planned or proposed applications with the top 11 most beneficial applications reveals 6 applications that are both planned/proposed for deployment and viewed as one of the top 11 most beneficial applications.

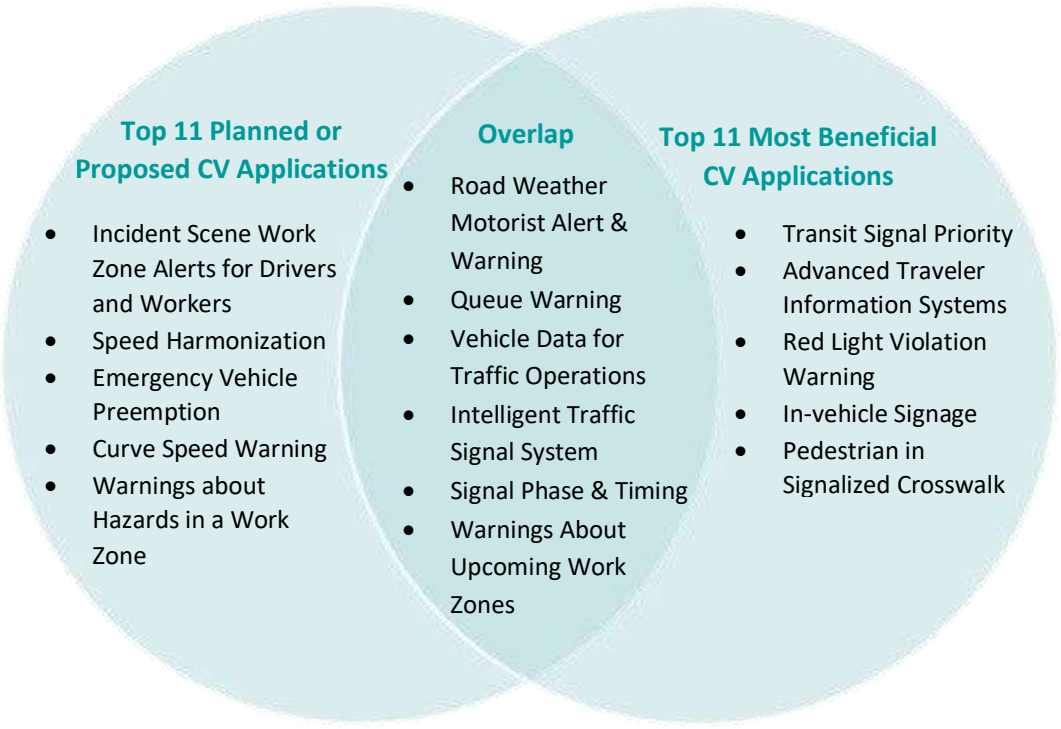

Figure 7:Overlap of Top 11 Connected Vehicle Applications Most Beneficial to Deploy and Top 11 CV Applications Planned or Proposed for Deployment

2.2.1.4 Deployed Connected Vehicles Applications

Survey respondents were asked which of the 72 connected vehicle applications included in the survey they had already deployed. Figure 8 shows the CV applications that were deployed by 2 or more agencies. Signal Phasing and Timing had the largest number of responses (4). Note: Signal Phase and Timing is identified as a support application in the CVRIA. However, this application was included in the survey because of the strong interest and discussions during the survey development.

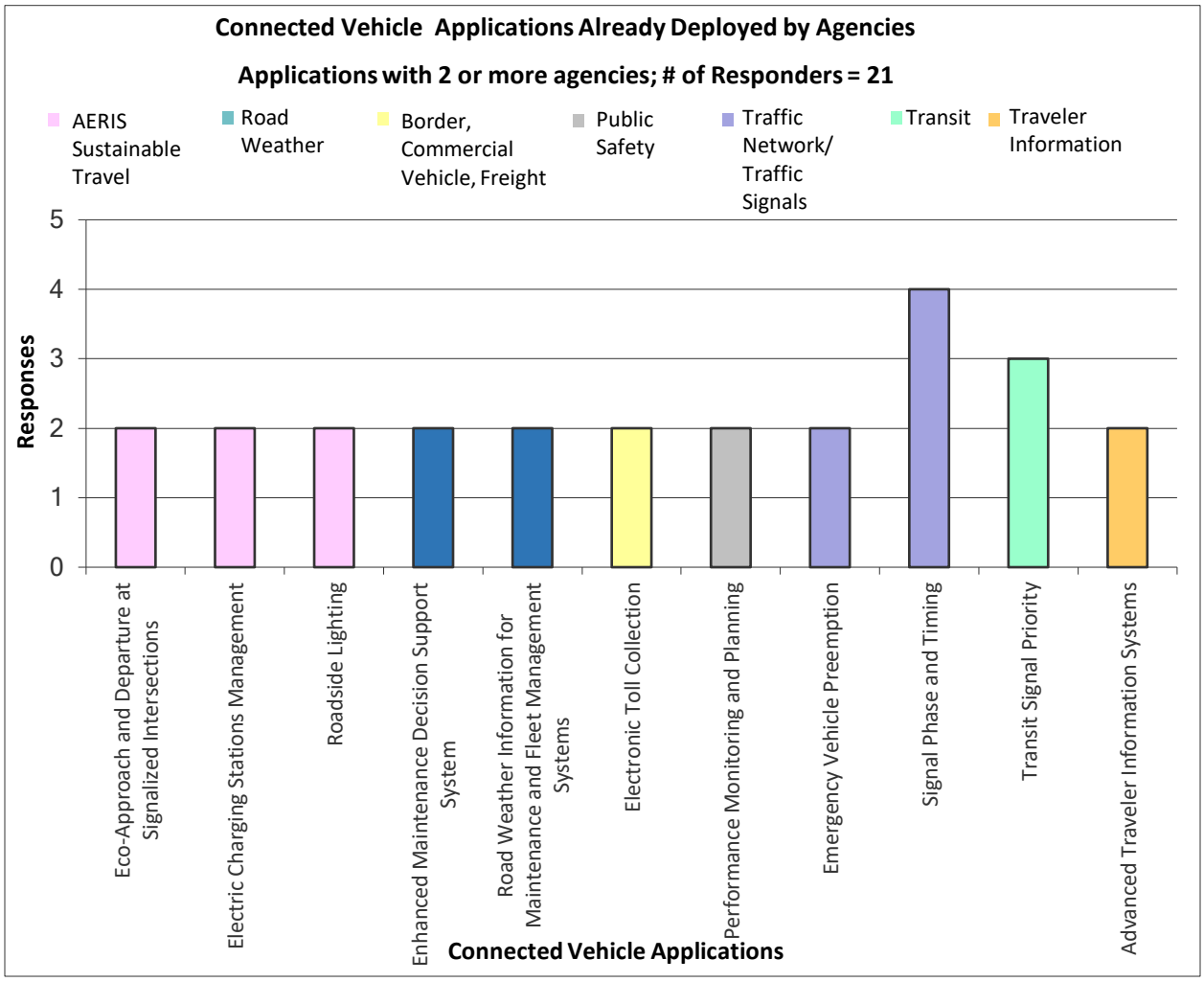

Figure 8: Connected Vehicle Applications Already Deployed by Agencies

Figure 9, below, maps the top 11 applications deployed against the V2I DC Executive Committee defined focus areas. Of the top 11 applications already deployed, Emergency Vehicle Preemption, Signal Phase and Timing, and Transit Signal Priority are all included in the Intersections focus area. No other focus areas are represented in these top 11 deployed applications.

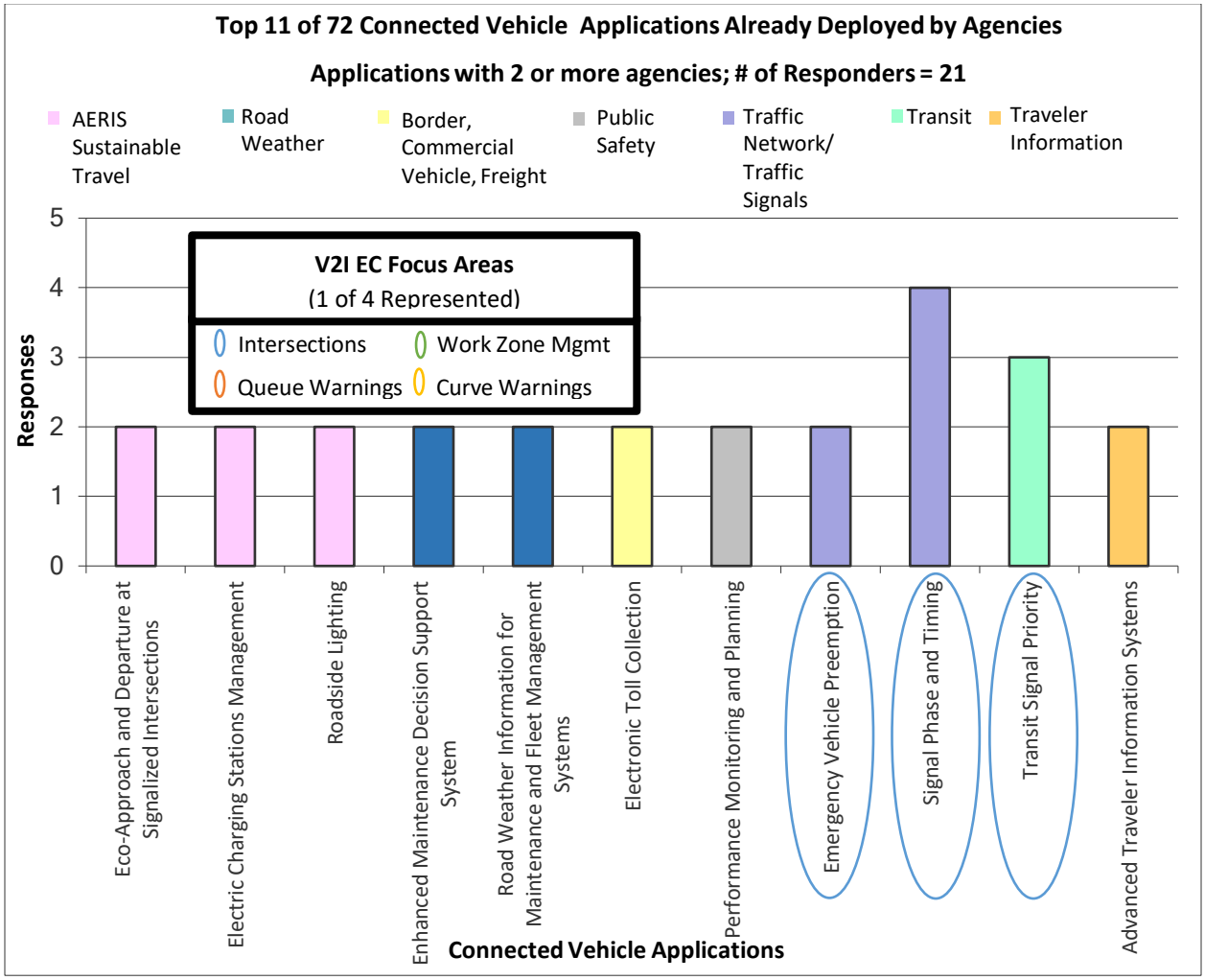

Figure 9: Top 11 Connected Vehicle Applications Already Deployed by Agencies – Mapped to V2I Focus Areas

2.2.2 CV Applications Considered but Not Included in Planned or Proposed Deployments

Survey responders were asked to identify applications that they considered deploying but chose not to include in their planned deployments as well as the reasons they made that decision. The types of applications most frequently considered but not deployed were transit and safety applications. Some identified applications included:

- Transit
- Applications that require a high saturation of DSRC enable vehicles
- T-Connect
- Safety applications
- Bicycle share stations and car share stations
- Commercial vehicles
- Intersection collision warning systems
- Monitoring vehicle traffic control, antilock braking systems and air bag deployment for snow removal operations and incident/crash detection

The primary reason for not deploying applications was the need for more vehicles to use the available technology. A complete list of survey responder comments is included in Section 3.0.

2.2.3 Problems Solved by Deploying Connected Vehicle Applications

Fifteen survey responders noted problems that are solved by deploying connected vehicle applications. These problems include the following samples:

- Response time
- Travel time of transit buses and trucks
- Mobility of general travelers
- Safety in congested corridors
- Safety of roadside works and first responders
- Safety at intersections
- Improve air quality

A complete list of survey responder comments is included in Section 3.0.

2.2.4 Communication Technology Approaches Included in Agency Plans and Proposals

Survey respondents were asked to identify the communication technology approaches that were included in their plans or proposals. Seventeen respondents identified their communication approaches. Many approaches were identified, however, DSRC was an overwhelmingly common approach. Cellular communication and fiber also received a notable response to a somewhat lesser degree. Additional approaches considered included existing backhaul communications, WiFi, GPS, and the Internet.

A complete list of survey responder comments is included in Section 3.0.

2.2.5 DSRC Messages Used or Planned for DSRC Communications

Fourteen survey respondents using a DSRC approach in their plan/proposal identified many DSRC messages they used or planned to use for DSRC communications. Basic Safety Message (BSM) and Signal Phase and Timing (SPaT) were the most common responses but there were a significant number of messages submitted including:

- Basic Safety Message (BSM)
- Signal Phase and Timing (SPaT)
- Common Safety Request
- Intersection Collision
- MAP
- NMEA Corrections
- Probe Data Management
- Probe Vehicle Data
- Roadside Alert
- Signal Request Message
- Signal Status Message
- Basic Infrastructure Message
- Basic Mobility Message
- PDM/PMM
- Personal Safety Message
- Road Weather Info
- RTCM Corrections
- Snow Plow Signal Priority Request
- Traveler Information
- TSP Requests
- Vehicle to Vehicle Communication
- Library of Accepted Message Packets
- To Be Determined

2.2.6 Processes or Challenges Preventing/Hindering Deployment CV Infrastructure

Responders were asked to identify any current infrastructure processes or other challenges that will prevent or hinder deployment. Responses from 15 survey responders are summarized by the following bullets.

- DSRC Security
- Existing Patents
- IT security – lack of guidance
- Combining 2 or more CV apps into a single app
- Lack of application readiness / developed applications
- Lack of documentation of application details
- Lack of supporting research
- Uncertain timing around NHTSA rule making & anticipated rollout of vehicles with DSRC
- Simple Terminology (CV vs. AV; V2I vs. V2V vs. V2X)
- Backhaul (the lack of)
- Cities have different set of operating philosophies than State DOTs

2.2.7 Important and Surprising Lessons Learned

Survey responders provided important or surprising things they discovered as they have worked toward connected vehicle deployment. Responses received were summarized into five categories: Technology Related Comments, Current Challenges, Rate of Change, Coordination/Communication, and Deployment Decisions. A sampling of responses is noted below.

Technology Related Comments

- DSRC works well in a hot climate and the range is greater than expected.
- Some of the pieces are far from being ready for real deployment; there are very few developed applications.
- Installation of connected vehicle infrastructure is not a "cookie cutter" process; each individual site has its own nuances requiring engineering judgement for such decisions as antenna

placement, cable runs through conduits, and choice of backhaul technology. Our agency has not determined the best way to begin including connected vehicle installations as part of our regular Planning process. It is different from our normal Capital Improvement process, so we will need to adapt our existing processes to accommodate it.
- It takes time for applications to mature to full deployment.

Current Challenges

- Many, especially local agencies, do not have the bandwidth to keep up, which is creating a large disconnect between federal initiatives, private industry, and local owners / operators.
- Successful CV will be highly dependent on partnerships across many modes to fully leverage regional benefits- one off agency specific applications will not ever move the needle in terms of benefits. Despite some information on costs and benefits, right now it is very hard to confidently quantify them so surprises (some perhaps unpleasant) are going to happen. Deploying CV at this point is risky. Agency access to private vehicle CV data is still undefined and therefore worrisome at this point.

Rate of Change

- The rapid development of automated vehicle technology and the projection of these vehicles operating on roadways in the near future.
- It is incredible how quickly the field is advancing right now.

Coordination/Communication

- Having a good relationship between IT and Operations is key.
- There is a lack of common vision between local agencies and State DOT's. That gap needs to be closed.
- It is difficult at this point to gain tremendous public input on this process. I feel it is a lack of understanding.
- Successful CV will be highly dependent on partnerships across many modes to fully leverage regional benefits.

Deployment Decisions

- Listening to the conversations of other submitting agencies, there appears to be a 'pick-and-choose' approach to application lists, rather than concentrating on transitioning existing job functions/responsibilities to new infrastructure….
- Transit agencies are very interested in deploying CV to improve transit operations.

A complete list of survey responder comments is included in Section 3.0.

3.0 Survey Reponses

Each section below presents the survey question, the number of responses, and each response as they were received.

Question 1: Please indicate the agency you are representing.

23 Responses:

- Arizona DOT, TSMO Division
- California DOT
- City of Alexandria, VA
- City of Chattanooga, TN
- City of Palo Alto
- King Count Metro Transit
- Louisiana DOTD
- Maricopa County
- Metropolitan Transportation Commission (MTC)
- Michigan DOT
- Minnesota DOT
- NYCDOT
- NYSDOT
- Oregon DOT
- Pennsylvania DOT
- The Ohio State University of Mobility Research and Business Development
- THEA Connected Vehicle Pilot Deployment
- Utah DOT
- Virginia DOT
- VTTI
- Washington State DOT
- Wisconsin DOT

Question 2: If you would like to discuss the responses to these questions by phone, instead of completing the survey, please provide a convenient way to contact you and we will do so.

Based on responses, two telephone interviews were conducted.

Question 3: Please identify the Connected Vehicle applications that are included in your agency's plan or proposal for Connected Vehicle deployment, or that you have already deployed. Please also indicate which 5 applications you feel are the most beneficial to deploy.

21 Responses:

Connected Vehicle Application	We are planning or have proposed to deploy this application	We have deployed this application	As an agency, select the 5 applications you feel are the most beneficial to deploy
Connected Eco-Driving (ST)	4	1	0
Dynamic Eco-Routing (ST)	3	0	0
Eco-Approach and Departure at Signalized Intersections (ST)	3	2	1
Eco-Cooperative Adaptive Cruise Control (ST)	2	0	0
Eco-Freight Signal Priority (ST)	4	1	1
Eco-Integrated Corridor Management Decision Support System (ST)	2	0	1
Eco-Lanes Management (ST)	3	0	0
Eco-Multimodal Real-Time Traveler Information (ST)	4	0	0
Eco-Ramp Metering (ST)	3	1	0
Eco-Smart Parking (ST)	3	0	2
Eco-Speed Harmonization (ST)	4	0	0
Eco-Traffic Signal Timing (ST)	4	1	1
Eco-Transit Signal Priority (ST)	3	0	1
Electric Charging Stations Management (ST)	3	2	0
Low Emissions Zone Management (ST)	2	0	0
Roadside Lighting (ST)	1	2	0
Enhanced Maintenance Decision Support System (RW)	0	2	1
Road Weather Information and Routing Support for Emergency Responders (RW)	5	1	1
Road Weather Information for Freight Carriers (RW)	5	1	1
Road Weather Information for Maintenance and Fleet Management Systems (RW)	7	2	3
Road Weather Motorist Alert and Warning (RW)	10	1	4
Variable Speed Limits for Weather-Responsive Traffic Management (RW)	5	0	1
Border Management Systems (BCVF)	3	0	0
Container Security (BCVF)	0	0	0
Container/Chassis Operating Data (BCVF)	1	0	0
Smart Roadside Initiative (BCVF)	1	0	1
Electronic Toll Collection (BCVF)	1	2	1
Road Use Charging (BCVF)	2	0	1
Freight Drayage Optimization (BCVF)	2	0	0

Connected Vehicle Application	We are planning or have proposed to deploy this application	We have deployed this application	As an agency, select the 5 applications you feel are the most beneficial to deploy
Freight-Specific Dynamic Travel Planning (BCVF)	4	0	0
Performance Monitoring and Planning (PS)	6	2	1
Advanced Automatic Crash Notification Relay (PS)	4	1	2
Emergency Communications and Evacuation (PS)	7	0	1
Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (PS)	6	0	2
Incident Scene Work Zone Alerts for Drivers and Workers (PS)	9	0	2
Cooperative Adaptive Cruise Control (TNTI)	3	0	1
Queue Warning (TNTI)	12	0	7
Speed Harmonization (TNTI)	9	1	2
Vehicle Data for Traffic Operations (TNTI)	11	0	8
Emergency Vehicle Preemption (TNTI)	9	2	3
Freight Signal Priority (TNTI)	6	1	2
Intelligent Traffic Signal System (TNTI)	17	0	9
Pedestrian Mobility (TNTI)	7	0	2
Signal Phase and Timing (TNTI)	11	4	7
Transit Signal Priority (Tran)	8	3	6
Dynamic Ridesharing (Tran)	2	0	0
Dynamic Transit Operations (Tran)	3	0	0
Integrated Multi-Modal Electronic Payment (Tran)	1	1	1
Intermittent Bus Lanes (Tran)	1	0	0
Route ID for the Visually Impaired (Tran)	4	0	0
Transit Connection Protection (Tran)	3	0	0
Smart Park and Ride System (Tran)	3	0	0
Transit Stop Request (Tran)	3	0	0
Transit Pedestrian Indication (Tran)	5	0	0
Transit Vehicle at Station/Stop Warnings (Tran)	3	0	0
Vehicle Turning Right in Front of a Transit Vehicle (Tran)	4	0	2
Advanced Traveler Information Systems (TI)	8	2	8
Receive Parking Space Availability and Service Information (TI)	3	1	0
Traveler Information- Smart Parking (TI)	5	1	0
Curve Speed Warning (V2IS)	9	0	3
In-Vehicle Signage (V2IS)	7	1	4
Oversize Vehicle Warning (V2IS)	3	1	2
Pedestrian in Signalized Crosswalk Warning (V2IS)	7	0	4
Railroad Crossing Violation Warning (V2IS)	2	0	0
Red Light Violation Warning (V2IS)	7	0	4
Reduced Speed Zone Warning / Lane Closures (V2IS)	6	1	3

Connected Vehicle Application	We are planning or have proposed to deploy this application	We have deployed this application	As an agency, select the 5 applications you feel are the most beneficial to deploy
Restricted Lane Warnings (V2IS)	4	0	0
Spot Weather Impact Warning (V2IS)	6	0	1
Stop Sign Gap Assist (V2IS)	5	1	0
Stop Sign Violation Warning (V2IS)	4	0	0
Warnings about Hazards in a Work Zone (V2IS)	10	0	3
Warnings about Upcoming Work Zone (V2IS)	11	0	4

Question 3 Comments:

- VDOT is in the process of developing a CV Program Plan. The column to the right, indicates the ones we felt would benefit our agency most.
- We are also implementing EEBL and FCW.
- Although I do not represent VDOT, our priorities reflect VDOT priorities.
- V2I Based Decision Support System for Integrated Corridor Management (should not be only limited to Eco-ICM as listed above).
- Comment on Question 3: Several of the applications are components of bundles of applications. For example, MMITSS includes Vehicle Data for Traffic Operations, Emergency Vehicle Preemption, Freight Signal Priority, Intelligent Traffic Signal System, Pedestrian Mobility, Signal Phase and Timing, and Transit Signal Priority and INFLO includes Queue Warning and Speed Harmonization and could include Variable Speed Limits for Weather-Responsive Traffic Management. In responding to the third column (….select the 5 applications that you feel are the most beneficial to deploy) we feel that the bundles should be considered as opposed to individual applications. Also, several applications, such as cooperative adaptive cruise control, curve speed warning, in-vehicle signing, red light violation warning, etc. require participation by the vehicle. These applications are highly desirable and the infrastructure side is possible and desirable if the vehicles are capable.
- We have just concluded a six route BRT deployment which includes CV infrastructure for Transit Signal Priority, including signal phase monitoring, intermodal electronic fare payment and roadside bus arrival signs.
  I did not select any proposed applications because we are currently in a strategic planning phase where we are considering many of these applications.
- Our ATIS is currently under development.
- We would like to be able to monitor vehicle traction control, antilock braking and air bag deployed systems to enable better snow removal operations and incident/crash detection.

Question 4: If there were additional applications that you seriously considered, but decided not to include in your proposed or planned deployment, please list those, together with an explanation of why you decided not to include the application(s).

10 Responses:

- We are in early stages of planning proposed applications. The initial application deployments will be applications that require little penetration. Some of the applications that we find beneficial would require more penetration.
- Additional applications of interest would include transit applications (as listed in Question 3) but they are not in the current plans.
- We have decided not to include applications that require a high saturation of DSRC enabled vehicles in order to realize the benefits of the application, such as I-SIG, CACC, and applications relating to Toll Collection. We had also initially considered using T-Connect, but determined that wouldn't be feasible to deploy that application in the near future because of the readiness of the application as well as the need to modify transit operations frameworks in order to take advantage of the functionality of the application. Also, the benefits and impacts of the T-Connect application, either to the individual users or the system as a whole, were not clear. Finally, road weather applications were considered, but the lack of severe weather in the Bay Area led to a lack of interest from stakeholders.
- There are several freight-related applications that we expect will be deployed by regional agencies located near ports or border crossings. While we support the implementation of these applications, we will not lead them.
- We focused on applications that could be beneficially deployed in the short term, which usually meant employing fleet vehicles. There are some important safety applications that we are interested in, but until there are significant numbers of private vehicles with CV technology, we don't see a short-term benefit. So, by deploying applications which can utilize fleets (buses, trucks, etc.), we can justify building infrastructure, and will then have that infrastructure for future applications.
- The difficulty is knowing which applications will be supported in the vehicle. We have prioritized items which we already have some infrastructure to support over things that would be new to us.
- Bicycle share stations and car share stations as part of our ITS and V2I network. The Bike Share information will be provided to our vision of the ATIS deployment to provide an informed modal choice to the public. It is assumed that the Bike industry will be included in the V2I discussion particularly in urban areas with significant bike infrastructure. This infrastructure requires exclusive ped phasing and will need to be relayed to the public in using other modes.
- Applications related to commercial vehicles and transit vehicles. The reason for not including is I am not quite sure the role of a state DOT in supporting/deploying these type applications.
- Monitoring vehicle traction control, antilock braking systems and air bag deployment for snow removal operations and incident/crash detection.
- Intersection collision warning systems - proposal was urban focused, these system have more benefit in the rural setting

Question 5: What are the problems you are solving by deploying these applications?

