

# V2IDC TWG 2 (Research) Upcoming Activities

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## Outline

1. Deployment Issues Addressed
2. Issue 1: V2X Applications
3. Issue 3: V2I Data
4. Issue 6: V2I Outreach
5. Issue 7: Understanding the Benefits and Costs of V2I Deployment and Operation
6. Appendix A: PPT Summary of Connected Vehicle Applications Survey Results
7. Appendix B: Webinar Summaries of Connected Vehicle Benefit / Cost Projects
8. Appendix C: PPT Summary of Issue 7 Discussion
9. Appendix D: PPT Summary of Report Out from April 20, V2IDC TWG Breakout Sessions
10. Appendix E: Activity 2 of TWG 3 of the V2I Deployment Coalition
11. Appendix F: V2I Safety Application Implementation: Safety Application Functionality

## Deployment Issues Addressed

Issue	TWG 1 Initiatives	TWG 2 Research	TWG 3 Partners	TWG 4 Guidance	TWG 5 Standards
Issue 1: V2X Applications	P	S	S	S	S
Issue 2: Complementary Communications to DSRC	N	P	N	N	N
Issue 3: V2I Data	N	S	P	N	S
Issue 4: Patents-Intellectual Property	N	P	N	N	N
Issue 5: Security	No action planned at this time				
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	N	P	N	S	N
Issue 10: V2I Synergies with Other Emerging Technologies	No action planned at this time				
Issue 11: V2I Consumer Messaging	N	N	N	P	N
Issue 12: V2I Multimodal Applications	No action planned at this time				
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

## Issue 1: V2X Applications

### Volunteers:

- Skip Yeakel, Volvo Group North America, [Skip.Yeakel@Volvo.com](mailto:Skip.Yeakel@Volvo.com)
- Bill Mahoney, National Center for Atmospheric Research, [mahoney@ucar.edu](mailto:mahoney@ucar.edu)
- Jianming Ma, Texas DOT, [jianming.ma@txdot.gov](mailto:jianming.ma@txdot.gov) **Leader for this activity.**
- Danjue Chen, Traffic Operations and Safety (TOPS) Lab at UW-Madison, [dchen24@wisc.edu](mailto:dchen24@wisc.edu)

**Role in coordination:** TWG 2 members will participate in reviewing the survey responses. TWG 2 members will also prepare a research definition for any additional research that might be needed towards identifying prioritized set of V2I applications, based on the survey results and comments received.

**Targeted Outcome:** Definition of any additional research proposed to further explore Issue #1.

**Timeline:** Give problem statements to TRB in June for consideration in NCHRP CAV Roadmap Project.

**Next Step:** Develop a problem statement for harmonization of V2X apps for CAV research roadmap? Analyze the two lists, see what is the same, define what those mean, and **assess the readiness**.

**Volunteers:** Rob Bertini, Cal Poly and Tom Timcho, WSP

**Assess the readiness of the V2X apps.** Is this a CV PFS activity? Is this the readiness of off-the-shelf software? Should there be a common platform? We need to know the software, the platform, and the hardware.

Do we need a trusted forum for sharing agency/OEM data?

### Issue 3: V2I Data

**Volunteers:**

- Tom West, California PATH/UC Berkeley, [tomwest@path.berkeley.edu](mailto:tomwest@path.berkeley.edu), **Leader for this activity**
- Jan-Mou Li, ORNL, [lij3@ornl.gov](mailto:lij3@ornl.gov)
- Chen Danjue, Traffic Operations and Safety (TOPS) Lab at UW-Madison, [dchen24@wisc.edu](mailto:dchen24@wisc.edu)
- Jianming Ma, Texas DOT, [jianming.ma@txdot.gov](mailto:jianming.ma@txdot.gov)
- Yang Cheng, Traffic Operations and Safety (TOPS) Lab at UW-Madison, [cheng8@wisc.edu](mailto:cheng8@wisc.edu)

**Role in Coordination:** TWG 2 (Research TWG) will take the definitions of the highest priority data related issues that TWG 3 produces, which are listed below, and develop research definitions that define the research activities (e.g. scope of research, anticipated results, cost estimate) that are recommended to address the prioritized issues over the coming 2-5 years.

**Targeted Outcome:** A research plan of action to research and resolve as many of the prioritized list of issues as possible over the coming 2-5 years.

**Next Step:** Develop a research problem statement for

1. Mechanisms for higher frequency dynamic map updates
2. Determine corrections for lane-level GPS positioning
3. Determine roadway friction indicators (e.g., skidding/braking)

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

**Volunteers:**

- Greg Larson, Caltrans, [greg.larson@dot.ca.gov](mailto:greg.larson@dot.ca.gov) **Co-leader for this activity**

- Rob Bertini, Cal Poly State University, [bertini.robert@gmail.com](mailto:bertini.robert@gmail.com) **Co-leader for this activity**
- Ray Derr, Transportation Research Board, [rderr@nas.edu](mailto:rderr@nas.edu)
- Skip Yeakel, Volvo Group North America, [Skip.Yeakel@Volvo.com](mailto: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.
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## Issue 7: Understanding the Benefits and Costs of V2I Deployment and Operation

### Volunteers:

- Bill Gouse, SAE International, [S.William.Gouse@sae.org](mailto:S.William.Gouse@sae.org)
- Dick Mudge, Compass Transportation and Technology, [Dick@compasstranstech.com](mailto:Dick@compasstranstech.com)
- Alan Korn, Meritor WABCO, [Alan.Korn@meritorwabco.com](mailto:Alan.Korn@meritorwabco.com)
- Doug Gettman, Kimley-Horn, [doug.gettman@kimley-horn.com](mailto:doug.gettman@kimley-horn.com) **Leader for this activity.**

**Role in Coordination:** TWG 2 members will participate in the demonstrations facilitated by TWG 1 and the case studies performed by TWG 3, which are attached as Appendix C, and make a determination about where gaps are in what has been delivered (or is planned) from the current studies and what TWG 3 was able to derive from the case studies. TWG 2 will prepare a Research Definition for additional research activities needed to further define anticipated costs and benefits of V2I.

**Targeted Outcome:** A Research Plan of Action will be created defining additional research needed to supplement both the current and completed B/C studies and the case study analyses conducted by TWG 3. Look at the 20% of curves that are 80% of the problem. There needs to be a range of assumptions. Develop an assessment of effectiveness.

**Recommended Next Steps:** Develop a research problem statement.

**Appendix A:**

**PPT Summary of Connected Vehicle Applications Survey Results**

Vehicle to Infrastructure Deployment  
Coalition (V2I DC)  
&  
AASHTO CAV TWG  
Connected Vehicle Applications Survey

PRELIMINARY Survey Results

January 28, 2016

# Background

- Survey questions were crafted by TWG 1 members
- AASHTO CAV TWG suggested one question (Question 9) that they had been planning to ask DOTs



# Preliminary Results

- 25 responses to the on-line survey
  - Some partially responded
- 2 phone calls instead of on-line survey responses

# Question 1:

Please indicate the agency you are representing

# Q1: Respondents

*25 responses*

- Virginia DOT
- Wisconsin DOT
- Metropolitan Transportation Commission (MTC)
- Carnegie Mellon University Traffic21 Institute
- Minnesota DOT
- Michigan DOT
- California DOT
- California PATH/UC Berkeley
- VTTI
- THEA Connected Vehicle Pilot Deployment
- Arizona DOT, TSMO Division
- Pennsylvania DOT
- Utah DOT
- King Count Metro Transit
- City of Palo Alto
- Oregon DOT
- NYSDOT
- City of Chattanooga, TN
- NYCDOT
- The Ohio State University of Mobility Research and Business Development
- Louisiana DOTD
- Prospect Silicon Valley
- City of Alexandria, VA
- City of Walnut Creek
- Santa Clara County Road and Airports Department
- Washington State 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.

- Two Agencies opted to participate in phone conversations
  - One (a local agency) explained their primary short-term emphasis for Connected Vehicles would likely be traffic signal control
  - The other had multiple comments, see the following slide:

# Phone Feedback – State DOT

- 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

# Phone Feedback – State DOT

- Described 3 levels of safety applications:
  1. Static alerts of threats to drivers (e.g. “30 MPH” warning on curves)
  2. Monitor vehicle performance, and warn if needed (e.g. display “30 MPH if vehicles going above XX speed)
  3. Potential Automation (external alert sent from the roadside work with on-board controls to adjust vehicle speed and with V2V to warn other vehicles)

# 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.

# Background on Q3

- Question 3 attempted to learn 3 things:
  - Which CV applications responding agencies had **included in their proposal or plan** for CV deployment
  - Which CV applications responding agencies felt **were most beneficial**; and
  - Which CV applications responding agencies **had already deployed**



# Background on Q3

- Related to Question 3:
  - TWG 1 members decided to provide a set of Connected Vehicle applications and ask survey responders to select from the list
  - TWG 1 members agreed to use the CVRIA list of Applications
    - ❖ 72 V2I applications from the CVRIA were included
      - Excluded V2V, Core Services,
      - Included Signal Phase and Timing (Support Application)
    - ❖ Grouping of applications was based on the CVRIA groupings

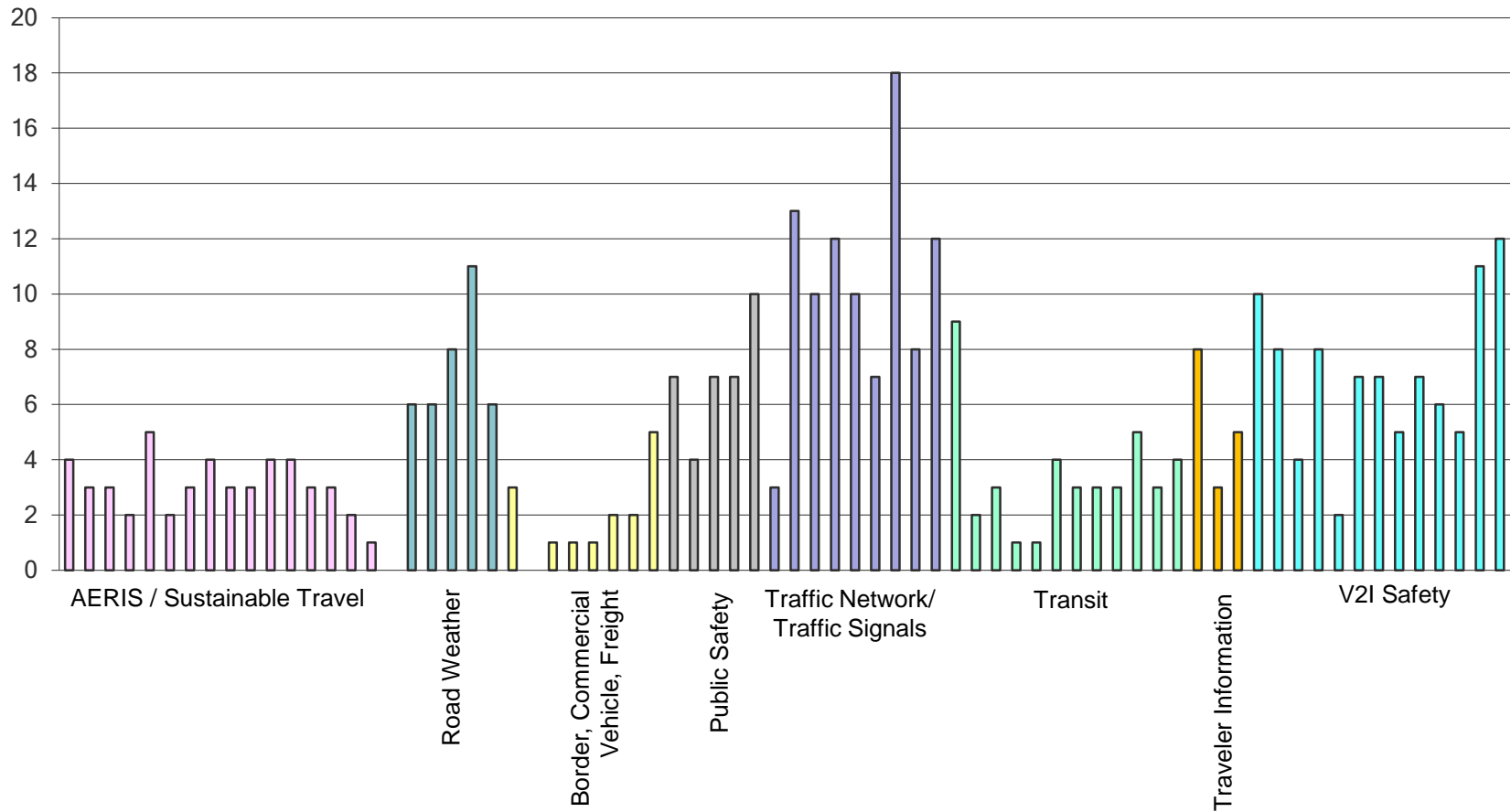
# Q3: V2I Applications

## 72 V2I Applications from CVRIA Website (presented in 8 categories)

Category	Number of V2I Applications
AERIS/Sustainable Travel	16
Border, Commercial Vehicle, Freight	8
Traffic Network/Traffic Signals	9
Traveler Information	3
Road Weather	6
Public Safety	5
Transit	12
V2I Safety	13

# CV Applications Included in Plans or Proposals

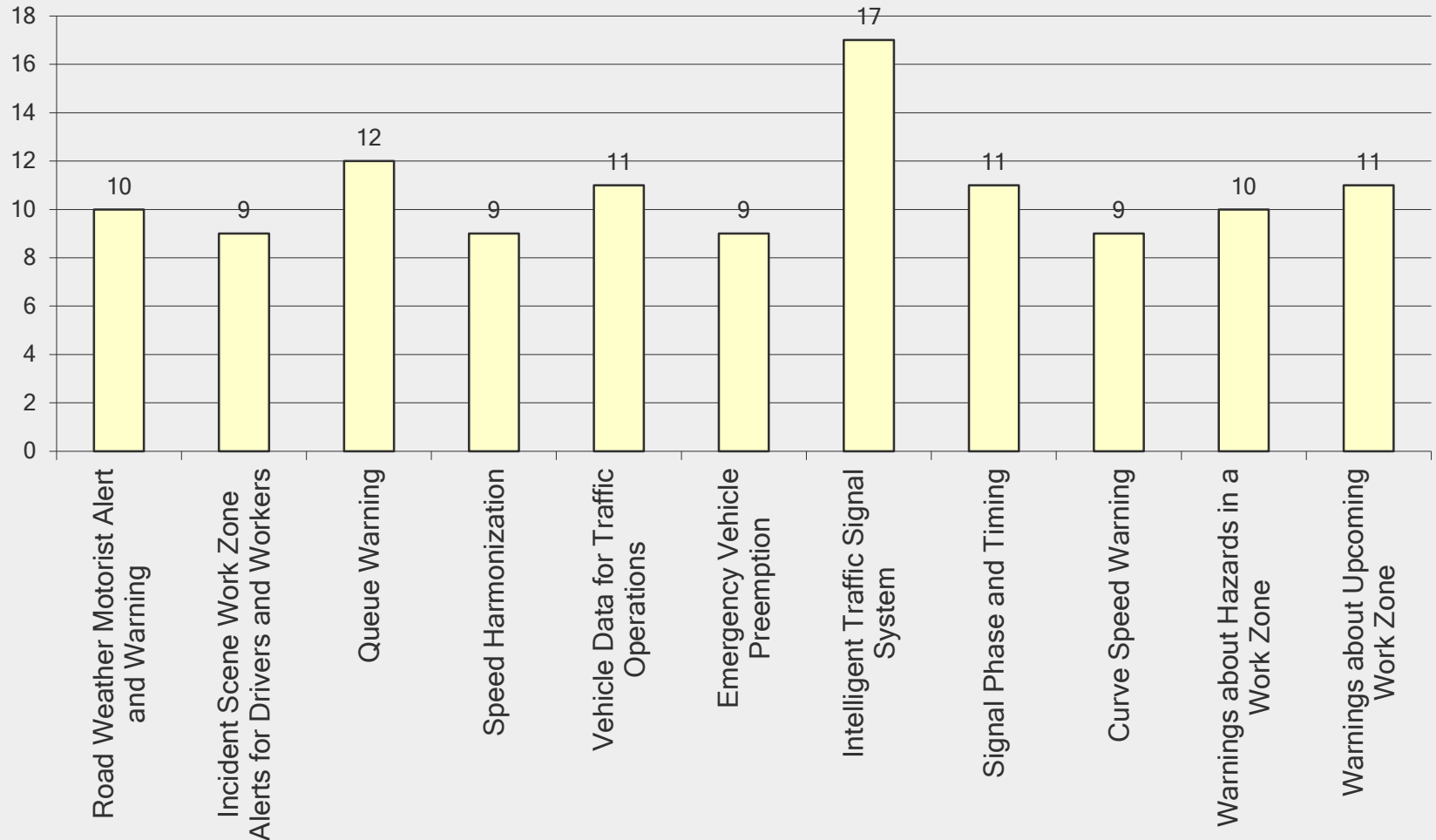
Q3: CV Applications Included in Agencies Plans or Proposals for Deployment  
 (# of Responders = 21)



