Connected Vehicles

ITE Midwestern District Meeting

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U.S. Department of Transportation
Federal Highway Administration

30 June 2015
Session Agenda

- USDOT Connected Vehicle (CV) Research Program
- V2V and V2I Safety, Mobility and Environment/Road Weather Applications
- Data Capture and Management
- CV Architecture and Standards Program
- V2I Enabling Technologies
- Path to Deployment
Overview of USDOT CV Research Program
Fully Connected Vehicles

Vehicle Data:
- Latitude, Longitude, Speed, Brake Status, Turn Signal Status, Vehicle Length,
  Vehicle Width, Bumper Height

Infrastructure Data:
- Signal Phase and Timing,
  Drive 35 mph,
  50 Parking Spaces Available
CV Communications Technology

- 5.9 GHz dedicated short range communication (DSRC), wireless
- 4G and older 3G cellular networks can provide wide-area data communications
- Other technologies such as Wi-Fi, satellite, and HD radio may have roles to play
- Fiber optic backhaul
USDOT/NHTSA Advance Notice of Proposed Rule Making on V2V Communications Technology

In May, Secretary of Transportation Anthony Foxx directed the National Highway Transportation Safety Administration (NHTSA) to:

Accelerate the timetable for V2V communications in new vehicles

• Rapid testing of V2V transmissions
• Work on regulatory framework
ITS JPO – Current Key Programs

The ITS JPO programs span a broad array of subject matter expert research:

• Connected Vehicles
  • Safety Applications
  • Dynamic Mobility Applications
  • Eco-Lanes / Eco-Traffic Signals
• Data System, Management and Use
• ITS Standards and Architecture
• Federal, State, and Local ITS Training
• Integrated Corridor Management (ICM)
• Automated Vehicle and Infrastructure Research
• Human Factors
ITS Strategic Plan: Program Categories

Strategic Areas:
- Connected Vehicles
- Automation research
- Emerging Capabilities
- Enterprise Data
- Interoperability
- Accelerating Deployment

New Areas for 2015-2019:
- Automated Vehicles
- Connected Vehicle Pilots
- Data Enterprise
Overview of CV Application Program Areas
Connected Vehicle Applications

Safety

CV Applications

Mobility

Environmental
Purpose and Goals

- Develop V2V and V2I safety applications that address the most critical crash scenarios
- Establish guidelines and standards for the components and systems required for the functional transfer of information for V2V and V2I
- Develop and evaluate a systems environment that allows transfer of information, particularly signal phase and timing (SPaT) data, between vehicles and infrastructure
- Provide tools and guidance based on objective benefits that will guide investment decisions by public agencies on deploying, operating, and maintaining a V2I system
- Ensure appropriate strategies are implemented for privacy, security and system certification, interoperability, scalability, oversight, and public acceptance
# Safety Applications: V2V

<table>
<thead>
<tr>
<th>V2V Safety Applications</th>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>Forward Collision Warning</td>
<td>FCW</td>
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<tr>
<td>Emergency Electronic Brake Light</td>
<td>EEBL</td>
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<tr>
<td>Blind Spot/Lane Change Warning</td>
<td>BSW/LCW</td>
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<tr>
<td>Do Not Pass Warning</td>
<td>DNPW</td>
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<tr>
<td>Intersection Movement Assist</td>
<td>IMA</td>
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<tr>
<td>Left Turn Assist</td>
<td>LTA</td>
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V2V Application Scenarios

V2V applications that may enhance the current “forward collision” driver assist technologies that rely primarily on “line-of-sight” sensing

Forward Collision Scenarios

V2V applications that may reduce “cross-path” collision risk

- Intersection Movement Assist
- Left Turn Assist
V2V Safety Applications Status

- Results from NHTSA 2014 V2V Readiness Report:
  - FCW, IMA and LTA have proven effective in preventing or mitigating crashes
  - EEBL could be revised to include different scenarios not covered by FCW
  - BSW/LCW and DNPW could address more crash situations if expanded beyond reliance on turn signal activation
Benefits of V2V Applications