15 Responses:

- VDOT is mapping all the applications that it plans to deploy to its overall business goals and performance measures. Crash reduction, travel time delay, etc.
- We believe that connected vehicle applications can address many transportation problems including response time of emergency vehicles/first responders (EV priority), travel time of transit buses and trucks, mobility of general travelers, safety in congested corridors (e.g. VSL, queue warning, speed harmonization), safety of first responders and roadside workers.
- Mainly addressing safety issues and providing drivers relevant information in a timely manner
- Right hand turn congestion and rear end collisions pedestrian safety crossing street congestion on Main Street (meridian).
- Reducing congestion - Improving transit reliability - Increasing transit mode share - Improving transit operations Addressing transit operator's communications needs – Improving roadway reliability – Improving safety – Reducing GHG and other environmental impacts – Improving operations at the Port of Oakland – Reducing incidents due to queues on freeways and major arterials.
- Improved mobility of goods and reduced emissions from commercial trucks.
- Congestion and work zone safety
- Reduce delays and improve safety through enhanced traffic signal operations and Integrated Corridor Management.
- We have assisted CMU with installing 35 DSRC units in signal controllers and are planning to install an additional 11 on PennDOT signals. The upgrades were initially performed when the controllers were replaced with adaptive signal. Right now the DSRC units are used to relay signal timing and phasing information to CMU's autonomous vehicle. In the future we plan to add additional applications to the signals.
- Improve transit schedule reliability, gather important road weather data from areas where we don't currently have good data so we can improve road safety and maintenance efforts, improve air quality.
- Similar problems that we are solving today -- just moving to technology we think can be more effective utilizing connected vehicle technology
- Because of exclusive bike phasing, there will be additional delay at signalized intersections within the urban core. We feel that the presence of bicycles constitutes an additional need for information by the driver of motor vehicles. Noting the bike presence in the network will provide that additional awareness.
- Safety at intersections.
- Better manage congestion, improve safety and reliability.
- Freight, transit, and general mobility efficiency.

Question 6: What communication technology approaches are included in your plan/proposal?

17 Responses:

- Take advantage of existing backhaul communications in urban areas for early deployment. Communications will be a challenge in rural areas. Many applications will only require cellular but some may require DSRC.
- We plan to include several wireless modes of communication including DSRC, Cellular and also the use of the internet for traveler information.
- DSRC, WiFi and WiFi Direct. Technology will not be selected until Con Ops and Requirements are complete. We do not want to select the technology and find a problem to solve.
- Cellular, DSRC, WiFi, GPS
- DSRC at intersections (signalized and non-signalized), and cell phone network everywhere else.
- DSRC and cellular
- DSRC and cellular
- DSRC, Cellular, Fiber backbone for backhaul
- DSRC and we are exploring cellular.
- Mostly DSRC, but we are considering cell communications for some applications. We want to leverage early applications to get DSRC infrastructure built.
- Both DSRC and non-DSRC approaches
- Direct fiber connections for the infrastructure, DSRC for the V2I connection.
- DSRC
- DSRC, Fiber Optic
- Expansion of the state's fiber optic network and some form of wireless, perhaps DSRC.
- Wireless communications to the traffic signal controller cabinet and then fiber from the controller cabinet back to central.
- DSRC and LTE (and possibly fiber for backhaul)

Question 7: If DSRC is a communication approach identified in #6 above, please provide the DSRC messages you used/plan to use for your DSRC communications?

14 Responses:

- BSM Part 1 but would need Part 2 for some applications
- We plan to implement systems to support any/all of the J 2735 (2015) messages: BasicSafetyMessage MapData SPaT CommonSafetyRequest IntersectionCollision NMEAcorrections ProbeDataManagement ProbeVehicleData RoadSideAlert RTCMcorrections SignalRequestMessage SignalStatusMessage Traveler Information PersonalSafetyMessage TestMessageOO
- BSMs
- Basic Safety Message - TBD
- SPaT, MAP In the future, we may use BSM or other means to optimize signal timing based on demand from approaching vehicles and advanced turning movement information.
- PDM/PMM
- Snow plow signal priority request. Road weather info.
- BSM, PDM and the new Basic Mobility Message
- BSM, MAP, SPaT, SignalRequestMessage, SignalStatusMessage, CommonSafetyRequest, IntersectionCollision, ProbeDataManagement, ProbeVehicleData, NMEAcorrections, RoadSideAlert and others
- SPaT is a primary message. If our weather application uses DSRC, I don't think there is a standard message for that data (I could be wrong). Ultimately, a Basic Infrastructure Message will be important, so we need to define that.
- We are not that far along.
- We feel there will be a library of accepted message packets to be transferred. Initially our system will accept TSP requests.
- Vehicle to Vehicle communication related to stop, lane change, turns, etc.
- These have not yet been determined

Question 8: If you have identified any current infrastructure processes (e.g. environmental reviews, MUTCD compliance, etc.) or other challenges (lack of backhaul, technical capability, lack of developed applications, security concerns, etc.) which will prevent or hinder your deployment of the Connected Vehicle infrastructure, please list those with a brief explanation.

15 Responses:

- IT security concerns Lack of guidance available
- Our biggest challenge is that we are combining 2 or more USDOT CV applications into a single app.
- Yes, several challenges has been identified as we have explore deploying connected vehicle equipment and solutions in the Bay Area. These include: - Complications due to the requirements of Caltrans controllers and AB3418 - Lack of application readiness - Lack of documentation on applications details - Lack of documentation and supportive research regarding the benefit of specific applications as well as the anticipated benefits of grouping applications in a connected vehicle environment - Uncertain timeline around the NHTSA rule making and anticipated roll out of vehicles with DSRC communications - Uncertain funding to support the planning, installation, and operations of connected vehicle environments and applications - Lack of clear standards to ensure interoperability of connected vehicle deployments - Lack of direction regarding security credentialing requirements - Lack of direction regarding cyber security threats and mitigation strategies - Work force development - Lack of outreach to local agencies and tools to help communicate details and expectations regarding connected vehicle programs - Simple terminology issues: CV vs. AV vs. V2I vs. V2V vs. V2X . Stakeholders often get confused and are unsure about what is being discussed so they just assume we are talking about Google Cars and fully self-driving vehicles.
- Security of DSRC transmissions is a big concern. If we decide to change signal timing at an intersection based on message that we receive from approaching vehicles, there has to be a mechanism for determining that the message is coming from a trusted source, and not a hacker. O&M costs for backhaul and equipment upkeep is another concern. Without an extensive fiber network, which we don't have, there will be a monthly phone bill for backhaul at each DSRC location. This will be a significant cost.
- Lack of developed applications, security concerns
- Lack of DSRC and V2I apps in passenger vehicles limits the usefulness of infrastructure deployments.
- Lack of V2I security system, negative public perception of security due recent auto hacking, IPv6 requirements, limited field maturity of applications, patent challenges
- We have identified the following challenges: DSRC Security - requirement for IPv6 in the backhaul Existing Patents - E.g. Qualcomm use of wireless (newly issued), GTT for signal preemption, …)
- Backhaul (the lack of). We have a limited backhaul network and less than 10% of our signals go back to a central location.
- Lack of developed applications: Although we have a long list of applications, and a few have published ConOps, there are very few actual applications. Most of the applications are just an idea at this point. I think that is part of the reason for the Pilot Deployments, is to get some real applications running. Technical Capability: Since there are only a handful of test beds, there isn't

much knowledge base out there about DSRC deployment and application development. There certainly isn't any of that in my area, so I am trying to build some expertise in my team. The learning curve is long, partly because of the lack of applications (above) and partly because of the nature of the hardware (below). DSRC maturity: In this age, we are used to plug-and-play devices. The DSRC devices are certainly not there. Coupled with the lack of developed applications, there is a real need for very specific software development and hardware integration expertise. Security: I'm not overly concerned about security with the small-scale applications we are starting with, but there are a lot of agencies looking to deploy applications and there is no SCMS system available to us. I realize that a system is being developed, but an early version won't be available until Sept 2016 (and then only to the Pilot teams), and a final version reportedly a year later.

- We are still waiting on the deployment guidelines document from FHWA. The lack of a clear security approach is a significant barrier. The lack of information about what applications the auto industry plans to support is also a barrier.
- We as a City have a different set of operating philosophies that we operate under than those of our State DOT. We has a more robust and complete system than they do and joint operating protocols would be helpful. Some State DOT's control sections of local roadways (State Hwy) that could have an adverse effect on the operations of a CVI system. I would strongly urge local agreements and agency interaction be part of the metrics used to deploy any system.
- Technical capabilities are maturing, but not at a level of proficiency yet. Also lack of developed applications.
- Lack of clear standards and concern over hackers getting into the system
- We are currently not aware of any.

Question 9: As you have worked toward deployment (planning, pilot proposal preparation, early deployment experience, etc.), what are the two most important or surprising things you have discovered that you think would be useful for others to be aware of?

14 Responses:

- The two most important/surprising observations: (important) Experience through pilot projects to understand the technology and applications (surprising) The rapid development of automated vehicle technology and the projection of these vehicles operating on roadways in the near future.
- How far some of the pieces are from being ready for real deployment. Getting local stakeholders and participants excited about participating in the project.
- 1) It is incredible how quickly the field is advancing right how. Many, especially local agencies, do not have the bandwidth to keep up with it, which is creating a large disconnect between federal initiatives, private industry, and local owners and operators of the infrastructure. A lot of work needs to be done to get everyone on the same page. 2) It has surprised me how much the transit agencies we've been working need and are very interested in deploying connected vehicle environments to improve their transit operations. They see the potential and are excited to get involved and to start realizing the benefits of a connected vehicle communications architecture and the many applications they will be able to tap into once that architecture is in place.
- Installation of connected vehicle infrastructure is not a "cookie cutter" process; each individual site has its own nuances, requiring engineering judgement for such decisions as antenna placement, cable runs through conduits, and choice of backhaul technology. Our agency has not determined the best way to begin including connected vehicle installations as part of our regular Planning process. It is different from our normal Capital Improvement process, so we will need to adapt our existing processes to accommodate it.
- Complexity in deploying SPaT The range of DSRC RSEs is greater than expected
- Gained significant experience in MMITSS applications in an active operational environment. It takes time for applications to mature to full deployment. DSRC works well in hot climate Automated vehicle technology gaining traction has been of some surprise.
- Having a good relationship between IT and Operations is key. When getting started, an experienced academic institution can assist with technical issues when the DOT lacks experience and/or expertise.
- There are really very few developed applications, as discussed above, and no security systems. The DSRC equipment is at a very fundamental level, requiring some hands-on programming, and we have yet to see v4.0 equipment, which has been promised for over a year. Don't expect to buy these devices, load some off-the-shelf software, and plug them in. And, make sure that your network can handle ipv6 devices somehow.
- Once again, we are only at a high level planning stage.
- As stated above there is a lack of common vision between local agencies and State DOT's. That gap needs to be closed. It is difficult at this point to gain tremendous public input on this process. I feel it is a lack of understanding. OEM's are promoting vehicles with on-board technology, but not indicating the connection between vehicles and infrastructure. Someone needs to start painting that picture.
- Not yet
- N/A

- Successful CV will be highly dependent on partnerships across many modes to fully leverage regional benefits- one off agency specific applications will not ever move the needle in terms of benefits. Despite some information on costs and benefits, right now it is very hard to confidently quantify them so surprises (some perhaps unpleasant) are going to happen. Deploying CV at this point is risky. Agency access to private vehicle CV data is still undefined and therefore worrisome at this point.

Appendix C: Research Definition for Cooperative Vehicle-Infrastructure Situational Awareness System

Research Definition for Cooperative Vehicle-Infrastructure Situational Awareness System

Despite advances in enforcement, public awareness strategies and improved infrastructure (e.g. dedicated bicycle lanes), vulnerable road user safety remains a serious issue. Automakers are implementing technology that utilizes the vehicle's sensors to warn the driver of the presence of pedestrians and bicyclists; however, the sensors are often occluded from directly sensing the vulnerable road user due to buildings, other vehicles, and intersection geometries. Additionally, infrastructure-based sensing can be more robust, utilizing higher-end sensors and processors than can be accommodated on a vehicle.

An increasing number of vehicles will be outfitted with DSRC in years to come which will enable vehicles to communicate with each other and an intelligent infrastructure. Current research in communication with vehicles and infrastructure to improve intersection safety has been primarily focused on sending information regarding signal phase and timing as well as the intersection geometry to the vehicle to assist in collision avoidance at intersections. This has also included very rudimentary pedestrian detection and warning systems which to date have not worked well due to the sensors inability to accurately detect and classify pedestrians. How can we take advantage of this to further improve safety for vulnerable road users? It is relatively straightforward to envision the development of the next generation of cooperative vehicle-infrastructure situational awareness as illustrated in the following figure:

The problem of the vulnerable road user is a significant one that cannot simply be solved by sensors on a vehicle platform, as they simply do not have the "sight lines" to detect all possible conflicts – the infrastructure needs to also be providing information. This concept merges advanced detection techniques with Connected Vehicle technology to demonstrate advanced vulnerable road user detection. We propose to study the feasibility of combining intelligent sensors and connected infrastructure to improve situational awareness for connected (and potentially automated) vehicles in intersections and other highly dynamic environments.

Appendix D: Research Definition for Readiness Assessment of CV Applications in the OSADP

Research Definition for Readiness Assessment of CV Applications in the OSADP

RESEARCH PROBLEM STATEMENT

USDOT has funded a great deal of work to develop prototype Connected Vehicle applications. A wide variety of these prototypes are now available for public re-use on the OSADP (Open Source Application Development Portal). State and Local DOTs that wish to re-use these applications and integrate their capabilities into other existing systems need guidance on the readiness of these applications for deployment; in particular to more realistically evaluate the costs of integration of these tools with other DOT systems, software, and databases.

OBJECTIVE

The objective of this research is to provide agencies guidance on the readiness of OSADP applications for re-use.

RESEARCH PROPOSED

The research team will review all applications on the OSADP intended for use in deployment of CV applications. Research tools and other applications for assessment of benefits or costs estimation are not necessary to review. The team will identify and consolidate into a single report the basic software structure, language, operating system, use of third-party tools/libraries/dependencies, databases, input files, and other characteristics of each package. Based on expertise and experience in developing similar types of software, the team will identify any potential observable issues in the software architecture and related components. The report will have sections that are digestible by non-software professionals with basic knowledge of information technology terms and concepts and more detailed analytical discussion of more complex software technology issues and details. The assessment will be objective and not biased towards the perceived superiority of any particular language, operating system, or technology except where the open market would clearly determine that a particular technique, tool, or technology selection would require significant effort by a DOT to adjust its current standards and allowable exceptions to re-use. The guidance will identify any gaps in the suite of tools on the OSADP that DOTs will have to fill to bring any particular application or suite of applications into a deployable state.

ESTIMATE OF THE PROBLEM FUNDING AND RESEARCH PERIOD

Recommended Funding: $100,000
Research Period: 6 months

URGENCY AND PAYOFF POTENTIAL

Agencies need guidance on how much effort it will take to re-use any prototype applications developed by USDOT on the OSADP for their own IT environments and use of existing traffic management systems and related software, databases, and web technologies. Thus, the research is considered reasonably urgent given the timeline of typical procurement processes, the expectation of rapid deployment, and need to address institutional issues related to project definition and funding estimates of V2I applications. V2I applications can be transformative in the ability of public agencies to provide a broad range of public benefits and re-use of applications through the OSADP is likely to help reduce agency costs.

RELATIONSHIP TO NCHRP STRATEGIC RESEARCH GOALS, STRATEGIC PRIORITIES, and/or TRB STRATEGIC, CRITICAL, AND EMERGING ISSUES

This research is an important component of cost estimation of DOT deployment of CV applications.

RELATED RESEARCH

No current NCHRP 20-102 project is evaluating OSADP application readiness. This is a niche task of primary interest to State and Local DOTs that have near-term interests to deploy CV applications.

PERSON(S) DEVELOPING THE PROBLEM

Douglas Gettman, Ph.D.
Director of AV/CV Consulting Services
Kimley-Horn
Doug.gettman@kimley-horn.com
(602) 906-1332

PROCESS USED TO DEVELOP PROBLEM STATEMENT

This RPS was developed by Dr. Gettman and members of the V2I Coalition Working Group 2 (Research) and was reviewed by Greg Larson and Rob Bertini.

DATE AND SUBMITTED BY

June 28, 2016; Submitted by Dr. Douglas Gettman on behalf of the V2I Coalition Working Group 2

Appendix E: Research Definition for How to Prepare TIM Responders for a Connected Vehicle / Automated Vehicle World

Research Definition for How to Prepare TIM Responders for a Connected Vehicle / Automated Vehicle World

Project subject cluster: Institutional and Policy Project

Problem Statement

From the time Traffic Incident Management programs were initiated until now, the roles of emergency responders have remained largely the same because the transportation system has remained largely the same. Today a revolution in vehicle technology is taking place and is being led by the private sector. Vehicles with connected technologies are on the roads today, and, every year, technology is taking over a larger part of the driving task. Even before we reach the implementation of fully automated vehicles, there are changes taking place that will impact incident response.

Auto companies have been designing these technologies for many years. The public sector and academia have gotten involved more recently. The focus of the CV/AV work has been from the driver's perspective with the general thinking that these CV/AV technologies will make driving safer. However, what will happen when a crash occurs? Will responders need to respond differently? Will the severity of crashes increase because when the technology fails, it will fail catastrophically? Will new players be involved in incident response? Will all crashes be treated like crime scenes until the cause of the crash is identified? Are there new or changing risks to responders?

There are many unanswered questions and, to date, the TIM community has not been involved in these conversations. The Intelligent Transportation Society of America (ITSA) and the Transportation Safety Advancement Group (TSAG) have initiated the *Connected Responder: Public Safety and Emergency Response Community Connected Vehicle Interest, Context, and Business Case Development* project to educate responders about, and make the business case for, CV. There is also a significant need to reverse the conversation and include responders in discussions about TIM needs in the coming CV/AV world.

Task Outline

This project will begin with developing a summary of CV/AV research and determining if emergency responders are involved in the research. This project will also include an investigation of how traffic incidents might change in a more connected transportation system and what the needs of traffic incident responders would be. Lastly, this project will create a process to ensure traffic incident responders are included in the CV/AV research agenda moving forward.

(1) Prepare summary of ongoing CV/AV research and determine if the work includes considerations for traffic incident response / responders.

(2) Investigate how traffic incidents might change as transportation system becomes more connected (number of incidents, severity, liability, etc.) – consider 5, 10, 20 years in the future.
    - This work should incorporate any considerations developed by the FHWA TIM Vision Work Group.

(3) Based on predicted incident trends, consider how traffic incident response will change – new roles for responders, new agencies / organizations / companies involved in response, etc.
    - Work on this task will coordinate closely with work on the ITSA/TSAG project *Connected Responder: Public Safety and Emergency Response Community Connected Vehicle Interest, Context, and Business Case Development*.

(4) Develop a plan to ensure traffic incident responders are included in continued development of the CV/AV research agenda and projects.

Deliverables

For each task, a report will be prepared that summarizes findings or provides a plan, as appropriate.

Resources

Approximately 2 person years over one year, with expertise in traffic incident response combined with knowledge of CV/AV technologies. $250 K

Urgency

High urgency because of the need to ensure the issues/ requirements of the traffic incident responder community are considered at the earliest stages of development (preferably) and implementation CV/AV technologies.

Appendix F: Background Information Prepared to Support the AASHTO SPaT Challenge Resolution

Background Information Prepared to Support the AASHTO SPaT Challenge Resolution

I. PURPOSE OF RESOLUTION

The purpose of the AASHTO SPaT Challenge resolution is to approve an AASHTO nationwide challenge to deploy Dedicated Short Range Communications (DSRC) infrastructure with Signal Phase and Timing (SPaT) broadcast in at least one corridor (approximately 20 signalized intersections) in each of the 50 states by January 2020.

II. INTRODUCTION

Connected and Automated Vehicle technology is advancing rapidly and many state and local agencies are wondering what they can do to support or be part of the deployment of these transformational transportation technologies. While the concept of autonomous vehicles has been around for 50 years, the reality of vehicle automation and fully autonomous driving has only recently emerged. This technology, however, has captured the imagination of the public. Autonomous vehicles are eagerly anticipated and skeptically feared, in about equal proportions. The potential of autonomous driving is in the public forum, but connected vehicle technology is less known or understood. For the most part, these two technologies will roll out in tandem, incrementally, as connected automation.

Anticipating the NHTSA DSRC mandate, automakers are busily preparing the hardware and software components of vehicle to vehicle (V2V) systems. Cadillac will deploy DSRC on at least one model in late 2016, with an estimated production of 40,000 vehicles. Other automakers will likely follow suit in the next year or two.

Pilot Deployment sites, and a few others, are developing Vehicle to Infrastructure (V2I) applications, mostly anticipated for use by fleets of cars which can be outfitted with DSRC devices as part of the deployment. Automakers are also developing V2I applications, funded, at least in part, by the US DOT through the Crash Avoidance Metrics Partnership (CAMP). Without infrastructure, these V2I applications will not function, and it is unlikely that the automakers will deploy them until there is a larger scale deployment of roadside DSRC. Car owners in various parts of the county need to see and appreciate these new features on roads where they live and drive.

In testimony before a Congressional Committee in March, 2016, Delphi Automotive Vice President Glen De Vos stated, “In an automated future, cars will need to be able to communicate not just with their owner but also the surrounding environment, other vehicles and infrastructure. Knowing when traffic signals are going to change and where traffic is heaviest not only adds to the safety of the vehicle but allows cars to be driven, or drive themselves, more efficiently.” His argument for the synergy between connected vehicle infrastructure and the new driverless paradigm is compelling.

While there is a clear interest in these new technologies, and a solid case for the role of connected vehicle infrastructure in both the connected and automated space, agencies are not prepared for deployment. In many cases, in this rapidly evolving and sometimes complex environment, they simply don’t know where or how to start. An additional challenge is the fact that very few, if any, connected vehicle applications are ready for deployment. Today’s emerging deployments involve considerable software

engineering effort. Further, many of those who are currently planning to deploy are working on a variety of applications. To incentivize the deployment of V2I applications in new cars, we need a consistent and uniform deployment across the nation, at least at some level and density.

Fortunately, there is one fairly basic connected vehicle element which is relatively simple to deploy and fundamental to a number of applications, the "signal phase and timing" (SPaT) message. SPaT defines the actions of a traffic signal. It is obtained from a traffic signal controller via a standard query protocol and is broadcast by most DSRC roadside devices as a standardized data message. In addition to the SPaT broadcast, V2I Applications rely on two supporting data broadcasts to enable vehicle equipped applications to interpret the SPaT broadcast:

- the broadcast of the Map Data Message (MAP), a detailed data file that describes the physical intersection; and

- the broadcast of Global Positioning System (GPS) correction information as standardized by the Radio Technical Commission for Maritime Services (RTCM), to achieve accurate vehicle positions.

The SPaT, MAP, and RTCM functionality can be deployed in phases, but are all identified as necessary to support V2I Applications

Deploying this SPaT, MAP, and RTCM data message broadcast in a number of locations around the country will accelerate V2I application deployment by the automakers, the private sector, and the public sector. A bold and measurable goal is needed to bring this about; it is the next logical step to a connected vehicle reality.

The AASHTO SPaT Challenge will provide a bold and measurable goal that allows the V2I community to join together and collectively work towards a near term milestone for V2I deployment. To the automobile equipment manufacturers, the AASHTO SPaT Challenge will demonstrate a commitment to DSRC-based V2I infrastructure deployment, enable individual application developments to occur in upcoming vehicle releases, and allow for testing and validation of the SPaT, MAP, and RTCM deployments using V2I Applications such as Red Light Vehicle Warning (RLVW).

The AASHTO SPaT Challenge will include the following provisions and details:

- The goal is to achieve DSRC infrastructure deployment of SPaT, MAP, and RTCM broadcasts in at least 20 signalized intersections in each of the 50 states by January, 2020, and to commit to operating the SPaT broadcasts for a minimum of 10 years. To this extent:

    - It is recognized that the 20 intersections may include either state, county, or local city intersections, as decided by each location.

    - In situations where the local technical or financial environment can only support a smaller number of intersection deployments, this is still encouraged. The most important aspect is to achieve some deployment within each state.