# CV Applications Included in Plans or Proposals

## 11 Most Selected Applications

Question 3: CV Applications Included in Agencies Plans or Proposals for Deployment  
(Top 11 Applications Selected; # of Responders = 21)



# 4 Focus Areas of the V2I DC

- At the September, 2015 V2I DC Executive Committee meeting, four focus areas were defined for the V2I DC

## Focus Areas Defined by V2I DC

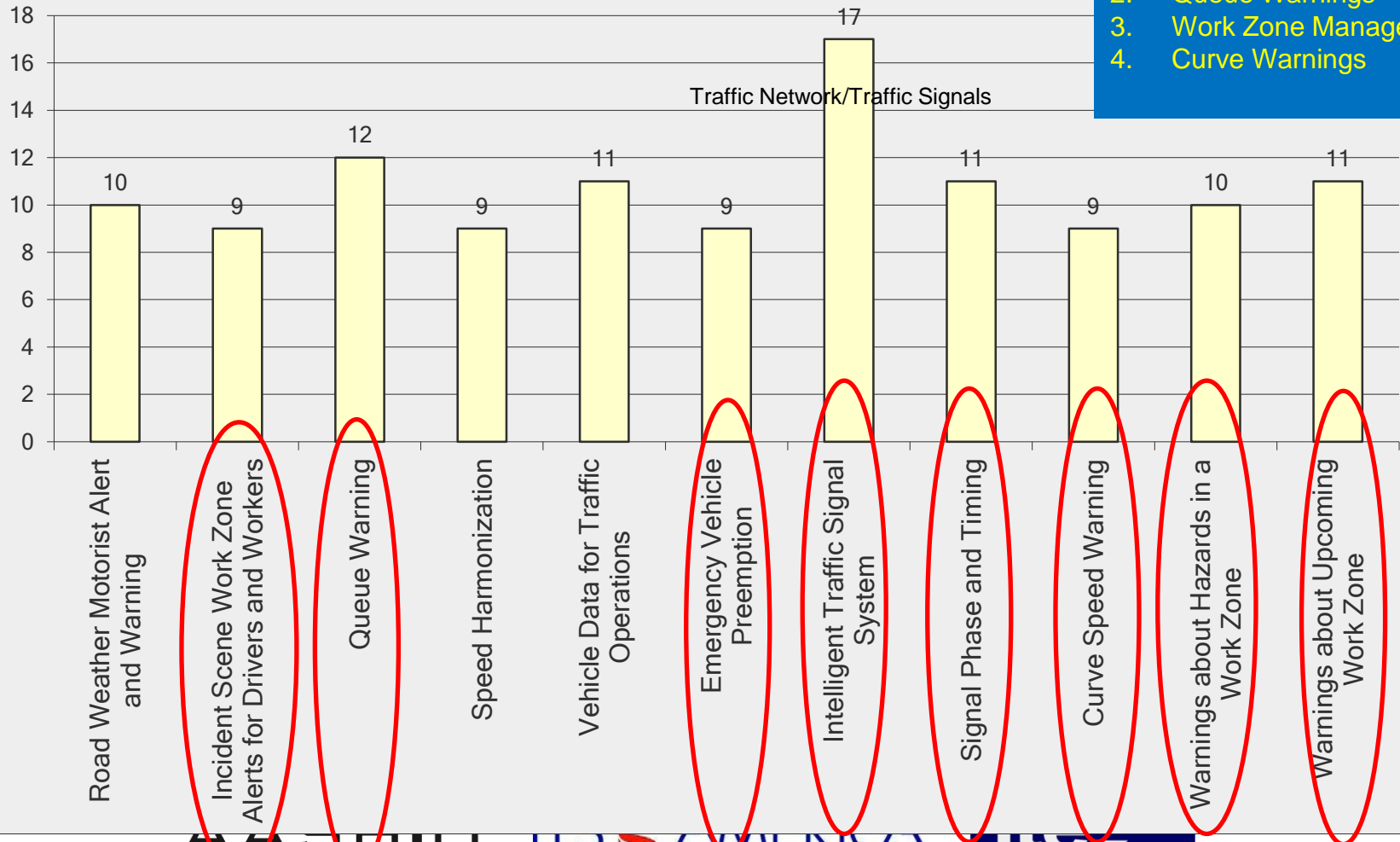
1. Intersections
2. Queue Warnings
3. Work Zone Management
4. Curve Warnings

# How do the most selected Applications map to the focus areas?

Question 3: CV Applications Included in Agencies Plans or Proposals  
(Top 11 Applications Selected; # of Responders = 24)

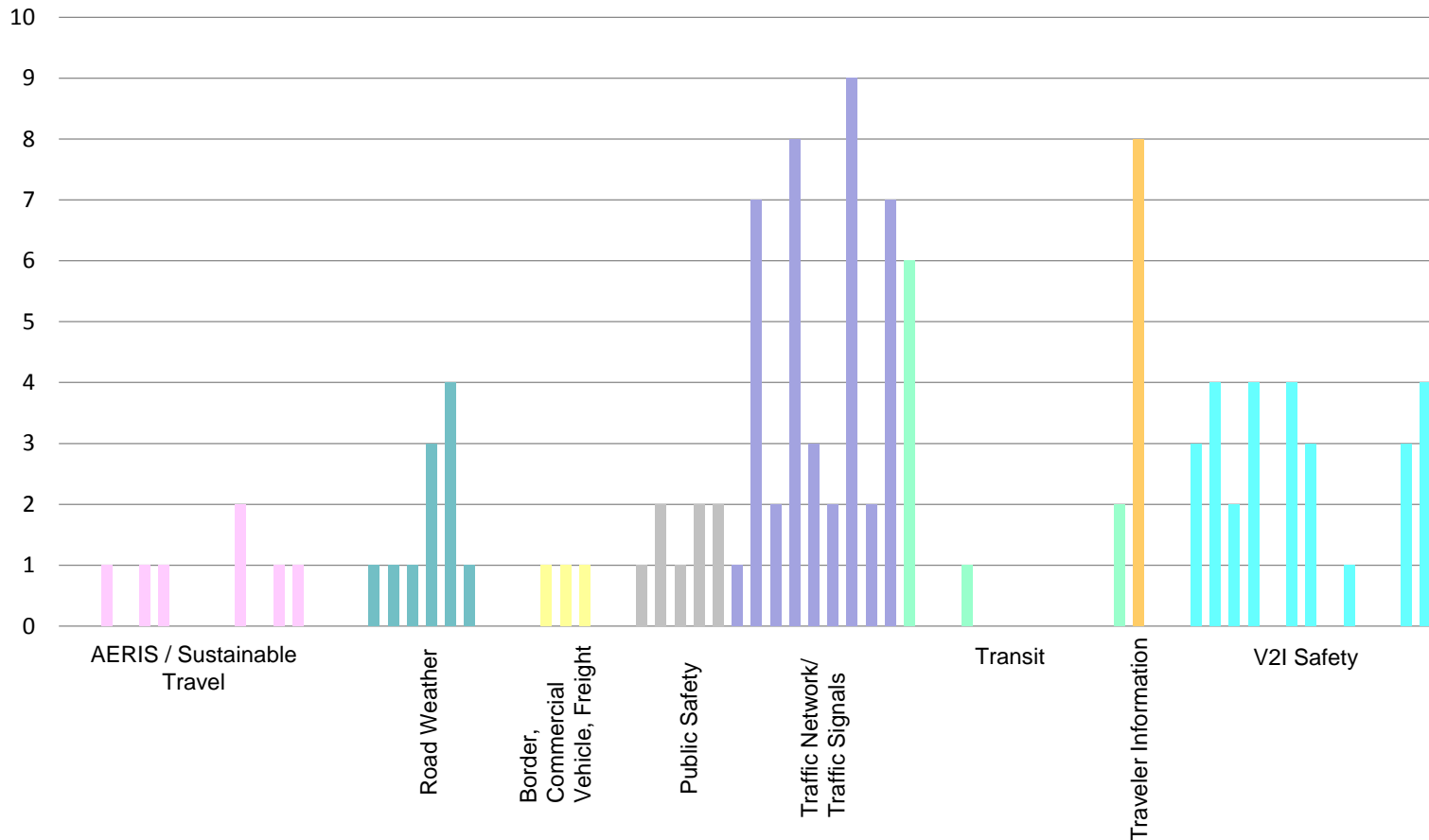
All Four Focus Areas Represented!

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



# CV Applications Responders Feel Would Be Most Beneficial to Deploy

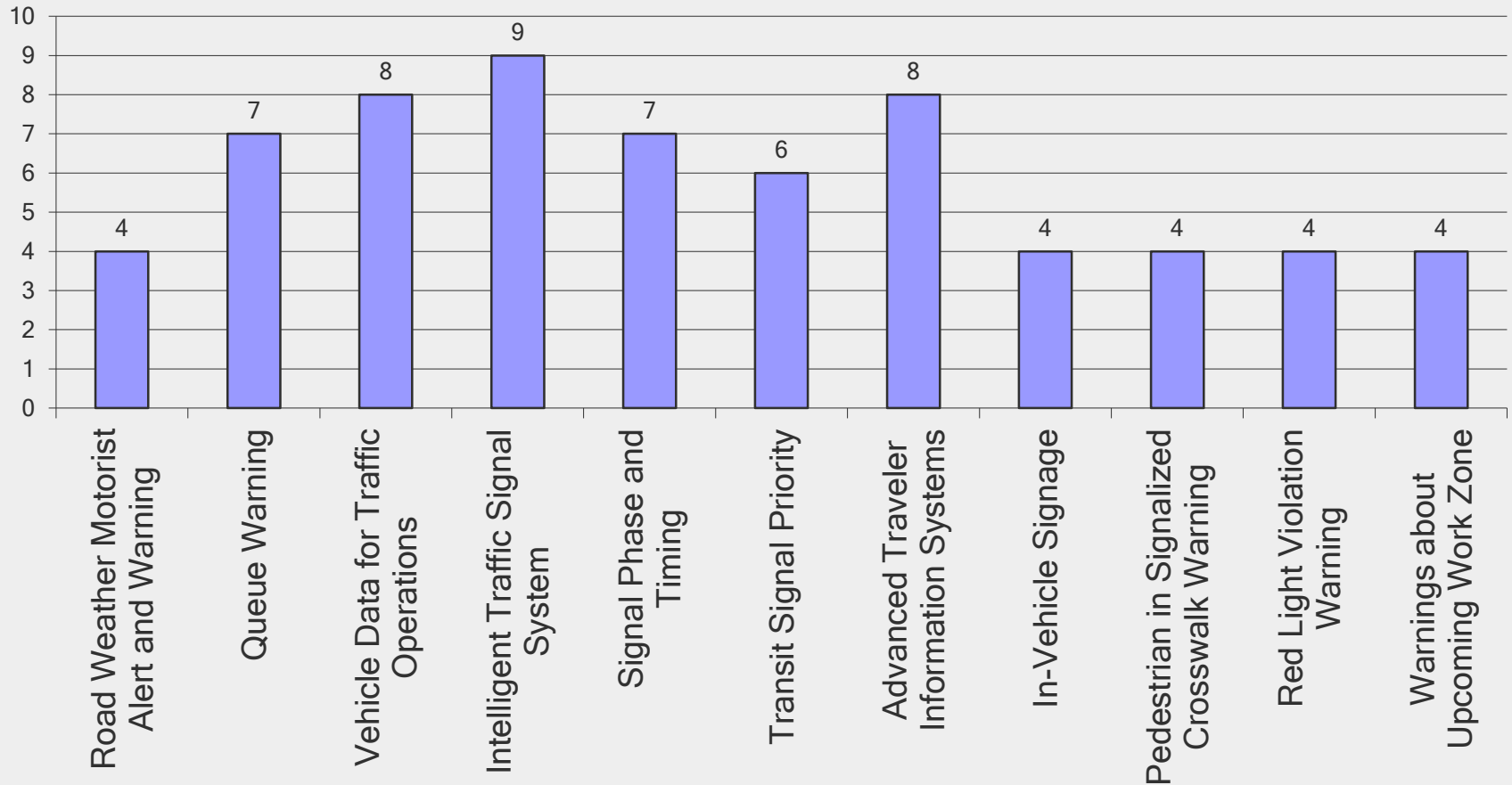
**Q3: Select the 5 Applications You Feel Would Be Most Beneficial to Deploy**  
 (# of Responders=21)



