CONNECTED VEHICLE APPLICATION ROADMAP FOR OREGON AS PART OF PREPARING A POSSIBLE OREGON ROAD MAP FOR CONNECTED VEHICLE/COOPERATIVE SYSTEMS DEPLOYMENT SCENARIOS

Task 5 Report

SPR 764

RESEARCH

Oregon Department of Transportation

Connected Vehicle Application Roadmap for Oregon as Part of Preparing a Possible Oregon Road Map for Connected Vehicle/Cooperative Systems Deployment Scenarios

Task 5 Report

SPR 764

By

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16. Abstract: The goal of this project was to lay the groundwork for Oregon to be prepared to lead in the implementation of a connected vehicle/cooperative systems transportation portfolio, and/or to avoid being caught by surprise as developments in this area evolve quickly. The project assessed ODOT's internal mechanisms for addressing connected vehicle/cooperative systems, scanned, reviewed and assessed the technical maturity of potential connected vehicle/cooperative system applications, developed preliminary goals, linked to prospective connected vehicle/cooperative systems applications, and refined/ranked/prioritized those that fit with potential ODOT role in advancing/leading these initiatives. The project identified opportunities for linking ODOT's current programs with national and international connected vehicle/cooperative system research, testing and deployment initiatives, and recommended a final shared vision and "road map" for Oregon's priority connected vehicle/cooperative system applications. This volume contains the connected vehicle roadmap for Oregon. Included is a review of the AASHTO connected/automated vehicle research roadmap, and additional context through an update on recent federal transportation initiatives related to connected and automated vehicles. Also included is a review of the ongoing vehicle to infrastructure (V2I) deployment coalition. Other state DOT actions are also summarized; including the AASHTO pooled fund study and work being done in California, Michigan, Texas and Virginia. A spatial analysis of ODOT roadside devices for potential V2I adaptation is also included. The connected vehicle roadmap contains 94 recommended actions under a total of 12 categories: DSRC and Backhaul Communications, Education and Outreach, Policy and Communications/Collaboration, Benefits/Business Case, Data Management and Strategies, Applications, Try Things, Research Questions/Challenges, Planning and Equity, Multimodal, Design and Construction, Operations and Maintenance. Each recommended action is ranked according to its priority, timing and cost.

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APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					**LENGTH**		
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					**AREA**		
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yd^2	square yards	0.836	meters squared	m^2	m^2	meters squared	1.196	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	kilometers squared	km^2	km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	milliliters	ml	ml	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.									
		MASS					**MASS**		
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C	°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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"Does your car have any idea why my car pulled it over?"

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1.0 INTRODUCTION

The goal of this project is to lay the groundwork for Oregon to be prepared for the future implementation of a connected vehicle/cooperative systems transportation portfolio, to consider whether to take an early national leadership role and/or to avoid being caught by surprise as developments in this area evolve quickly. To achieve this, the following objectives are established:

- Assess ODOT’s current internal mechanisms for addressing connected vehicle/cooperative systems including consideration of technical readiness/compatibility, planning, operational, maintenance and governance perspectives. Include consideration of ODOT’s own fleet, and potential for connection to DMV operations.

- Scan, review and assess technical maturity of potential connected vehicle/cooperative system applications.

- Develop preliminary goals, link to prospective connected vehicle/cooperative systems applications, and refine, rank and prioritize those that fit for future Oregon application and in relation to a potential ODOT role in advancing/leading these initiatives. Link to key agency safety priority, as well as other priorities contained in the OTP and other governing documents.

- Identify opportunities for linking ODOT’s current programs with national and international connected vehicle/cooperative system research, testing and deployment initiatives.

- Consistent with ODOT priorities, consider possibility to arrange for available low/no cost demonstrations of applications to aid in education and refinement of ranking/assessment for Oregon.

- Identify and recommend scenarios for implementation through means to be identified.

- Recommend and publish a final shared vision and "road map" including priorities, for high payoff infrastructure opportunities for Oregon's priority connected vehicle/cooperative system applications.