  - In some situations, agencies may decide to begin with the SPaT broadcast alone, and add MAP and RTCM as funding is allowed. This is recognized as a valid approach as long as the understanding is that MAP and RTCM will be required before vehicle equipped applications recognize the benefits of the broadcast.

  - In some cases, agencies will choose to deploy applications beyond the SPaT, MAP, and RTCM broadcasts. While this will be encouraged, it will not be expected. To maintain a uniformity around the country, and provide a base for broad-scale application deployment, the SPaT, MAP, and RTCM messages needs to be an element of every deployment.

- State and local agencies responding to the challenge will have access to resources developed by the V2I Deployment Coalition and the AASHTO Connected and Automated Vehicle Working Group (CAV WG) within the Subcommittee on Transportation Systems Management and Operations (STSMO). Additional technology transfer is expected to include webinars.

III. PURPOSE OF THE AASHTO SPAT CHALLENGE

The primary purposes of the AASHTO SPaT Challenge are:

- To provide state and local departments of transportation with a tangible first step for deploying V2I technology and operations. The benefits of this will be valuable experience and lessons learned regarding procurement, licensing, installation, and operations of DSRC infrastructure.

- To promote future, more advanced, V2I applications. As state and local transportation agencies select subsequent V2I applications to deploy, they will understand and feel more comfortable committing to these deployments having been through the process.To show a commitment to DSRC-based V2I deployments that the automobile original equipment manufacturers (OEMs) need to enable them to commit to deploying in-vehicle V2I technologies.

- To enable some level of testing and validation of DSRC broadcasts using the RLVW V2I Application, therefore expanding the understanding of the interoperability of V2I Applications as vehicles travel between states and interact with intersections operated by different DOTs.

- To bring the V2I community together to foster cooperation and coordination in deployment of an initial level of DSRC-based V2I infrastructure.

IV. CONTEXT

AASHTO, working with the Institute of Transportation Engineers (ITE) and ITS America under FHWA guidance, has created and currently leads the Vehicle to

Infrastructure Deployment Coalition (V2I DC). V2I DC membership exceeds 200 members and includes representatives from state and local infrastructure owners and operators, automobile OEMs, after-market suppliers, private sector contractors, USDOT, and members and staff from ITE, ITS America, and AASHTO. The V2IDC has selected four focus areas for the coalition as areas with the highest potential safety benefits. One of these focus areas is "Intersections" (signalized and non-signalized) where the majority of crashes and congestion occur. As noted in the introduction, OEMs are beginning to sell DSRC equipped vehicles. While there are infrastructure deployments of DSRC based broadcasts equipped to communicate with the "connected vehicles" in Arizona, California, Michigan, and other locations, these deployment sites represent the only locations where DSRC equipped vehicles could currently communicate with the infrastructure. V2I DC members recently identified a priority focus on Red Light Violation Warning (RLVW) Applications and believe the outcome of the SPaT Challenge will enable multiple agency testing and validation of RLVW functionality and eventually a nationwide rollout of RLVW. Finally, V2I DC members believe the SPaT Challenge is the initial step in the long term vision of wide scale deployment of DSRC broadcasts nationwide, enabling vehicles to be connected to the infrastructure.

As the V2I Deployment Coalition transitions into Phase 2, V2I DC members, with confirmation from the V2I DC Executive Committee, have identified the AASHTO SPaT Challenge as one of the highest priorities. In addition to the V2I DC, the AASHTO CAV WG members are also committed to supporting the SPaT Challenge. As such, Technical Working Group 1 of the V2I DC will lead this initiative, with support from other TWGs and the AASHTO CAV WG.

A number of technical reference documents will be available as resources to be used by state and local agencies that accept this challenge and participate by deploying SPaT broadcasts. In addition, a series of topic specific webinars will be conducted in cooperation with the AASHTO National Operations Center of Excellence (NOCoE) to help increase the likelihood of success.

V. Benefits of SPaT Deployments

Immediate and Short-term Benefits of SPaT Deployments

As noted earlier, SPaT is very much an entry-point into V2I deployment and operations. The immediate and short term benefits of deploying SPaT broadcasts will largely be internal benefits to the agencies in the form of lessons learned and overall knowledge gained about deploying DSRC based V2I infrastructure (e.g. understanding the DSRC licensing process, gaining experience with site selection, deployment, and operations). The experiences deploying SPaT now will benefit agencies as they deploy more complex DSRC V2I deployments in the years to come. In addition to the increased knowledge about DSRC, agencies participating in the

SPaT Challenge will also be deploying the early stages of their eventual V2I infrastructure. The benefits of this are best understood in the context of early fiber optic installations. Some DOTs installed fiber backbones years before there were technologies on both ends of the fiber to benefit from the data communications. In these early years, a benefit/cost analysis of the fiber deployments would have been negative, however as technologies have been deployed on both ends of the fiber backbones, fiber is now critical to communicating data and video. With SPaT broadcasts, the financial, safety, and mobility benefits will come later, as agencies deploy V2I Applications at SPaT equipped intersections and as the percentage of vehicles equipped with DSRC increases. The intent of the SPaT Challege is to serve as an 'enabler' to help agencies eventually reach positive benefit/cost situations with regards to V2I deployments.

Finally, automakers will be able to see the progress of the deployment and use this in their consideration of when to install V2I applications in their cars. Private application developers will respond similarly.

Long-term Anticipated Benefits of SPaT Deployment and Operation

Ultimately, the mobility, safety, and efficiency benefits of DSRC SPaT broadcasts will be recognized as infrastructure owners and operators, public sector fleets (e.g. transit and emergency response), and OEMs deploy specific V2I Applications (i.e. SPaT is a technology required to support multiple V2I Applications), and as the percentage of vehicles with DSRC communications increases. Some examples of the V2I Applications supported by SPaT broadcasts, and the anticipated benefits of these applications are summarized as follows:

- ***Transit Signal Priority Applications*** operating in areas with SPaT broadcast equipped intersections could be enhanced, allowing more sophisticated decisions regarding priority requests and ultimately reducing delay of all vehicles at these intersections. An advantage to this would be the inclusion of local transit agencies with fleets already equipped with V2I communications.
- ***Red Light Violation Warning (RLVW) Applications*** could warn drivers of an approaching signalized intersection when a potential of running the red light is determined based on the SPaT, MAP, and RTCM data received from the infrastructure and the vehicle data, creating the opportunity to reduce red light running related crashes.
- ***Intelligent Signal Systems (ISIG) Applications*** would require DSRC broadcasts from the vehicles as well as the SPaT broadcasts from the infrastructure. However, when achieved, the benefits would be improved signal timings for reduced congestion and delay for all vehicles traveling through SPaT equipped intersections.
- ***In-vehicle displays of countdowns*** describing green or red time remaining could be developed as in-vehicle or mobile hand-held applications informing the drivers approaching intersections of when the green light phase will end. Similarly, drivers stopped at intersections could see a countdown to the light change from red to green.

These are just a few examples of the types of additional applications that agencies, OEMs, or after-market providers may decide to add to the SPaT functionality.

VI. KEY SERVICES OFFERED BY THE AASHTO SPaT Challenge

As state and local agencies assess whether they will deploy SPaT, they will require some level of technical guidance and support. Similarly, those agencies that decide to accept the challenge and deploy the SPaT broadcast will need additional technical support and resources throughout the process.

While a dedicated funding source is not available, the V2I Deployment Coalition (led by AASHTO, ITE, and ITS America) and the AASHTO CAV WG both have the resources of volunteer members and funded technical support to develop resources to be used as reference materials as the infrastructure owners and operators deploy SPaT broadcasts. The resources that are expected to be developed to support the challenge include:

- Guidelines to assist agencies in selecting corridors for deployment;
- Procurement guidance;
- DSRC licensing information;
- Implementation guidance (including additional information about the role of MAP and RTMC and deployment dependencies for successful SPaT deployment);
- Estimated costs for installation, operations, and maintenance; and
- Identification of existing funding sources that agencies may consider.

To measure progress against this goal, and to provide a forum to encourage other locations to participate, the AASHTO National Operations Center of Excellence (NOCoE) web site will be used to track all of the deployment locations. The map will indicate which locations have committed to this challenge, and which have operational systems. Details of the deployment will also be described. Best practices can also be shared on this site.

VII. EFFECTIVE DATE

The Policy Resolution for the AASHTO SPaT Challenge will be jointly supported by the Subcommittee on Transportation Systems Management and Operations (STSMO) and the Subcommittee on Traffic Engineering (SCOTE), and shall become effective upon approval by at least a two-thirds majority of the AASHTO Standing Committee on Highways (SCOH).

Appendix G: Data Issues in V2I Deployment

Data Issues in V2I Deployment

The primary objective of Activity 2 for TWG 3 was to identify, define and prioritize data issues in V2I Deployment. The approach to this task is as follows:

1. Facilitate discussions with DOTs and OEMs to identify data issues
2. Focus the discussion on the 4 focus areas
   - Intersections (signalized & non-signalized)
   - End of Queue Warnings
   - Work Zone Management
   - Curve Warning Systems
3. Prioritize the identified issues

The attachment was sent to participating infrastructure owners and operators (IOOs) and Automobile Original Equipment Manufacturers (OEMs) to help frame the discussion. The results of these discussions are summarized in this document.

Infrastructure Owner and Operator (IOO) discussion

On Thursday, December 3rd, a conference call was held with a group of IOO and agency representatives who were participating in a connected vehicle pooled funds study meeting. Represented were:

- Virginia DOT
- Minnesota DOT
- New York State DOT
- Caltrans
- Utah DOT
- Pennsylvania DOT
- Road Commission for Oakland County (MI)
- Arizona DOT
- Maricopa County DOT (AZ)
- FHWA
- Transport Canada
- Texas DOT
- Wisconsin DOT
- Michigan DOT

Discussion centered around the expected data needs from the vehicle in a V2I world in to deploy applications related to the 4 focus areas above.

During these discussions, the general consensus from the IOOs was that for the safety-related applications, the infrastructure side would not be looking for any data from the vehicle. Primarily with "agency benefit" and mobility applications, will the IOOs be looking for data from equipped vehicles.

OEM discussion

Feedback on data needs for the 4 focus areas was obtained from the Collision Avoidance Metrics Partnership (CAMP), Volkswagen, and Nissan.

Intersections (signalized / non-signalized)

OEMs indicated that, for intersections of both types, SPaT and MAP data is needed. These include elements such as signal phase and timing, intersection geometry, operational status, approaching vehicle information, road friction, location of signs, and road geometry and markings.

End of Queue Warnings

End of queue warnings necessitate a combination of data elements, including information regarding the speed and position of the queue and the affected lanes. If an intersection is involved, the information necessary for intersections is needed as well. If dynamic message, variable speed limit, or dynamic lane signs or control devices are present, their location and status are also necessary.

Work Zone Management

For a work zone, the information necessary for end of queue applies. Additionally, needed information includes the location, direction and length of the work zone, lanes leading to the work zone, lane closures and their position, speed limit information, and an indication of the presence of workers.

Curve Warning Systems

Curve warning systems require information on Roadway characteristics, weather conditions, field equipment, and traffic status as follows:

- Roadway characteristics – friction, roadway geometry such as curve entry point, curve radius, banking angle
- Weather conditions should preferably be measured by road surface sensors and can include surface temperature, subsurface temperature, moisture/precipitations, icing, treatment status and visibility
- Field equipment may include dynamic messaging and variable speed limit signs.
- Traffic status includes information on approaching vehicles, such as speed and location.

Summary

Information needed for all three focus areas included roadway geometry, with road condition information needed for most. Therefore, these two data element categories should be prioritized for V2I deployment activities in the four focus areas identified for this exercise.

Conclusions

There appears to be a gap in the data needs and availability for a variety of different applications. These gaps and needs can only be addressed through further cooperative work between the infrastructure owners and operators and the automobile OEMs. We would recommend the exploration of these data needs and availability be the primary focus of future TWG# activities.

Appendix H: Research Definition for I2V for Automated Vehicle Navigation

Research Definition for I2V for Automated Vehicle Navigation

Many automated vehicles under development require an *a priori*, high-fidelity map of the environment in which they are operating. This map is typically used for static and dynamic object segmentation, as well as for vehicle self-localization. It contains critical information required by the automated vehicle for navigation and decision making, including things like the number of lanes on a roadway and their directionality, intersection stop locations, crosswalks, etc. Any unanticipated changes to the information contained in these digital maps can prove to be incredibly problematic for the vehicles that rely on them. It is anticipated that these maps will need to be periodically updated to incorporate more permanent changes; however, temporary changes to the road structure, such as construction work zones and detours, will be present substantial challenges that must still be appropriately handled by automated vehicles. For vehicles with automation capabilities falling under NHTSA-defined Levels 3 and below, this could simply involve alerting the driver/operator, and relinquishing control; however, even for these Levels, as well as Level 4 automation, it would be preferred/necessary for the automated system to be able to seamlessly handle these situations.

Connected infrastructure represents a means to provide temporary map updates to connected-automated vehicles. Permanent connected infrastructure installed at intersections or along highways preceding an upcoming work zone or detour can send updates or routing recommendations to the vehicles before they reach the area, providing them time to make navigation decisions, rather than having to react when the change is detected. Alternatively, temporary, portable connected infrastructure could be deployed around the work zone to provide the same information, if permanent infrastructure is not present. It is also important to consider if vehicle probe data, whether from CV or AV, further define the map. For example, if no travel is detected on a known lane, can it be assumed it is 'closed'?

We propose to work with a representative digital map structure and experimental automated vehicle to study the benefits of using connected vehicle technology to improve automated vehicle navigation in areas where the expected road structure has temporarily changed.

Appendix I: Comments on the 2015 FHWA Vehicle to Infrastructure Deployment Guidance and Products

Vehicle-to-Infrastructure Deployment Coalition (V2I-DC) Technical Working Group Four (TWG-4) Comments on the 2015 FHWA Vehicle to Infrastructure Deployment Guidance and Products

#	Section	Page	Para	Comment	Comment Resolution Status
6.	Introduction	4	1	There should either be a statement of the purpose and benefit of V2I or a reference (link) to another document which has a clear and concise statement of purpose. I agree with Steve Lockwood's comment that "Even without any V2I, here will be significant impacts on vehicle and operational characteristics and use …". My opinion is that it is important for this document to provide transportation system owners/operators a high level executive understanding of the safety and mobility benefits that will come with the inevitable growth of V2V equipped vehicles on our roads, and separately the added benefits of adding V2I technology in selected locations. The universal addition of V2V features into the vehicles on America's roadways will reduce traffic accidents, injuries and deaths in a subset of all accidents between unimpaired drivers. V2I will contribute the additional safety capabilities not possible with short range V2V alone. It will also make dramatic improvements in mobility at signalized intersections, and in safety at all intersections. Automated Vehicles (AV) has the potential to reduce traffic deaths caused by impaired drivers, moving us toward the ultimate safety goal of "Zero Deaths". These technologies must work together in order to reach the zero fatalities level. It is important for transportation planners and executives to understand what contribution each technology makes to DOT's long term vision of roadway safety.	Closed. The item is addressed in Sections 1.3-1.6 of this document.
7.	V2I Products	4	4	There is another set of tools not listed which would be extremely useful to roadway agencies. Please consider adding them to this section. · SET-IT "The Systems Engineering Tool for Intelligent Transportation (SET-IT) Version 1.2 provides a single software tool that integrates drawing and database tools with the Connected Vehicle Reference Implementation Architecture (CVRIA) so that users can develop project architectures for pilots, test beds and early deployments." [http://www.iteris.com/cvria/html/resources/tools.html] · MAP Tool now in development by RITA has the capability of displaying a map of the agency's jurisdiction and showing CV movement and intersection signal phase and timing (SPaT) status in real time. · Co-Pilot Cost Estimator was launched 12/19/14 and used by some if not all CV Pilot Phase 1 proposal teams.	The SET-IT is not discussed but it should be addressed in the revised 2016/2017 guidance update. The CVRIA is mention 13 times along with weblinks. The MAP Tool should be mention in the revised 2016/2017 guidance update. The Co-Pilot was not mention because there is a more accurate cost estimating tool under development (see 4.6. NEAR-TERM (0- TO 5-YEAR) V2I TRANSITION AND PHASING ANALYSIS).
8.	Significance of V2I	6	1	"New and emerging V2I technologies offer an opportunity to significantly enhance safety through communications between vehicles, … through interaction with the road infrastructure (2) (3)." But communication between vehicles is the definition of V2V. Apparently the authors intent was to discuss V2V and V2I in this sentence as indicated by reference (2) and (3). And this paragraph would be a great place to introduce or reinforce the concept of V2X, i.e., that V2V and V2I work together to reduce crashes, injuries and fatalities. References (2) and (3) quantify these benefits.	Closed. General comment. No action required.

9.	Available Connected Vehicle Standards	6	5	first sentence touts CVRIA as a … "means of detecting gaps, overlaps, and inconsistencies between the standards (6)." This is of little concern to an agency planning for or evaluating its deployment of V2I. Harmonizing all the standards is a role of government and industry associations. This paragraph seems to ignore the real significance of CVRIA to a transportation system owner/operator (TSO)). Contrary to the impression provided in this section "that CVRIA is an initiative that defines the architecture views for connected vehicle technologies … to analyze where standards may be optimized ….", CVRIA plays a much more significant role in the planning of an agency's deployment. To the agency, CVRIA provides the tool set (SET-IT) through which the agency can define its own customized deployment of connected vehicles and remain completely interoperable with other jurisdictions across North America. In the Enterprise view, it can define the agency's specific organizational structure and interrelationships with other governmental and private entities such as adjacent or overlapping jurisdictions, law enforcement agencies, first responders, etc. In the Physical view, the agency/operator can define its existing physical ITS and communication infrastructure down to several levels of detail. Other views can and should also be customized to the specific transportation agency's priorities. Not all agencies will have a transit facility in their jurisdiction, and thus, would not include transit interfaces and functions in their model.	Closed. General comment. No action required.
10.	Definition of a Connected Vehicle Environment	7		Overall, this section is important for what it needs to convey but does not yet do so. It identifies key "support" facilities such as the SMS, the SCMS, the ORDS, and some unidentifiable entities called the Data Distribution System and the Operational Data Environment. These support facilities are all colored olive in the CVRIA to indicate that they are "support" facilities, but nowhere in this document is the transportation owner/operator told that the support facilities are provided by either US DOT or a private company (wide area data distribution). Please note that the SCMS is described in section 3.20 without mention of the US DOT intent to provide this national facility either directly or through privatization.	This comment could be addressed in the revised 2016/2017 guidance update. The USDOT's SCMS approach was not fully conceptualized by the time this guidance was drafted and circulated for internal review/approval.
11.	Definition of a Connected Vehicle Environment	9	2	The Internet is not a communications type. Access to the internet might be a better phrase.	Consider rephrasing to read "access to the internet" in the revised 2016/2017 guidance update.
12.	Definition of a Connected Vehicle Environment	8		Is the figure title meant to read Connected Vehicle Environment (instead of Deployment)?	Closed. Minor change. The figure name does not match the section name or topic of discussion.
13.	Figure 1	8		The figure is a SET-IT generated diagram which has too much detail about data flows with too little narrative to make sense of them. And some of the titles of support objects do not make sense and are not defined. For example, "Data Distribution System" is actually three objects in the latest SET-IT model – "US DOT Situation Data Clearinghouse" and "US DOT Situation Data Warehouse" are the two that store all vehicle data. The higher level of abstraction is ok if it is at least explained by reference and a sentence or two explaining that data will flow from the roadside equipment to the US DOT managed data storage facility where its authenticity will be validated and its privacy will be ensured. Anyone wishing access to this data (including the TSO) will have to subscribe to the data by specifying its geographical area of interest and receiving a data stream back from the US DOT Data Warehouse through the Internet. Thus the data is public, and any individual, business or TSO can subscribe to any geographic area's data.	Closed. The comment is valid; however, this is beyond the full intent of the guidance and section 1.6. This section and figure are focused on a high level overview.

14.	Figure 1	8		The "Data Distribution System" object also includes a 3rd entity call the "Wide Area Situation Data Distributor (WASDD)". The function of this (non-government) entity is vitally important to TSOs planning deployments. Imagine a vehicle driving into the TSO's jurisdiction for the first time. It would not know local roads, speed limits, locations of curves, bridges, construction zones, etc. except what is provided commercially by Google, Garmin and other manufacturers. And the TSO cannot communicate with all of these companies and alter any of this information in real time. But with the WASDD, the TSO can upload static information regarding its roadways (compliant with MUTCD) that can then be downloaded from satellites to any requesting vehicle in North America. Then vehicles operating within the jurisdiction can all have the latest regulations and traffic warnings from the TSO's Traffic Management Center. The TSO has to plan and budget for the data entry required to create a database of its static signs (and optionally its PCMS messages). Then on board displays built into V2X equipped vehicles will be able to display them or otherwise inform the driver of the signage content at an appropriate distance ahead of the static	Closed. The comment is valid; however, this is beyond the full intent of the guidance and section 1.6. This section and figure are focused on a high level overview.
15.	Definition of a Connected Vehicle Environment	9	4	The first sentence lists the major V2I components but does not mention supporting communication with "Personal Information Devices" for pedestrians, bikers, etc. That is important information for TSOs who have significant pedestrian traffic.	Closed. This is beyond the full intent of the guidance and section.
16.	National Environmental Policy Act (NEPA) and National Historic Preservation Act (NHPA)	18		The title should also list the "Communications Act" which created the Federal Communications Commission. And the 3rd paragraph should list CFR Part 90 and 95 as the basis for FAA requirements. And this paragraph should also refer the reader to section 3.17 for details of DSRC licensing.	Closed. The language in section 3.3 was recommended by the FCC (via OST) and extracted directly from the FCC's website. Also, it was reviewed and received concurrence by the USDOT's NHPA group.
17.	Interoperability	19	3	The last paragraph states that "Table 2 illustrates the types of messages and the message handler required …" This use of the term "message handler" was unexpected. Please provide a reference for it as its source is questioned as a standard Connected Vehicle software design term. This is a technical / engineering issue and is of no concern to TSOs. Maybe table 2 should be revised or removed.	Closed. The term "message handler" should be defined in the revised 2016/2017 guidance update. Also, the reference for table 2 was provided as number (6).
18.	Procurement Process	27	4	Sixth bullet point "Apply the Connected Vehicle Footprint Analysis" produced by AASHTO …" should be cited and the correct document name used. Do you mean "National Connected Vehicle Field Infrastructure Footprint Analysis" Final Report V1 6/27/14?	Closed. The title should be corrected and reference (14) should be inserted.
19.	Legacy Systems and Devices	28	2	Second paragraph is unclear. An example of a legacy controller which must be replaced because it cannot accept input from the RSU and a legacy controller that does not need replacement because it can accept RSU signals and, if needed has extra cabinet space for additional electronics such as a V2I application processor.	Closed. No change
20.	Data Connection and Latency	29	4	First paragraph, 4th sentence needs to be changed to read … "For optimal performance, it requires an uninterrupted line of sight between the transmitter and receiver and a clear path to multiple (3 or better) GPS satellites. In the first paragraph, 6th sentence, "In many cases, the applications and radio will be capable of selecting the best communication mode …" should be changed to "In many cases, the vehicle or roadside communication system will be capable of selecting the best communication mode …".	Closed. No change
21.	Data Connection and Latency	29	5	In the second paragraph, change 3) to "Detection of failures / weak signal in real time".	Closed. No change

22.	Data Connection and Latency	30	1	In the last sentence of this section, "The low latency will be based on the communication media; …" is not a technically accurate statement.	Closed. This was explained in details in a Report to Congress titled, Status of the Dedicated Short-Range Communications Technology and Application (FHWA-JPO-15-218). Once this report is made public, the refernce will be included in the revised 2016/2017 guidance update.
23.	Security and Privacy in a Cooperative ITS Environment	32	6	last paragraph, 3rd sentence … "There are at least 2 types of RSEs that a vehicle can communicate with. …" I do not believe that this statement is compatible with FHWA RSU Specification V4.0 dated 4/15/2014 which makes no mention of these two types of RSEs. It is my understanding that all certified RSUs must meet the requirements of this specification and can, therefore perform both functions described in this section.	Closed. No change. Please see the NHTSA Technology Readiness (reference 17, DOT HS-812-014, page 69)
24.	Incorporation of Connected Vehicles into the Transportation Planning Process	37	3	item 3) first bullet point refers to "connected vehicle applications such as V2I, V2I, and vehicle to device (e.g., connected handheld devices utilized by pedestrians)". First, V2V, V2I and vehicle to device are not "applications". I recommend that "vehicle to device" not be used at all as it is confusing and undefined. The terminology now being used by the designers is that V2V and V2I include communication with all types of motor vehicles as well as all types of Personal Information Devices for pedestrians, bikers, and persons utilizing other forms of non-motorized transportation.	Closed. This title could be rephrased to remain in line with Table 1 - Connected Vehicle Applications.
25.	Incorporation of Connected Vehicles into the Transportation	37	3	referenced subsection should be rewritten.	Closed. No change.
26.	Figure 1	8		Existing Center to Field communication from TMC to Signals is also secured	Closed. No change.
27.	Figure 1	8		There is a communication flow from the CV RSE to Signals and Field Devices priority on preemption request and processing requires two-way communication	Closed. No change.
28.	Connected Vehicle Applications	15		As an example suggest illustrating through diagram concept of one freeway and one arterial connected vehicle application. The visual will support better understanding of those new to connected vehicle technology.	Closed. General comment. No further action required.
29.	Pre-Deployment Guidance	41	6	The agencies also have interest in mobility applications that have completed design and prototype deployment phase. Such applications should also be considered in the pre-deployment guidance. Should there also be FHWA recommendation on the safety and mobility applications based on the needs of state and local operating agencies?	Closed. No Change. Other V2I applications will be considered once funding becomes available.
30.	General			Generally a good effort.	Closed. General comment. No further action required.
31.	General			Need to create a section which is focused directly on planning and one which is focused directly on deployment.	Closed. General comment. No further action required.
32.	General			Need to develop good installation and maintenance standards to support local traffic agencies.	Closed. General comment. No further action required.
33.	Significance of V2I	5	5	"V2I deployments may also require additional tasks (e.g., evaluation of surrounding roadway geometry necessary for proper antennae placement to ensure adequate line-of-sight distance of 300 meters on all intersection approaches for optimal performance)." This is not good advice for deployments where RSEs will be deployed at multiple intersections. Deployments should be set up so that there is a "dead spot" between RSE units. Overlapping signals will be rejected by the OBE radios.	Closed. Details with be available the V2I product 4.4. GUIDE TO LICENSING DSRC RSUs