# CV Applications Most Beneficial to Deploy

## 11 Most Selected Applications

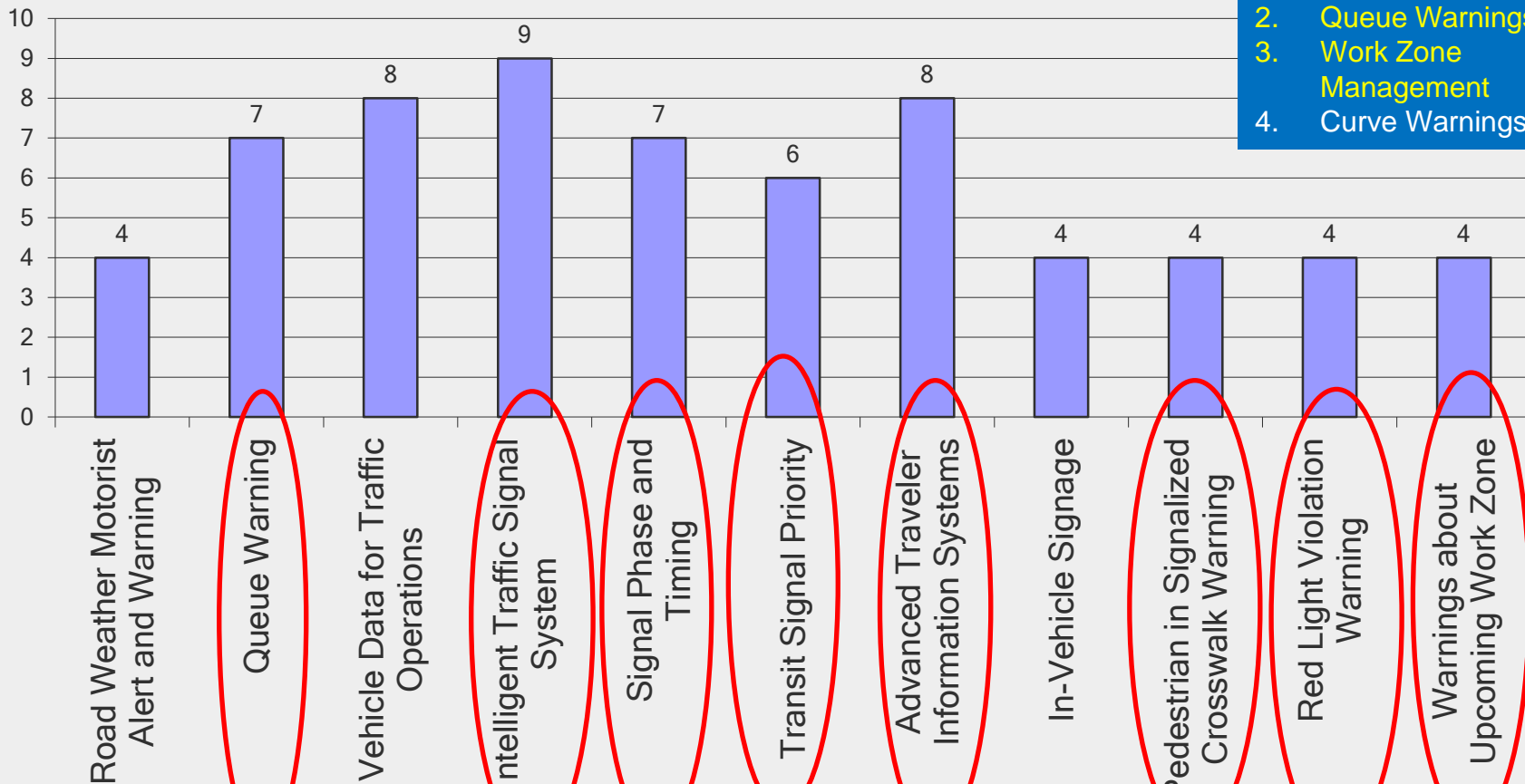
Question 3: Select the 5 Applications You Feel Would be Most Beneficial to Deploy  
(Top 11 Applications; # of Responders = 21)





# How do the Applications selected as most beneficial map to the focus areas?

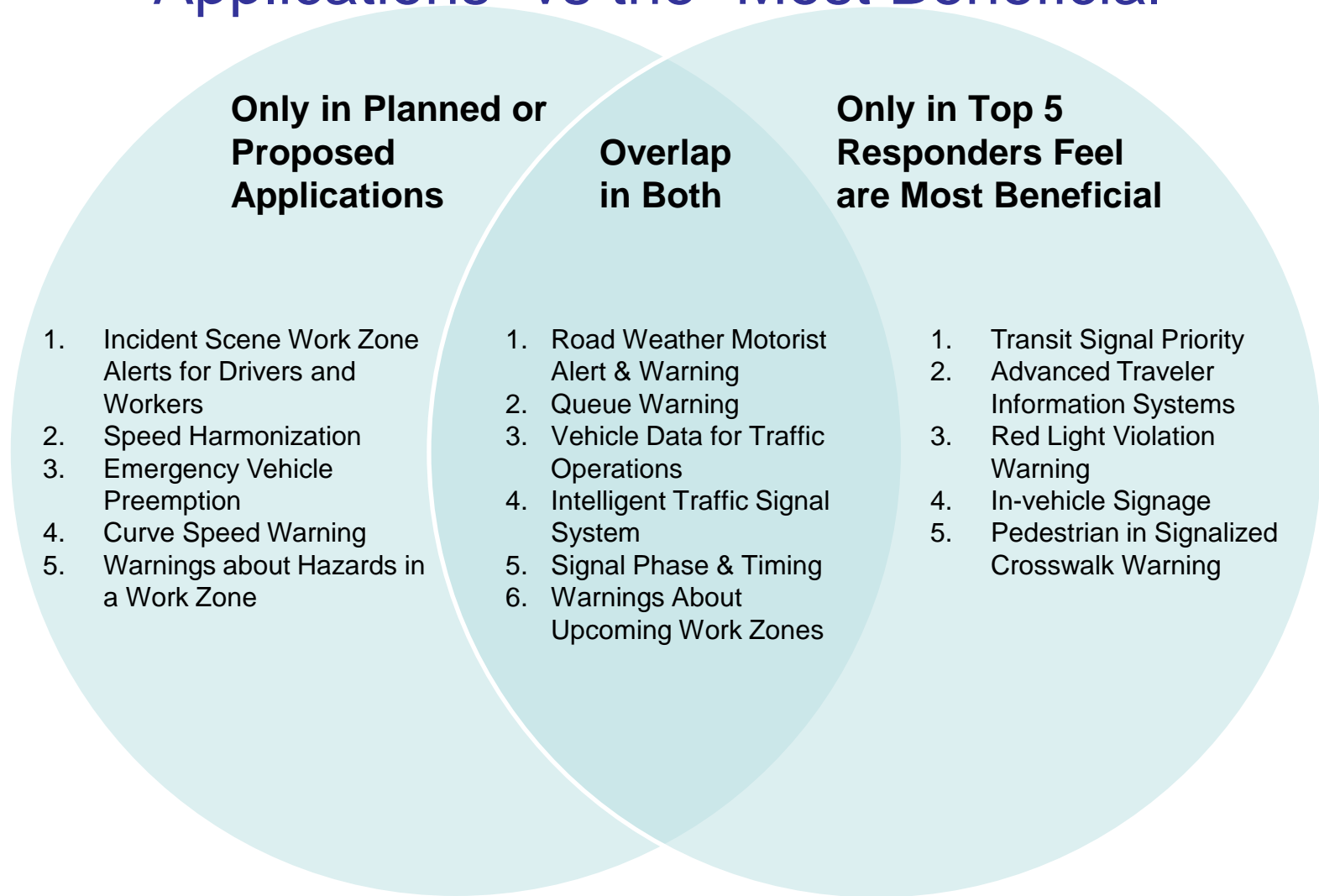
Question 3: Select the 5 Applications You Feel Would be Most Beneficial to Deploy  
(Top 11 Applications; # of Responders = 21)



3 of 4 Focus Areas Represented

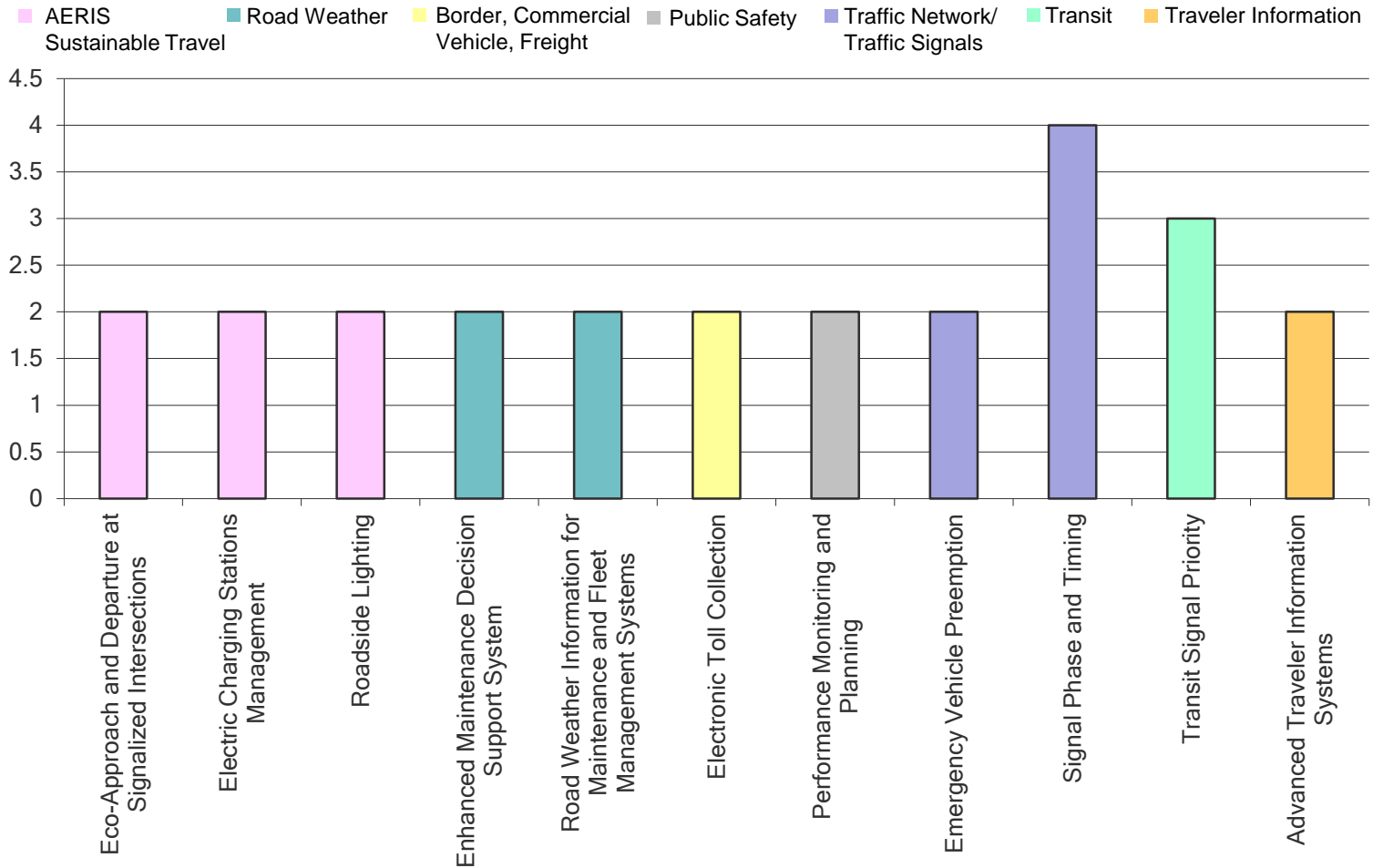
1. Intersections
2. Queue Warnings
3. Work Zone Management
4. Curve Warnings

# Comparing the Most Selected “Planned/Proposed Applications” vs the “Most Beneficial”



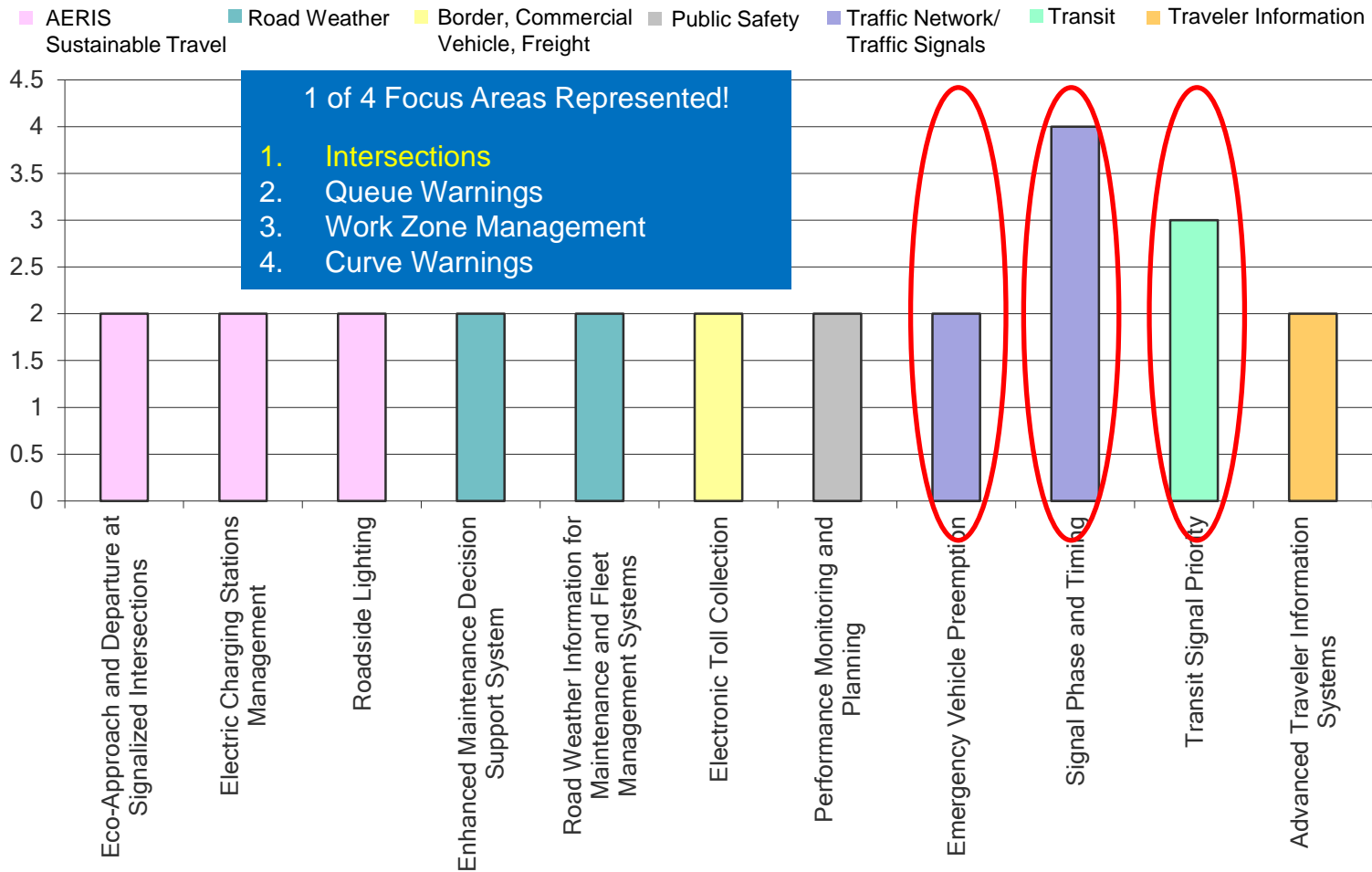
# CV Applications Already Deployed by Responding Agencies

Question 3: CV Applications Already Deployed by Agencies  
(Applications with 2 or more agencies; # of Responders = 22)



# CV Applications Already Deployed Mapped to the V2I DC Focus Areas

Question 3: CV Applications Already Deployed by Agencies  
(Applications with 2 or more agencies; # of Responders = 22)



# 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 received*

# Q4: Additional applications not included in deployment plans

- 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... for snow removal operations and incident/crash detection

# Question 5:

What are the problems you are solving by deploying these applications?

*15 responses received*

# Q5: Problems solved by deploying applications

- 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



# Question 6:

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

*17 responses received*

# Q6: Communication Technology Approaches

- Existing backhaul communications
- DSRC
- Cellular
- Internet
- WiFi
- GPS
- Fiber

# 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 received*

# Q7: DSRC Messages

- BSM
- Any/all of the J 2735 (2015) Messages
- SPAT
- MapData
- Probe Data Management (PDM)
- Snow plow signal request
- Road weather info
- *“Basic Infrastructure Message will be important so we need to define that”*

# 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 received***

Note: This question relates to ***Issue #13 Infrastructure Processes as V2I Obstacles*** – Added by TWG 1

# Q8: Infrastructure Processes that will prevent or hinder deployment

- 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

# 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?

*12 responses received*

# Q9: Most Important or Surprising

Comments are Grouped into **5 Categories** & Highlights are Summarized in this Presentation

(All responses will be in the written report)

## **Categories include:**

1. Technology Related Comments
2. Current Challenges
3. Rate of Change
4. Coordination / Communication
5. Deployment Decisions



# Q9: Most Important or Surprising

## Sample Comments: **Technology**

- 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.....
- It takes time for applications to mature to full deployment.

