WHAT ARE CONNECTED VEHICLES?

Could potentially address up to 80% of non-impaired driver crash scenarios
• Understand how connected vehicle applications work and their potential benefits
• Prepare for USDOT decision on requiring vehicle-to-vehicle (V2V) technology on new vehicles

Goal: Advance the Connected Vehicle Program to an earliest possible deployment readiness state
AASHTO’S ROLE

• Developed a Strategic Plan and Action Plan for the Connected Vehicle Program
• Identify departments of transportation (DOT) needs
  – Evaluate and document the benefits and costs of public sector investment in vehicle-to-infrastructure (V2I) technologies
  – Equip agencies to develop deployment plans and justify necessary investments to decision-makers
NCHRP 03-101: ABOUT THE STUDY

• **Purpose:** Describe agency benefits and costs associated with connected vehicle technologies to assist DOTs with deployment decisions
  – Benefits: Safety, Mobility, and Environment
  – Costs: Deployment, Operations, and Maintenance

• **Inputs:**
  - Structured interviews with early adopters
  - Cost-benefit analyses for three case studies
  - Connected vehicle deployment guidance
  - Assessment of DSRC technology readiness to support deployment
NCHRP 03-101: PROJECT OBJECTIVES

- Application Impact Analysis
- Catalog of Useful Applications
- Business Impact Analysis
- Benefit-Cost Estimation
- Benefit-Cost Assumptions
Select and Analyze Three Deployments
- Michigan Test Bed
- I-66 (Virginia) Test Bed
- Maricopa Countywide (Arizona) Deployment

Collect Data
- Actual cost data for each deployment
- Specific benefits related to each deployment

Conduct Sensitivity Analysis
- Focus on the most critical factors of the project
- Decide where to invest any additional efforts
## NCHRP 03-101: BENEFITS

<table>
<thead>
<tr>
<th>Quantifiable Benefits</th>
<th>Other Potential Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced need for traveler information system infrastructure</td>
<td>Improved access to data for planning studies</td>
</tr>
<tr>
<td>Reduction of traffic monitoring infrastructure</td>
<td>Potential for improved long-term planning, program management</td>
</tr>
<tr>
<td>Lower cost of pavement condition detection</td>
<td>Faster, more cost effective response to public issues/policy change</td>
</tr>
<tr>
<td>Crash response and clean up cost reduction</td>
<td>Ability to measure performance of DOT operations on an accelerated schedule</td>
</tr>
<tr>
<td>Work zone accident clean up and project impact reduction</td>
<td>Cost savings to transit agencies by better optimizing fleet</td>
</tr>
<tr>
<td>DOT vehicle fleet insurance reduction</td>
<td>Reorganization of DOT roles</td>
</tr>
<tr>
<td>Adaptive Lighting</td>
<td></td>
</tr>
</tbody>
</table>
CASE STUDIES DIRECT MONETARY BENEFITS

- Crash clean up cost reduction
- Work zone accident reduction
- Lower cost of pavement condition detection
- Reduced winter maintenance costs
- Reduction of infrastructure required to monitor traffic

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Year 0</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
<th>Year 7</th>
<th>Year 8</th>
<th>Year 9</th>
<th>Year 10</th>
<th>Total</th>
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<tbody>
<tr>
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<td>0</td>
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<td>1,538</td>
<td>3,264</td>
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**Virginia**

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<td>1,550</td>
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<td>1,550</td>
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**Michigan**

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<th>Year 4</th>
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<th>Year 8</th>
<th>Year 9</th>
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<tr>
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<td><strong>Total Benefits</strong></td>
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<td>363,175</td>
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**Maricopa County**

<table>
<thead>
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<th>Benefit</th>
<th>Year 0</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
<th>Year 7</th>
<th>Year 8</th>
<th>Year 9</th>
<th>Year 10</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash clean up cost reduction</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Workzone accident reduction</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
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</tr>
<tr>
<td><strong>Total Benefits</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
CASE STUDIES NON-RECURRING COSTS

• Program Oversight
• RSE-equipment buys
• Installation
• Comm set-up
• Integration
• Testing
• Incidentals
CASE STUDIES RECURRING COSTS

- On-going oversight
- Maintenance

Case study allocations based on equipment costs

Virginia ~12.5%
Michigan ~3.5%
Maricopa ~15%
<table>
<thead>
<tr>
<th>Case Study</th>
<th>Number of RSEs</th>
<th>Initial Cost (per unit)</th>
<th>80 Percentile Range of Recurring Costs (per unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Michigan</td>
<td>50</td>
<td>$17,360</td>
<td>$1,430</td>
</tr>
<tr>
<td>Virginia</td>
<td>55</td>
<td>$12,327</td>
<td>$1,157</td>
</tr>
<tr>
<td>Maricopa County</td>
<td>2,680</td>
<td>$11,940</td>
<td>$1,646</td>
</tr>
</tbody>
</table>
CASE STUDIES RSE HW-SW-INSTALL COSTS

- **Hardware**
  - RSEs
  - Signal Phase and Timing (SPaT) Listener
  - RSE trailers
  - Back end servers

- **Software**
  - RSE Monitoring System (RMS)
  - Security Credential Management System (SCMS)
  - SPaT Messaging
  - Data management systems

- **Installation**

$11,000 - $20,000 per installation
$1,200 - $2,000 annual recurring costs
GLOBAL ASSUMPTIONS