- NHTSA report produced the following potential benefits of IMA and LTA deployment:
  - 41 to 55% of target intersection accidents avoided
  - 36 to 62% of left-turn accidents avoided
  - 413,000 to 592,000 crashes prevented annually
  - 777 to 1,083 lives saved annually
  - Reduction of 191,000 to 270,000 Abbreviated Injury Scale (AIS) injuries annually
Key Challenges

• Technical
  • Wireless spectrum
  • V2V device certification issues
  • Test procedures, performance requirements, and driver-vehicle interface issues

• Institutional
  • Standing up security and communications systems to support V2V
  • Liability of manufacturers
  • Privacy
  • Customer acceptance
Safety Applications: V2I

<table>
<thead>
<tr>
<th>V2I Safety Applications</th>
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<tbody>
<tr>
<td>Curve Speed Warning</td>
<td>CSW</td>
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<tr>
<td>Red Light Violation Warning</td>
<td>RLVW</td>
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<tr>
<td>Spot Weather Information Warning</td>
<td>SWIW</td>
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<tr>
<td>Reduced Speed Zone Warning</td>
<td>RSZW</td>
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<tr>
<td>Stop Sign Gap Assist</td>
<td>SSGA</td>
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<tr>
<td>Smart Roadside</td>
<td>SRI</td>
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<tr>
<td>Transit Pedestrian Warning</td>
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</tbody>
</table>
Curve Speed Warning

Alerts the driver if current speed is too fast for an approaching curve

- Target crashes approaching horizontal curves on segments or interchange ramps that are speed-related
- Alert cars and trucks they are entering a curve at too high a speed to negotiate it safely
- Improve:
  - Reduction in truck rollover and in road departure crashes
Red Light Violation Warning

- Target crashes that result from signal violations
- Wireless exchange of critical safety and operational data
- Reduce the frequency and severity of safety-related incidents
- Improves:
  - Significant reduction in collisions, injuries, and fatalities at intersections
  - Non-recurring congestion resulting from incidents is reduced
Benefits of V2I Applications

• V2I applications could potentially target approximately 2.3 million crashes costing $202 billion annually, including:
  • Red light running - 234,881 crashes, costing $13.1 billion
  • Driver gap assist at stop-controlled intersections - 278,886 crashes, costing $18.2 billion
  • Curve speed warning - 168,993 crashes, costing $29 billion
  • Infrastructure pedestrian detection - 17,812, costing $3.33 billion
Key Challenges

• Technical
  • Standardized 5.9 GHz DSRC Roadside Units (RSU) to serve as communications nodes,
  • Traffic signal controller interfaces to provide signal phase and timing (SPaT) data
  • Mapping and positioning services for resolving vehicle locations with high level of precision
  • Data servers for collecting and processing data provided by vehicles and for distributing information, advisories, and alerts

• Institutional
  • Standards setting
  • Systems and processes for security credential management
  • Funding mechanism for public agencies
Connected Vehicle Applications: Mobility

**Purpose and Goals**

- Develop open-source applications that use synthesized, multisource ITS data to transform surface transportation management and information
- Develop tools (e.g. an open source portal), metrics, and concepts that support application development
- Develop related applications together in bundles for greater efficiency, less stove-piping, and greater safety and operational awareness

**CV Applications**

- **Mobility**
- **Environmental**
# Dynamic Mobility Applications

<table>
<thead>
<tr>
<th>Application</th>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>Multimodal Intelligent Traffic Signal System</td>
<td>MMITSS</td>
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<tr>
<td>Intelligent Traffic Signal System</td>
<td>I-SIG</td>
</tr>
<tr>
<td>Transit Signal Priority</td>
<td>TSP</td>
</tr>
<tr>
<td>Mobile Accessible Pedestrian Signal System</td>
<td>PED-SIG</td>
</tr>
<tr>
<td>Freight Signal Priority</td>
<td>FSP</td>
</tr>
<tr>
<td>Emergency Vehicle Preemption</td>
<td>PREEMPT</td>
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<tr>
<td>Intelligent Network Flow Optimization</td>
<td>INFLO</td>
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<tr>
<td>Dynamic Speed Harmonization</td>
<td>SPD-HARM</td>
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<tr>
<td>Queue Warning</td>
<td>Q-WARN</td>
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<tr>
<td>Cooperative Adaptive Cruise Control</td>
<td>CACC</td>
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## Dynamic Mobility Applications