# Q9: Most Important or Surprising

## Sample Comments: **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.
- OEM's are promoting vehicles with on-board technology, but not indicating the connection between vehicles and infrastructure...
- Despite some information on costs and benefits, right now it is very hard to confidently quantify them....

# Q9: Most Important or Surprising

## Sample Comments: **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.

# Q9: Most Important or Surprising

## Sample Comments: **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.

# Q9: Most Important or Surprising

## Sample Comments: **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.
- Deploying CV at this point is risky. Agency access to private vehicle CV data is still undefined...

# Next Steps with the Survey

## Sharing Survey Results

- Written Report summarizing findings and including all the text/data received from survey responders – Sometime in February

# Next Steps for TWG 1

**Next Webinar: February 25, 2016**

## **Proposed Topics:**

1. Issue #13: Infrastructure Processes as V2I Obstacles (Question 8 in the Survey)
  - Open discussion about next steps / additional actions needed
  - Full responses to Question 8 will be circulated before the next webinar
2. Issue #14: Follow-up Discussion on Federal V2I Policy Statement

**Appendix B:**

**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*

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### 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 Term V2I 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://athecreek.webex.com/athecreek/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 developed 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:
  - o Penetration of connected vehicle components in the vehicle fleet; and
  - o 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:
  - o Are there synergistic benefits that are bigger than the sum of individual benefits when multiple applications are deployed together?
  - o 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)

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**Presented on:** December 4, 2015

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

**Webinar Recording Link:**

<https://athycreek.webex.com/athycreek/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 C:**

**PPT Summary of Issue 7 Discussion**

# Discuss Issue 7: Understanding the Benefits and Costs of V2I Deployment

Navin Katta, Savari

*\*\* TWG 2 Participation*

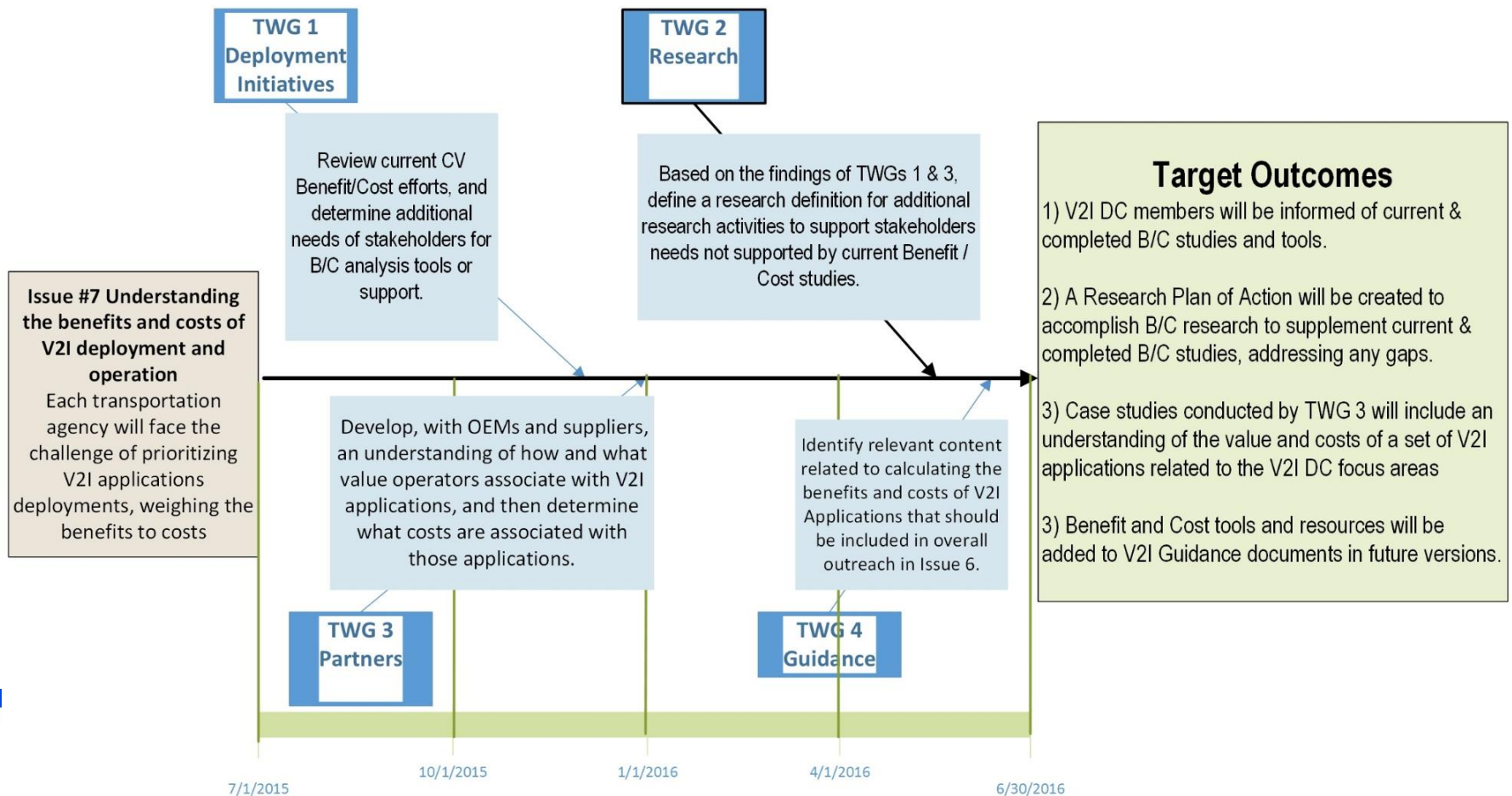


# Issue 7: Background

“The potential benefits of V2I applications have been researched and identified through a number of deployment initiatives. 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 emerge and facilitate decision-making. Analyses of the benefits and costs and prioritization of specific applications are just some of the discussions that would fold into an eventual business model. 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. **This issue will review how agencies can assess benefits and costs** to prioritize V2I applications and accelerate deployment in accordance with a business plan.

# Issue 7: Background

- Recap of what each TWG planned for issue



# Issue 7: Background

- TWG 1 hosted two webinars in Nov and Dec featuring new B/C resources
  - Desk Reference Tools for Estimating Local, Regional and Statewide Economic Development Benefits of CV Infrastructure
    - ❖ “Benefit Tool”
  - Near Term V2I Transition and Phasing Analysis of CV Life Cycle Cost Model
    - ❖ “Cost Tool”

# Issue 7: Background

- Benefit Tool
  - Desk reference and analysis tool
  - Sketch planning level analysis
    - ❖ Similar to TOPS-BC tool
  - Tool is MS Excel workbook
  - Benefits only – no costs
    - ❖ There are links to Cost Tool
  - V2I apps from CVRIA

# Issue 7: Background

- Benefit Tool (cont.)
  - Estimates benefits from theoretical to steady state based on assumed deployment maturity
  - Benefit content based on available research
    - ❖ Flat file database used to allow continued additions of benefit information

# Issue 7:

## Guidance Review – Benefits

- What benefit related details should be considered during review of V2I Deployment Guidance?
  - How to modify content in tool
  - How to continue identifying additional benefit info to add to tool
  - How to use tool framework to calculate benefits in absence of relevant content
  - How to factor benefits in business planning
  - Is there a Federal plan for maintaining content?

# Issue 7:

## Research Review – Benefits

- Are there benefit related details that could be further addressed by research?
  - Identifying benefits when so little is still known due to limited deployment – especially quantifiable benefits
  - Aggregating benefits of multiple apps
  - Distributing benefits to users – multiple users, conflicting user benefits
  - Timing recognizing benefits near vs. long-term
  - User and economic benefits identified but economic development benefits unclear

# Issue 7: Background

- Cost Tool
  - Estimates all costs
    - ❖ Installation, maintenance, customization and operation
  - Costs are estimated over 20 year period
    - ❖ Provided in annual and aggregate set of individual component costs
  - Works with
    - ❖ Benefit Tool
    - ❖ Application Prioritization Tool



# Issue 7: Background

- Cost Tool (cont. )
  - Content based on available research
    - ❖ May be revised similar to Benefit Tool
  - Costs available for approximately 70 apps

# Issue 7:

## Guidance Review – Costs

- What cost related details should be considered during review of V2I Deployment Guidance?
  - Are four priority apps identified by V2I DC included?
    - ❖ Intersections
    - ❖ Queue warning
    - ❖ Work zone management
    - ❖ Curve warning
  - Similar to benefits (e.g. modify tool content in tool, identifying additional cost info, factoring costs in business planning, Federal plan to maintain)

# Issue 7:

## Research Review – Costs

- Are there cost related details that could be further addressed by research?
  - Identifying accurate costs when so little is still known due to limited deployment

# Issue 7: Background

- TWG 3 has been talking with owners, operators and OEMs to understand how they value V2I apps
  - Also identifying relevant costs
- Draft summary to-date covers
  - Reduced speed zone warning
  - Red light violation warning

# Issue 7: Background

- General concepts are presented
- Known benefits are noted
  - Primarily safety
  - Acknowledges there could be additional mobility and environmental benefits but none are cited
  - RSZW based on RESCUME INC-ZONE modeling and simulation results
  - RLVW references NHTSA studies, Footprint Analysis and Wisconsin intersection crash study

# Issue 7: Background

- Known costs are highlighted
  - Infrastructure
    - ❖ Approximately \$54,650 per intersection
  - Vehicle
    - ❖ New vehicle cost approximately \$330
    - ❖ Aftermarket installation approximately \$326-387

# Issue 7: Guidance Review

- What additional B/C details should be considered during review of V2I Deployment Guidance?

# Issue 7: Research Review

- Are there additional B/C details that could be further addressed by research?



**Appendix D:**

**PPT Summary of Report Out from April 20, 2016, V2IDC TWG Breakout Sessions**

# V2I Deployment Coalition Spring 2016 Meeting

Plenary Session

April 21, 2016

*Detroit, MI*

# Welcome

Gummada Murthy, AASHTO

Matt Smith, MDOT

King Gee, AASHTO

# Opening Remarks

Carlos Braceras, Utah DOT

Jeff Lindley, USDOT

# TWGs Updates on Efforts and Progress

# TWG 1 (Initiatives) Report

Bill Legg, WSDOT

# V2I Deployment Coalition Spring 2016 Meeting

Report for  
TWG 1  
April 21, 2016  
*Detroit, MI*

# Deployment Issues Addressed

Issue	TWG 1 Initiatives	TWG 2 Research	TWG 3 Partners	TWG 4 Guidance	TWG 5 Standards
Issue 1: V2X Applications	P	S	S	S	S
Issue 2: Complementary Communications to DSRC	N	P	N	N	N
Issue 3: V2I Data	N	S	P	N	S
Issue 4: Patents-Intellectual Property	N	P	N	N	N
Issue 5: Security		No action planned at this time			
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	N	P	N	S	N
Issue 10: V2I Synergies with Other Emerging Technologies		No action planned at this time			
Issue 11: V2I Consumer Messaging	N	N	N	P	N
Issue 12: V2I Multimodal Applications		No action planned at this time			
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



# Issue 1: V2X Applications

- Survey of Infrastructure Owners & Operators
- We wanted to capture the knowledge gained by agencies who had planned or proposed V2I applications
- About 25 Responses

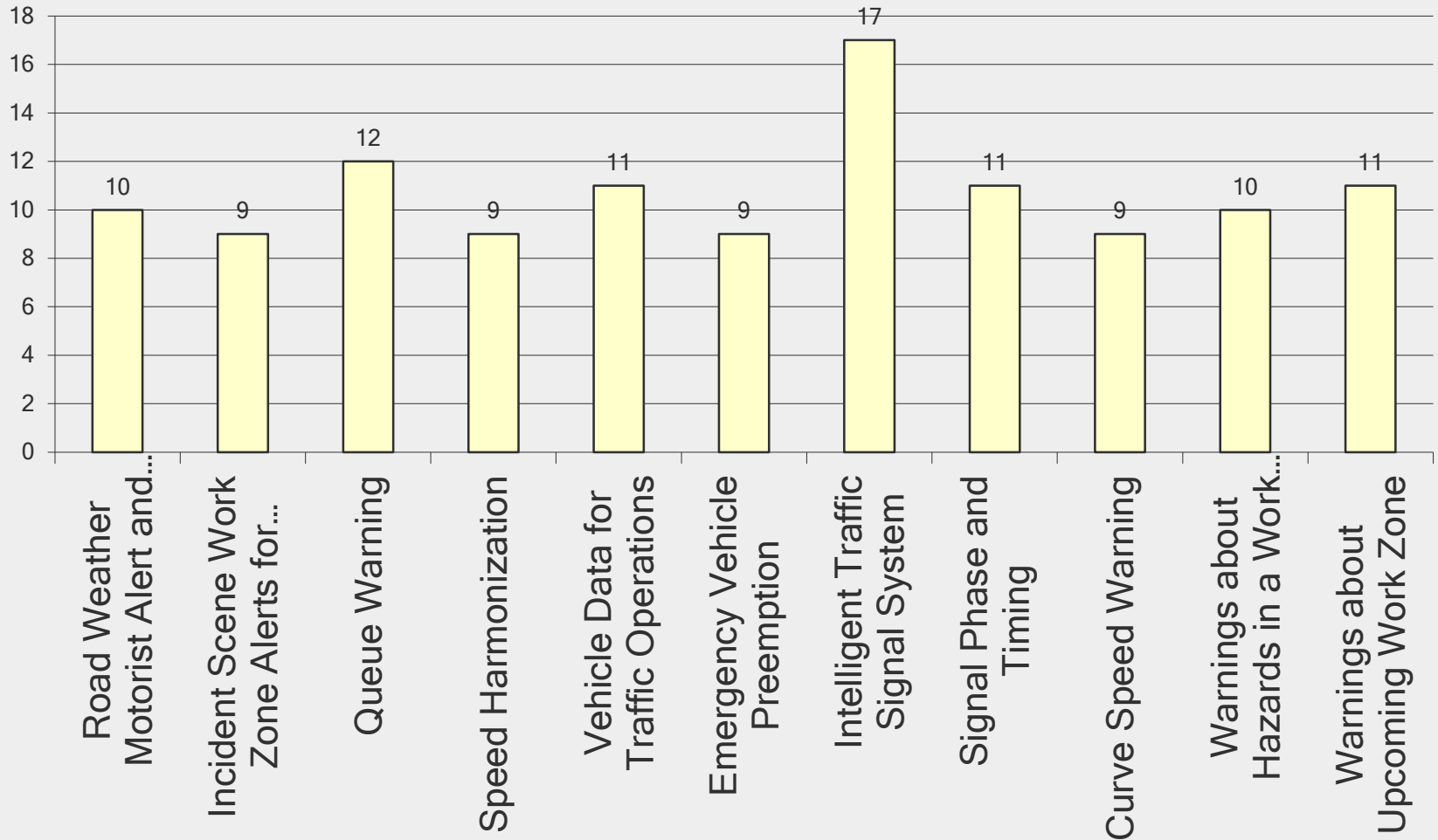
# Primary Question in Survey

- Question 3 attempted to learn 3 things:
  - Which CV applications responding agencies had **included in their proposal or plan** for CV deployment
  - Which CV applications responding agencies felt **were most beneficial**; and
  - Which CV applications responding agencies **had already deployed**

# CV Applications Included in Plans or Proposals

## 11 Most Selected Applications

Question 3: CV Applications Included in Agencies Plans or Proposals for Deployment  
(Top 11 Applications Selected; # of Responders = 21)