34.	Definition of a Connected Vehicle Environment	7		USDOT has not published an RSE hardware specification. The IEEE 802 and 1609 standards are not specifications. We need a published set of features and performance specifications so that all RSE hardware manufactures will design and build products which meet minimums.	Closed. General comment. No further action required.
35.	Figure 1	8		good overview diagram, but we need to break this into smaller pieces to help local traffic agencies provide training for their personnel.	Closed. General comment. No further action required.
36.	Interoperability	18	7	Interoperability between local traffic agencies must be mandated. Regional plans should be developed to help agencies understand that they must work together. Funding should be provided to support this effort.	Closed. General comment. No further action required.
37.	Interoperability	18	7	Consider that an arterial passes through 5 municipalities. Three of the five decide to deploy V2I, but are separated by 2 municipalities which do not. It's important that the V2I be a common system, and deployed on at least a countywide basis.	Closed. General comment. No further action required.
38.	General			V2X is part of the conversation today and should be mentioned and defined.	Closed. General comment. No further action required.
39.	General			The vision and policy statement are helpful, but leave the reader wondering where V2I fits in with the more familiar terms of Connected Vehicles and Autonomous Vehicles. More on this is included in Chapter 1, but it might be worth including in the vision and/or policy statement as well.	Closed. General comment. No further action required.
40.	Guidance	4	3	Rephrase "reducing the learning curve."	Closed. General editorial comment. No further action required.
41.	Definition of a Connected Vehicle	5	2	Good to start to address the definition of CV and how it relates to V2I. AV should also be mentioned here.	Closed. General comment. No further action required.
42.	Significance of V2I	6	2	Importance of using the technology to address needs should be mentioned in this section. Last bullet uses the term, "dynamic pace." Consider rewording.	Closed. General comment. No further action required.
43.	Available Connected Vehicle Standards	6	6	The importance of the four viewpoints could either be expanded or removed if they are going to be referred to.	Closed. General comment. No further action required.
44.	Definition of a Connected Vehicle Environment	7		Overall, this section is somewhat confusing and I'm not sure what it adds. In preparation for my own presentations on these topics, I've gotten feedback from others that the term "connected vehicle environment" is ambiguous jargon and shouldn't be used. It seems like V2I Deployments and CVE are used interchangeably depending on the author of the section. I think using the term "V2I deployments" in this document makes sense in most cases.	Closed, general comment. No further action required.
45.	Definition of a Connected Vehicle Environment	9	2	The Internet is not a communications type. Access to the internet might be a better phrase.	Consider rephrasing to read "access to the internet" in the revised 2016/2017 guidance update.
46.	Figure 1	8		Is the figure title meant to read Connected Vehicle Environment (instead of Deployment)?	Closed. General comment. No further action required.
47.	Figure 1	8		The figure is too detailed and the terms used in it haven't been defined. It would be better if it were replaced with a higher level, less technical, more graphical figure. Something similar to what was used in the video or the CVPD presentations would be more effective.	Closed. General comment. No further action required.
48.	General			More figures over all would be helpful	Closed. General comment. No further action required.

49.	Brief Summary of Federal-Aid Programs for V2I Activities	12		Are there more federal aid program? Where do you go to find the latest info? How will eligibility work given V2I Deployment's cross-cutting goals and funding opportunities with FTA, DOE, etc.?	Closed. The language was written, reviewed, and approved by the FHWA staff members responsible for administrating and/or overseeing the eligible (i.e., FHWA Environmental, Planning, and Reality, Office of Operations, etc). FHWA collaborates with other USDOT offices (e.g., FTA) and agencies (e.g., DOE); however, FHWA does not have the authority to write guidance for other offices or agencies.
50.	Brief Summary of Federal-Aid Programs for V2I Activities	12		Going to the references for more info is mentioned but could be emphasized more. Perhaps in a table that summarized the key references?	Closed. General comment. No further action required.
51.	Guidance	15		The V2I vs. CV terminology is somewhat confusing.	Closed. General comment. No further action required.
52.	Connected Vehicle Applications	15		Footprint analysis should also be mentioned as a product (or tool).	Closed. General comment. No further action required.
53.	Connected Vehicle Applications	16		Add "As an example…" or other additional language to make it clear that the CV applications listed on page 16 is not all inclusive. Private sector and other CV applications already exist, but this section doesn't make it seem that way.	Closed. General comment. No further action required.
54.	Planning for V2I Activities	17		Can more be added about the data requirements for planning activities or what is anticipated to be available?	Closed. Details with be available the V2I product 4.2. INCORPORATION OF CONNECTED VEHICLES INTO THE TRANSPORTATION PLANNING PROCESS.
55.	Interoperability	19	1	The use of CVE and BSM seems out of place and somewhat confusing. (See comment from Definition of a Connected Vehicle Environment commenter 4)	Closed. General comment. No further action required.
56.	Table 2	20		Add "example" or "sample" to table title.	Closed, general comment. The table is illustrative.
57.	Use of Existing Structures and	25		Important info, but needs to be rewritten.	Closed. General comment. No further action required.
58.	Procurement Process	26		CVE (See comment from Definition of a Connected Vehicle Environment commenter 4)	Closed. General comment. No further action required.
59.	Communication Technology	28		This seems like a good place to state the FHWA is communications agnostic for non-safety applications. This is an important point that could be emphasized with a figure to illustrate when DSRC makes the most sense and when other communications alternatives may be considered as part of the systems engineering process.	Closed. General comment. No further action required.

60.	Privacy	30	1	Who is "we"?	Closed. Worked with FHWA Chief Counsel, the Chief Privacy Officer, and VOLPE to draft language acceptable for internal approval as it relates to privacy, security, and data sections of guidance.
61.	Data Access	32		This seems like a good section to mention the Open Source Application Dev Portal and the Research Data Exchange.	Closed. Worked with FHWA Chief Counsel, the Chief Privacy Officer, and VOLPE to draft language acceptable for internal approval as it relates to privacy, security, and data sections of guidance.
62.	V2I Products	35		There were 9 products/tools in the last version I reviewed of this guidance. What happened to the other ones?	Closed. General comment. No further action required.
63.	V2I Products	35		Change bulleted list into a table showing the product/tool, use category, and timeframe until available.	Closed. General comment. No further action required.
64.	V2I Products	35		The "V2I Products" section is one of the most important pieces that should be highlighted within this document, however the term "V2I Products" doesn't really grab the reader. The previous version of this called the section products/tools. The noun you use really depends on your point of view. To FHWA these are products of the program being developed. To the audience (FHWA staff and facility owner/operators) these are guidance tools. I suggest aiming the terminology toward the audience and changing the terminology.	Closed. General comment. No further action required.
65.	V2I Products	35		Rephrase CVE (See comment from Definition of a Connected Vehicle Environment commenter 4)	Closed, repeat comment on the use of CVE.
66.	References	44		The way this is laid out makes it very difficult for a practitioner to follow and use. To be technically correct, I understand why it is how it is shown here. Could applicable references be included in an easier to read/use/understand table at the end of each chapter? This is how it was done in the Guidelines for Dissemination Road Weather Advisory and Control Information (FHWA-JPO-12-046) and I thought it was a good way to link everything together.	Closed, general comment pertaining to format.
67.	Definitions	48		Suggest moving up to Chapter 1.	Closed. General comment. No further action required.
68.	Definitions	48		Add CVE if CVE ends up remaining in the text.	Closed. General comment. No further action required.
69.	Definitions	48		Add V2X	Closed. General comment. No further action required.
70.	Symbols and Abbreviations	52		Suggest moving up to Chapter 1	Closed. General comment. No further action required.
71.	Index	54		BSM could be spelled out.	Closed. General comment. No further action required.
72.	General			The document starts with the assumption of the public sector owning and operating the equipment, then it changes and introduces the private sector and doesn't really explain why to go one way or the other.	Closed. General comment. No further action required.
73.	General			The public/private issue of who will own and operate the system is filtered throughout many different sections.	Closed. General comment. No further action required.
74.	General			Seems like the addition of a simple checklist of how to deploy CV would be helpful. The document itself provides a lot of good information, but it doesn't flow or provide a step by step guide.	Closed. General comment. No further action required.

75.	General			I did NOT see anything that was glaringly missing. All important topics and areas seem to be addressed.	Closed. General comment. No further action required.
76.	Allowance of Private	25	1	I think the last sentence is very important, but there is typo in here which greatly affects the meaning relative to eligibility.	Closed. Revised.
77.	Design Consideration for	25	2	I think the last sentence in the first paragraph is a very powerful statement. Can we really start talking about CV being used to support geometric design exceptions? I think this whole section should be scratched at this point in time and for this type of document.	Closed. General comment. No further action required.
78.	DSRC Service Licensing	28		This is a very important section as most of the typical public sector road employees are not familiar with the licensing and radio requirements. This section needs to be much more informative but still be kept at the level that can be understood by public sector road and traffic engineers.	Closed. General comment. No further action required.
79.	General			The deployment guidance fails to consider the need of DOT needs in V2V. For example, we would like our maintenance, work zone and incident management vehicles to talk to vehicles on the road.	Closed. The comment is valid; however, this is beyond the full intent of the guidance. In addition, this will be govern by the standards (see section 1.5).
80.	Introduction	3		fails to "sell" V2I. It assumes that the decision to invest has been made. What is the "why" or business case for executive leaders to invest in V2I? That needs to be part of the deployment guidance.	Closed. General comment. No further action required.
81.	Table 1	16		Connected Vehicle Applications should include a brief definition of each.	Closed. General comment. No further action required.
82.	Table 1	16		Table 1 should identify 3-4 "priority" deployments	Closed. General comment. No further action required.
83.	Guidance	15		Section 3 should be reorganized as Virginia Langham suggested: a. Planning and Needs b. Regulatory and Policy c. Data d. Design and Deployment e. ?	Closed. General comment. No further action required.
84.	Planning for V2I Activities	17		Section 3.2 should identify the foundational requirements for an agency to support V2I a. Communication b. GIS c. ATMS d. Fleet Management e. ?	Closed. General comment. No further action required.
85.	National Environmental Policy Act (NEPA) and National Historic Preservation Act (NHPA)	18		what about v2v in last paragraph?	Closed. The language in section 3.3 was recommended by the FCC (via OST) and extracted directly from the FCC's website. Also, it was reviewed and received concurrence by the USDOT's NHPA group.

86.	General		V2I Guidance needs to be nested in overall "Impact of Automation Guidance". --- The big changes in safety (reduction in crashes, incidents), mobility (changes in traffic density, capacity speed) environment (operational regimes) will come from increasing automation – in vehicle and V2V. The unique V2I contributions (beyond what can be achieved by in-vehicle and V2V systems) to public benefit are meaningful – but limited. Even without any V2I, there will be significant impacts on vehicle and operational characteristics and use – and therefore on the amount, type and configuration of roadway infrastructure and its operations and maintenance. Even without V2I, transportation agencies will have to consider the impacts of future roadway design characteristics, (geometrics, signs/signals/markings, appurtenances – regarding design standards, planning, budgeting, etc. Even with any V2I there will also be significant impacts on TSM&O – reduction in incidents, reduction in recurring congestion, increases in capacity, new traveler information sources, etc. The point is that V2I Guidance needs to be nested within broader considerations of the overall impacts of various	Closed. General comment. No further action required.
87.	General		Time frame –given the rate of market penetration (may be 15-20 years before significant penetration – what should be done now vs thought about.	Closed. General comment. No further action required.
88.	General		Agency vs Private sector roles – Automation changes the balance and roles of the public and private sectors in providing transportations services – and infrastructure. Within TSM&O, outsourcing continues to increase – especially in the more technical areas. V2I raises the capability and resource requirements to a new level. We have a very complete and realistic understanding of the current levels of current state DOT capabilities. At the same time, there is no effective institutionalized way of engaging the private sector suppliers of capability within FHWA and AASHTO. This is true both with respect to the need to relate to the OEMs, and the technology and	Closed. General comment. No further action required.
89.	Connected Vehicle Applications	15	What is the status of the following products? Are they being done it house, by contract, roughly when available, etc.? 1. System engineering process for V2I 2) Incorporation of connected vehicles into the transportation planning process 3) Desk reference and tools for estimating the local, regional, and state-wide economic development benefits of connected V2I deployments 4) Guide to licensing dedicated short-range communication (DSRC) roadside units (RSUs) 5) V2I message lexicon 6) Near-term (0- to 5-year) V2I transition and phasing analysis 7) V2I pre-deployment guidance 8) White paper on U.S. Department of Transportation (USDOT) connected vehicle training resources	Closed. General comment. No further action required.
90.	Connected Vehicle Applications	15	Where do we stand re the Day One Applications priorities (for which standards will be developed). The NHTSA list is (understandably) all safety apps. What is the process for reconciling "public" priorities (who are the "stakeholders"? and how will reconciliation with OEMs be accomplished for the necessary match?	Closed. General comment. No further action required.
91.	Connected Vehicle Applications	15	The development, operations and maintenance of each of the elements in the "CV environment" the same set (only more so) to agency capabilities then that presented by best practice TSM&O (for example, ATMS, ICM) Is there a program element to assess and develop these technical, process, organization and management capacities. Is there a view about what (new) form of PPP might be appropriate (ref the role of private sector in the CV pilot activities).	Closed. General comment. No further action required.

92.	Connected Vehicle Applications	15	What is the time frame for the Reference Architecture? There are still a lot of unresolved issues related to security, BSM, etc. Also, there doesn't seem to be much discussion of the "enterprise layer". Who is doing that work? When available?	Closed. General comment. No further action required.
93.	Connected Vehicle Applications	15	The Footprint analysis is an excellent document. However it presumes a very aggressive approach – but is not really about start up, or early deployment – and doesn't really address the necessary baby steps –or what might be logical start-up applications (talks about a wide range). Thus while it is great background, it stops short of guiding early deployment opportunities. Some follow up on it would be useful. Also, it provides some cost data (as do subsequent Booz studies) but notably does not sum them up for a typical metro or statewide plan that would be helpful for planning and programming purposes. Could that be done?	Closed. General comment. No further action required.
94.	Connected Vehicle Applications	15	Is anyone addressing (guidance?, concepts?) early deployment opportunities (beyond pilots) ? What can be done with limited infrastructure and equipped vehicles (beyond fleets). TFHRC seems to have some ideas. For example, to what degree is IBTTA involved.	Closed. General comment. No further action required.
95.	Planning for V2I Activities	17	Not clear if any work is going on addressing planning methodologies critical to determining impact of AV or CV. i.e. Just off the top of my head. Big issue is rate of market penetration (time frame) and impact of after-market devices. May not have significant impacts for 15-20 years? · Time frame of interest and variance of impacts with market penetration – at what point does automation, connection become of interest in plans, budges · Impacts of AV functions on capacity at various levels of market penetration of L1, L2, etc. · Impacts of AV/CV on recurring, non-recurring congestion · Impact of CV-based traveler information on system performance, circuitry · Market penetration of CV, V2I related to cost, affordability · Planning related to early deployments – fleets, corridors, enclaves, mixed traffic · Infrastructure requirements of AV/CV related to signs, signals, markings, geometrics · Costs of V2I infrastructure, systems, · Etc	Closed. General comment. No further action required.
96.	National Environmental Policy Act (NEPA) and National Historic Preservation Act	18	Critical permitting issue likely to be how state/local governments collaborate regarding deployment of V2I infrastructure. If implementation is done individually, coordination burdens will be (too) intense. If infrastructure is deployed by PPP, there will be significant permitting issues.	Closed. General comment. No further action required.
97.	Interoperability	18	"*BSM must conform to SAE J2735 and should also be "signed" with a valid certificate to establish a trust relationship with those receiving and acting upon the message. Since vehicles and devices may interact with equipment from all over the nation, the requirements for transmission and receipt of BSMs, including certificates, should be standard across the nation and across vehicle makes and models; device makes and models; and applications* " How is this going to happen? Roles of SDOs, SDOTs OEM, etc. (note this is not just NHTSA jurisdiction, since it goes beyond safety.	Closed. General comment. No further action required.
98.	Evaluation	21	This will still be pilot oriented. NHTSA documents suggest some of the V2I applications may offer marginal benefits, and/or be preempted in the next 10-15 years by more advanced V2V functions	Closed. General comment. No further action required.
99.	ITS Equipment Capability and Compatibility	21	40+ State DOT capability maturity workshops provide a pretty good estimate of agency capabilities – funding and staff limits, technical capabilities) – to deploy and maintain existing (much less new/more complex) equipment. This challenge should be discussed.	Closed. General comment. No further action required.

100.	ITS Equipment Capability and Compatibility	21	It might be interesting to investigate the current ITS deployment survey with regard to its V2I applicability. Is there any good document that compiles "lessons learned" from the pilots to date?	Closed. General comment. No further action required.
101.	Hardware and Software	23	Who are the "three entities"?	Closed. The three entities and all associated details are provided in reference 21 on the official USDOT.
102.	Reliability	23	Are mods being built into the existing systems engineering guides, courses? Does FHWA expect that agency staff is going to conduct such work themselves? If not, what measures are being made to reach the pertinent professional audiences?	Closed. General comment. No further action required.
103.	Use of Right-of-Way/ Allowance of Private Sector Use	24	This issue needs to be combined with 14 and 23. As a point of departure It is hard to believe that most agencies are going to have the capacity to design/develop/deploy/operate/maintain significant V2I systems. It is generally believed that automation is going to require new types of sectoral arrangements. Insofar as private entities are going to have some kind of contractual/partnership/franchise arrangements with state/local government, there is widespread agreement that the existing procurement, ROW access, resource-sharing and other PPP arrangements need a lot of work. Note that PPP arrangements may not be the typical supply of standard "facilities" – but private supply of services using public resources. If there is to be a "trade" of private use for public access, there will be some complex legal issues – not the least of which will be competition, length/renewability of agreement – and the "not charged for use" clause (what is that business model?) In addition, many of the potential key players are not going to be interested in such arrangements on a limited geographical or scope basis. Most states have no or very limited experience with anything other than contract-for-	Closed. Worked with the FHWA Office of Planning, Environment, and Realty (HEP) to draft language acceptable for internal approval.
104.	Design Consideration for	25	One issue (that cuts across the entire guidance) is that V2I activities will take place in an environment of various levels of automation, the impacts of which will be much greater that V2I alone. In the short run, signs, signals and markings. In the long run, geometrics, roadside devices, etc. V2I needs to consider this, as well.	Closed. General comment. No further action required.
105.	Use of Existing Structures and Other Infrastructures	25	See similar comments regarding right-of-way and Private sector use	Closed. Worked with the FHWA Office of Planning, Environment, and Realty (HEP) to draft language acceptable for internal approval
106.	Use of Public Sector Fleets	25	Presume FTA funds can also be used for transit V2I?	Closed. The language was written, reviewed, and approved by the FHWA staff members responsible for administrating and/or overseeing the eligible (i.e., FHWA Environmental, Planning, and Reality, Office of Operations, etc). FHWA collaborates with other USDOT offices (e.g., FTA) and agencies (e.g., DOE); however, FHWA does not have the authority to write guidance for other offices or agencies.

107.	Procurement Process	26	See similar comments regarding right-of-way and Private sector use This section doesn't really deal with the unique features likely to be associated with the actual competitive procurement process and form of contract. Procurement process, funding and form of contract. Projects that combine hardware/software/services will increasingly be key issues. There is limited expertise on this subject at FHWA or AASHTO (or anywhere!!) –and limited experience with provision of device networks, continuing services, long-term contracts, intellectual property, no-disclosure, allocation of revenues – including contracts for services, franchises, resource-sharing and risk-sharing partnerships and establishing collaborative outsourcing. We need service acquisition models to replace adversarial constructs that encourage zero-sum or win/lose scenarios. It is not difficult to imagine that this is going to become one of the 2-3 principal impediments, once we get beyond pilots	Closed. General comment. No further action required.
108.	Legacy Systems and	28	You would be surprised how many statewide and regional architectures are out-of date – and the limited resources to deal with it	Closed. General comment. No further action required.
109.	Communication Technology	28	"Selection of the V2I communication technology will be based on a systems engineering analysis and consistent with application interoperability across the nation. Use should comply with established requirements for non-interference ……" Who is going to do this?	Closed. General comment. No further action required.
110.	DSRC Service Licensing	28	The guide will be important. As discussed in Pittsburgh, separate licenses are requiring for each radio device?	Closed. Details with be available the V2I product 4.4. GUIDE TO LICENSING DSRC RSUs
111.	Data Connection and	29	During early deployments, we will discover what the useful role of cellular and wifi is? Is there any clear discussion of this somewhere?	Closed. General comment. No further action required.
112.	Privacy/Security/ Data Access	30-33	This could be a wildcard, as there are some very aggressive privacy constituencies. While there is considerable work going on regarding SCMS, the approach seems very complex (unprecedented) and involves a number of players (OEMs, auto dealers – as well as a separate system (even if combined with normal V2I devices). Not clear how all this works without any RSUs (pre V2I) and nationally. Studies are not widely available? Key issue is what to state/local agencies need to know? Will there be any direct involvement (infrastructure, verification, etc.)? Seems like we are still in the "white paper" stage?	Closed. Worked with FHWA Chief Counsel, the Chief Privacy Officer, and VOLPE to draft language acceptable for internal approval as it relates to privacy, security, and data sections of guidance.
113.	Manual on Uniform Traffic Control Devices	33	This discussion begs the question of the relationship between MUTCD an in-vehicle "signing'. How is consistency going to be enforced? Has anyone addressed this?	Closed. In general, the MUTCD does not regulate in-vehicle "signing." Worked with staff members responsible for MUTCD to draft language acceptable for internal approval.
114.	Public-Private Partnerships (P3s)	34	This deserves much more consideration. See similar comments regarding right-of-way, private sector use, and procurement process	Closed. Worked with the FHWA Office of Planning, Environment, and Realty (HEP) to draft language acceptable for internal approval

Appendix J: V2I Outreach – Summary Input

V2I DC TWG 4: Deployment Guidance
Issue 6: V2I Outreach – Summary Input

October 2015

Introduction

The Vehicle to Infrastructure Deployment Coalition (V2I DC) is organized through AASHTO, ITS and ITS America. The first meeting of the V2I DC and technical working groups (TWGs) was held in June 2015, where the top V2I deployment issues were presented and discussed by five technical working groups.

Technical Working Group 4 (TWG 4) has been established to address V2I Deployment Guidance. The group will review and provide input to the USDOT Deployment Guidance document; will review and identify other deployment guidance materials currently available as well as those that are planned/under development; and will identify gaps and provide recommendations to USDOT for additional products that may be needed by the V2I deployment community.

This summary document is expected to be the first of several that will be used to share TWG 4 feedback with USDOT on current and future V2I deployment guidance efforts. This document specifically addresses Issue 6: V2I Outreach, described by the coalition as follows.

> *Since the state and local transportation agencies will be directly involved with operating a connected vehicle system there is a sense that they should be more prominently and directly involved with the OEMs and USDOT in developing the system. It is essential for the USDOT to have broad stakeholder input into the Guidance and the program.*
>
> *V2I information sharing topics should include planning and investing for V2I deployments; control, operations and maintenance of V2I applications; adding DSRC devices to roadside ITS devices; and other physicality related issues that surround a transition to supporting large scale RSE that will be required for V2I applications.*
>
> *Additional outreach, education, and information sharing is needed within the V2I community.*

As part of its contribution to this issue, TWG 4 will identify outreach that may be needed to increase awareness and support of V2I among transportation agencies and service providers. Two rounds of input aimed at addressing Issue 6 are planned for TWG 4 – one now and another in Q2-2016.

During its August 12 meeting, TWG 4 reviewed a sampling of existing and developing outreach materials and discussed outreach needs which is summarized in the remainder of this document.

Outreach Materials (Existing)

The following list of materials reviewed by TWG 4 is far from comprehensive. It is merely a reflection of outreach materials that TWG 4 members were aware of and able to share to-date.