<table>
<thead>
<tr>
<th>Application</th>
<th>Acronym</th>
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<tbody>
<tr>
<td>Integrated Dynamic Transit Operations</td>
<td>IDTO</td>
</tr>
<tr>
<td>Connection Protection</td>
<td>T-CONNECT</td>
</tr>
<tr>
<td>Dynamic Transit Operations</td>
<td>T-DISP</td>
</tr>
<tr>
<td>Dynamic Ridesharing</td>
<td>D-RIDE</td>
</tr>
<tr>
<td>Freight Advanced Traveler Information Systems</td>
<td>FRATIS</td>
</tr>
<tr>
<td>Dynamic Travel Planning and Performance</td>
<td></td>
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<tr>
<td>Drayage Optimization</td>
<td></td>
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</tbody>
</table>
# Dynamic Mobility Applications

<table>
<thead>
<tr>
<th>Service</th>
<th>Code</th>
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<tbody>
<tr>
<td>Response, Emergency Staging and Communications, Uniform Management, and Evacuation</td>
<td>R.E.S.C.U.M.E.</td>
</tr>
<tr>
<td>Incident Scene Pre-Arrival Staging Guidance for Emergency Responders</td>
<td>RESP-STG</td>
</tr>
<tr>
<td>Incident Scene Work Zone Alerts for Drivers and Workers</td>
<td>INC-ZONE</td>
</tr>
<tr>
<td>Emergency Communications and Evacuation</td>
<td>EVAC</td>
</tr>
<tr>
<td>Enable Advanced Traveler Information Systems</td>
<td>Enable ATIS</td>
</tr>
</tbody>
</table>
MMITSS Overview

• Comprehensive traffic signal system that services multiple modes of transportation

• Demonstration of the MMITSS Prototype:
  - Anthem, AZ
  - Northern CA
MMITSS Application Descriptions

- Intelligent Traffic Signal System (I-SIG)
- Transit Signal Priority (TSP) & Freight Signal Priority (FSP)
- Emergency Vehicle Preemption (PREEMPT)
- Mobile Accessible Pedestrian Signal System (PED-SIG)
MMITSS Basic Concepts

Priority Hierarchy

- Rail crossings
- Emergency vehicles
- Freight
- Transit
  - BRT
  - Express
  - Local (late)
- Coordination
- Pedestrians

A Traffic Control System

Section 1
- Priority for freight

Section 2
- Priority for transit
- Pedestrians
Key Challenges

• Institutional
  • Training
• Technical
  • Broadcast overlap
  • Lack of mode information
• Acknowledgement of SRMs
Connected Vehicle Applications: Environment

AERIS

- Identify connected vehicle applications that could provide environmental impact reduction benefits via reduced fuel use, improved vehicle efficiency, and reduced emissions.
- Facilitate and incentivize “green choices” by transportation service consumers (i.e., system users, system operators, policy decision makers, etc.).
- Identify vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-grid (V2G) data (and other) exchanges via wireless technologies of various types.
- Model and analyze connected vehicle applications to estimate the potential environmental impact reduction benefits.
- Develop a prototype for one of the applications to test its efficacy and usefulness.