As a reminder of the vision, Figure 1.1 indicates that the future of connected vehicles includes vehicles of all kinds (cars, trucks, buses, and fleets of all kinds, including motorcycles, bicycles and pedestrians), the drivers and operators of those vehicles, wireless devices carried or used by the drivers and operators, the infrastructure including roadside devices, and also interfaces with other modes such as rail and maritime at grade crossings and terminals.

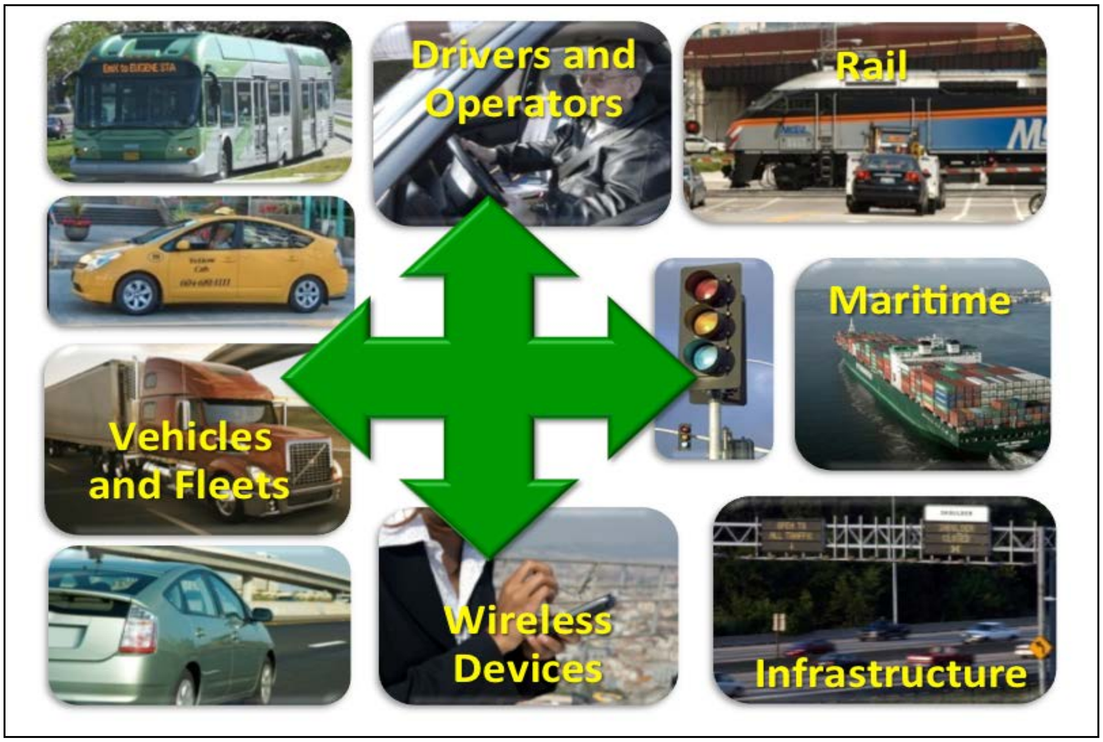

Figure 1.1: U.S. DOT Vision for a Connected Future

As shown in Figure 1.2, the U.S. DOT has been undertaking a number of efforts aimed at supporting and encouraging the deployment of CVs. The figure indicates that future actions in the next several years will include:

- Publication of Final Draft FHWA V2I Deployment Guidelines *(FHWA 2014)*
- Notice of Proposed Rulemaking for Connected Vehicle Pilot Deployment Standards
- Wave 2 Connected Vehicle Pilot Deployments
- Security Credential Management System Prototypes
- Publication of Final FHWA V2I Deployment Guidelines *(FHWA 2014)*