1. How Connected Vehicles Work – ITS JPO (fact sheet)
2. Planning for the Future of Transportation: Connected Vehicles and ITS – ITS JPO (fact sheet)

3. Connected Vehicles: The Future of Transportation – ITS JPO (video)
4. Road Weather – Connected Vehicle Applications – ITS JPO (infographic)
5. The US Department of Transportation to Unveil New Connected Vehicle 102 Course at the ITS America Annual Meeting in Pittsburgh – ITS JPO (news release/training)
6. Connected Vehicle Field Infrastructure Footprint Analysis – AASHTO (executive briefing)
7. Connected Vehicles and Autonomous Vehicles: Where Do ITE Members Stand? – ITE (12/2013 article)
8. Transportation: Connecting the Past to the Future – ITE (4/2015 article)
9. Fundamental Issues for Road Transport Automation – ITS America (webinar)
10. Concept of Operations for C-ITS Core Functions – Austroads Research Report AP-R479-15 (report)
11. C-ITS Interoperability with Existing ITS Infrastructure – Austroads Research Report AP-R458-14 (report)
12. NCHRP 20-102 – Impacts of Connected Vehicles and Automated Vehicles on State and Local Transportation Agencies
13. NCHRP 20-24(98) – Connected/Automated Vehicle Research Roadmap for AASHTO

Outreach Needs (Gaps)

The initial needs that were discussed during the June workshop were recapped for the group and additional needs were expressed after reviewing the sample of outreach materials listed above.

- Talking points for executive agency officials to address the **what/why/how/benefits/ opportunities** of Connected Vehicles and V2I.
- **Supporting statements** from executive agency officials for Connected Vehicles and V2I.
- Cursory, high-level materials for executive agency officials to understand the **business case** for Connected Vehicles and V2I.
- Information about **big picture issues** regarding funding, benefits/costs, priorities, maintenance/operations and staffing.
- Emphasize the **need for V2I** when there will be so many benefits from V2V.
- **All levels of transportation agency staff** – executive to technical, state to local – need to learn more about Connected Vehicle and V2I deployment.
- **Elected officials and local level associations** (e.g. city and county engineer associations) need to learn more about Connected Vehicles and V2I deployment.
- **Manufacturers and suppliers** of products that will support Connected Vehicle and V2I need to learn more about deployment.

It was noted that there have been similar conversations recently about outreach to similar audiences regarding transportation systems management and operations (TSM&O). There may be opportunities to combine V2I messaging in some TSM&O outreach or, at a minimum, there may be an opportunity to follow the outreach patterns being used for TSM&O.

Bob Sheehan also noted that USDOT recently issued a task order for V2I Knowledge/Technology Transfer and Outreach. The task order is being led by Karen Timpone at USDOT and it requests the development of an outreach plan, website and marketing materials, and gathering feedback from stakeholders. Work is expected to begin in the coming month. The TWG 4 discussion offers good feedback for the KTT work, as well as the Professional Capacity Building effort being led by Mac Lister at USDOT and cooperative ITS deployment platform discussions about outreach in Europe. Mike Pina is another good staff resource to touch base with as he has been developing materials for ITS JPO. Bob Sheehan offered to serve as a USDOT coordination point for TWG 4 to have further discussions about when and how the group can provide additional feedback on outreach.

For more information about this summary or TWG 4, please contact:

Faisal Saleem, Chair – Maricopa County, Arizona, faisalsaleem@mail.maricopa.gov, 602-506-1241
Navin Katta, Co-Chair – Savari, Inc., navin@savarinetworks.com, 412-273-0376
Ginny Crowson, Liaison – Athey Creek Consultants, crowson@acconsultants.org, 651-600-3338

Appendix K: One-Stop Shop for Research

Issue 6: V2I Outreach (One-Stop Shop for Research)

Volunteers:

- Greg Larson, Caltrans, greg.larson@dot.ca.gov Co-leader for this activity
- Rob Bertini, Cal Poly State University, bertini.robert@gmail.com Co-leader for this activity
- Ray Derr, Transportation Research Board, rderr@nas.edu
- Skip Yeakel, Volvo Group North America, Skip.Yeakel@Volvo.com

Timeframe: Now

Role in Coordination: TWG 2 will develop a description of the concept and intent for a "one-stop-shop" for Connected Vehicle research sharing. This concept will be available to allow entities that may be able to serve the purpose of the "one-stop-shop" (e.g. NoCOE or other entities) to be able to understand what resources would be required to develop and support the "one-stop-shop". The intent would be that the "one-stop-shop" (as defined by TWG 2 could be developed in subsequent years by one or more entities to be determined based on the concept.

Status: TWG 2 has engaged the NOCoE to help develop the one-stop shop, and the Center will use its resources to help develop and maintain the one stop shop. We are now in Task 2 of the list of recommended next steps.

Targeted Outcome: "One-stop-shop" for V2I related research concept described to the point where entities could estimate the costs and resources required to create and operate the 'shop'.

Recommended Next Steps:

Task 1: Email the CV/AV stakeholder group responsible for CV/AV research/operations in TRB, AASHTO, V2IDC, and et.al. to frame the early discussions on this initiative and the proposed approach below. The group will include (in its initial engagement):

- Rob Bertini and Greg Larson, V2I Deployment Coalition Research Working Group Co-chairs (Rob Bertini is also TRB Operations Section Chair)
- Skip Yeakel, V2I Deployment Coalition Working Group Member
- Dean Deeter, V2I Deployment Coalition and Executive Team Leadership Liaison
- Jane Lappin and Greg Krueger, TRB ITS Committee Current and Incoming Chairs
- Jon Obenberger, TRB Freeway Operations Committee Chair
- Steve Shladover TRB Vehicle Highway Automation Committee Chair
- Galen McGill and Scott Marler, AASHTO TSM&O Subcommittee Research Working Group
- Melissa Lance and Dean Gustafson, Virginia DOT and the Connected Vehicle Pooled Fund Study
- Carl Anderson, Collision Avoidance Metrics Partnership (CAMP)
- Brian Cronin, US DOT Joint Program Office
- Rich Cunard, TRB Operations Committees Liaison
- Ray Derr, TRB NCHRP
- Gummada Murthy and Patrick Zelinski, AASHTO TSM&O Committee Liaisons

- Siva Narla, Senior Director, Transportation Technology, ITE
- Adrian Guan and Patrick Son, ITS America Program Department/Coordinating Council and V2IDC Liaisons

Task 2: Reach out to the Transportation Research International Documentation (TRID) Database (http://trid.trb.org/) at the Transportation Research Board and the National Transportation Library (http://ntl.bts.gov/) in the Office of the Assistant Secretary for Research and Technology at the US Department of Transportation (Amanda Wilson is the head of the National Transportation Library at BTS (http://ntl.bts.gov/), and Alasdair Cain oversees the Transportation Research Hub at OST-R (http://ntlsearch.bts.gov/researchhub/index.do) and capture their CV/AV knowledge resources for compilation in the NOCoE Knowledge Center.

Task 3: Review and identify a desirable taxonomy to ensure effective key word tagging of CV/AV content.

Task 4: Engage the CV/AV community proactively to obtain new content.

Task 5: Identify strategy for promotion and outreach of these knowledge resources: NOCoE newsletter stories, webinars, listserv/discussion forums, etc.

Appendix L: Webinar Summaries of Connected Vehicle Benefit / Cost Projects

Vehicle to Infrastructure (V2I) Deployment Coalition

Technical Working Group 1: Deployment Initiatives

Webinar Summaries of Connected Vehicle Benefit / Cost Projects
December 2015

INTRODUCTION

The Vehicle to Infrastructure (V2I) Deployment Coalition (DC) Technical Working Group (TWG) 1: Deployment Initiatives recently facilitated two webinars that highlighted ongoing research projects related to connected vehicle benefit/cost analyses. The intent of the webinars was to share project information with all TWGs who are working on V2I benefit/cost efforts.

This brief summary was prepared to synthesize key information presented in each webinar. It is not intended to be a comprehensive summary of all information presented. In addition, each webinar was recorded, and anyone is welcome to view the webinar recordings.

Webinar 1: Desk Reference and Tools for Estimating the Local, Regional, and State-wide Economic Development of Benefits of Connected Vehicles to Infrastructure

- Webinar 1 Summary
- Webinar 1 Recording

Webinar 2: AASHTO Near TermV2I Transition and Phasing Analysis Connected Vehicle Life Cycle Cost Model (LCCM)

- Webinar 2 Summary
- Webinar 2 Recording

Webinar 1 Summary

Desk Reference and Tools for Estimating the Local, Regional, and State-wide Economic Development Benefits of Connected Vehicles to Infrastructure

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Presented on: November 16, 2015

Presented by: Chris Williges, HDR. Presenting on behalf of Max Azizi, USDOT.

Webinar Recording Link:

https://atheycreek.webex.com/atheycreek/lsr.php?RCID=6ed3d99e57c23833f0dcc75a49514147

Project Purpose:

The purpose of this project is to develop a desk reference and analysis tool to estimate the economic benefits associated with connected vehicle technologies, with an emphasis on Vehicle to Infrastructure (V2I) applications. The project has focused on user benefits and economic impacts of connected vehicles.

Planned Project Deliverables

The primary outcomes of the project are expected to include:

- ***Desk reference report*** – A Microsoft Word or PDF document describing the tool and providing details of the research conducted; and
- ***Sketch planning benefit tool*** - An interactive Microsoft Excel workbook that allows users to enter one or more planned connected vehicle application deployments and receive information about the projected benefits of each application (or aggregate benefits of multiple applications).

Details of the Sketch Planning Benefit Tool

The benefit tool is based on and shares similarities with the FHWA Tool for Operations Benefit Cost Analysis (TOPS-BC). The tool being develop for this project is intended to be a companion to the TOPS-BC, focusing on V2I applications. The following bullets provide highlights of the tool, as presented in the webinar:

- The tool is intended to be used to estimate the benefits of V2I technologies.
- The tool does not estimate the costs of V2I technologies. However, this project is coordinating with the AASHTO Life Cycle Cost Model (LCCM) Project that identifies costs of connected vehicle deployment, operations, and maintenance – see Webinar 2 Summary for additional information. A link between the LCCM and this tool would enable cost projections to be inserted automatically without the need to re-enter the data.
- The tool is a Microsoft Excel workbook. Users considering connected vehicle applications are able to enter information on single or multiple V2I deployments and receive information about the project benefits of each application.
- Definitions of V2I applications in the tool are based on the definitions found in the Connected Vehicle Reference Implementation Architecture (CVRIA).
- Benefit estimates generated by the tool are based on what the research team found in a literature search as well as results of other previous projects. For example, if the literature search revealed

a source that defined a quantified benefit of a V2I application was 10% improvement in travel time, this is the value used in the tool to generate benefits.

- The tool takes the theoretical benefits derived in previous studies and identifies steady state benefits (benefits that would be derived when you had full mature deployment of V2I applications). This research project then developed the functionality into the tool to adjust these theoretical steady state benefits using two factors:
    - Penetration of connected vehicle components in the vehicle fleet; and
    - Efficacy adjustment factor – e.g. given a certain penetration rate, what percent of benefits could occur. For some applications you can see mature benefits for low penetration rates, while other applications only achieve mature benefits with high penetration rates.
- A flat file database is used to store all the quantified benefits associated with V2I applications. Therefore, as more benefits are researched and estimated, these results can be added to the flat file to increase the V2I applications supported by the tool.

Technical challenges faced

- ***Linking benefits to V2I Applications.*** Identifying and linking benefits to applications is difficult. Some connected vehicle applications are in preliminary design and the definitions are still evolving, and knowledge of the potential benefits is limited.

- ***Aggregating benefits of multiple applications***. Beyond considering V2I applications in isolation, when multiple V2I applications are deployed together, the concept of accruing the benefits of multiple simultaneous applications is also a difficult task. The question of how multiple simultaneous V2I applications will benefit users is an open research question. There is not a lot of research to date that has focused on multiple V2I applications deployed and operated together. Questions include:

    - Are there synergistic benefits that are bigger than the sum of individual benefits when multiple applications are deployed together?

    - Are there diseconomies where certain applications have already produced benefits and there are limited or no benefits remaining for additional applications to achieve?

- ***Distributing benefits to users.*** Figuring out how to distribute the benefits across stakeholders is a challenge. The timing of when the benefits are recognized, and the actual users who recognize the benefits is also a challenging question. For example, some benefits are only achieved over time, while others are recognized very soon after deployment.

- ***Lack of Economic Development Benefit Research.*** No existing literature attempts to measure economic development benefits. This project originally was intended to identify the following three types of V2I application benefits: user benefits, economic impact benefits, and economic development benefits. However, the project was adjusted to focus on two types of V2I applications:
    - User Benefits, and
    - Economic Impact Benefits.

- ***Limited quantified benefits defined for V2I Applications.*** The literature search revealed that there have only been a small number of projects that quantified and monetized the user benefits of V2I technologies. There are more studies on the safety benefits of V2I applications, however the research tends to be limiting by focusing on theoretical, rather than on specific details.

Project Status

As of November 2015, the research team has developed a preliminary desk reference and tool. These draft deliverables are being reviewed by an internal review group. The next step will be to develop case studies to test the deliverables.

The project is estimated to be completed in May of 2016. The final tool and desk reference will be posted on the FHWA website.

Conclusion

This research project will deliver a framework that will allow users to enter planned V2I applications and view a report of the likely benefits of the application deployments. When combined with the AASHTO Life Cycle Cost Model, the pair of tools will provide information on the expected costs and benefits should V2I applications be deployed.

The tool for this project uses a flat file structure that enables additional V2I application benefits (quantified and monetized) to be entered into the tool as additional information is gathered. As additional benefits are entered, the tool will take into account the additional benefits entered. Therefore, if additional research were to be conducted to identify quantified and monetized benefits of V2I applications, this tool is a resource that can take these benefits and support end users in understanding the projected user benefits, based on anticipated penetration and efficacy. Therefore, needs in the area of V2I benefits and costs understanding include:

- More studies on V2I benefits, quantifying and monetizing them to the extent possible; and
- Understanding of what happens when you have multiple V2I applications at the same time.

Webinar 2 Summary

AASHTO Near Term V2I Transition and Phasing Analysis Connected Vehicle Life Cycle Cost Model (LCCM)

Presented on: December 4, 2015

Presented by: Keith Platte, AASHTO and Dominie Garcia, Booz Allen Hamilton

Webinar Recording Link:
https://atheycreek.webex.com/atheycreek/lsr.php?RCID=fea5d81316a883d4de72d72a2e028f1b

Project Purpose

As part of a suite of tools, AASHTO is developing a life cycle cost model for V2I applications that will detail all cost components associated with deployment of V2I applications over a 20 year period. The model has researched costs included, but also has the flexibility for users to change costs. It is anticipated the cost model will be released in 2016 and will provide users with insight and detailed estimates for installing, maintaining, customizing, and operating all needed elements of V2I applications.

Summary of the Suite of Tools

This project is developing three tools that will work together, including:

- ***Application Prioritization Tool*** – A tool that guides users through a series of three questions to narrow down a list of suggested applications based on the responses.
- ***Life Cycle Cost Model (LCCM)*** – a Microsoft Excel based tool that guides users through a set of inputs that trigger a calculation of established cost components required for the planning, design, deployment, operations, and maintenance of the application(s).
- ***Infrastructure Planning Tool*** – A tool to provide supplemental information to assist in V2I deployments. Users answer a set of questions related to size and scope of the project, initial capital, etc. The results provide ancillary information to assist in the timing and phasing of deployments.

Details of the Life Cycle Cost Model (LCCM) Tool

The tool is an interactive MS Excel workbook. Functions are as follows:

- Users have a series of input opportunities;
- Based on the input, the user is presented with a very detailed set of component costs per application;
- Tool returns annual and aggregate set of individual component costs and total costs over a 20 year time period;
- The tool provides details to help with budgeting and planning process;
- The tool is built to support the flexibility that end users will need. A considerable amount of research has focused on cost information that are included in the tool defaults. However, users can change costs information (that serve as the basis for calculations) based on their own experiences or knowledge. For example, if a user already has equipment and knows they will save on costs, they can adjust the costs.

Functionality of the tool

1. The tool allows users to select one or more applications from approximately 70 applications (this may be adjusted in the final version).
2. The next step asks the users to answer a set of questions about the 'Building blocks' of the applications. These are questions related to the size and complexity of the deployment (e.g. "how many drivers for transit vehicles?" "how many signalized intersections will be included?"). Note: a companion user guide accompanies the tool with definitions of each of these building blocks.
3. After answering these initial questions, the tool provides the user with a year by year, and element by element cost breakdown. Some details of the cost breakdown include:
    - Discount rate is adjustable by the user.

- Costs include such things as training of drivers (i.e. based on the number of drivers entered by the user).
- Costs include all aspects, including: planning, designing, installing, operations and maintenance.
- All the component costs are changeable. They can either be left at the default value, identified as "most likely", or users can override this. There are also options to select other defaults that have been created by the research team, including: minimum, maximum value defaults.

Availability of the Tool

The tool is in the final stages of development. This version is a prototype/proof of concept tool. A final decision about the process to finalize the tool for use by end users will be determined in 2016.

AASHTO and USDOT will update members of the V2I Deployment Coalition once the tool is available for use.

Appendix M: V2I Safety Application Implementation Benefits and Costs

V2I Safety Application Implementation – Discussion Draft

Safety Application Functionality[2]

Reduced Speed Zone Warning / Lane Closure (RSZW/LC)

The objective of the RSZW/LC application is to leverage V2I communication to inform/warn drivers when they are operating at a speed higher than the posted speed limit and/or by providing information regarding changes in roadway configuration (e.g., lane closures, lane shifts), particularly for a driving scenario requiring a lane change.

When an equipped vehicle approaches a zone that requires reduced speed and/or presents a change in roadway configuration, the application evaluates vehicle speed and position and if appropriate, warns the driver. For example, in the case of a vehicle approaching a work zone, the OBE receives a message from the RSE about the work zone speed limit, geometric configuration and lane closure information for use by the application to inform and warn the driver appropriately. Figure 1 illustrates the RSZW/LC application concept and the application information flow is shown in Figure 2.

Figure 1: Illustration of RSZW/LC Application Concept

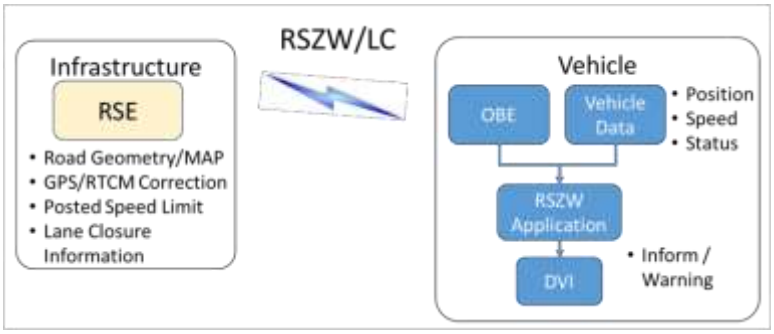

Figure 2: Information Flow for RSZW/LC Application

[2] Contents of this section excerpted from "Vehicle-to-Infrastructure (V2I) Safety Applications Project - Task 6, 7 and 8 Combined Interim Report: Application Development, Vehicle Build and Infrastructure Build", CAMP V2I Consortium, as Pre-publication Materials Provided for Comment Only.

The RSZW application considers vehicle-centric elements such as vehicle speed in addition to environmental elements such as road work zone geometry, lane closures, presence of workers and speed limits to appropriately provide Inform / Warning messages to the driver. The effectiveness of this application is dependent upon timely updates of the information noted which may require frequent updates for work zones as configuration and presence of workers change.

Red Light Violation Warning (RLVW)

The objective of the RLVW application is to advise drivers of the signal phase of an approaching signalized intersection and, based on data from infrastructure- and vehicle- based sensors, warn them if they are at risk of violating a red signal phase if they do not stop.

The RLVW application receives Signal Phase and Timing (SPaT) and intersection geometry information from the infrastructure RSE and combines it with vehicle kinematic data to determine the potential to violate a red signal phase at an approaching signalized intersection. The RLVW application concept is illustrated in Figure 3. The infrastructure application component provides information to the vehicle application component, which generates a vehicle-specific warning to notify the driver in sufficient time to stop before entering the intersection on a red phase. The information flow for the RLVW application is shown in Figure 4.

Figure 3: Illustration of RLVW Application Concept

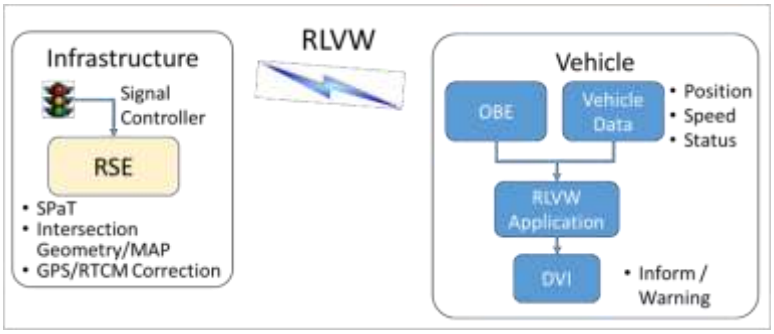

Figure 4: Information Flow for RLVW Application

Wireless Information Exchange

In order to support the operation of vehicle-based and infrastructure-based elements of V2I safety applications, information relevant to each specific application must be exchanged in a common format. As shown, RSZW/LC requires Road Geometry/MAP, GPS/RTCM Corrections, Posted Speed Limit, and Lane Closure information while RLVW uses SPaT, Intersection Geometry/MAP, and GPS/RTCM Corrections. Other V2I safety applications may employ different combinations of information.

The Basic Information Message (BIM) is a proposed new message format that enables the transmission of all required data elements for V2I safety applications in a single message and is extensible to support future event based applications. The BIM structure

is based on the European Telecommunications Standards Institute (ETSI) standard for the Decentralized Environmental Notification Message (DENM). This concept of message structure uses existing SAE J2735 data elements. As shown in Figure 5, the BIM

structure is made of a container concept consisting of a common container that provides basic information elements about an event such as event location, type, time and duration. The event-specific container provides data elements relevant to the event (e.g., speed limits, event MAP, associated flags) for use by on-board applications. Such a concept provides flexibility to extend the message structure by adding containers for future event types (use cases) yet maintaining backward compatibility.

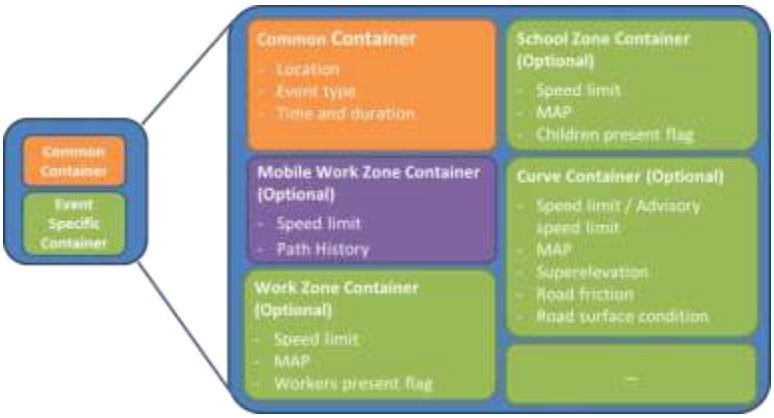

Figure 5: Basic Information Message Structure

Potential Safety Benefits

Reduced Speed Zones

The Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E) Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) application was based on the functionality and design that was defined for the Reduced Speed Zone Warning Application.[3] The R.E.S.C.U.M.E. INC-ZONE application was developed, prototyped and tested in a controlled environment as part of the Dynamic Mobility Applications program.[4],[5] The corridor modeling and simulation conducted by Booz Allen Hamilton of the INC-ZONE application as part of these activities revealed important conclusions regarding the effectiveness of the applications under test conditions. The following are the major conclusions.

Network-Wide Performance

- The average network-wide reduction in delay and increase in speed was higher for dry conditions than rainy conditions. The percent benefit was greater for average delay than for average speed.
- The reduction in network delay was between 1 percent and 14 percent, and the increase in average speed was between 1 percent and 8 percent for dry conditions. These benefits were more for long incident than short incident scenarios.
- The reduction in network delay was between 1 percent and 7 percent, and the increase in average speed was between 0.25 percent and 3 percent for rainy conditions. These benefits were more for short incident than long incident scenarios.[6]

Incident-Zone Level Performance

- In terms of mobility, the increase in section throughput increases with market penetration, with values ranging between 1 percent and 14 percent.
- Mobility improvement at the incident zone, as reflected by the increase in section throughput, was found to be higher under dry conditions than rainy conditions for all levels of market penetration. The average improvement under dry conditions was around 2 percent higher than under rainy conditions.

[3] Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) is a communication approach that will improve protection of incident sites where there have been crashes, accidents, or other events impacting traffic such as stalled vehicles or vehicles pulled over for moving violations.

[4] The R.E.S.C.U.M.E application bundle aims to advance vehicle to vehicle safety messaging over dedicated short-range communications (DSRC) to improve the safety of emergency responders and travelers. Three applications, Incident Scene Pre- Arrival Staging Guidance for Emergency Responders (RESP-STG), Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE), and Emergency Communications and Evacuation (EVAC) are included in the R.E.S.C.U.M.E.
application bundle.