# Issue 1: V2X Applications

- Remaining Work:
  - Follow up with other TWGs to track progress on Issue #1
  - Structured process to follow up with each other TWG on related issue

# Issue 7: Understanding the Benefits & Costs of V2I & Issue 15: Maintaining V2I Infrastructure

- Conducted 2 Webinars to share ongoing or completed USDOT funded B/C research
- Both webinars summarized & recorded
- Remaining Work:
  - Offer to Trial Cost/Benefit Tools with work Oregon DOT is doing
  - Webinars sharing UMTRI V2I Maintenance Issue Costs

# Issue 13: Infrastructure Processes as V2I Barriers

- Identified a set of Barriers, some previously known (security, App maturity), some new (roadside sign to in-vehicle display consistency, pavement striping, etc.)
- Developed a Position Paper
- Outreached to other TWGs
- Remaining Work:
  - Follow-up Coordination with other TWGs

# Issue #14 – Federal V2I Policy Statement

At the June meeting in Pittsburgh:

- TWG 1 members identified a need for a Federal V2I Policy Statement.
- A new Issue (#14) was added to the issues
  - **“...The V2I industry needs a strong message from a federal agency encouraging V2I deployment.”**

# Issue #14 - Status

- In January, core members of TWG 1 and TWG 4 met by webinar to discuss topics for a Federal Statement
- USDOT representatives on TWG 4 shared that many (perhaps all) of the topics would be addressed by the V2I Deployment Guidance and Supporting Products
- Remaining Work:
  - Suggestion is that TWG 1 & 4 not prepare any requests until the Deployment Guidance documents are released



# Potential Future Work – TWG 1

## Identified a Future Work Plan to Support Deployment of V2I

- Put together a plan to facilitate the deployment of SPaT in as many urban areas as possible in the next 5 years:
  - At least 20 Agencies to deploy SPaT on corridors of at least 15 Intersections
  - Commit to O&M for at least 10 years
  - Will give the OEMs an option to develop applications

# Contact for more information about TWG 1: Deployment Initiatives

Bill Legg, Chair

Joe Averkamp, Co-Chair

Dean Deeter [deeter@acconsultans.org](mailto:deeter@acconsultans.org), Liaison

# TWG 2 (Research) Report

Greg Larson, Caltrans

# V2I Deployment Coalition Spring 2016 Meeting

Report for  
TWG 2: Research  
April 21, 2016  
*Detroit, MI*

# Deployment Issues Addressed

Issue	TWG 1 Initiatives	TWG 2 Research	TWG 3 Partners	TWG 4 Guidance	TWG 5 Standards
<b>Issue 1: V2X Applications</b>	P	S	S	S	S
<b>Issue 2: Complementary Communications to DSRC</b>	N	P	N	N	N
<b>Issue 3: V2I Data</b>	N	S	P	N	S
<b>Issue 4: Patents-Intellectual Property</b>	N	P	N	N	N
<b>Issue 5: Security</b>	No action planned at this time				
<b>Issue 6: V2I Outreach</b>	N	S	N	P	S
<b>Issue 7: Understanding the Benefits and Costs of V2I Deployment and Operation</b>	S	S	P	S	N
<b>Issue 8: V2I Standards</b>	N	N	N	N	P
<b>Issue 9: Understanding V2I Liability Assignment</b>	N	P	N	S	N
<b>Issue 10: V2I Synergies with Other Emerging Technologies</b>	No action planned at this time				
<b>Issue 11: V2I Consumer Messaging</b>	N	N	N	P	N
<b>Issue 12: V2I Multimodal Applications</b>	No action planned at this time				
<b>Issue 13: Infrastructure Processes as V2I Obstacles</b>	P	N	N	S	N
<b>Issue 14: Federal V2I Policy Statement</b>	P	N	N	S	N
<b>Issue 15: Maintaining V2I Infrastructure</b>	P	N	N	N	N
<b>Issue 16: Operator and OEM Goals for V2I</b>	N	N	P	N	N

# Issue 1: V2X Applications

## Volunteers:

- Skip Yeakel, Volvo Group North America
- Bill Mahoney, National Center for Atmospheric Research
- Jianming Ma, Texas DOT, **Leader for this activity**
- Danjue Chen, Traffic Operations and Safety (TOPS) Lab at UW-Madison

**Role in coordination:** TWG 2 members will participate in reviewing the survey responses. TWG 2 members will also prepare a research definition for any additional research that might be needed towards identifying prioritized set of V2I applications, based on the survey results and comments received.

**Targeted Outcome:** Definition of any additional research proposed to further explore Issue #1.

**Timeline.** Give problem statements to TRB in June for consideration in NCHRP CAV Roadmap Project.

# Issue 1: V2X Applications

**Next Step:** Develop a problem statement for harmonization of V2X apps for CAV research roadmap? Analyze the two lists, see what is the same, define what those mean, and **assess the readiness**.

**Volunteers:** Rob Bertini, Cal Poly and Tom Timcho, WSP

**Assess the readiness of the V2X apps.** Is this a CV PFS activity? Is this the readiness of off-the-shelf software? Should there be a common platform? We need to know the software, the platform, and the hardware.

# Issue 3: V2I Data

## Volunteers:


- Tom West, California PATH/UC Berkeley, **Leader for this activity**
- Jan-Mou Li, ORNL
- Danjue Chen, Traffic Operations and Safety (TOPS) Lab at UW-Madison
- Jianming Ma, Texas DOT
- Yang Cheng, Traffic Operations and Safety (TOPS) Lab at UW-Madison,

**Role in Coordination:** TWG 2 (Research TWG) will take the definitions of the highest priority data related issues that TWG 3 produces and develop research definitions that define the research activities (e.g. scope of research, anticipated results, cost estimate) that are recommended to address the prioritized issues over the coming 2-5 years.

**Targeted Outcome:** A research plan of action to research and resolve as many of the prioritized list of issues as possible over the coming 2-5 years.

**Next Step:** Develop a research problem statement for

1. Mechanisms for higher frequency dynamic map updates
2. Determine corrections for lane-level GPS positioning
3. Determine roadway friction indicators (e.g., skidding/braking)
4. Determine what owner/operators want from OEMs



Do we need a trusted forum for sharing agency/OEM data?



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

## Volunteers:

- Greg Larson, Caltrans
- Rob Bertini, Cal Poly State University  
Ray Derr, Transportation Research Board
- Skip Yeakel, Volvo Group North America

**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.

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

**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.
- **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.

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

## Recommended Next Steps (continued):

- **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.

# Issue 7: Understanding the Benefits and Costs of V2I Deployment and Operation

## **Volunteers:**

- Bill Gouse, SAE International
- Dick Mudge, Compass Transportation and Technology
- Alan Korn, Meritor WABCO
- Doug Gettman, Kimley-Horn, **Leader for this activity.**

**Role in Coordination:** TWG 2 members will participate in the demonstrations facilitated by TWG 1 and the case studies performed by TWG 3, and make a determination about where gaps are in what has been delivered (or is planned) from the current studies and what TWG 3 was able to derive from the case studies. TWG 2 will prepare a Research Definition for additional research activities needed to further define anticipated costs and benefits of V2I.

**Targeted Outcome:** A Research Plan of Action will be created defining additional research needed to supplement both the current and completed B/C studies and the case study analyses conducted by TWG 3. Look at the 20% of curves that are 80% of the problem. There needs to be a range of assumptions. Develop an assessment of effectiveness.

**Recommended Next Steps:** Develop a research problem statement.

# Potential Future Work

- One-stop shop for research
- Other future research needs as they arise

# Contact for more information about TWG 2: Research

Greg Larson, [greg.larson@dot.ca.gov](mailto:greg.larson@dot.ca.gov), Chair

Rob Bertini, [rbertini@calpoly.edu](mailto:rbertini@calpoly.edu), Co-Chair

Pat Zelinski, [pzelinski@aashto.org](mailto:pzelinski@aashto.org), Liaison

# TWG 3 (Partners) Report

Matt Smith, MDOT

# V2I Deployment Coalition Spring 2016 Meeting

Report for  
TWG 3: Infrastructure Operator, OEM and  
Supplier Partnerships

April 21, 2016

*Detroit, MI*



# Deployment Issues Addressed

Issue	TWG 1 Initiatives	TWG 2 Research	TWG 3 Partners	TWG 4 Guidance	TWG 5 Standards
Issue 1: V2X Applications	P	S	S	S	S
Issue 2: Complementary Communications to DSRC	N	P	N	N	N
Issue 3: V2I Data	N	S	P	N	S
Issue 4: Patents-Intellectual Property	N	P	N	N	N
Issue 5: Security	No action planned at this time (future work)				
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	N	P	N	S	N
Issue 10: V2I Synergies with Other Emerging Technologies	No action planned at this time				
Issue 11: V2I Consumer Messaging	N	N	N	P	N
Issue 12: V2I Multimodal Applications	No action planned at this time				
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

# Issue 3: Data Strategies

- Identification of research priorities for TWG 2
  - Road friction
  - RTCM correction/lane level correction
- Infrastructure O/O's need data from vehicles – even for some safety applications
- Desire for further concept development for end-of-queue application(s)
- Three step strategy:
  - 1. What is needed for each application'
  - 2. What is common across applications
  - 3. What is “low-hanging” fruit.
  - 4. Address these data needs
- OEM's focus is on developing/perfecting current data elements (BSM, etc) before opening up new data sources

# Issue 7: Understanding the B/C of V2I Deployments

- Can only make assumptions based on research
  - Information available from European model deployment
  - CV Pilot research and results important
- Value for benefits is dependent on the method of delivery
- Gaps
  - Specific benefits from work zone applications
  - Evolving infrastructure costs
  - Application development / “maintenance” costs
  - Security costs
- Needs to be consistently updated

# Issue 16: Operator and OEM Goals for V2I

- Safety is a common goal for all
- Private sector providing solutions and services are in line with Public sector's overall mission and goals
- Private industry
  - Provide new technological solutions for Owner/Operators
  - New business opportunities
- Public Sector
  - Understand and look for technology that will allow them to achieve their mission and goals

# Coordination with TWG 2

- Two research ideas:
  - Road Friction data needs and availability
  - GPS correction data

# Remaining Work

- Issue 3 – Identify Infrastructure O/O Data needs
- Issue 7 – Incorporate additional information
  - European deployment
  - CV Pilots
  - Ongoing updates
- Issue 16 – Summarize work

# Potential Future Work

- Continued identification of data needs
- Continued update of Benefits/Costs
- Security
  - Possible approach for V2I DC
- International Harmonization
  - Explore common concept development

# Contact for more information about TWG 3: Infrastructure Operator, OEM and Supplier Partnerships

Matt Smith, [Smithm81@michigan.gov](mailto:Smithm81@michigan.gov), Chair

Roger Berg, [roger\\_berg@denso-diam.com](mailto:roger_berg@denso-diam.com), Co-Chair

Adrian Guan, [aguan@itsa.org](mailto:aguan@itsa.org), Liaison



# TWG 4 (Guidance) Report

Faisal Saleem, Maricopa County

# V2I Deployment Coalition Spring 2016 Meeting

Report for  
TWG 4: Guidance  
April 21, 2016  
*Detroit, MI*

# Deployment Issues Addressed

Issue	TWG 1 Initiatives	TWG 2 Research	TWG 3 Partners	TWG 4 Guidance	TWG 5 Standards
Issue 1: V2X Applications	P	S	S	S	S
Issue 2: Complementary Communications to DSRC	N	P	N	N	N
Issue 3: V2I Data	N	S	P	N	S
Issue 4: Patents-Intellectual Property	N	P	N	N	N
Issue 5: Security	No action planned at this time				
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	N	P	N	S	N
Issue 10: V2I Synergies with Other Emerging Technologies	No action planned at this time				
Issue 11: V2I Consumer Messaging	N	N	N	P	N
Issue 12: V2I Multimodal Applications	No action planned at this time				
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

# Issue 1: V2X Applications

- Reviewed results of TWG 1 survey – specifically question 3 – regarding priority apps
- Will identify if and to what extent new V2I Deployment Guidance addresses planned/most beneficial issues identified in survey
  - Road Weather Motorist Alert & Warning
  - Queue Warning\*
  - Vehicle Data for Traffic Operations
  - Intelligent Traffic Signal System\*
  - Signal Phase & Timing\*
  - Warnings About Upcoming Work Zones\*

*Apps with \*  
are also  
considered  
priority by  
V2I DC*

# Issue 6: V2I Outreach

- One of two primary issues and most significant for TWG 4
- Review of V2I Deployment Guidance was completed under this issue
  - Completed first review in June 2015
    - ❖ Provided nearly 200 comments

# Issue 6: V2I Outreach

- Planning second review once new Guidance is released
  - ❖ Second review will include additional review of eight new support products

*Began  
reviewing  
products  
with \*  
yesterday*

1. Systems Engineering Guide
2. Connected Vehicles and the Planning Process\*
3. Guide to Licensing
4. V2I Message Lexicon
5. Pre-Deployment Guidance for V2I Safety Applications\*
6. Estimating Benefits and Economic Impacts
7. Near Term Transition and Phasing\*
8. Connected Vehicle Training Resources

# Issue 6: V2I Outreach (cont.)

- Also under this issue, TWG 4 reviewed existing outreach and USDOT future plans for additional outreach, training and education
  - Provided summary feedback to USDOT
  - Participated in focus group (yesterday) regarding outreach plan content

# Issue 7: Understanding B/C of V2I Deployment and Operation

- Reviewed summary work from TWG 1 and TWG 3 (yesterday)
- Will identify if and to what extent new V2I Deployment Guidance addresses how to:
  - Modify content in B/C tools
  - Share additional B/C info to add to overall tool
  - Use tool framework to calculate B/C in absence of relevant content
  - Factor B/C into business planning



# Issue 9: Understanding V2I Liability Assignment

- Scheduled to discuss information from TWG 2 on this issue in June
- Will identify if and to what extent new V2I Deployment Guidance addresses liability

# Issue 11: Consumer Messaging

- Reviewed samples of existing public and private sector messaging to consumers on Connected Vehicle and V2I in particular
- Identified messages that were:
  - Common: Used by all or most
  - Supportive: Clear, factual
  - Questionable: Confusing, potentially misleading
- Provided summary feedback to USDOT

# Issue 13: Infrastructure Processes as V2I Obstacles

- Reviewed results of TWG 1 survey – specifically question 8 – regarding obstacles
- Will identify if and to what extent new V2I Deployment Guidance addresses obstacles identified in survey, *some* of which include:
  - DSRC security
  - Existing patents
  - Simple terminology (CV vs. AV; V2I/V2V/V2X)