- Crash response and cleanup costs have a mean of $500 and a range between $200 and $5,000
- The average cost associated with a work zone accident is $3,687 based on previous studies
- Accident reduction from connected vehicles technology is modeled as a single-sided normal distribution with a
  - maximum value of 26% at full market penetration of DSRC technology equipped vehicles
  - minimum value of 10% representing the assumption of a crash reduction of up to 26%
- Market Penetration of DSRC technology will reach 90 percent in 15 years
<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
<th>Reference</th>
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</thead>
<tbody>
<tr>
<td>Accident Response and Cleanup costs</td>
<td>Crash requiring a single police officer generally costs $200 for the officer while a crash that requires fire/EMS costs an average of $800. Assume each occur with equal frequencies.</td>
<td>The Florida Senate Issue Brief 2009-303: Cities and Counties Charging “Accident Responses” Fees to Drivers and Insurers.</td>
</tr>
<tr>
<td>Average Cost of Work Zone Accidents</td>
<td>$3,687</td>
<td>Determining the major causes of highway work zone accidents in Kansas, Yong Bai, Ph.D., University of Kansas, October 2007.</td>
</tr>
<tr>
<td>Market Penetration Curve</td>
<td></td>
<td>This is based conversations with AASHTO members at the November 19th 2012 meeting in Pittsburgh, PA on the potential of a mandate for DSRC technology in new vehicles, and on the rate of new vehicle replacements derived from NADA data.</td>
</tr>
</tbody>
</table>
90% MARKET PENETRATION ASSUMPTION

- Disruptive Impact
- Accelerated Impact
- Baseline
## VDOT Test Bed Cost-Benefit Results

<table>
<thead>
<tr>
<th>Costs</th>
<th>Year 0</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
<th>Year 7</th>
<th>Year 8</th>
<th>Year 9</th>
<th>Year 10</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Benefit/Cost</td>
<td>-668</td>
<td>-64</td>
<td>-42</td>
<td>-40</td>
<td>-36</td>
<td>-27</td>
<td>39</td>
<td>113</td>
<td>193</td>
<td>332</td>
<td>403</td>
<td>223</td>
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## Michigan Cost-Benefit Results ($K)

<table>
<thead>
<tr>
<th>Costs</th>
<th>Year 0</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
<th>Year 7</th>
<th>Year 8</th>
<th>Year 9</th>
<th>Year 10</th>
<th>Total</th>
</tr>
</thead>
</table>

## Maricopa County Region Cost-Benefit Results

<table>
<thead>
<tr>
<th>Costs</th>
<th>Year 0</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
<th>Year 7</th>
<th>Year 8</th>
<th>Year 9</th>
<th>Year 10</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Benefit/Cost</td>
<td>-31,718</td>
<td>-4,594</td>
<td>-4,262</td>
<td>-3,609</td>
<td>-2,432</td>
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<td>1,627</td>
<td>4,250</td>
<td>5,811</td>
<td>6,766</td>
<td>7,304</td>
<td>-21,467</td>
</tr>
</tbody>
</table>
• RSEs will become less costly through maturing technology, competition, and mass production.

• As concentration of connected vehicles increases, benefits can offset the operational expense required to maintain the RSE and some initial capital investment.
THE VALUE OF DEPLOYMENT

- Reduce crash response and cleanup costs
- Reduce work zone accidents
- Lower cost of pavement condition detection
- Produce savings related to traveler information systems or traffic monitoring systems
- Improve agency business practices

Benefits will gradually offset a significant portion of the annual cost, and over time produce savings that outweigh annual operations and maintenance costs
THE RISK OF FORGOING DEPLOYMENT

• Loss of time to ramp up on potential infrastructure needs in the event of a positive NHTSA ruling
• Miss out on benefits related to:
  – Safety
  – Mobility
  – DOT operations/asset management
  – Data collection and analysis
  – Environment
  – Safety is the area that connected vehicles will most impact

Current technology and operations methods in the field will become obsolete – connected vehicle technology may replace these methods
Launching new services that leverage CV technology that consumers pay for receiving the benefit enabling proliferation and self-sustainment

- Freight dispatching and in-transit visibility
- Critical infrastructure security
- Roadway signage communications
- Parking
- Airport ground services
DISRUPTIVE CV ADOPTION

~190-200 Million Licensed Drivers
~150-160 Million Smartphone Users
Evaluate the potential benefit and potential issues associated with the transmission of probe and safety messages from hand-held mobile devices via cellular communications and compile and describe current and emerging technology trends influencing the role of mobile devices within the context of a connected vehicle deployment.
Describe the Operational Concepts and Costs for a Cellular Communication Approach in Connected Vehicle Applications

• Investigate/describe the OEM models for the cellular/Connected vehicle approaches (e.g. GM describes theirs as the “Connected Consumer”)

• Investigate/describe the carrier models for cellular/connected vehicle approaches (look at impacts of HERE, INRIX, others)

• Investigate/describe current data storage and “common software interface” model to see if compatible with industry approaches

• Investigate/describe cost centers for cellular communications, i.e. capitol, operational, maintenance for agencies

• Provide examples on possible operational scenarios for agencies using cellular for the V2I applications
AVAILABLE RESOURCES

NCHRP Final Report
Deployment Plan
CVAST v1.0 Tool
Deployment Guidance
Excel-based tool prioritizes applications specific to needs and interest of the deploying agency.
• TRB NCHRP Reports -
  http://www.trb.org/Publications/PubsNCHRPProjectReports.aspx

• AASHTO Subcommittee on Systems Operations and Management -
  http://ssom.transportation.org/Pages/default.aspx

• USDOT ITS Joint Program Office Connected Vehicle Research -
  http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm
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