[5] The Dynamic Mobility Applications program was initiated to create applications that fully leverage frequently collected and rapidly disseminated multi-source data
gathered from connected travelers, vehicles and infrastructure to increase efficiency and improve individual mobility while reducing negative environmental impacts and safety risks.

[6] Impact Assessment of Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) and
Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG) - Final Report. May 8, 2015. FHWA-JPO-15-203

- Reduction in maximum deceleration was found to be between 1 and 89 percent for different operational conditions, with the highest improvement being for the dry conditions with long incident case.
- Reduction in sublink speed ranged between 0 and 14 percent with the highest reduction for the dry conditions with long incident case.[7]

User Level Value

- The increase in average speed and average following distances for equipped users versus non-equipped users were studied. Use of INC-ZONE in rainy conditions with short incidents showed more user benefits than for other operational conditions.
- The increase in average speed for INC-ZONE users was between 13 percent and 40 percent over non-users.
- The increase in average following distance for INC-ZONE users was between 2.5 percent to
- 19 percent over non-users.
- The difference between average speed and average following distance of users and non- users of INC-ZONE increased with rising market penetration.[8]

Signalized Intersections

The following excerpt from AASHTO's series of Connected Vehicle (CV) deployment analyses[9] highlights the potential for RLVW to improve safety.

> "Improving safety is a primary objective, and estimates of the potential for safety improvement with V2I systems could provide insight.
>
> - The 2010 NHTSA report on *Frequency of Target Crashes for IntelliDrive Safety Systems* asserts that V2I systems as the primary countermeasure would "potentially address about 25% of all crashes involving all vehicle types," including crashes at intersections.[10] The report does not specifically address the fraction of crashes occurring at intersections.
> - A 2010 NHTSA report on *Crash Factors in Intersection-Related Crashes* determined that 36% of crashes in the U.S. in 2008 were intersection-related, and 52.5% of vehicles involved in those crashes were traveling on signal-controlled roadways.[11]
> - A 2009 Noblis document, *Footprint Analysis for IntelliDrive[SM] V2V Applications, Intersection Safety Applications, and Tolled Facilities*, found in a study of intersections and

[7] Impact Assessment of Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) and Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG) - Final Report. May 8, 2015. FHWA-JPO-15-203
[8] Impact Assessment of Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) and
Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG) - Final Report. May 8, 2015. FHWA-JPO-15-203
[9] National Connected Vehicle Field Infrastructure Footprint Analysis: Deployment Footprint, Timelines and Cost Estimation, Draft Report v1, February 21, 2014
[10] National Highway Transportation Safety Administration; Frequency of Target Crashes for IntelliDrive Safety Systems Report Number DOT HS 811 381; October 2010.
[11] National Highway Transportation Safety Administration; Crash Factors in Intersection-Related Crashes: An On-Scene Perspective; Report Number DOT HS 811 366; September 2010.

collision frequency in three large metro areas that 20% of intersections account for 50% of collisions, and that 50% of intersections account for 80% of collisions.[12]

- An earlier 2005 study, *Intersection Crash Summary Statistics for Wisconsin*, found in a state-wide study that crashes at signal-controlled intersections represented 68.8% of crashes at controlled intersections, although only 48.5% of intersections studied were signalized. Crashes at intersections with greater than 25,000 vehicles per day entering the intersection represented 48.3% of crashes at controlled intersections, although those represented only 28.1% of controlled intersections.[13]

Although none of these studies directly address warrants for V2I-enabling signalized intersections, it can be inferred that there are likely safety benefits, that deployment at signalized intersections would address a greater fraction of potential crashes than at non-signalized intersections, and that deployment at high-volume intersections would address the greatest likelihood of crashes. Any consideration for mobility and environmental benefits would further increase deployment incentives and would likely reinforce the safety warrants."

[12] Noblis, Inc.; Footprint Analysis for IntelliDriveSM V2V Applications, Intersection Safety Applications, and Tolled Facilities; prepared for the U.S. DOT / RITA / ITS JPO; March 2009; Accessed February 2014 at http://www.its.dot.gov/research_docs/pdf/12Footprint.pdf.

[13] Traffic Operations and Safety Laboratory, University of Wisconsin-Madison; Intersection Crash Summary Statistics for Wisconsin; June 2005.

Deployment Cost Estimates

Infrastructure Side

The following excerpt from AASHTO's series of deployment analyses[14] summarizes the range of infrastructure costs to be expected when implementing CV technology.

> "Based on preliminary designs and the limited experience with pilot deployments, with all estimates in constant 2013 dollars:
>
> - The average direct (Dedicated Short Range Communications) DSRC roadside unit (RSU) deployment cost per site is estimated to be $17,600.
> - The cost to upgrade backhaul to a DSRC RSU site is estimated to vary between $3,000 and $40,000, at an estimated national average of $30,800.
> - The typical cost of signal controller upgrade for interfacing with a DSRC RSU is estimated to be $3,200.
> - The annual operations and maintenance cost for a DSRC RSU site are estimated to be $3,050."

Vehicle Side

The following excerpts from NHTSA's report entitled "Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application"[15] provide initial insight into anticipated vehicle side costs to deploy CV technology.

Summary of Likely Costs in Year 1 for New Vehicles (2012 dollars)

(Excerpt from Table XI-2)

	Consumer Costs
Supplier Costs	$327.13
Installation Costs	$15.67
Minus Current GPS Installation	$13.89
Total	**$329.14**

Aftermarket Consumer Cost Estimates for Year 1 (2012 dollars)

(Excerpt from Table XI-12)

	Equipment	Installation	**Total**
Retrofit	252.20	135	**387.20**
Self-contained	213.20	112.5	**325.70**

[14] National Connected Vehicle Field Infrastructure Footprint Analysis: Deployment Footprint, Timelines and Cost Estimation, Draft Report v1, February 21, 2014.
[15] DOT HS 812 014, August 2014

Appendix N: Research Definition for Cost-Effectiveness Assessment of Vehicle to Infrastructure Applications

Research Definition for Cost-Effectiveness Assessment of Vehicle to Infrastructure Applications

RESEARCH PROBLEM STATEMENT

Connected Vehicle (AV) technologies offer potential to significantly improve safety and efficiency of travel. Vehicle-to-infrastructure (V2I) applications in particular can reduce fatalities and injuries at traffic signals and other critical areas such as work zones and curves. There is very limited deployment of CV-enabled vehicles and/or infrastructure. This means that benefits must be estimated using simulation models or forecasts rather than by direct observation. This research will assess current tools and benefits estimation frameworks and approaches and identify any gaps in methodology, process, or information. The project will then develop the methodology, tools, or processes to fill those gaps.

OBJECTIVE

The objective of this research is to provide agencies with tools for large-scale assessment regarding the cost effectiveness of V2I applications. Without demonstrated cost-benefit of CV technology, agencies have limited incentive to invest in unproven technology and lack the information needed to compare the likely return from V2I expenditures with other transportation investment opportunities.

RESEARCH PROPOSED

The research team will review literature in V2I applications benefits estimation to include the AASHTO footprint analysis, the NHTSA V2V readiness report, the USDOT tools, and related academic research. The team will identify gaps in these approaches and propose a plan to fill those gaps with new tool development, research, and data collection. This work should build on lessons learned from CVPD projects in Wyoming, New York, and Florida. The research team will focus on the four high-priority V2I application areas identified by the V2I Coalition: (1) work zones, (2) curve warning, (3) traffic signals, and (4) queue warning. To a lesser extent they should consider positive synergies among these applications both in terms of cost savings and increased net benefits to safety and mobility and the ability of the field deployments to handle other secondary applications. In particular, technology investments in contrast to more straightforward infrastructure projects generate network impacts that are difficult to quantify. The research team will apply the benefits estimation approach to a variety of deployment scenarios, and in particular evaluate the effects of penetration level of equipped vehicles and geographic locations. At least six alternative locations and deployment organizational types will be considered ranging from isolated rural to dense urban environments (rural agency, suburban agency, urban agency, State agency, multi-state coalition, regional coalition). The scenarios should illustrate the effect on cost effectiveness of 1) different levels of market penetration among the vehicle fleet, 2) different levels of RSE deployment density, and 3) different levels of development density. The assessment will identify where V2I applications perform best. It should also identify when V2I reach break-even returns based on market penetration among vehicles and on the density of deployment of RSEs. The team will then summarize the findings and recommendations for the best plan of action towards implementation of further deployment.

ESTIMATE OF THE PROBLEM FUNDING AND RESEARCH PERIOD

Recommended Funding: $400,000.

Research Period: 15 months.

URGENCY AND PAYOFF POTENTIAL

Agencies need evidence that investment in CV V2I technologies will be cost-effective use of their resources. Thus, the research is considered quite urgent given the timeline of typical procurement processes, the expectation of rapid deployment of required equipment in vehicles in the near future, and need to address institutional issues related to project definition and funding. V2I applications can be transformative in the ability of public agencies to provide a broad range of public benefits at reduced cost but limited public funds also call for evidence of the expected return on investment.

RELATIONSHIP TO NCHRP STRATEGIC RESEARCH GOALS, STRATEGIC PRIORITIES, and/or TRB STRATEGIC, CRITICAL, AND EMERGING ISSUES

This research is an important component of the AASHTO AV/CV research roadmap.

RELATED RESEARCH

No current NCHRP 20-102 project is developing a benefits estimation approach. This research should extend from current FHWA/USDOT sponsored work on benefits estimation, NCHRP 03-103, NCHRP 20-102 (08), and other methodologies developed and available in the literature.

PERSON(S) DEVELOPING THE PROBLEM

Douglas Gettman, Ph.D.
Director of AV/CV Consulting Services
Kimley-Horn
Doug.gettman@kimley-horn.com
(602) 906-1332

Dick Mudge, Compass Transportation
William Gouse, SAE
Alan Korn, Meritor WABCO

PROCESS USED TO DEVELOP PROBLEM STATEMENT

This RPS was developed by Dr. Gettman and members of the V2I Coalition Working Group 2 (Research) and was reviewed by Greg Larson and Rob Bertini.

DATE AND SUBMITTED BY

June 23, 2016; Submitted by Dr. Douglas Gettman on behalf of the V2I Coalition Working Group 2

Appendix O: Research Definition for Planning Analysis Methods for Assessing the Mobility and Reliability Impacts of Connected and Autonomous Vehicles

Research Definition for Planning Analysis Methods for Assessing the Mobility and Reliability Impacts of Connected and Autonomous Vehicles

This research project will synthesize findings from the wide range of technical literature, initial field tests, supplemented with exploratory microsimulation, to ascertain the likely capacity and operational effects of connected and autonomous vehicles (CV/AV) at a planning level decision making. This will be examined in light of recent federal, state, and commercial field tests of CV/AV while considering current and emerging trends in vehicle technology. This work will convert the reported CV/AV performance into a simple set of macroscopic planning analysis procedures (suitable for incorporation in Planning Guides) that agencies can use to make infrastructure investment decisions to support and take advantage of the operational, capacity, reliability, and cost savings benefits of CV/AV. By shortcutting the need for conducting expensive microsimulation analyses of each CV/AV investment decision, this project will greatly facilitate the roll-out of CV/AV supporting infrastructure investments throughout the United States.

RESEARCH NEED

The Highway Capacity Manual (HCM) is the pre-eminent resource for highway investment decisions by state DOTs. Connected and autonomous vehicles are emerging on the highways at this very moment, yet the HCM provides no guidance on estimating the impacts of connected and autonomous vehicles on highway capacity, reliability and quality of service. The HCM also lacks information on how state DOTs might adjust their infrastructure investment decisions to take advantage of operational and capacity improvements expected with increasing market penetration of advanced vehicle technologies (CV/AV).

In general, the presence of CV/AV alters current HCM analysis paradigms in two ways: first, it increases both the spatial extent (CV/AV are ubiquitous all over the entire network) and temporal resolution level (seconds or sub-seconds) of highway capacity analysis performance measures, including segment and facility capacities, speeds, travel times and delays, giving pause to the notion of whether massive investments in the physical infrastructure can continue to be justified. In fact, many state DOT's in recent years are opting to use third party probe data (e.g. INRIX, HERE, TomTom) to assess their mobility and reliability performance on both freeways and surface streets. Secondly, CV/AV presence enables the implementation of a host of active traffic management measures including speed harmonization, queue detection and warning, real time diversions, optimized merging patterns, lane closure warnings, enhanced two-lane highway passing (reducing the design passing sight distance), reductions in critical gap size at signals at stop controlled intersections, communicating with intelligent traffic signals and the list goes on. Neither paradigm is accounted for in current or forthcoming releases of the HCM. In summary, federal and state agencies will likely face several hard choices regarding CV's and AV's:

1. Should they keep investing in and maintaining highly dense installations of costly fixed detectors (loop, radar, etc.) for performance monitoring when a sufficient number of CV's can provide the same or superior information on facility operating status?
2. Should they invest in and install DSRC units to support CV or does employing the commercial cellular network achieve the similar operational benefits?

3. Will higher levels of automation for AVs and higher market penetration rates eventually match or exceed the capacity and benefits of installing freeway ramp metering and other Active transportation and demand management (ATDM) strategies?
4. Should they invest in physical roadway capacity or will automated and connected vehicles provide a substantial increase in capacity and reliability?

Thus, State DOTs need to rethink and retarget their Intelligent Transportation Systems (ITS) and ATDM investment programs in light of recent and anticipated advances in CV/AV. A set of investment benefit/cost analysis procedures tailored to the state of the art and technology trends of CVs/AVs are needed to answer these questions. The estimation of the benefits of CV/AV will require planning-level procedures for estimating the capacity, operations, and reliability benefits of different ATDM/ITS and CV/AV infrastructure investment options that are suitable for planning/programming and investment decision making. The proposed research addresses this need head-on.

OBJECTIVE

The objective of this research project is to develop a set of simple, cost-effective, macroscopic computational procedures that state DOT's can use to produce planning level estimates of capacity, travel time, and reliability effects of connected and autonomous vehicles, under different ATDM/ITS and CV/AV infrastructure investment options. The procedures should cover the entire set of points, segments and facilities found across the HCM. A technical challenge will be how to synthesize the high spatial and temporal nature of the CV/AV-generated data into the broader category of capacity and travel time effects. The procedures should be sensitive to developing technology trends in CV and AV and to the changing market penetration levels for CV/AV. The procedures should be suitable for eventual incorporation into the Planning Applications Guide of the Highway Capacity Manual

POTENTIAL BENEFITS

One state alone, New Jersey, has plans to spend $1 billion over ten years to build out its ITS network.[1] Between 40% and 80% of the transportation agencies in the US are contemplating expanded or new investments in ITS for freeways and arterials. [2] As the investment costs grow, and as more agencies contemplate extensive investments in ITS and ATDM, there is a need for analysis tools to better allocate scarce capital and operating funds among the various ITS and ATDM investments that can best support and take advantage of CV/AV. This research project can improve decision making for better than $20 billion in ITS investments over the next 10 years.

RELATIONSHIPS TO THE EXISTING BODY OF KNOWLEDGE

The need for better decision making tools for ITS and ATDM infrastructure investments has not escaped the notice of the State DOTs, AASHTO, USDOT and FHWA.

- The NCHRP 20-24(98) Connected/Automated Vehicle Research Roadmap for AASHTO (Roadmap) states that: "Traditional transportation system design and planning models are not well equipped to assess the effects that CV and AV systems will have on transportation system operations, particularly in terms of traffic congestion, energy consumption and emissions [3]."
- The AASHTO Roadmap calls for a research project to develop "Tools to predict the Impacts of CV and AV systems on highway operations. The Roadmap also identifies the need for enhancements

to existing planning models to realistically represent the effects of different levels of market penetration of vehicles and infrastructure investments.

- FHWA is sponsoring a "Wave 1" CV pilot test sites at three sites in Wyoming (I-80), New York City and Tampa Florida [4]
- FHWA sponsored the development of the Intelligent Transportation System Deployment Analysis System (IDAS) tool [5]. This is a complex demand model post-processor sketch planning software tool employing elasticities from the literature to estimate the benefits of ITS deployments. It does not address CV/AV impacts.
- The USDOT's (ITS JPO) has established an automation program within the overall ITS program starting with a Multimodal Program Plan for Automated Vehicles [6].
- FHWA sponsored the development of the Guide for Highway Capacity and Operations Analysis of ATDM Strategies [7]. This guide does not address CV/AV impacts.
- NCHRP 3-114 is developing a guide for Planning and Evaluating Active Traffic Management Strategies [8]. This research and guide does not address CV/AV impacts.
- A recent paper [9] discussed the effects of automated *cooperative* vs. automated a*utonomous* vehicles on system capacity. The study indicated that the first type, using microsimulation as the test environment, could increase the capacity of an exclusive lane to over 8,000 vph and that of a shared lane (assuming 50% market penetration) to upwards of 4,000 vph.

While the investment analysis tools for CV/AV infrastructure investment decisions are missing, the literature on the potential effects of connected and autonomous vehicle has exploded in the last few years. A TRID search identified no fewer than 188 papers, articles, and reports on connected vehicles and capacity. Another search on autonomous vehicles and capacity yielded an additional 147 citations. So, this research will be able to draw on an already rich set of literature that are focused on CV/AV deployment on capacity and quality of service. In addition to the wealth of literature, this research project is very timely in that FHWA is currently sponsoring several research projects involving microsimulation modeling, small scale demonstrations, and larger scale pilot tests to evaluate the traffic operations impacts of different traffic management strategies designed to take advantage of CV/AV technology [10, 11]. Some of this work can be extended to consider HCM-specific impacts.

TASKS

An outline of the tasks required to complete this research is provided below. Phase I will encompass Tasks 1 through 5 and Phase II Tasks 6 through 9.

Task 1: Literature Review – Document the literature on the potential and observed impacts of various traffic management strategies employing CV/AV on capacity, travel time, and reliability. These strategies should include the Dynamic Mobility Applications (DMA) currently being researched and pilot tested by FHWA. Pilot test and small scale demonstration results should be examined and if needed identify required extensions via analytical or simulation tools.

Task 2. Identify CV/AV Technology Trends – Interview original equipment manufacturers (OEMs) and experts in the field to identify emerging trends in CV/AV technology and posit a likely deployment schedule and scenarios by truck and auto OEMs.

Task 3. Identify Trends in Traffic Management Strategies employing CV/AV – interview key experts to assess and posit an evolutionary trend for traffic management strategies employing CV/AV.

Task 4. Develop, performance measures, sensitivities and an outline for CV/AV analysis procedure and/or changes to existing procedures to be carried out in Phase II. Procedures would predict the travel time, capacity, and reliability effects of different market penetration levels and supporting infrastructure investment levels. While this task will assess the feasibility of applying those impacts to all interrupted and uninterrupted flow procedures, it is likely to end up focusing on a select subset, based on the availability of the literature and results from CV/AV testbeds to support any changes to the existing procedures.

Task 5. Interim Report summarizing the findings of Phase I, followed by a meeting with the project panel, which must approve it, before proceeding to Phase II.

Task 6. Develop CV/AV planning analysis procedures for the selected facilities defined in Task 4. For cost-effectiveness purposes, the procedures should take advantage as much as possible of adapting and/or extending existing Highway Capacity Manual planning analysis procedures. This task may also involve some microsimulation modeling to fill in gaps (for example on the effect of CV/AV market penetration) and calibrate some of the planning level parameters,

Task 7. Validate CV/AV planning and operations analysis procedures against FHWA DMA (Dynamic Mobility Application) data sets currently being posted on FHWA's data sharing site.; against data from AMS testbeds; from Wave 1 test sites for CV and AV's and from data in the archival literature,

Task 8. Demonstrate CV/AV procedures through case studies and worked example problems suggested by state DOTs.

Task 9. Final Report with recommendations on procedure updates for the Planning Application Guide of the HCM (NCHRP 7-22). Report will include worked example problems demonstrating the procedures for as many of the procedures that were developed in Task 7 and validated in Task 8.

FOLLOW-ON AND IMPLEMENTATION ACTIVITIES

The potential follow-on and implementation activities for this research include:

1. Adoption by AHB 40, Committee on Highway Capacity and Quality of Service, and incorporation into the next update of the Highway Capacity Manual
2. Webinars, course Syllabi, and training workshops on the AV/CV analysis methods
3. Development of software tools to support the application of the new AV/CV analysis methods.

ESTIMATED FUNDING REQUIREMENTS

$750,000, 18 months

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Appendix P: Standards Context Diagram

V2I Deployment Coalition TWG 5
White Paper - Standards Context Diagram

The standards context diagram in Figure 1 was developed by Technical Working Group 5 - Standards (TWG 5), of the V2I Deployment Coalition (V2I DC). The diagram provides a perspective of the different components that are part of a connected vehicle environment and the relationships among those components.

Circles and graphics in the diagram represent components that are part of the connected vehicle environment. Components consist of systems, centers and devices that exchange information to support connected vehicle applications. Systems that enable or support the connected vehicle environment, such as the Security Credentialing Management System (SCMS), are found in the upper left corner of the standards context diagram while centers that manage other connected vehicle components or connected vehicle data are found in the upper right corner of the diagram. Field and roadside equipment at fixed locations are found in the bottom right corner, while vehicles are found in the bottom left corner, and traveler devices (in the form of Vulnerable Road Users) are found in the bottom center of the diagram.

Lines represent a relationship that exists or is expected to exist between two components in the connected vehicle environment. Each line depicts one or more ITS standards that support that relationship (or interface). Text in black indicates existing standards while standards in green or cyan text are proposed standards currently under development. TBDx (TBD1, TBD2, and TBD3) indicates that no standards have been identified or developed to support the interface between those two components.

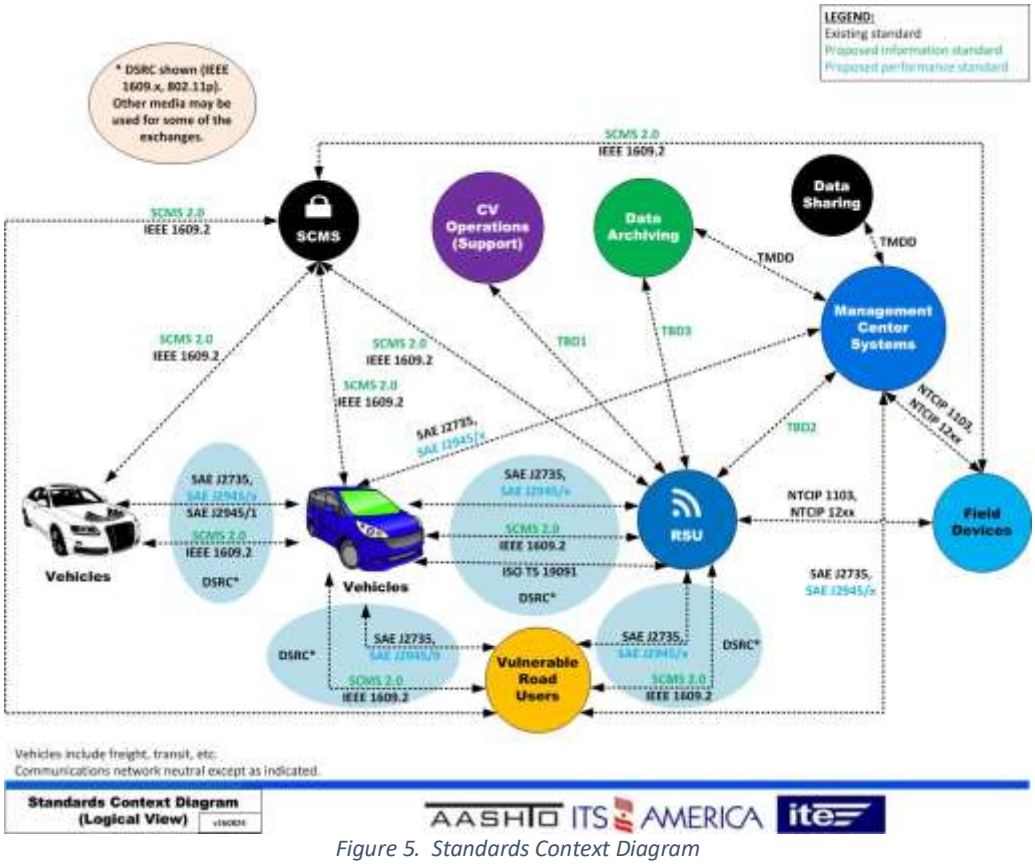


Figure 5. Standards Context Diagram

The remainder of this document provides the background on the development of the diagram, how it can be used and describes in more details the components that forms the Standards Context Diagram.

BACKGROUND

The development of the standards context diagram was identified as the first activity to be undertaken at the initial meeting of TWG5 of the V2I DC. The concept for the diagram originated when the TWG 5 needed to identify available and potential new standards between vehicles, vulnerable road users, infrastructure, and roadside units that make up the connected vehicle environment. The diagram serves as a framework showing the relationship of V2I standards, both current and needed, and how they relate to the vehicles, roadside units, and infrastructure; and can be used to facilitate discussions about current and needed standards, and to discuss gaps and needs for new standards.

The TWG 5 members collaborated to develop the standards context diagram, and continues to maintain and update the diagram based on feedback from TWG 5 members, from other Technical Working Groups, and Standards Development Organization (SDOs). While the focus of TWG 5 is on V2I, the entire connected vehicle environment is shown.