Road Weather

- Understand the impacts of weather on roadways.
- Conduct applied research to develop strategies and tools to mitigate those impacts.
- Promote the deployment of these strategies and tools.
# Environment Applications: AERIS

Cleaner Air Through Smarter Transportation

<table>
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<th>ECO-SIGNAL OPERATIONS</th>
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<tr>
<td>Eco-Approach and Departure at Signalized Intersections</td>
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<tr>
<td>Eco-Traffic Signal Timing</td>
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<tr>
<td>Eco-Traffic Signal Priority</td>
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<tr>
<td>Connected Eco-Driving</td>
</tr>
<tr>
<td>Wireless Inductive/Resonance Charging</td>
</tr>
</tbody>
</table>
Eco-Signal Operations Overview

- Eco-Approach and Departure
- Eco-Traffic Signal Timing
- Eco-Traffic Signal Priority

Use connected vehicle technologies to: reduce idling, number of stops, unnecessary accelerations/decelerations, and improve traffic flow to decrease fuel consumption and emissions.

Automated Longitudinal Control using V2V Communications

Combined Modeling of Applications:
Resulted in a 9.6% reduction in fuel consumption.

Source: USDOT, July 2013
Road Weather Applications

• Motorist Advisories and Warnings (MAW)

• Enhanced Maintenance Decision Support System (MDSS)

• Vehicle Data Translator (VDT)

• Weather-Responsive Traffic Information (WxTINFO)
Data Capture & Management
Research Data Exchange

• Promotes sharing of archived and real-time connected vehicle data collected in USDOT-sponsored research efforts and field tests

• 2 TB of well-organized and documented data

• Drawn from a dozen geographic locations across the country

• Multi-source data (traditional sensor plus probe and connected vehicle data)

• Search and download functions

• RDE release 2.0 is now available

www.its-rde.net
Open Source Application Development Portal (OSADP)

• Web-based portal for sharing open source code and documentation from USDOT-sponsored transportation application to the public

• Open to the public
  • 14 different application packages available now including all of the DMA bundles
  • Applications are free to download, edit, and modify under open source licenses.

www.itsforge.net
Overview of
CV Architecture and Standards Program
Prepare to Implement Connected Vehicle Applications

Establish framework for integrating connected vehicle technologies and identified interfaces for standardization

- Collect and aggregate connected vehicle needs/requirements
- Develop a multi-faceted system architecture
- Identify and prioritize candidate interfaces for standardization
- Support policy analysis
CVRIA: A Framework for integrating technologies and identifying interfaces for standardization

http://www.iteris.com/cvria/

- The Systems Engineering Tool for Intelligent Transportation (SET-IT) is available for download
- On-line training for CVRIA and SET-IT are available
V2I Enabling Technologies
V2I – Enabling Technologies

- Goal – Develop and integrate the infrastructure components necessary to provide the foundation for V2I deployment
  - Signal Phase and Timing (SPaT)
  - Mapping
  - Positioning
  - Communications
  - Roadside Unit (RSU)
  - Integrated V2I Prototype
Signal Phase and Timing (SPaT)

Develop interface between signal controllers and RSU to enable 2-way data exchange between vehicles and controllers.
Signal Phase and Timing (SPaT)

- Past and current activities
  - Interface testing at Safety Pilot
  - Lessons learned from Safety Pilot and other studies, and industry comment, used to refine SPaT message
- Planned near-term steps
  - Analyze SPaT Prototype in test beds to support field testing of Multimodal Intelligent Traffic Signal System (MMITSS)
  - Refine SPaT and MAP messages and software to conform to SAE J2735 (2015 updated version)
5.9 GHz DSRC Roadside Unit (RSU)

A Roadside Unit is the link for DSRC communications between vehicles and the infrastructure.
Evolution of RSU

- Specification 3.0
  - Used for Safety Pilot
- Specification 4.0
  - Improve performance reliability, strengthen security protocols and promote common configurations and user interfaces across different vendors
  - Pre-production units under procurement for testing and certification
  - Limited purchase to refresh test beds
V2I Reference Implementation

- System of specifications and requirements that allow various components of V2I hardware, software, and firmware to work together
- Agencies will be able to select capabilities and applications desired at a given installation
- Based on Integrated V2I Prototype with physical manifestation at TFHRC
- Incorporated into CVRIA
Integrated V2I Prototype (IVP)