# Remaining Work

V2I Deployment Issues	Anticipated TWG 4 Actions	Anticipated Completion Date
<b>Issue 1: V2X Applications</b>	<ul style="list-style-type: none"> <li>Identify relevant content from this issue that should be included in the overall outreach in Issue 6 based on TWG 3 findings.</li> </ul>	Q1-2016 (Underway)
<b>Issue 6: V2I Outreach</b>	<ul style="list-style-type: none"> <li>Provide input to USDOT on V14 of Deployment Guidance.</li> </ul>	6-29-2015 (Completed)
	<ul style="list-style-type: none"> <li>Identify outreach that may be needed to increase awareness and support of V2I among transportation agencies.</li> </ul>	Q3-2015 (Completed) and Q2-2016 (Underway)
	<ul style="list-style-type: none"> <li>Provide input to USDOT on next version of Deployment Guidance and corresponding support products.</li> </ul>	Q4-2015 (Underway)
<b>Issue 7: Understanding the Benefits and Costs of V2I Deployment</b>	<ul style="list-style-type: none"> <li>Identify relevant content related to calculating the benefits and costs of V2I applications based on work by TWG 1 that should be included in overall outreach in Issue 6.</li> </ul>	Q2-2016 (Underway)
<b>Issue 11: V2I Consumer Messaging</b>	<ul style="list-style-type: none"> <li>Develop a description of the type of content and guidelines that are needed to be developed to enable consistent, accurate consumer messaging related to V2I applications.</li> </ul>	Q4-2015 (Complete)
<b>Issue 13: Infrastructure Processes as V2I Obstacles</b>	<ul style="list-style-type: none"> <li>Identify relevant content related to infrastructure processes based on work completed by TWG 1 and TWG 3 that should be included in overall outreach in Issue 6.</li> </ul>	Q1-2016 (Underway)
<b>Issue 14: Federal V2I Policy Statement</b>	<ul style="list-style-type: none"> <li>Identify relevant content related to a Federal V2I policy statement based on work done by TWG 1 that should be included in feedback on the V2I Guidance documents.</li> </ul>	Q4-2015 (Underway)

# Contact for more information about TWG 4: Guidance

Faisal Saleem, [faisalsaleem@mail.maricopa.gov](mailto:faisalsaleem@mail.maricopa.gov), Chair

Navin Katta, [navin@savarinetworks.com](mailto:navin@savarinetworks.com), Co-Chair

Ginny Crowson, [crowson@acconsultants.org](mailto:crowson@acconsultants.org), Liaison

# TWG 5 (Standards) Report

Ed Seymour, TTI

# V2I Deployment Coalition Spring 2016 Meeting

Report for  
TWG 5: Deployment Standards Working  
Group

April 21, 2016

*Detroit, MI*

# Deployment Issues Addressed

Issue	TWG 1 Initiatives	TWG 2 Research	TWG 3 Partners	TWG 4 Guidance	TWG 5 Standards
Issue 1: V2X Applications	P	S	S	S	S
Issue 3: V2I Data	N	S	P	N	S
Issue 6: V2I Outreach	N	S	N	P	S
Issue 8: V2I Standards	N	N	N	N	P



# Issue 1: V2X Applications

- Gathering CV Pilots lessons (New York)
- Reviewing "ITS Standards for the Data Capture and Management Program"
- By June
  - Review CV Pilot lessons
  - Webinar on Data Capture document
  - Map Application Priorities by TWG 1 with priorities from other groups

# Issue 3: V2I Data

- Liaison with WG 3 – context diagram
- By June or summer
  - Joint meeting with WG 3
  - Meeting with WG 5 and SAE V2I Task Force

# Issue 6: V2I Outreach

- Share context drawing with other WGs and SAE DSRC Cmte
- By June
  - Recommendations including SAE Task Force, training, SDOs

# Issue 8: V2I Standards

- Identify standards gaps
  - Context diagram, Docs, CV Pilots, Liason TWGs
  - Move the RSE Specification to an SDO
- Candidate actions to fill gaps
  - SAE Task Force

# Potential Future Work

- Maintain the standards context drawing, complete white paper & use for training, resource for deployers
- Engage in Smart Cities and Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD)
- Engage with telecommunications providers
- Conformance with appropriate standards
- Monitor certification – currently limited to and focused on CV Pilots

# Potential Future Work

- Monitor Security needs and engage as it comes forward
- Consider standard specification for an ASD, subject to the contents of the NPRM
- Focus on and look for gaps in fleet-related standards if a NPRM for heavy vehicles is released. Perhaps broader engagement with commercial vehicle fleets
- Stay involved with the SAE I2V/V2I Task Force, and other SDOs

# Contact for more information about TWG 5: Deployment Standards

Ed Seymour, [e-seymour@tti.tamu.edu](mailto:e-seymour@tti.tamu.edu), Chair

Gary Duncan, [gduncan@econolite.com](mailto:gduncan@econolite.com), Co-Chair

Siva Narla, [snarla@ite.org](mailto:snarla@ite.org), Liaison

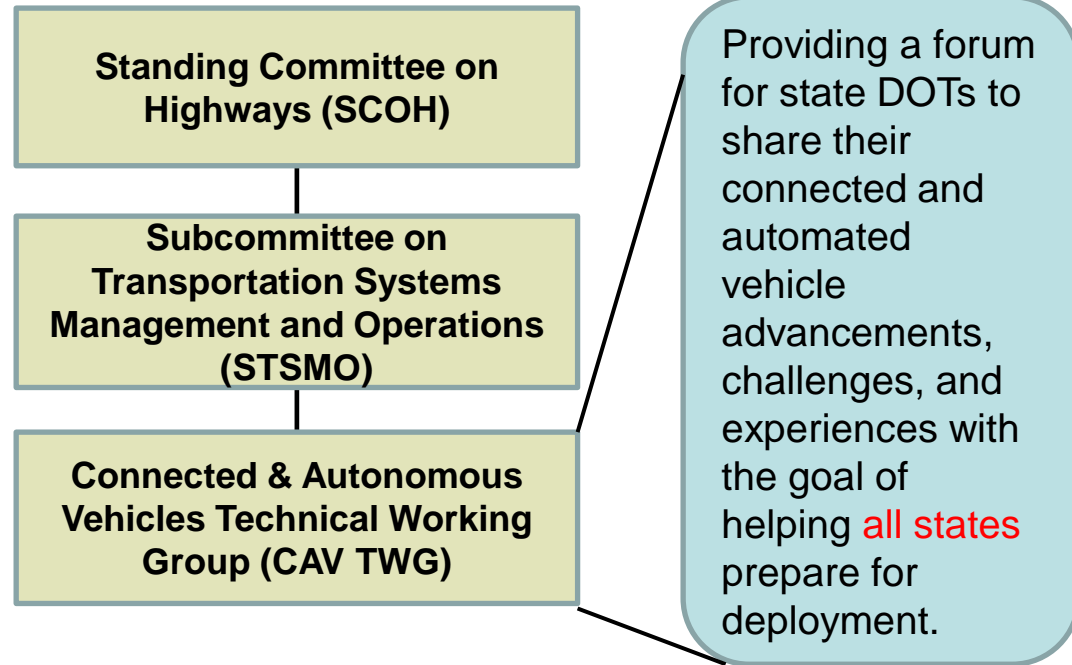
# V2I DC Coordination with Other Efforts



# AASHTO CAV TWG & Other AASHTO Efforts

Blaine Leonard, Utah DOT

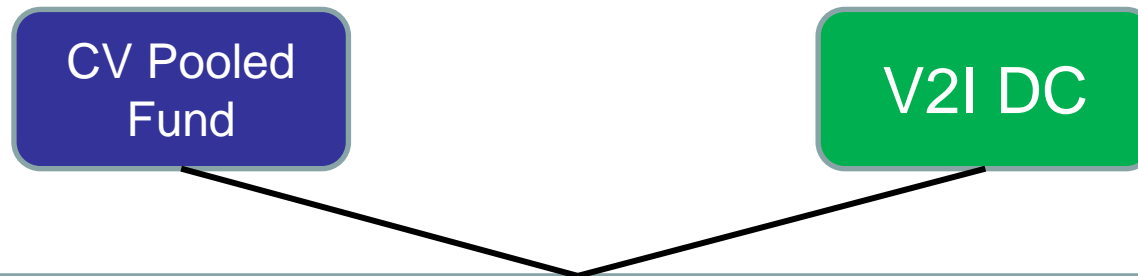
# AASHTO SCOH CV Leadership



# Current CAV TWG Member States

Washington	Minnesota
California	Utah
Arizona	Idaho
Texas	New York
Florida	New Jersey
Virginia	Iowa
Pennsylvania	Texas
Michigan	Wisconsin

# Relationship to V2I DC & CV Pooled Fund



## AASHTO CAV TWG Involvement

Participate in the activities of the V2I DC and the Connected Vehicle Pooled Fund Study, as individual members, to:

- promote collaboration and
- identify projects and efforts appropriate for each group.
- Facilitate the selection of projects to be sponsored or undertaken by the CAV TWG.

# CAV TWG -- Recent Activities

## Joint V2I Application Survey with V2I DC TWG 1

- Both groups wanted to survey infrastructure owners & operators
- Avoided multiple surveys
- Involved more individuals in the creation of the survey and discussion of results

# CAV TWG -- Recent Activities

## Presentations by the three Pilot Deployment Sites

- Allowed more dialog between members & the pilot sites than other venues
- Allowed members to understand the applications planned and the planned use of DSRC at each site
- Enabled Pilot Sites to communicate to all CAV TWG members at one time

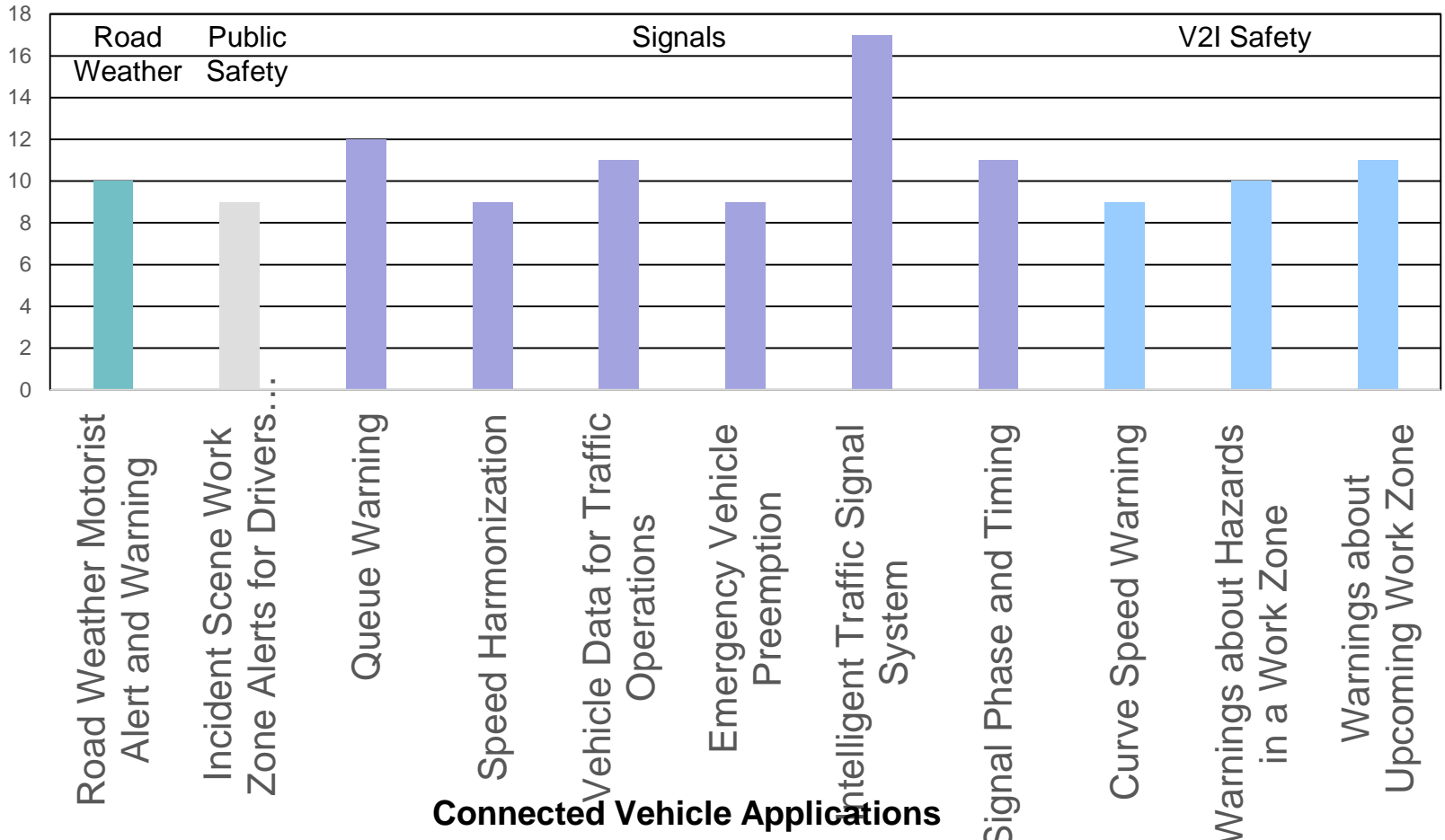
# CAV TWG -- Recent Activities

Discussion about each members approach / progress towards AV Policy / Legislation

- Open dialog among members
- Sharing of draft policy statements
- Agreed for continued discussion

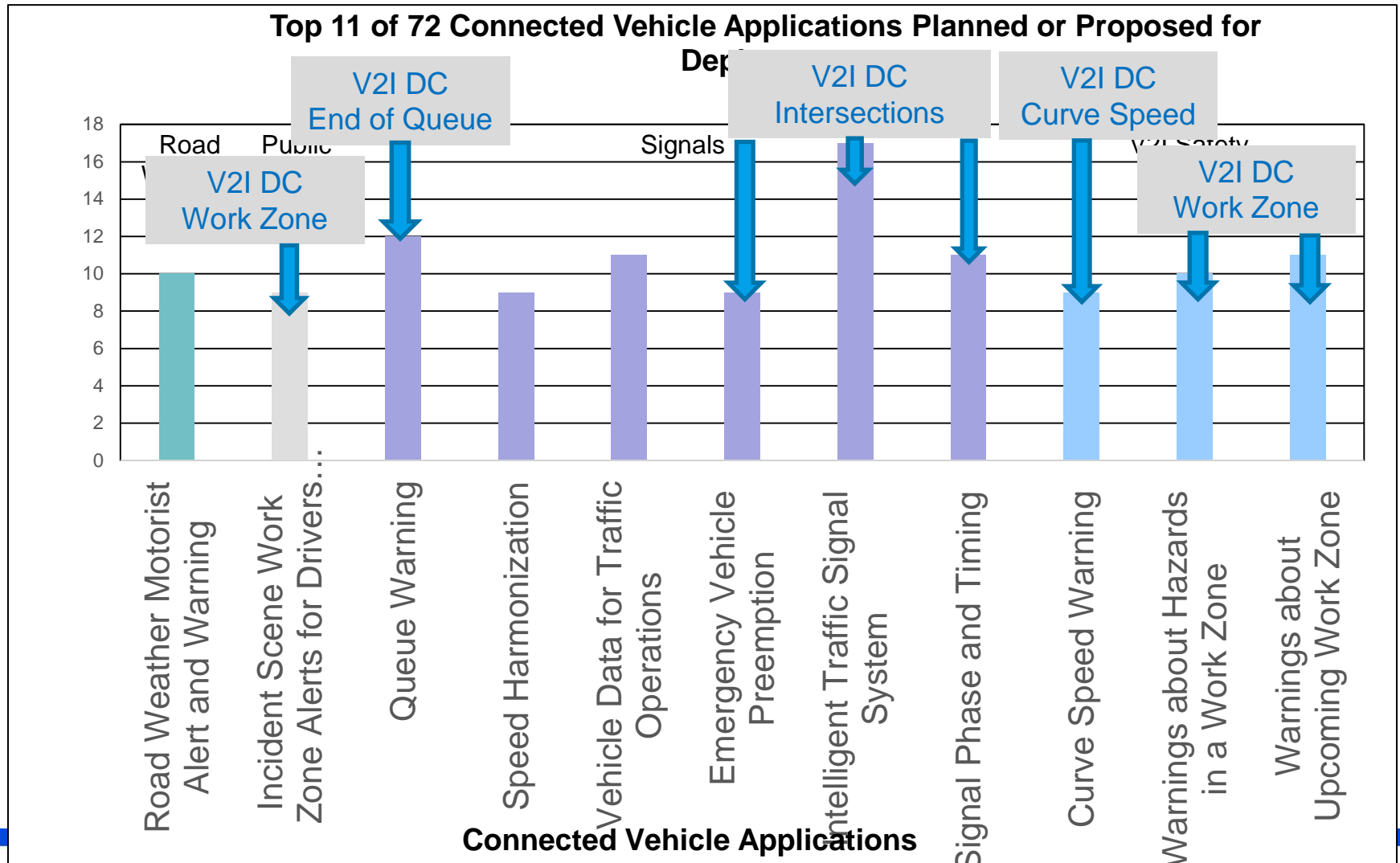
# Priority Applications – Results of TWG 1 Survey