TWG 5 continues to maintain the standards context diagram. Potential benefits motivating this maintenance include:

- Standards developers, such as SDOs, can determine what gaps or needs exists for additional standards to specify the connected vehicle environment.
- Agency managers can identify the standards that should be considered to define the interface between two entities, such as for a specification. The standards presented may not address all the user needs and requirements, but is a good starting point for defining the interface specifications that need to be developed by deployers.

CONTEXT DIAGRAM OVERVIEW

This section describes the different components that are found in the standards context diagram. The components in the standards context diagram consists of physical objects, the communications interfaces between those physical objects, and the standards that make up the connected vehicle environment.

Entities

Entities are the devices that makes up the connected vehicle environment. It includes the traveler devices on the surface roadway, the devices on the roadway, and the centers maintained by the stakeholders.

- Centers.
    - Security Credential Management System (SCMS). The center(s) to provide the security services for connected vehicle environment. Services may include receiving public keys from devices, verifying the identity of requesting devices, and providing security certificates.
    - Management Center Systems. The center system(s) to exchange information with devices on the roadside or traveler devices. The center systems monitor information from the devices, such as status, and may send information or commands to the devices. The center systems may also manage field devices and Roadside Units (RSUs).
    - Data Sharing. Centers that gather data from management center systems, and process that data. The processed data may then be shared with other users. Users of the

processed data may include the management center systems as inputs to help manage their assets and roadway, and travelers via traveler information systems.
    - Data Archiving. Centers that gather data from other entities for the purpose of archiving the data. The archived data can be used for research or as inputs to management center systems.
    - CV Operations (Support). The center system(s) to manage the Roadside Units (RSUs).
- Roadway Devices.
    - Field devices. Represents traditional ITS roadway devices, such as traffic signal controllers, dynamic message signs, roadway loop detectors, etc.
    - RSU. A Roadside Unit (RSU) is a device that facilitates communications between the transportation infrastructure and vehicles and other mobile devices using Dedicated Short Range Communications (DSRC).
- Traveler Devices.
    - Vehicles. Represents the devices on vehicles that communicates kinematic information about the vehicle to other devices or centers. Vehicles may include light-duty vehicles, freight vehicles, public safety vehicles and transit vehicles.
    - Vulnerable Road Users. A device on a road user not within or on a motorized vehicle, that communicates kinematic information about the road user to other devices or centers. Vulnerable road users may include pedestrians, cyclists, or road workers.

Communications

The standards context diagram does not define a specific communications media to be used for the exchange of information between the entities. The standards context diagram allows agencies and manufacturers to determine which communications media are to be used across the interface.

However, DSRC is expected to be used, at least in the near future, the communications interface with the traveler devices for safety-related applications (such as Forward Collision Warning), that require low latency. This expectation is demonstrated in the standards context diagram with light-blue ovals. This light-blue oval does not mean that DSRC has to be used for communications across that interface for all applications, but DSRC will be used for low latency applications. For example, WiMAX might be used between a vehicle and the RSU or 5G cellular data between a vehicle and management center systems for non-low latency applications such as traveler information.

Standards

The standards context diagram provides the standards or family of standards that may be address the needs for a communications interface between two entities. Only standards or family of standards that have already published or under development by the SDOs are presented.

Not all possible standards are presented - only the most common ones. For example, there may be transit standards that may be applicable but are specific to transit vehicles. There are different types of standards that are presented. They can be classified as transmission standards, information standards and interface standards.

- **Data Transmission Standards** define how data is exchanged. Since the focus is on V2I, these are radio system standards, and involves the capability for over-the-air transmission.
    - IEEE 802.11p. Technically part of IEEE 802.11, this standard provides wireless connectivity among fixed, portable, and moving stations within a local area. http://standards.ieee.org/about/get/802/802.11.html

  - IEEE 1609.x. This family of standards defines the "rules" and procedures on how data will be exchanged between two devices in a wireless, vehicular environment. IEEE 1609.2 defines the secure message formats and the administrative functions necessary to support the core security functions in the CV environment. https://standards.ieee.org/develop/wg/1609_WG.html
  - NTCIP 1103. This standard defines a composite, application-layer protocol for the management of transportation field devices. http://ntcip.org/library/standards/default.asp?documents=yes&qreport=no&standard=1103

- **Information Content Standards** defines the information to be exchanged between entities.
  - SAE J2735. This data standard contains the data dictionary defining the messages and data elements to be exchanged among vehicles, vulnerable road users and other connected devices. https://www.sae.org/standardsdev/dsrc/
  - NTCIP 12xx. This family of standards define the object definitions that allows a management station to manage and monitor field devices. http://ntcip.org/
  - TMDD. This standard defines the messages and data elements to exchange transportation-related information between management centers. http://www.ite.org/standards/tmdd/

- **Operational, Performance, and Security Standards** define the characteristics necessary to allow the exchange of information between two systems or devices.
  - SAE J2945/x. This family of standards define the operational and performance requirements for applications that uses data exchanged between devices. SAE J2945/1 specifies the system requirements for an on-board vehicle-to-vehicle (V2V) safety communications system for light vehicles, including standards profiles, functional requirements, and performance requirements. SAE J2945/9 is currently in ballot as a proposed recommended practice containing minimum performance requirements for vulnerable road users safety messages. http://standards.sae.org/j2945/1_201603/
  - ISO TS 19091. This international standard defines the operational and performance requirements for V2I (and I2V) communications at signalized intersections. This standard is currently in ballot.
  - SCMS 2.0. This proposed standard defines the security functions and processes to support the core security functions for the connected vehicle environment.

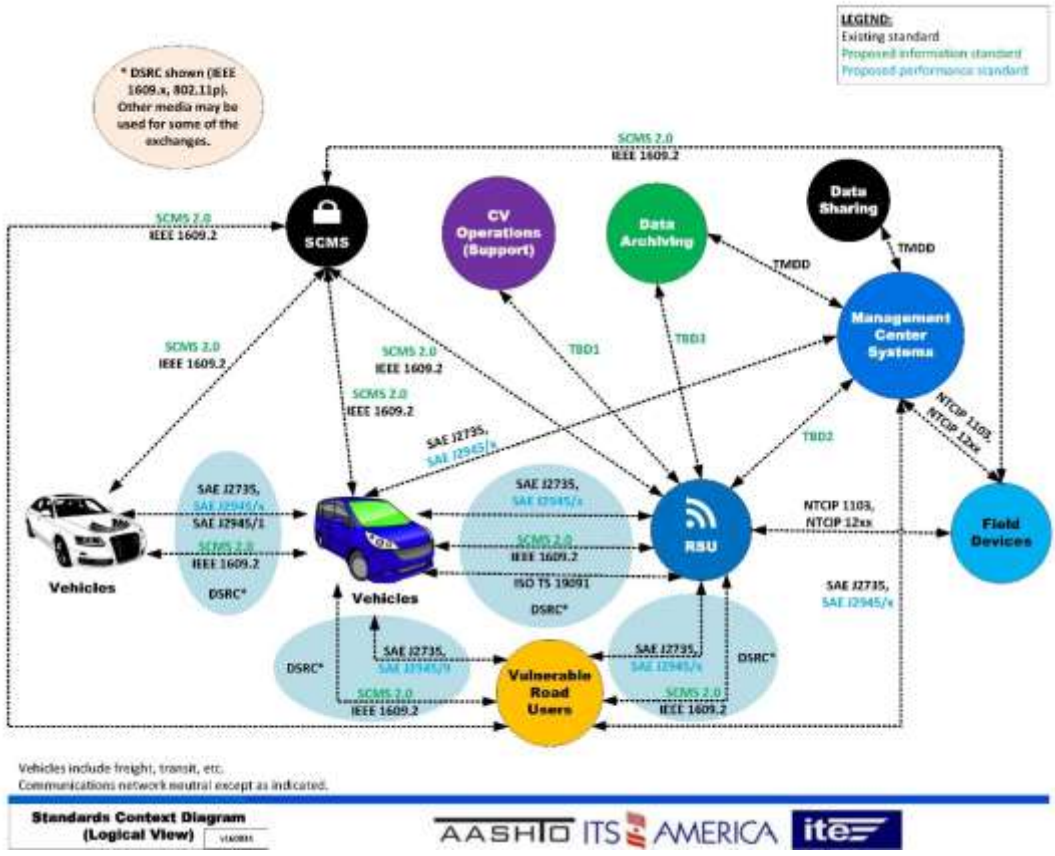
Appendix Q: V2I DC Standards Recommendations

V2I Deployment Coalition

Standards Working Group (WG 5) Recommendations – Summer 2016

Recommendations

1. **Maintain and Update the Standards Context Diagram as a Tool for Framing V2I Standards Activities**
   - Recommendation: Maintain and update the standards context diagram.
   - Recommendation: Develop a white paper to provide an overview of the standards context diagram, and how it can be used.
   - Recommendation: Write a white paper to identify potential gaps in the standards using the framework of the Standards Context Diagram, identify current activities, and define future activities to address the standards gaps.
   - The standards context diagram has proven to be a useful visual framework for the V2I-DC Standards Working Group while exploring the interaction of standards in a connected vehicle environment and seeking gaps in standards and guidelines. Because many of the standards are data and information standards, the Context Diagram also provides a basis for describing data in the V2I ecosystem.
   - WG 5 Contacts: Patrick Chan, Jim Misener, Bob Rausch, Ed Seymour
   - The following is the current version of the diagram.



2. SAE I2V/V2I Task Force Liaison

- Recommendation: Representatives from the V2I Deployment Coalition Standards Working Group should interact with the SAE DSRC Technical Committee. The reciprocal interaction should also occur.
- Discussion: The new Task Force is the group within the SAE DSRC Technical Committee responsible for developing the information and performance standards for V2I and I2V.
- WG 5 Contacts: Jim Misener, Bob Rausch, Blake Christie, Patrick Chan,

3. Move the RSU Specification to an SDO

- Recommendation: Once the DSRC Roadside Unit (RSU) "specification" is stabilized it should be transferred to an appropriate standards development organization (SDO) and updated to a consensus driven standard.
- Discussion: The DSRC Roadside Unit (RSU) is currently covered by a specification (version 4.1) developed by the USDOT and its contractor. The RSE specification is currently undergoing changes to reflect issues noted by suppliers and users of the current specification and changes to the DSRC requirements. It is anticipated that a further update will occur after these changes. The RSE is critical to the success of the Connected Vehicle program and important that requirements for the RSE be standardized rather than being left to the status of a specification. Once the RSE "specification" is stabilized it should be transferred to an appropriate SDO and updated to a consensus driven standard. This update effort should draw upon the lessons learned from the Connected Vehicle Pilot Deployments, Smart City and other early Connected Vehicle deployments efforts.
- WG 5 Contacts: Gary Duncan

4. Explore Development of Testing Tools

- Recommendation: Explore development of automated testing tools for roadside units (RSUs) to ensure they meet applicable standards. It is imperative that operating agencies and their contractors can readily validate the operation of infrastructure-based communications units (RSUs) and ensure system reliability and operations.
- Discussion: The infrastructure industry has developed tools to test communications, hardware, and data exchange in the past. As an example for the NTCIP standards effort, an NTCIP exerciser software package was developed as well as an NTCIP field device simulator. In addition, operating agencies currently rely on test configurations and equipment to validate field equipment such as traffic signals.
    - Perhaps the private sector will provide this capability, or it may benefit from public seed funding. However it is financed, operating agencies and testing organizations should lead a discussion on the utility and requirements for such capability.
- WG 5 Contacts: Suzanne Murtha, Raman Patel

5. Support Standardization and Expansion of SCMS

- Recommendation: The V2I Deployment Coalition partners should encourage the standardization of the Security Credential Management System (SCMS).
- Discussion: Actions in support of the recommendation could include engagement with the IEEE 1609 Working Group and providing sites for deployment, stress testing and assessment of the evolving standard.

  - SCMS is currently a technical document. Version 1.1 "Security Credential Management System Proof–of–Concept Implementation EE Requirements and Specifications Supporting SCMS Software Release 1.1" is at http://www.its.dot.gov/pilots/pdf/SCMS_POC_EE_Requirements.pdf.
  - An IEEE 1609 Working Group has opened a Project Action Request (i.e., new work item request) for an amendment to accommodate corrections, additional rationale and examples, and new proposed features to IEEE 1609.2, which defines the security and certificates for DSRC communications.
- Recommendation: Consider including additional devices in the "ecosystem" of security credential management.
- Discussion: These additional devices and systems could include:
  - Security credential management for vulnerable field devices such as traffic signal controllers and pedestrian devices.
  - Security credential management for central systems that provide server-side, backend services.
  - Existing field management systems, including field devices and central systems, were designed and built before the advent of broad personal connectivity. There are many examples of central system spoofings of field devices such as the posting of bogus roadside sign messages. The potential for further nefarious intrusion into the connected vehicle environment could be mitigated with expansion of the credential management system and the increased certainty about the legitimacy of the source of messaging and data exchange.
- WG 5 Contacts: Bob Rausch, Gary Duncan

6. Monitor Device Certification Activities

- Recommendation: Monitor these RSU certification activities as actual deployments occur and look for opportunities to incentivize a comprehensive certification process for roadside units that can be performed on a national scale.
- Discussion: Device certification activities, supported by the US DOT are currently focused on certification for the CV Pilot Deployments, Smart Cities activities, and other deployments. This is appropriate given the evolution of the standards and the lack of a specification for the equipment.
  - TWG 5 will continue to monitor these certification activities as deployments occur and look for opportunities to incentivize a comprehensive certification process for roadside units that can be performed efficiently on a national scale.
- WG 5 Contacts: Suzanne Murtha, Dave Miller, Gary Duncan

7. Explore Reliability Standards for Operations

- Recommendation: Explore the move from best practices to "enforceable" or "gradable" performance that helps ensure acceptable reliability. ITE is a candidate Standards Development Organization (SDO) to help lead this activity because of their infrastructure operator membership while engaging AASHTO and others.
- Discussion: The objective is to provide V2I and machine driver guidance to infrastructure deployers and operators with respect to the level of reliability, monitoring, mean time to repair (MTTR), and operational responsibility for the infrastructure.
  - A key issue for this topic is whether and what kinds of operational guidance or standards will be acceptable to the infrastructure owners.

- WG 5 Contacts: Bob Rausch, Raman Patel, Gary Duncan (link to the SPaT Challenge in WG 1)

8. Adjust MUTCD and Other Guidance for V2I and AV

- Recommendation: Encourage and work with AASHTO, ITE, ITS America and their partners to support efforts to update the Manual on Uniform Traffic Control Devices (MUTCD) and other guidance documents. A candidate organization that may take a lead in this activity is TRB.
- Discussion: The V2I Deployment Coalition Working Group 5 identified the potential need to adjust the Manual on Uniform Traffic Control Devices (MUTCD) and other guidance documents to align the forthcoming technologies and infrastructure elements both in vehicles and along the roadside.
    - For the past three years, the TRB Automated Vehicle Symposium has hosted breakout sessions focused on the highway infrastructure. These breakout sessions have been attended by a mix of transportation agencies and automotive industries. A recurring discussion at these meetings has been related to the need to reassess traffic control device design and application with machine driver concepts in mind. An action item that has emerged from these sessions is the need to develop a collaborative group (automotive and infrastructure professionals) to review the MUTCD (and possibly other highway engineer professional reference documents) to identify and prioritize topics and ideas that can alleviate today's challenges and provide accelerated benefits of automated vehicles.
- WG 5 Contacts: Suzanne Murtha, Paul Carlson

9. Webinar Reviews for US DOT Standards Documents

- Recommendation: Conduct a webinar based workshop to review the US DOT Data Capture Management (DCM) document with all V2I Deployment Coalition working groups.
    - Discussion: The gap analysis document is the "Recommended Modifications and Additions to ITS Standards" from the Dynamic Mobility Application (DMA) bundle of the US DOT Data Capture Management (DCM) program. It was prepared by consultants under contract to the US DOT.
    - A future document will include design proposals to address standards gaps that have been discovered. Some of the standards gaps support applications identified as high priority by the V2I Deployment Coalition.
    - Objectives of the webinar are to (1) comment on the findings listed in the document and (2) opine about additional standards reviews that the V2I Deployment Coalition might endorse to be funded and performed.
- Recommendation: Continue to monitor US DOT V2I standards efforts and leverage those investments in engineering and standards development. Periodically explore defining new gap efforts that could be performed by the SDOs and the US DOT.
- WG 5 Contacts: Patrick Chan

10. Smart Cities and ATCMTD Tech Transfer

- Recommendation: Engage with Smart Cities and Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) projects to identify lessons learned especially with regard to standards and other needed guidelines.

- Recommendation: Review the Smart Cities and Connected Vehicle Pilot proposals to determine if there is standards insight that can be gained from those local investments.
- Discussion: Millions of dollars of engineering, public engagement and thought leadership were invested in formulating proposals for the Smart Cities Challenge and the FAST Act Connected Vehicle Pilot Deployment Program. Millions more will be spent developing ATCMTD proposals. These efforts represent more than $20M (conservatively) of the most comprehensive, diverse forecasting of the future of transportation and its relationship to other critical infrastructure, its impact on economic outcomes, and the public's interaction with transportation including transit, automated vehicles and connected infrastructure. Mining this data could provide insights into the transportation systems of tomorrow, and the needs of standards. The US DOT has posted the Smart Cities vision statements at (https://www.transportation.gov/smartcity). Some states and municipalities have posted their connected vehicle pilot proposals online.
- WG 5 Contacts: Bob Rausch

11. Engage Telecommunications and IT Providers

- Recommendation: Identify mechanisms and engage with the telecommunications and information technology (IT) industries to ensure that standards and guidelines for connectivity in the V2I ecosystem are robust and reflect current technologies.
- Discussion: The telecommunications marketplace is changing rapidly and providing new paths, value propositions, and products to deliver vehicle to infrastructure communications and backend connections. Mobile-edge computing and 5G communications are examples of emerging technologies that could impact deployment of V2I applications. Given the budget capabilities of infrastructure providers there is significant incentive to ensure that scarce funding is applied as effectively as possible - including telecommunications and IT. Keeping informed of technologies and appraising these industries of infrastructure needs can help align deployment and marketplace opportunities. Professional groups like the Telecommunications Industry Association (TIA)
- WG 5 Contacts: Jim Misener, Dave Sparks

12. Fleet-related Connected Vehicle Standards

- Recommendation: Focus on and look for gaps in fleet-related standards if an NPRM for heavy vehicles is released.
- Recommendation: Encourage an engagement with commercial vehicle fleet operators and the V2I Deployment Coalition if an NPRM for heavy vehicles is released.
- WG 5 Contacts: TBD

Appendix R: V2I Consumer Messaging – Summary Input

V2I DC TWG 4: Deployment Guidance
Issue 11: V2I Consumer Messaging – Summary Input

December 2015

Introduction

The Vehicle to Infrastructure Deployment Coalition (V2I DC) is organized through AASHTO, ITS and ITS America. The first meeting of the V2I DC and technical working groups (TWGs) was held in June 2015, where the top V2I deployment issues were presented and discussed by five technical working groups.

Technical Working Group 4 (TWG 4) has been established to address V2I Deployment Guidance. The group will review and provide input to the USDOT Deployment Guidance document; will review and identify other deployment guidance materials currently available as well as those that are planned/under development; and will identify gaps and provide recommendations to USDOT for additional products that may be needed by the V2I deployment community.

This summary document is expected to be the first of several that will be used to share TWG 4 feedback with USDOT on current and future V2I deployment guidance and outreach efforts. This document specifically addresses Issue 11: V2I Consumer Marketing, described by the coalition as follows.

> *As V2I applications spread throughout the United States, public education and marketing will become increasingly important. There are potentially a number of issues associated with common marketing messages between public and private marketing campaigns. For example, consumers may not understand the role the public sector plays in the product or service they have purchased. The approach that transportation agencies and vendors take towards marketing could play a large role in managing expectations while generating enthusiasm for new products and services.*
>
> *In the near future, the V2I industry will need messaging to end consumers that is consistent and accurate to inform and educate consumers about V2I applications.*

For this particular issue, TWG 4 observed the value of also sharing their input with the AASHTO Subcommittee on Transportation Communications (TransComm). TransComm is made up of public affairs professionals from the 50 states, Puerto Rico and the District of Columbia. It promotes excellence in communications through the exchange of ideas and educational programming, presents annual skills awards and advises other committees on communications issues. Sharing the TWG 4 observations about V2I consumer messaging could encourage greater consistency in the messages that transportation agencies use to describe Connected Vehicle and V2I in particular.

Approach

As part of its contribution to this issue, TWG 4 has reviewed samples of public and private sector materials targeted at consumers to identify those messages regarding V2I deployment that are:

- Common: Used by all or most
- Supportive: Clear, factual

- Questionable: Confusing, potentially misleading

The following materials were briefly reviewed by the group as a sample of messages currently being directed to the consumer:

- USDOT ITS-JPO: Future of Transportation (video)
  - http://www.its.dot.gov/library/media/15cv_future.htm
- USDOT ITS-JPO Images and Infographics
  - http://www.its.dot.gov/press/its_images.htm
  - http://www.its.dot.gov/infographs/index.htm
- UMTRI: A survey of public opinion about connected vehicles in the U.S., the U.K., and Australia
  - http://www.umtri.umich.edu/our-results/publications/survey-public-opinion-about-connected-vehicles-us-uk-and-australia
- Volvo Intellisafe
  - http://www.volvocars.com/us/about/our-innovations/intellisafe
- Ford Smart Mobility
  - https://media.ford.com/content/fordmedia/fna/us/en/news/2015/09/01/ford-smart-mobility-tour.html
- Google Self-Driving Car
  - http://www.google.com/selfdrivingcar/
- USA Today: Six big hurdles before cars can drive themselves (7/28/15)
  - http://www.usatoday.com/story/money/cars/2015/07/28/six-hurdles-self-driving-cars/30770727/
- New York Times: The Web-Connected Car is Cool, Until Hackers Cut Your Brakes (7/23/15)
  - http://www.nytimes.com/2015/07/24/business/the-web-connected-car-is-cool-until-hackers-cut-your-brakes.html

Additional materials were shared by members of TWG 4 outside of the meeting discussions and they are noted below for further reference.

- LinkedIn Pulse: Security through connectivity (8/12/15)
  - https://www.linkedin.com/pulse/security-through-connectivity-roger-c-lanctot?trk=hp-feed-article-title-like
- Vanhawks Valour All-In-One Smart Bike
  - https://vimeo.com/93113021
- FRATIS Outreach from Gateway Cities (1/25/13)
  - https://www.youtube.com/watch?v=c71Qm6HxVTY&feature=youtu.be
- Automatic: Your Smart Driving Assistant (3/12/13)
  - http://youtu.be/_AyXNeRbpRk

Discussion Summary

Following review of these sample materials, TWG 4 discussed what messages were common, supportive or conflicting. Some of the messages that were noted as **common** across the samples included: safety, mobility, drivers in control, vehicle focus (vs. bike, pedestrian or truck), and message tone focused on emotion first and technology second. The group also agreed that safety and mobility messages are **supportive** of V2I. It was also noted that the insurance industry has successfully offered performance-based insurance incentives for several years by focusing on the consumer benefit – saving money.

In regard to potentially **questionable** messages, it was noted that those related to anonymity, drivers in control, and being hacked could be conflicting. Drivers remaining in control could be a particularly confusing message when talking about autonomous vehicles and connected vehicles simultaneously.

Additional research was done to determine what if any statements were issued in response to the Chrysler Jeep hack. There were responses highlighted in various news articles from Chrysler (vehicle recall), NHTSA (investigation of Chrysler resolution to prevent future hacks), and Congress (SPY Act Legislation by Markey-Blumenthal). The hackers themselves also shared their story during the 2015 Black Hat Conference presentation, "Remote Exploitation of an Unaltered Passenger Vehicle."

- Computerworld, "Update: Chrysler recalls 1.4M vehicles after Jeep hack"
  - http://www.computerworld.com/article/2952186/mobile-security/chrysler-recalls-14m-vehicles-after-jeep-hack.html
- Reuters, "NHTSA says will assess Fiat Chrysler hacking recall fix"
  - http://www.reuters.com/article/2015/07/24/us-fiat-chrysler-nhtsa-idUSKCN0PY21S20150724
- Wired, "Senate bill seeks standards for cars' defenses from hackers"
  - http://www.wired.com/2015/07/senate-bill-seeks-standards-cars-defenses-hackers/
- Huffington Post, "Senate bill aims to lock hackers out of connected cars"
  - http://www.huffingtonpost.com/entry/spy-act-car-hackers-senators-security_55ae4e72e4b0a9b94852748b
- Markey-Blumenthal SPY Act Legislation
  - http://www.markey.senate.gov/imo/media/doc/SPY Car legislation.pdf
- 2015 Black Hat Conference, "Remote exploitation of an unaltered passenger vehicle"
  - https://www.youtube.com/watch?v=OobLb1McxnI

It was suggested that there could be a need for different messages geared toward different audiences – those deeply involved in V2I, those simply in the transportation industry, and those with no transportation involvement at all. It was also suggested that **supportive** messages highlight benefits and examples. For example, the images showing data being transmitted from vehicles is useful but still raises questions about what kind of data (e.g. personal or otherwise) may be transmitted. For example, consumers may wonder if and how data may be shared with law enforcement. A basic video on data privacy and security may be useful to counteract **questionable** messages. It was also noted that most consumers won't likely be overly concerned about data being transmitted and additional messages should be considered to tell consumers what new vehicles will do to make transportation better for everyone. It was further observed that

consumers are already "connected" today – through their mobile devices. In general, supportive messages are needed to decrease unfounded fears and focus on benefits.