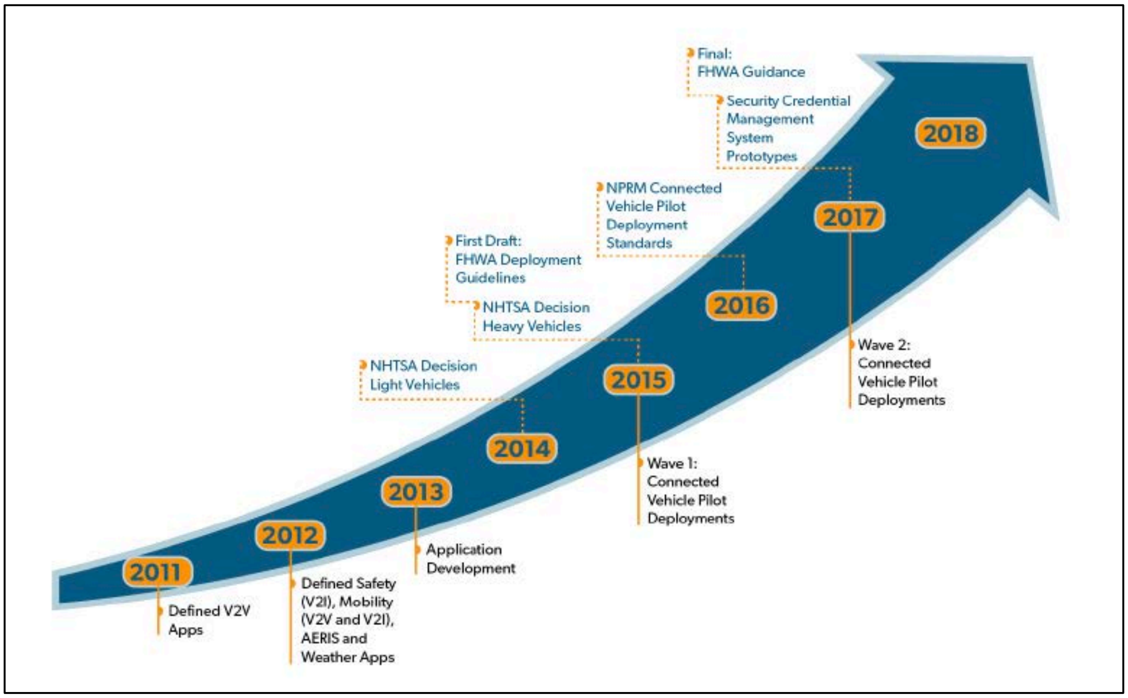

Figure 1.2: U.S. DOT Connected Vehicle Timeline *(U.S. DOT 2014)*

While some are conceiving of the developments of automated/self-driving vehicles as being in competition with connected vehicle developments, the U.S. DOT is emphasizing a combined approach that would attempt to leverage developments in both arenas (Figures 1.3 and 1.4). The idea is that increasing levels of automation combined with increasing levels of connectivity will lead to a synergy that would leverage the strengths of both approaches.