**Top 11 of 72 Connected Vehicle Applications Planned or Proposed for Deployment**



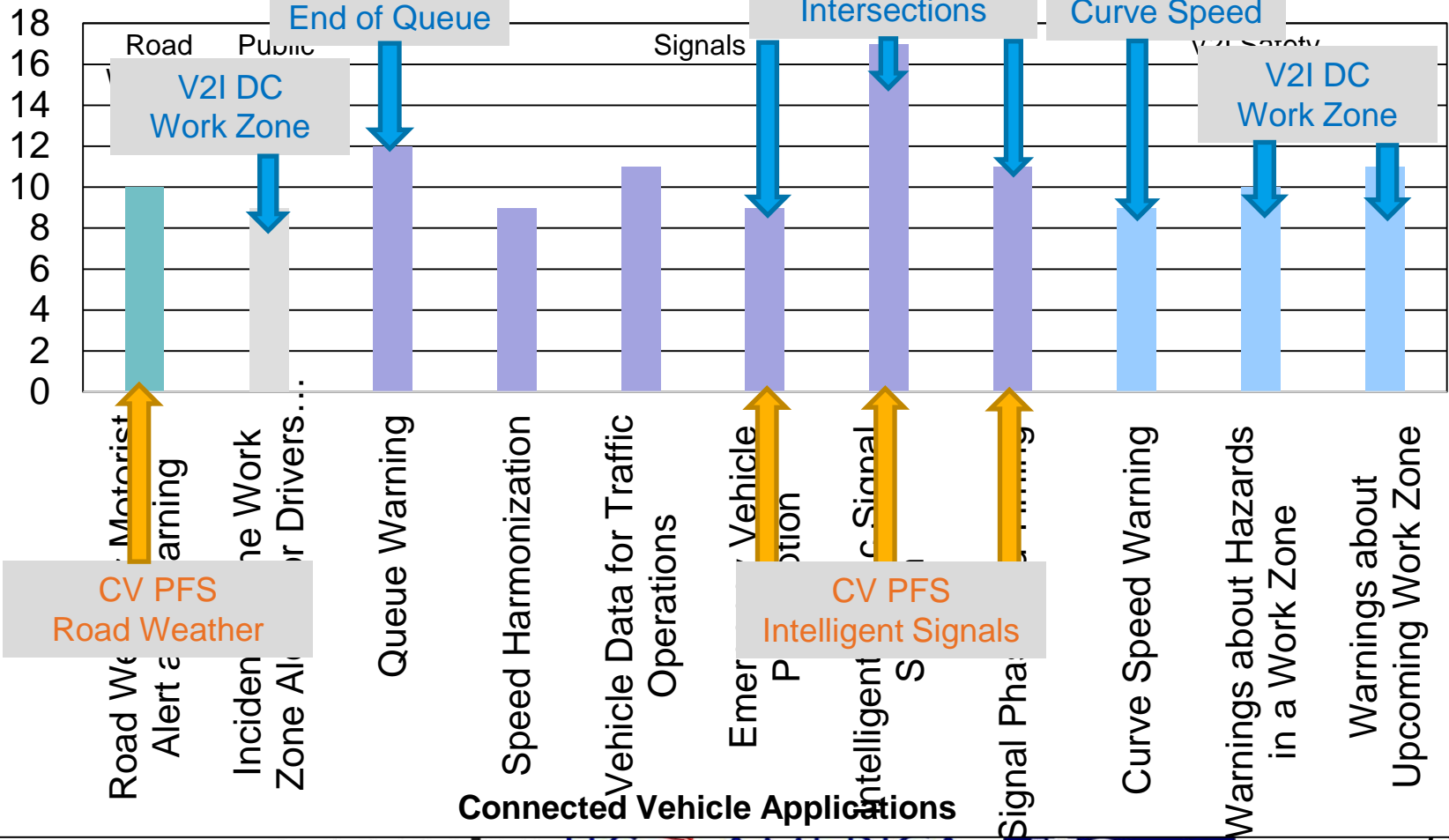


# Priority Applications – Addition of V2I DC Priority Areas

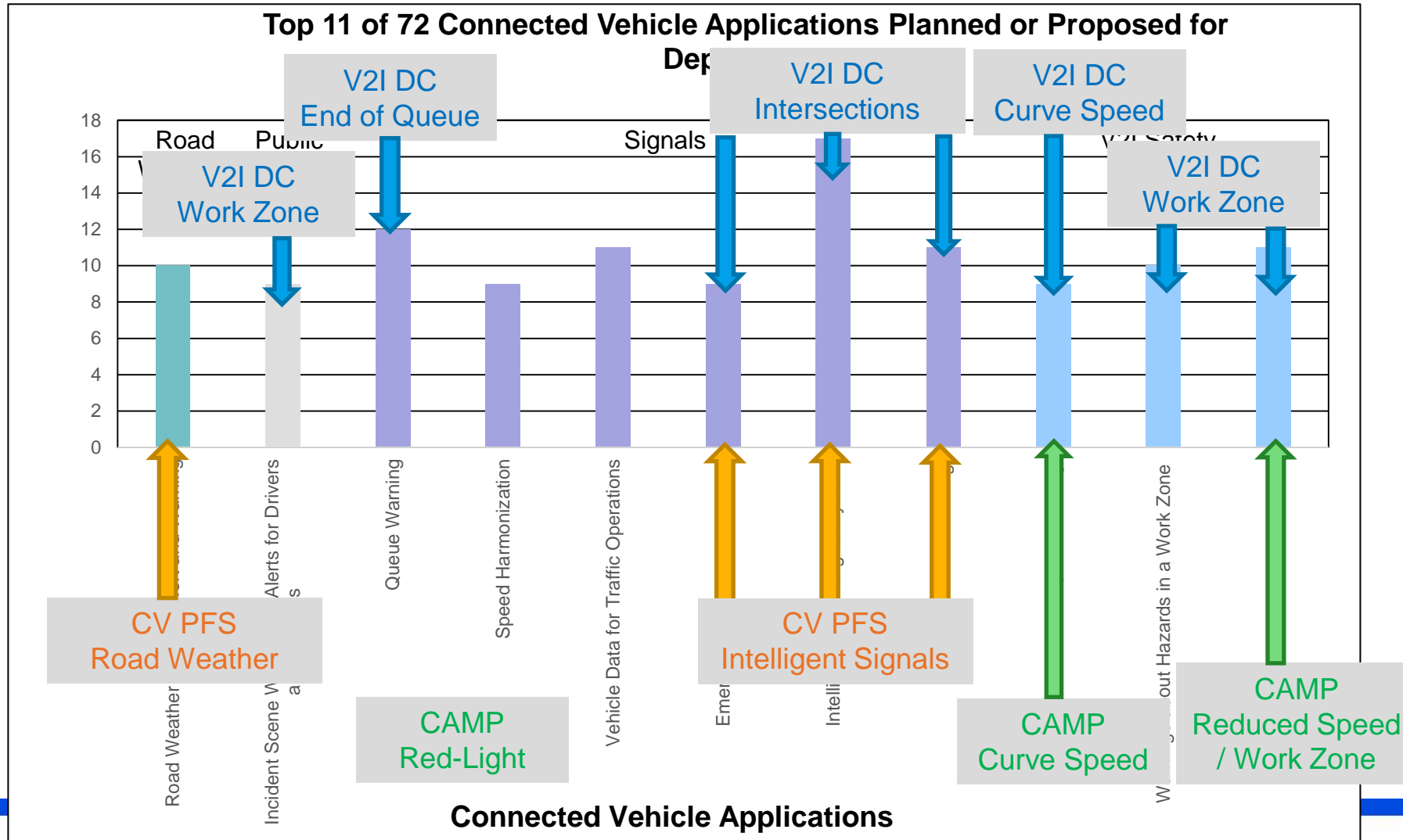


# Priority Applications – Addition CV Pooled Fund Projects

## Top 11 of 72 Connected Vehicle Applications Planned or Propose



# Priority Applications – Addition CAMP Demo Applications



# CAV Executive Leadership Team (CAV-ELT)

Gummada Murthy, AASHTO

# Executive Leadership Team (ELT)

## Meeting since 2005, Original Focus:

- Provide strategic guidance,
- Recommend policies and national deployment approaches,
- Provide critical program reviews,
- Assess the risks associated with deployment,
- Commit the resources of their organizations,
- Educate their organizations and supporting institutions

# CAV ELT Roster

Entity	# of Members
USDOT	7 Liaisons
State DOTs	15 members
Local Governments	5 members
AASHTO	3 members
ITE / ITS America	1 member each
Automotive Industry	15 – 20 members
TRB	1 member
NACO / NACTO / IBTTA / VII / AAMVA/ Others	9 members

# Automated Vehicle Public Policy Workshops

A series of workshops were conducted to discuss AV Public Policy. Locations included:

- Michigan
- Iowa
- Nevada

# Automated Vehicle Public Policy Workshops

## Objectives of the workshops:

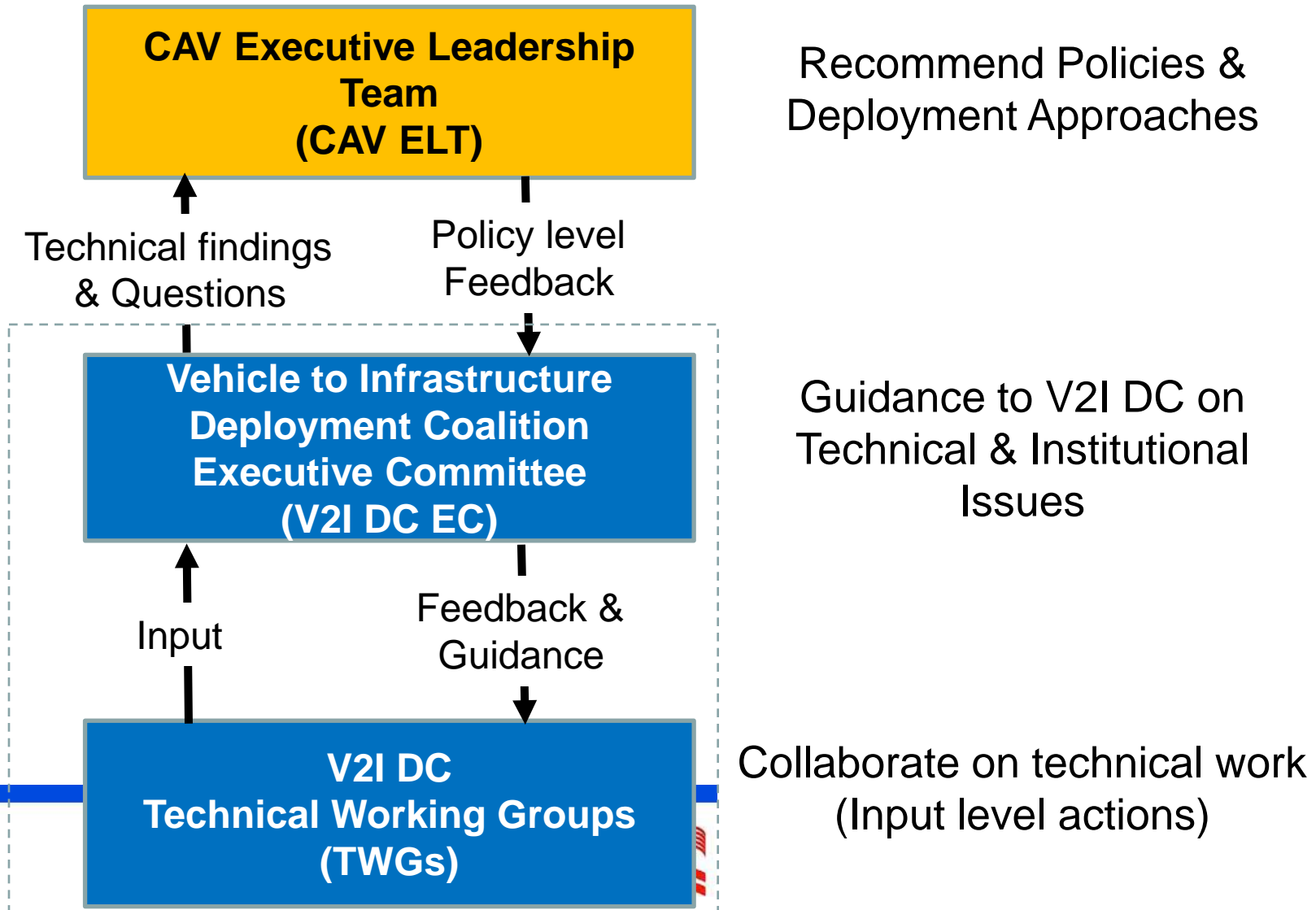
1. Raise awareness of policy issues for various national, state and local organizations and agencies
2. Identify and refine near term urgent or important policy issues for further study, collaboration or advocacy
3. Determine future form of any follow-on automated vehicle public policy forum



# CAV Institutional Framework

## Entity

## Role



# TRB AV/CV Roadmap

Ray Derr, TRB

# Cyber Security Task Force

Siva Narla, ITE

# Plans for Consolidating Results of the V2I DC

Dean Deeter, Athey Creek Consultants

# Last June in Pittsburgh

- 5 TWGs met for the first time
- TWGs were presented with 12 issues to discuss
- 4 new issues were identified

# 16 Issues

# 5 TWGs

Issue	TWG 1 Initiatives	TWG 2 Research	TWG 3 Partners	TWG 4 Guidance	TWG 5 Standards
Issue 1: V2X Applications	P	S	S	S	S
Issue 2: Complementary Communications to DSRC	N	P	N	N	N
Issue 3: V2I Data	N	S	P	N	S
Issue 4: Patents-Intellectual Property	N	P	N	N	N
Issue 5: Security	No action planned at this time				
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	N	P	N	S	N
Issue 10: V2I Synergies with Other Emerging Technologies	No action planned at this time				
Issue 11: V2I Consumer Messaging	N	N	N	P	N
Issue 12: V2I Multimodal Applications	No action planned at this time				
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

# Activities of the V2I DC

Issue	TWG 1 Initiatives	TWG 2 Research	TWG 3 Partners	TWG 4 Guidance	TWG 5 Standards
Issue 1: V2X Applications	P	S	S	S	S
Issue 2: Complementary Communications to DSRC	5 TWG Work Plans				
Issue 3: V2I Data					
Issue 4: Patents-Intellectual Property					
Issue 5: Security					
Issue 6: V2I Outreach	Surveys		Webinars		
Issue 7: Understanding the Benefits and Costs of V2I Deployment and Operation					
Issue 8: V2I Standards	Technical Diagrams				
Issue 9: Understanding V2I Liability Assignment					
Issue 10: V2I Synergies with Other Emerging Technologies	Documents / Papers				
Issue 11: V2I Consumer Messaging					
Issue 12: V2I Multimodal Applications	Guidance Feedback				
Issue 13: Infrastructure Processes as V2I Obstacles					
Issue 14: Federal V2I Policy Statement					
Issue 15: Maintaining V2I Infrastructure					
Issue 16: Operator and OEM Goals for V2I					

# Activities of the V2I DC

Issue	TWG 1 Initiatives	TWG 2 Research	TWG 3 Partners	TWG 4 Guidance	TWG 5 Standards
Issue 1: V2X Applications	P	S	S	S	S
Issue 2: Complementary Communications to DSRC					
Issue 3: V2I Data					
Issue 4: Patents-Intellectual Property					
Issue 5: Security					
Issue 6: V2I Outreach					
Issue 7: Understanding the Benefits and Costs of V2I Deployment and Operation					
Issue 8: V2I Standards					
Issue 9: Understanding V2I Liability Assignment					
Issue 10: V2I Synergies with Other Emerging Technologies					
Issue 11: V2I Consumer Messaging					
Issue 12: V2I Multimodal Applications					
Issue 13: Infrastructure Processes as V2I Obstacles					
Issue 14: Federal V2I Policy Statement					
Issue 15: Maintaining V2I Infrastructure					
Issue 16: Operator and OEM Goals for V2I					

5 TWG Work Plans

How will the findings all get consolidated?