• “Identify, develop, implement, test, document and deploy a roadside prototype system that supports an integrated, interoperable deployment of multiple V2I safety, mobility, and environmental applications.”
  • Incorporate all parts of the enabling technologies program to work seamlessly to enable V2I applications
  • Integration and testing of a complete infrastructure system
    • Data flows
    • Information exchange
    • Standards
### IVP Detailed System View with Potential Message Handlers

<table>
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<tr>
<th>Infrastructure Sensor Systems</th>
<th>Integrated V2I Prototype Platform</th>
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<tbody>
<tr>
<td>Ped &amp; Bicycle Infra Sensor Systems</td>
<td>GPS Positioning</td>
</tr>
<tr>
<td>CMV Virtual Weigh Station Sensor Systems</td>
<td>Low Latency Wireless Message Service (e.g. DSRC)</td>
</tr>
<tr>
<td>Local Road Surface Infra Sensor Systems</td>
<td>High Latency Wireless Message Service (e.g. cellular IP)</td>
</tr>
<tr>
<td>Local Weather Infra Sensor Systems</td>
<td>High Latency/Quasi-Static Message Storage</td>
</tr>
<tr>
<td>Veh Detection Sensor Systems (radar, loop det)</td>
<td>Vehicle and Nomadic Device App Platform(s)</td>
</tr>
<tr>
<td>Pedestrian Crossing Request Sensor</td>
<td>Basic Safety Message Generator</td>
</tr>
<tr>
<td>CMV Oversize Vehicle Sensor Systems</td>
<td>Onboard Positioning Service</td>
</tr>
</tbody>
</table>

#### Traffic Management Entity

- INFLO TME App (incl SPD-HARM, Q-WARN)
- Road Weather TME App (incl WRTM)
- MMITIS Central System
- AERIS/Ecodriving TME App
- FRATIS TME App

#### V2I Safety Application Infra Platform

- INFLO Message Handler (incl SPD-HARM, Q-WARN)
- Local Weather & Road Surface Message Handler
- AERIS/Ecodriving Message Handler
- Pedestrian Crossing Request Sensor

#### Pedestrian & Bicycle Infra Sensor Systems

- CMV Oversize Vehicle Sensor Systems
- Pedestrian Crossing Request Sensor
- CMV Virtual Weigh Station Sensor Systems
- Local Road Surface Infra Sensor Systems

#### Road Weather Vehicle Data Translator

- Road Weather Vehicle Data Translator
- Rail Crossing Signal Request Sensor

#### Traffic Signal Controller

- Traffic Signal Controller

#### Dynamic Roadside Message System

- Dynamic Roadside Message System

#### Low Latency Radio Communications (e.g. DSRC)

- Low Latency Radio Communications (e.g. DSRC)

#### Security Certificate Manager

- Security Certificate Manager

#### INFLO TME App (incl SPD-HARM, Q-WARN)

- INFLO TME App (incl SPD-HARM, Q-WARN)

#### MMITS Central System

- MMITIS Central System

#### Ped, Bicycle, Nomad Dev Data Aggregator

- Ped, Bicycle, Nomad Dev Data Aggregator

#### V2I Safety Application Infra Platform

- V2I Safety Application Infra Platform

#### GPS Positioning

- GPS Positioning

#### Onboard Map Service

- Onboard Map Service

#### Vehicle Weather Data Message Generator

- Vehicle Weather Data Message Generator

#### CORRIDOR Peer-to-Peer Message Service

- CORRIDOR Peer-to-Peer Message Service

#### Onboard Map Service

- Onboard Map Service

#### AERIS/Ecodriving Application

- AERIS/Ecodriving Application

#### Driver/User Message Arbitrator

- Driver/User Message Arbitrator

#### Local/BO IVP User Interface

- Local/BO IVP User Interface

#### Local/BO IVP QR-Code Data File Upload (incl Map)

- Local/BO IVP QR-Code Data File Upload (incl Map)
Traffic Signal Controller Interface