TWG 4 also discussed how the news articles regarding the Jeep hack seem to convey a **supportive** message that emphasizes how manufacturers and government can learn from mistakes and still deploy Connected Vehicle technology to save lives. The group noted a similar hack happened a few years ago with signal controllers which highlighted need for and then drove the implementation of better security. The group concluded their discussion on consumer messaging with the observation that further information should be released about the outcome of the Jeep experience to demonstrate improved security for Connected Vehicles.

For more information about this summary or TWG 4, please contact:

Faisal Saleem, Chair – Maricopa County, Arizona, faisalsaleem@mail.maricopa.gov, 602-506-1241
Navin Katta, Co-Chair – Savari, Inc., navin@savarinetworks.com, 412-273-0376
Ginny Crowson, Liaison – Athey Creek Consultants, crowson@acconsultants.org, 651-600-3338

Appendix S: Summary Report of Infrastructure Processes as V2I Obstacles

V2I DC TWG 1 – Summary Report of Consideration Regarding Issue 13: Infrastructure Processes as V2I Obstacles

Draft – Version 1

Background

During the June 2015 V2I Deployment Coalition meeting, TWG 1 members identified and described Issue 13 as follows:

> "The next iteration V2I technologies and systems are being invented quickly. There are existing processes, procedures, and/or regulations (e.g. the environmental review process, the MUTCD and established process to add or edit infrastructure uses in the MUTCD) that could be obstacles for a DOT wishing to implement V2I.
>
> ***The V2I industry needs to understand the extent to which existing processes (e.g. MUTCD, environmental reviews) are obstacles to V2I.***"

This paper presents the findings and conclusions from TWG 1 on this issue. The intent is to share this paper with other TWGs, inviting input and feedback. After feedback is received, this paper would be submitted as a deliverable from the V2I DC representing the current thoughts and perspective on Issue 13.

Approach to Research the Issue

TWG 1 developed, administered, and summarized the results of a survey of infrastructure owners and operators (consisting of state and local level DOTs) to ask a number of questions regarding recent V2I proposals, deployments, or plans. The premise behind the survey was to benefit from the considerable knowledge and experiences of DOTs who recently prepared proposals for the Connected Vehicle Pilot Deployment Sites.

As part of this survey, a question was included that asked responders to share their actual or planned challenges related to this issue. It was decided by TWG 1 members not to lead responders to the expected topic, but to leave the question open and invite expressions of any concerns. The exact question asked related to this issue was as follows:

> *"If you have identified any current infrastructure processes (e.g. environmental reviews, MUTCD compliance, etc.) or other challenges (lack of backhaul, technical capability, lack of developed applications, security concerns, etc.) which will prevent or hinder your deployment of the Connected Vehicle infrastructure, please list those with a brief explanation."*

Summary of Findings

A total of 15 responses were received to this question. The full responses are included at the conclusion of this deliverable. In summary, the responses are summarized as follows:

- No survey responses identified issues related to MUTCD compliance or environmental reviews;

- The most often cited concerns included:
    - Security concerns, including concerns that there is not a clear security approach;
    - Concerns that there is a lack of guidance and/or documentation about Connected Vehicles;
    - Concern that many agencies have a lack of communications backhaul;
    - Concerns about the maturity of V2I applications
    - Concerns about the lack of DSRC capabilities in passenger vehicles, and the uncertain timelines for the rollout of mature DSRC technologies in vehicles.

- In addition to the survey responses, TWG 1 members discussed this issue on the February, 2016 webinar. During this discussion, the group agreed that there was a concern that regarded the MUTCD, described as follows: *As in-vehicle displays of information become more prevalent, it would be desirable for the in-vehicle displays to be consistent with messages on Dynamic Message Signs (DMS). As the messages that DOTs display on DMS are largely dependent on MUTCD restrictions and in-vehicle displays are not, there is potential for conflicting messages (either in content or display approach).*

Conclusions Regarding Issue 13

TWG 1 members agreed to the following:

1. The responses to the question asked in the survey relate to concerns with V2I deployment in general, and are not specific to infrastructure processes as was originally suspected. Therefore, TWG 1 members agreed that the 15 ***responses to the survey should be passed along to TWG 4 such that they can be incorporated into feedback to USDOT on the V2I Deployment Guidelines***.

2. In regards to the responses that described the ***challenge of a lack of developed applications and limited maturity of applications***, the recommendation is to share these responses with the initiatives actively working to develop, test, and deploy V2I applications (e.g. including the USDOT funded pilot deployment sites, CAMP, M-City, and a variety of other research organizations). After sharing this feedback, the proposal is to engage these entities to discuss and respond to the challenges expressed. It is possible that the maturity of V2I Applications is higher than what is understood by the agencies that expressed this concern, and therefore it is an education issue. Similarly, it is possible that the maturity of V2I Application is a concern, and these entities can share their vision for resolving the issue.

3. The challenge of ***potentially conflicting messages between in-vehicle displays (not regulated by MUTCD) and dynamic messages displayed on roadside signs*** is a concern and should be advanced with both the infrastructure owners / operators and the OEMs.

    - TWG 1 members will approach TWG 3 to discuss this issue, determine if it has been discussed, and (if not) ask if it can be added to the list of discussion points to be addressed between DOTs and OEMs.

4. The challenge related to ***security*** reflects an issue identified by the V2I DC but not yet being addressed by any of the TWGs (due to the large and complex nature of the issue, V2I DC has identified the security issue as a priority beyond the initial 18 months of the coalition. The recommendation is continue recommending focused effort be dedicated to Security in the coming year, and to share survey response with the TWG(s) that address the issue in the coming years.

Next Steps

TWG 1 proposes to share a revised draft of this summary document with other TWGs, inviting feedback and further input, especially in regards to the recommendations.

Full Text of the 15 Responses to the Survey Question #8

15 Responses:

1. IT security concerns Lack of guidance available
2. Our biggest challenge is that we are combining 2 or more USDOT CV applications into a single app.
3. Yes, several challenges has been identified as we have explore deploying connected vehicle equipment and solutions in the Bay Area. These include: - Complications due to the requirements of Caltrans controllers and AB3418 - Lack of application readiness - Lack of documentation on applications details - Lack of documentation and supportive research regarding the benefit of specific applications as well as the anticipated benefits of grouping applications in a connected vehicle environment - Uncertain timeline around the NHTSA rule making and anticipated roll out of vehicles with DSRC communications - Uncertain funding to support the planning, installation, and operations of connected vehicle environments and applications - Lack of clear standards to ensure interoperability of connected vehicle deployments - Lack of direction regarding security credentialing requirements - Lack of direction regarding cyber security threats and mitigation strategies - Work force development - Lack of outreach to local agencies and tools to help communicate details and expectations regarding connected vehicle programs - Simple terminology issues: CV vs. AV vs. V2I vs. V2V vs. V2X . Stakeholders often get confused and are unsure about what is being discussed so they just assume we are talking about Google Cars and fully self-driving vehicles.
4. Security of DSRC transmissions is a big concern. If we decide to change signal timing at an intersection based on message that we receive from approaching vehicles, there has to be a mechanism for determining that the message is coming from a trusted source, and not a hacker. O&M costs for backhaul and equipment upkeep is another concern. Without an extensive fiber network, which we don't have, there will be a monthly phone bill for backhaul at each DSRC location. This will be a significant cost.
5. Lack of developed applications, security concerns
6. Lack of DSRC and V2I apps in passenger vehicles limits the usefulness of infrastructure deployments.
7. Lack of V2I security system, negative public perception of security due recent auto hacking, IPv6 requirements, limited field maturity of applications, patent challenges

8. We have identified the following challenges: DSRC Security - requirement for IPv6 in the backhaul Existing Patents - E.g. Qualcomm use of wireless (newly issued), GTT for signal preemption, …)
9. Backhaul (the lack of). We have a limited backhaul network and less than 10% of our signals go back to a central location.
10. Lack of developed applications: Although we have a long list of applications, and a few have published ConOps, there are very few actual applications. Most of the applications are just an idea at this point. I think that is part of the reason for the Pilot Deployments, is to get some real applications running. Technical Capability: Since there are only a handful of test beds, there isn't much knowledge base out there about DSRC deployment and application development. There certainly isn't any of that in my area, so I am trying to build some expertise in my team. The learning curve is long, partly because of the lack of applications (above) and partly because of the nature of the hardware (below). DSRC maturity: In this age, we are used to plug-and-play devices. The DSRC devices are certainly not there. Coupled with the lack of developed applications, there is a real need for very specific software development and hardware integration expertise. Security: I'm not overly concerned about security with the small-scale applications we are starting with, but there are a lot of agencies looking to deploy applications and there is no SCMS system available to us. I realize that a system is being developed, but an early version won't be available until Sept 2016 (and then only to the Pilot teams), and a final version reportedly a year later.
11. We are still waiting on the deployment guidelines document from FHWA. The lack of a clear security approach is a significant barrier. The lack of information about what applications the auto industry plans to support is also a barrier.
12. We as a City have a different set of operating philosophies that we operate under than those of our State DOT. We has a more robust and complete system than they do and joint operating protocols would be helpful. Some State DOT's control sections of local roadways (State Hwy) that could have an adverse effect on the operations of a CVI system. I would strongly urge local agreements and agency interaction be part of the metrics used to deploy any system.
13. Technical capabilities are maturing, but not at a level of proficiency yet. Also lack of developed applications.
14. Lack of clear standards and concern over hackers getting into the system
15. We are currently not aware of any.

Appendix T: Federal V2I Policy Statement Briefing

V2I DC TWG 1: Deployment Initiatives and TWG 4: Deployment Guidance Issue 14: Federal V2I Policy Statement – Briefing

January 28, 2016

Introduction

The Vehicle to Infrastructure Deployment Coalition (V2I DC) is organized through AASHTO, ITE and ITS America. There are five technical working groups (TWGs) established to address issues related to various aspects of V2I deployment. TWG 1 is designed to address V2I deployment initiatives. They exchange information about past and current V2I deployment initiatives, and they discuss needs for future initiatives to address issues identified by the Coalition. TWG 4 is intended to address V2I deployment guidance. The group has and will continue to provide input on the USDOT V2I Deployment Guidance document and other guidance-related materials, and the group will provide recommendations to USDOT for additional products that may be needed by the V2I deployment community.

TWG 1 and TWG 4 are working together to address Issue 14: Federal V2I Policy Statement. This briefing describes the focus of Issue 14; highlights initial policy topics of interest identified by TWG 1 and TWG 4; and, recommends a process for moving forward.

Issue 14: Federal V2I Policy Statement

This issue has been described by the Coalition as follows:

> *The recent NHTSA resolution regarding vehicle-to-vehicle communications has helped the V2V industry. Similar strong encouragement from a federal agency to give infrastructure owners and operators a push to deploy V2I would also help V2I. It is recognized that a rulemaking is likely not possible, but perhaps another strong encouragement from a federal agency (e.g. something similar to the "Every Day Counts" model) could be released.* ***The V2I industry needs a strong message from a federal agency encouraging V2I deployment****.*

The above referenced policy statements that have been issued by NHTSA to-date include the following:

- Preliminary Statement of Policy Concerning Automated Vehicles
- Federal Motor Vehicle Safety Standards: Vehicle-to-Vehicle (V2V) Communications Advance Notice of Proposed Rulemaking

Initial Policy Topics of Interest

Following is a list of initial topics of interest that TWG 1 and TWG 4 have identified for consideration in a potential federal V2I policy statement. This list is very preliminary and was developed after two meetings on January 19 and 20. It is being shared as an indication of current thinking and awareness among TWG 1 and TWG 4. It is expected that this list of topics will be further revised after the USDOT releases the V2I Deployment Guidance document and supporting deployment products.

- Explanation of **why agencies should deploy V2I**

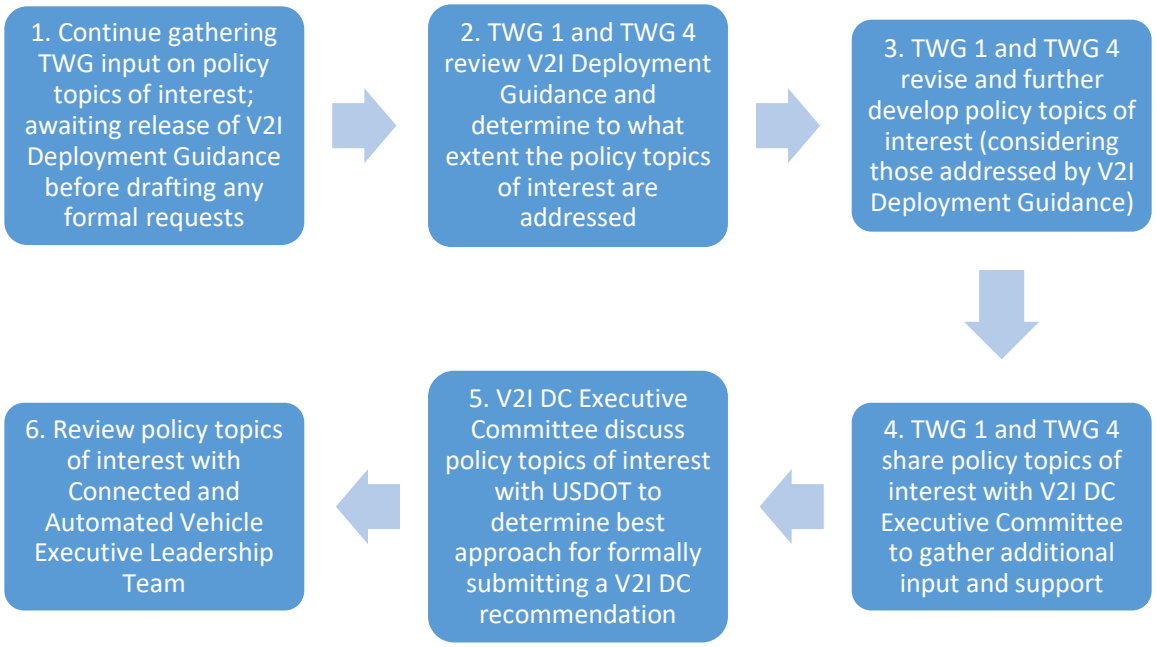
- **Sample legislative language** for agency consideration
- Clarification of **aftermarket device role** in V2I deployment
- Requirements for deploying, operating and maintaining **V2I equipment**
- Statement on potential **liability implications**
- Direction on **how data should be protected** by vendors and agencies
- Explanation of how USDOT is **protecting DSRC** band for V2I
- Recommendations on **use of DSRC** band and related channels within the band for V2I

Process for Moving Forward

On January 20, USDOT representatives participated in the TWG 4 monthly meeting where this topic was discussed. USDOT shared with TWG 4 members attending the meeting that many of the initial policy topics of interest will be addressed in the upcoming release of the V2I Deployment Guidance and supporting products. USDOT confirmed that the guidance and products will be issued in the first quarter of 2016. They also shared the following excerpt from the V2I Deployment Guidance regarding the current policy statement:

> *Vehicle-to-Infrastructure (V2I) technology will take advantage of and build upon emerging vehicle-based technologies being deployed to support vehicle-to-vehicle (V2V) technology. When leverages with V2V, a V2I deployment will result in significant safety, mobility, ad environmental benefits that will be of significant interest to state, regional, and local transportation agencies. Deployment will be encouraged by FHWA but public agencies will not be required to implement V2I technology. Nevertheless, state, regional, and local agencies will have guidance and products available to ensure efficiency and interoperability.*

Based on this information and preliminary discussions to-date, the following process is suggested for moving forward.



For more information about this briefing, please contact:

Bill Legg, TWG 1 Chair – Washington State DOT, leggb@wsdot.wa.gov, 360-705-7994
Joe Averkamp, TWG 1 Co-Chair – Xerox, joseph.averkamp@xerox.com, 703-581-5293

Faisal Saleem, TWG 4 Chair – Maricopa County, Arizona, faisalsaleem@mail.maricopa.gov, 602-506-1241
Navin Katta, TWG 4 Co-Chair – Savari, Inc., navin@savarinetworks.com, 412-273-0376

Appendix U: Webinar Summary of Vehicle to Infrastructure (V2I) Infrastructure Maintenance Costs

Vehicle to Infrastructure (V2I) Deployment Coalition

Technical Working Group 1: Deployment Initiatives

Webinar Summary of Vehicle to Infrastructure (V2I) Infrastructure Maintenance Costs
September 2016

INTRODUCTION

The Vehicle to Infrastructure (V2I) Deployment Coalition (DC) Technical Working Group (TWG) 1: Deployment Initiatives recently facilitated a webinar to enable the sharing of experiences that multiple agencies have had with maintenance costs of V2I infrastructure. The intent of the webinar was to share information with all TWGs who are working on V2I infrastructure maintenance efforts.

This brief summary was prepared to synthesize key information presented in this webinar. It is not intended to be a comprehensive summary of all information presented. In addition, the webinar was recorded, and anyone is welcome to view the webinar recording.

Webinar Date: September 13, 2016

Presentations:

1. UMTRI: V2I Maintenance Insights – Safety Pilot Model Deployment / Ann Arbor CV Test Environment, Scott Shogan, WSP/PB;
2. NYC Connected Vehicle Pilot Deployment, Mohamad Talas, NYC;
3. Caltrans Experiences with V2I Maintenance: Corridor Selection and Test-Bed Development, Asfand Siddiqui, Caltrans;
4. USDOT Update on V2I Deployment Guidance Products & Tools, Jonathan Walker, USDOT

Webinar Recording Link
https://atheycreek.webex.com/atheycreek/lsr.php?RCID=1281fff230aa41f90eef1e85eefb9c8a

Webinar Purpose:

The purpose of this effort is to begin a process to learn about anticipated V2I infrastructure maintenance costs. Three of these presentations focused on experiences to date with maintaining V2I infrastructure, while the final presentation provided an update on anticipated V2I deployment guidance being developed by the USDOT.

1. UMTRI: V2I Maintenance Insights – Safety Pilot Model Deployment / Ann Arbor CV Test Environment

Scott Shogan presented the experiences of the Ann Arbor Connected Vehicle test environment. The infrastructure elements, which have been in use since 2012, include:

- 5.9 GHz DSRC roadside units,
- Upgraded signal controller cabinets,
- Backhaul communications and data management, and

- Infrastructure-based messaging.

Maintenance considerations for the deployment can be separated into four areas:

- Equipment operation and failure mitigation,
- State of health monitoring,
- Security management, and
- Data and network management.

Actual maintenance costs for the equipment deployed in Michigan are misleading given continuous updates, constant improvements, and lessons learned with first generation technology. The experimental research nature of the deployments in Michigan meant the inclusion of additional equipment and data storage than will be necessary as technologies and processes are streamlined. The expectation is that more mature products will be deployed in future efforts that have longer time between failures, improved communications and integration, standard security measures, and streamlined tools for data collection, processing, and storage, all of which would lower maintenance costs in future deployments. Additionally, as the industry matures and an economy of scale is reached, new equipment and commercial tools will become available that further reduce maintenance costs.

2. NYC Connected Vehicle Pilot Deployment

Mohamad Talas presented experiences of the NYC Pilot Deployment. The NYC Pilot Deployment focuses largely on Manhattan and Brooklyn pedestrian and arterial V2V and V2I safety applications, and involves installation and future maintenance responsibilities for:

- Aftermarket devices on a fleet of up to 8,000 vehicles including taxis, buses, sanitation and DOT vehicles, and UPS trucks,
- Roadside units at 327 intersections and 49 non-intersection locations,
- New computing resources for database, systems, and security management, and
- Backhaul communications for increased bandwidth and network complexity.

Connected vehicle applications related to operations, maintenance, and performance analysis are included as part of the deployment.

Procurement is currently underway for the NYC deployment and has a major influence on future maintenance. Given the large network and size of the deployment involved with the pilot, the latest standards are being used with demonstrated qualifications expected from the vendor. A warranty period is also anticipated, as well as continuous (versus one-time) supply from the vendor for ongoing expansion and replacement, in addition to procurement of an additional 20% spares for roadside units and aftermarket devices for immediate replacement within the first year, as necessary.

In anticipation of ongoing and expanding operations during and after the pilot demonstration period, maintenance activities for the roadside units and NYC vehicle aftermarket safety devices will be conducted in-house. NYC is contracting with in-vehicle systems companies for taxi maintenance, and vendors for transit installation and maintenance during the pilot period. Afterward, memoranda of understanding will be established with other stakeholders specifying that the owners of the private vehicles are responsible for the aftermarket safety device maintenance. To facilitate fleet maintenance, staffing and training needs are being considered, and about 20% of resources are devoted to spares for

quick replacement of failed units. Some techniques have also been developed for system monitoring to expedite the identification of maintenance issues.

Additional maintenance costs arise from concerns related to:

- Radio frequency interference – getting new interference tracking equipment,
- Radio maintenance – vendor repair and extended warranty,
- Tracking system outages, and
- Repair cost complications.

3. Caltrans Experiences with V2I Maintenance: Corridor Selection and Test-Bed Development

Asfand Siddiqui presented Caltrans experience deploying V2I equipment in Palo Alto. The test-bed began in 2011 with many unknowns with new technologies. Corridor selection should include stakeholder engagement, an initial survey of equipment, and consideration of intersection spacing and pedestrian crossings. For high-volume corridors, consider the costs of conducting maintenance during off-peak hours, e.g., 5:00 a.m. to 8:00 a.m. on Saturday; note that low-volume corridors may not derive as many benefits. Equipment age and hardware and software issues can present challenges and added cost to achieve compatibility and functionality. Cost and delivery speed will be affected by choosing to do activities in-house versus hiring an external vendor. Following installation, the consensus within the office was that the deployment cost was approximately $50,000 per intersection, however since this was a research effort this number is likely higher than a wider deployment would be.

4. USDOT Update on V2I Deployment Guidance Products & Tools

Jonathan Walker provided updates on the USDOT products and tools availability , as follows:

- *V2I Deployment Guidance* – on hold due to V2V rulemaking and the USDOT approval process; related products are still under development and will be released following release of the guidance document.
- CV and Planning Process – some documents are available; more are in the USDOT approval process and will be released soon.
- *Model Approach to Agile System Engineering* – development is underway and should be available in 2017.
- *Recommended Practices for DSRC Licensing and Spectrum Management* – now available.
- *Pre-Deployment Guidance for V2I Safety Applications* – a contract is now being issued to develop this.
- *Estimating Benefits and Impacts on V2I* – on-hold until CV pilots are underway in order to do a better assessment.
- *V2I Messaging Lexicon* – will be released following release of the guidance document.
- *Near-Term Transitioning Phrasing for V2I Deployments* – completed, but being transitioned from an Excel spreadsheet to a web-based solution.
- *Connected Vehicle Training Resource* – document will be available in a month or so following the USDOT approval process.

Appendix V: Common Goals for V2I Technologies and Systems

V2I Deployment Coalition
Technical Working Group 3
Issue 16 – Common Goals

At the V2I Deployment Coalition workshop in April 2016, Technical Working Group 3 spent part of the workshop in brainstorming and identifying the expected goals of participants regarding the deployment of V2I technologies and systems. From these, a set of common goals that the participants, and the Coalition, can focus on can be determined.

The identified goals of each sector of participants are summarized below.

Infrastructure Owners and Operators

Most of the infrastructure owners and operators (IOOs) indicated that their primary goals of pursuing V2I technology and deployments is to meet the general mission of the agencies, which is to provide a safe and efficient transportation system to move people and goods. Achieving these missions includes the goals of:

- Improve safety of transportation system users
    - Reduce number of crashes
    - Reduce severity of crashes
- Improve travel time reliability for transportation system users
    - Reduce congestion
- Improve agency operations
- Develop and use data to help support agency mission of ensuring safety and improving operations
- Increase investment in technology in communities
- Improve transportation system performance measures
- Plan for what a "future" transportation system looks like – what should investments be.
- Pursue "alternate" funding strategies to improve the transportation system and network.

Automobile OEMs

In general, the automobile industry is pursuing V2I technology to ensure the safety of their customers, and to provide additional tools and options for their customers. Achieving these missions includes the goals of:

- Improve vehicle safety
- Show value to customer of additional technology
- Leverage technology that may be installed to meet federal mandates
- Limit exposure to risk by improving transportation safety

Other participants in Technical Working Group 3 included representatives from other interested parties (outside of Automobile OEMs and Infrastructure Owners and Operators), such as non-profit industry associations, engineering and management consulting entities, equipment manufacturers, and mapping companies. These participants indicated the following goals for participating in V2I deployments:

- Assist and guide IOOs with mobility solutions

- Develop products for use by OEMs
- Provide performance testing of DSRC equipment
- Keep current with transportation technology
- Develop standards for deployment
- Provide security credential distribution options for a V2I network

In summary, the overarching factor and common goal between the automobile OEMs and the Infrastructure OOs is that with a V2I system, we are both looking to serve the same customer – the transportation system user, i.e., the vehicle driver/operator – and ensure and improve their safety. The goal of reducing crashes, and reducing the number and of injury and fatalities on the transportation system, ties together all of the partners in a V2I deployment.

There are secondary goals that may be unique to each user set, but most of these goals can also be realized by focusing on the common focus on transportation system safety.