Documents / Papers

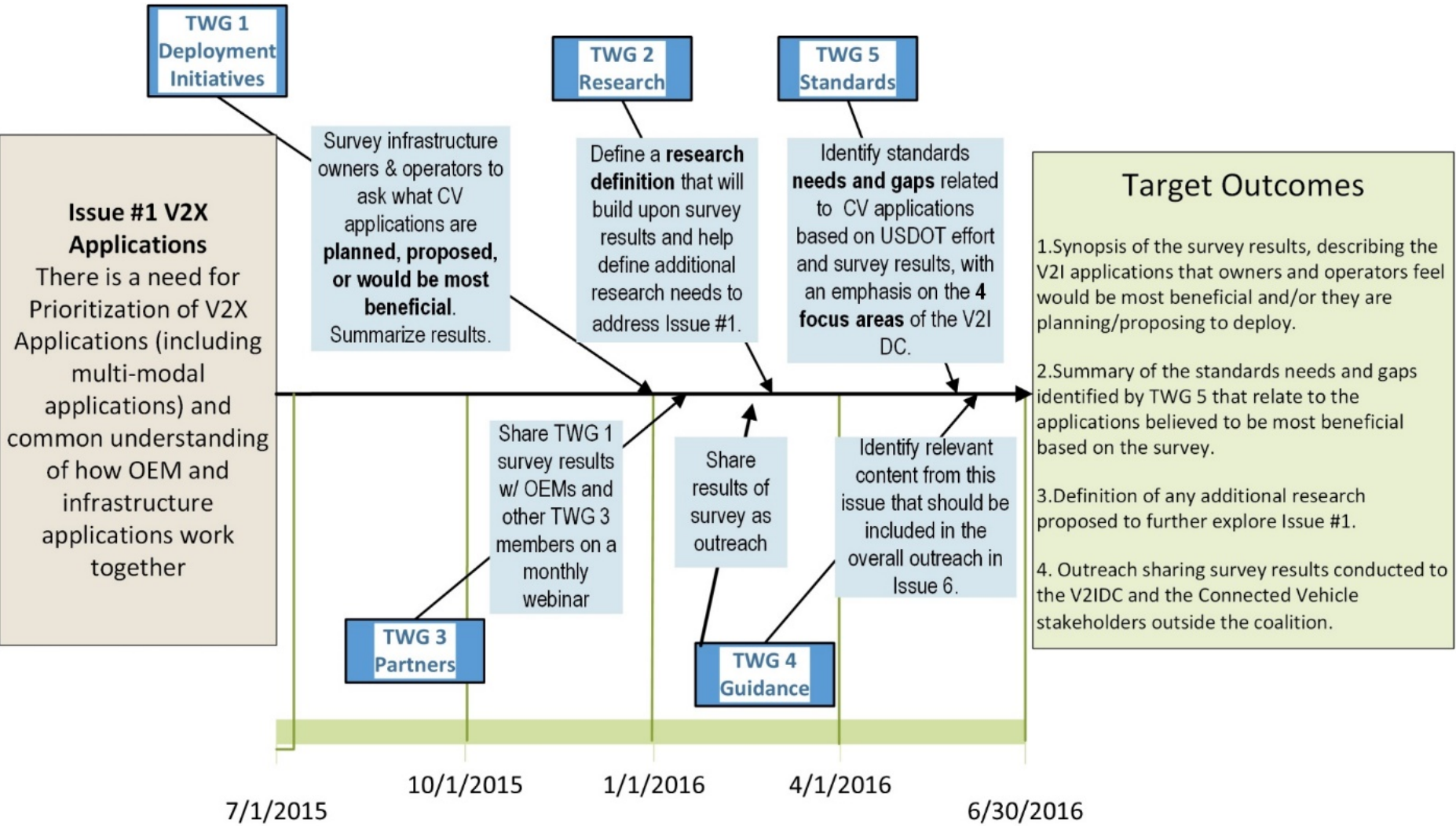
Guidance Feedback



# Issue Specific Summaries

- Consolidate the findings of the TWGs by Issue.
- 3 Categories of actions taken on the Issues:
  - 1. No Action Taken** in the Initial 18 months
  - 2. Primarily One TWG** performing the actions on a particular issue
  - 3. Multiple TWGs** collaborating together

# Multiple TWGs Collaborating (Issue #1: V2X Applications)



# Issue #1: V2X Applications

***One Summary*** that includes:

- Results of the V2I Applications Survey
- Discussion on the extent to which the highest ranked applications are addressed in the V2I Guidance documents
- Description of the Additional Research needs identified by TWG 2
- Any V2I standards gaps related to the highest ranked applications

# Consolidation to Include

- 16 summaries describing the activities related to issues
  - Range from a paragraph describing why no activities occurred to multi-page documents
- All 16 summaries pulled together into an overall Technical Memorandum
- July to August Timeframe

# V2I DC Future Plans

Gummada Murthy, AASHTO

Bob Arnold / Jonathan Walker, USDOT

**Appendix E:**

**Activity 2 of TWG 3 of the V2I Deployment Coalition**

## Activity 2 of TWG 3 of the V2I Deployment Coalition

The primary objective of Activity 2 was to identify, define and prioritize data issues for both Automotive OEM's and Infrastructure owners and operators 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 potential DOTs and OEMs to help frame the discussion. The results of these discussions are summarized in this document.

### DOT discussion

On Thursday, December 3<sup>rd</sup>, a conference call was held with a group of DOT and agency representatives who were participating in a pooled fund 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 their data needs from the OEMs to implement the 4 focus areas above.

It was determined that the data concerns for DOTs/Agencies are primarily with the mobility and "agency benefit" type of applications, rather than the safety-focus areas identified. For the most part, infrastructure owners/operators don't seem to need data as part of the safety applications identified, therefore to summarize:

- For the 4 identified focus areas, agencies don't need data from the vehicles. This changes when looking at mobility agency-specific applications, which should be a focus of this Technical Working Group after the March/April timeframe of our current deliverables.

## **OEM discussion**

After considerable outreach to the OEM community, feedback on data needs for the 4 focus areas was obtained from CAMP, and individually from 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.



## Attachment

### What is Activity 2 of Technical Working Group 3 of the V2I Deployment Coalition?

Activity 2's primary task is 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

#### For today's discussion:

1. Discuss each focus area and what data needs might be
2. Identify data elements needed for each focus area
3. Discuss challenges in obtaining, analyzing and/or using each data element

Note: the data elements on the following two pages were taken from the Michigan DOT-sponsored report **Connected v. Automated Vehicles as generators of Useful Data**, authored by Qiang Hong and Richard Wallace of CAR, and Gregory Krueger of Leidos.

#### Who is on the phone?

**Melissa S. Tooley, PhD, PE**

Director of External Initiatives  
Director, Southwest University Transportation Center  
Texas A&M Transportation Institute  
The Texas A&M University System  
3135 TAMU | College Station, TX 77843-3135  
Tel 979.845.8545  
[m-tooley@tti.tamu.edu](mailto:m-tooley@tti.tamu.edu)

tti.tamu.edu | **Saving Lives, Time and Resources**

		Focus Areas			
		Intersections (sig & non-signalized)	End of Queue Warnings	Work Zone Mgmt	Curve Warning Systems
Vehicle Data	Type and Characteristics				
	Time Stamp				
	Speed and heading				
	Acceleration and yaw rate				
	Turn signal status				
	Brake status				
	Stability control status				
	Driving Wheel angle				
	Vehicle Steering				
	Tire pressure				
	Traction Control State				
	Wiper status and run rate				
	Exterior lights				
	GPS Status and Vehicle Position (long, lat, elev)				
	Obstacle Direction				
	Obstacle distance				
	Road friction				
	Current and avg. fuel consumption				
	Vehicle Emissions Data				
	Air temp and pressure				
Weather information					
Electronic Stability Control					

			Focus Areas			
			Intersections (signalized & non- signalized)	End of Queue Warnings	Work Zone Management	Curve Warning Systems
Infrastructure Data	Roadway Characteristics	Friction				
		Road geometry and markings				
	Road Conditions	Surface temp				
		Subsurface Temp				
		Moisture				
		Icing				
		Treatment Status				
	Road Surface Weather Conditions	Air temp				
		Wind Speed				
		Precipitation				
		Visibility				
	Intersection Status	Current operational status				
		Signal Phase and timing				
		Intersection Geometry				
		Approaching vehicle information				
	Field Equipment Status	Dynamic Message Signs				
		Variable Speed Limit Signs				
		Dynamic lane signs or control devices				
		Ramp meters				
	Parking Information	Location of parking facilities				
Spaces available						

## **Appendix F:**

### **V2I Safety Application Implementation: Safety Application Functionality**

# Safety Application Functionality<sup>1</sup>

## 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

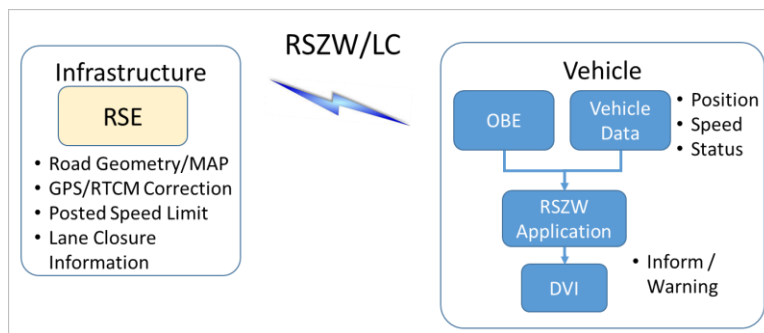


Figure 2: Information Flow for RSZW/LC Application

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

<sup>1</sup> 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.

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

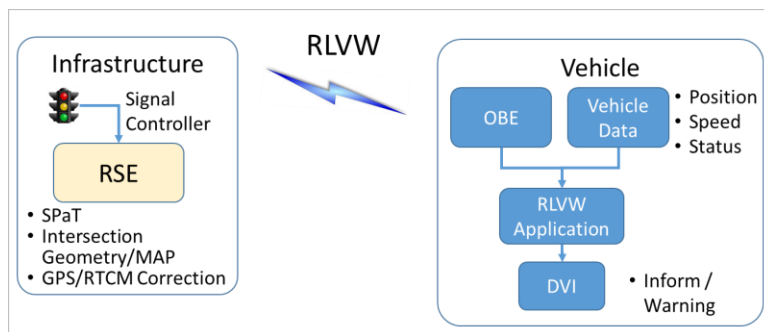


Figure 4: Information Flow for RLVW Application

## 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.

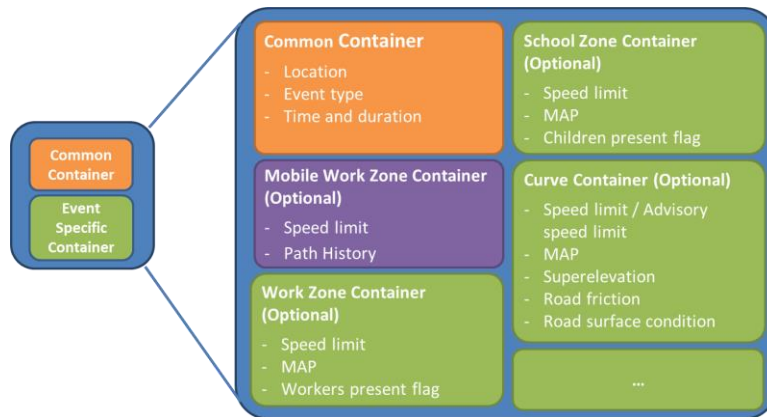


Figure 5: Basic Information Message Structure

# Potential Safety Benefit(s)

## 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.<sup>2</sup> 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.<sup>3,4</sup> 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.<sup>5</sup>

### 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

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<sup>2</sup> 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.

<sup>3</sup> 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.

<sup>4</sup> 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.

<sup>5</sup> 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



- penetration. The average improvement under dry conditions was around 2 percent higher than under rainy conditions.
- 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.<sup>6</sup>

#### 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.

## Signalized Intersections

The following excerpt from AASHTO's series of Connected Vehicle (CV) deployment analyses<sup>8</sup> 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.<sup>9</sup> 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.<sup>10</sup>
- A 2009 Noblis document, *Footprint Analysis for IntelliDrive<sup>SM</sup> V2V Applications, Intersection Safety Applications, and Tolled Facilities*, found in a study of intersections and collision frequency in three large metro areas that 20% of

<sup>6</sup> 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

<sup>7</sup> 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

<sup>8</sup> National Connected Vehicle Field Infrastructure Footprint Analysis: Deployment Footprint, Timelines and Cost Estimation, Draft Report v1, February 21, 2014

<sup>9</sup> National Highway Transportation Safety Administration; *Frequency of Target Crashes for IntelliDrive Safety Systems* Report Number DOT HS 811 381; October 2010.

<sup>10</sup> National Highway Transportation Safety Administration; *Crash Factors in Intersection-Related Crashes: An On-Scene Perspective*; Report Number DOT HS 811 366; September 2010.

intersections account for 50% of collisions, and that 50% of intersections account for 80% of collisions.<sup>11</sup>

- 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.<sup>12</sup>

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.”

## Deployment Cost Estimates

### Infrastructure Side

The following excerpt from AASHTO’s series of deployment analyses<sup>13</sup> 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<sup>14</sup>” provide initial insight into anticipated vehicle side costs to deploy CV technology.

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

<sup>11</sup> Noblis, Inc.; *Footprint Analysis for IntelliDrive<sup>SM</sup> 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](http://www.its.dot.gov/research_docs/pdf/12Footprint.pdf).

<sup>12</sup> Traffic Operations and Safety Laboratory, University of Wisconsin-Madison; *Intersection Crash Summary Statistics for Wisconsin*; June 2005.

<sup>13</sup> National Connected Vehicle Field Infrastructure Footprint Analysis: Deployment Footprint, Timelines and Cost Estimation, Draft Report v1, February 21, 2014

<sup>14</sup> DOT HS 812 014, August 2014

(Excerpt from Table XI-2)

	<b>Consumer Costs</b>
Supplier Costs	\$327.13
Installation Costs	\$15.67
Minus Current GPS Installation	\$13.89
<b>Total</b>	<b>\$329.14</b>

**Aftermarket Consumer Cost Estimates for Year 1 (2012 dollars)**

(Excerpt from Table XI-12)

	Equipment	Installation	<b>Total</b>
Retrofit	252.20	135	<b>387.20</b>
Self-contained	213.20	112.5	<b>325.70</b>