- NTCIP 1202 - Object Definitions for Actuated Traffic Signal Controller (ASC) Units
- Interface to legacy systems
- Includes:
  - Rail crossing signal request
  - Standalone 2 wire interface
  - Integrated Rail crossing traffic signal
  - Pedestrian crossing signal request
  - MMITSS, Freight, Transit,
  - Integration and optimization of all of the above
Traffic Management Entity Interface

- Internet Protocol Interface / continuous broadband communications
- Center-to-Center: Traffic Management Data Dictionary (TMDD) Standard v3.03
- Local Area Net: IEEE Standards
- Interface to central communications hub and “arterial” or “regional” application components
- Integrate and process data from multiple IVPs / deliver data to multiple IVPs for distribution of coordinated, synchronized operations
Path to Deployment
2015 FHWA Vehicle to Infrastructure Deployment Guidance and Products

- FHWA Guidance to State and local agencies for implementing V2I to ensure interoperability and efficient and effective planning, procurement, and operations
- Goal is to provide:
  - Initial advice
  - Best practices
  - Technical support tools
- Draft release September 2014, with planned release in September 2015

- Products and Tools:
  - Systems Engineering Process for V2I
  - V2I Benefit Cost Analysis Tool
  - V2I Planning Guide
  - Guide to V2I Cyber-Security
  - Guide to Licensing DSRC Roadside Units
  - Guide to V2I Communication Technology Selection
  - V2I Message Lexicon
AASHTO National CV Field Infrastructure Footprint Analysis

• Phase 1 Final Report available on USDOT National Transportation Library (NTL)
  • http://ntl.bts.gov/lib/52000/52600/52602/FHWA-JPO-14-125_v2.pdf

• Next Phase Overview
  • Process & tool for prioritizing application deployments
  • Process & tool for phasing V2I infrastructure deployments
  • Life cycle costs for V2I application deployments
  • Propose phasing scenarios
  • Plan to create decision tool for agencies
Connected Vehicle Pilot Deployment
Program ITS Joint Program Office

• CV Pilot Program Goals

- Spur Early CV Tech Deployment
- Measure Deployment Benefits
- Resolve Deployment Issues

- Wirelessly Connected Vehicles
- Safety
- Technical

- Mobile Devices
- Mobility
- Institutional

- Infrastructure
- Environment
- Financial

• Resources

  - ITS JPO Website: http://www.its.dot.gov/
  - CV Pilots Program Website: http://www.its.dot.gov/pilots
CO-PILOT

The Cost Overview for Planning Ideas & Logical Organization Tool (CO-PILOT) is a high-level tool supporting stakeholders considering connected vehicle pilot deployments. These pilot deployments will combine connected vehicle and mobile device technologies innovations to **Improve Traveler Mobility** and **System Productivity** while **Reducing Environmental Impacts** and **Enhancing Safety**.

The CD-PILOT allows stakeholders to **Easily Estimate Costs of your Proposed Pilot Deployments**. This initial tool allows cost estimation for 56 applications in the Vehicle to Infrastructure Safety, Vehicle to Vehicle Safety, Agency Data, Environment, Road Weather, Mobility, and Smart Roadside application groups.

**Start Using The Tool**

**HAVE YOUR ESTIMATED COST IN 4 EASY STEPS:**
Moving Towards Automation

• The technology opportunities enabled by connected vehicles will grow over the next few years

• Market penetration of L1/L2 active safety as well as driver assistance systems will increase penetration as costs drop

• OEMs will start introducing highway L3 “autopilot” applications

• L1/2 platooning capabilities (via DSRC) will be introduced for motor carriers and possibly for private light vehicles
Path To Deployment

- 2011: Defined V2V Apps
- 2012: Defined Safety (V2I), Mobility (V2V and V2I), AERIS and Weather Apps
- 2013: Application Development
- 2014
- 2015
- 2016
- 2017: Wave 1: Connected Vehicle Pilot Deployments
- 2018: Wave 2: Connected Vehicle Pilot Deployments
- FHWA Guidance
- Security Credential Management System Prototypes
- NPRM Connected Vehicle Pilot Deployment Standards
- NHTSA Decision Light Vehicles
Concluding Remarks
Contact Information

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