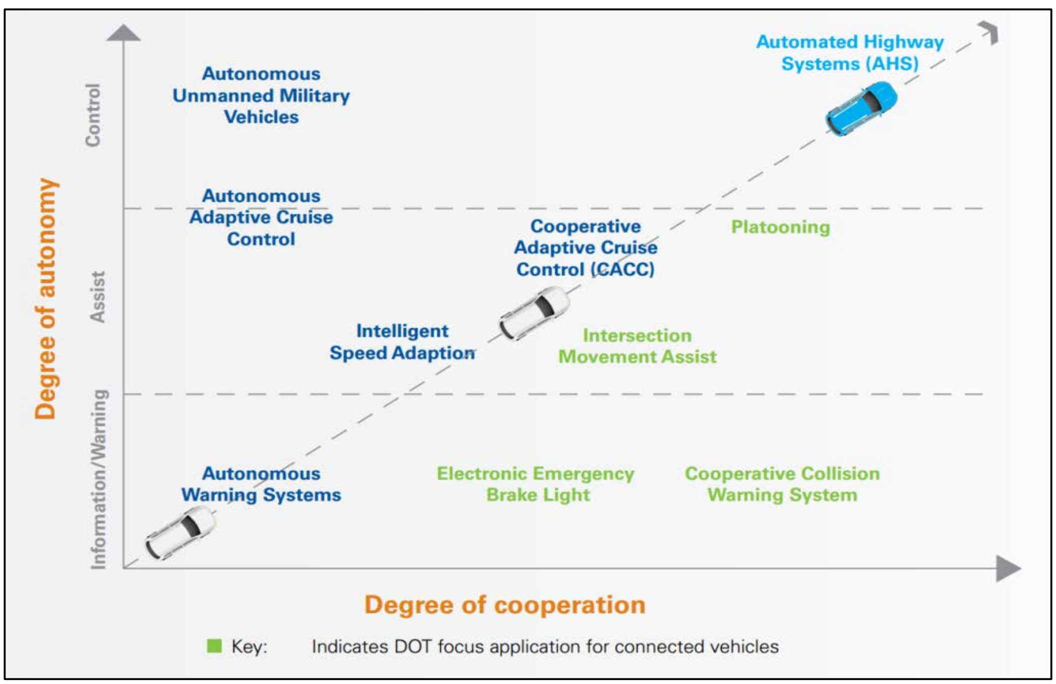

Figure 1.3: Degrees of Autonomy and Cooperation *(Wallace and Silberg 2014)*

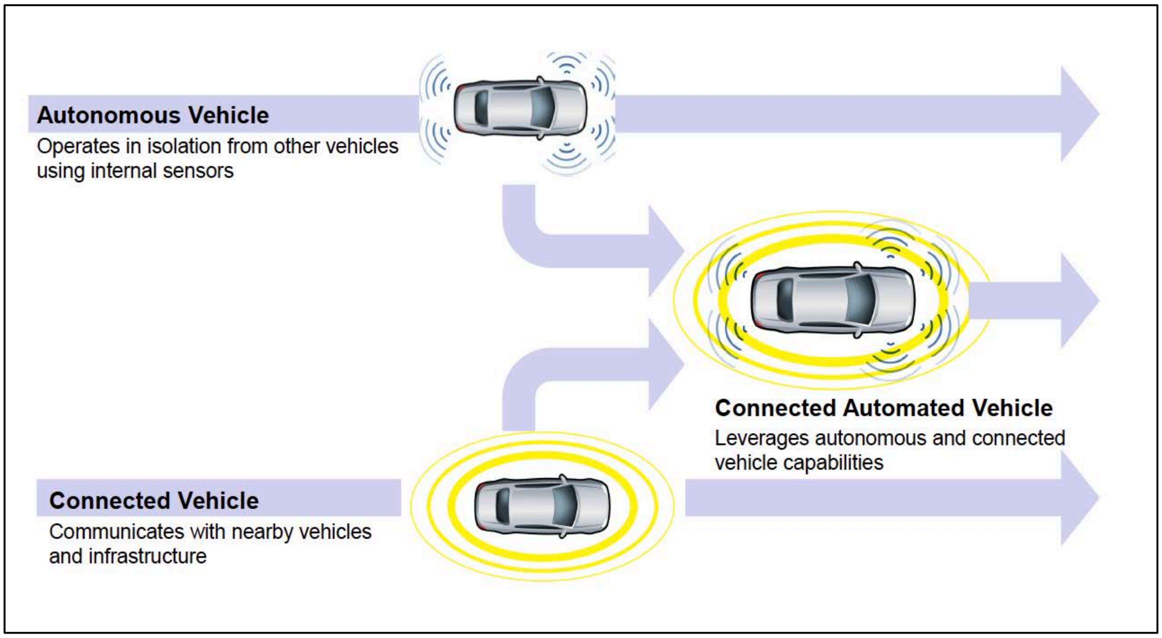

Figure 1.4: U.S. DOT Approach to Connected Automation

Toward this end the U.S. DOT has laid out the vision shown in Figure 1.5 that charts a trajectory toward a future with crashless vehicles. The steps along this path will include the realization of connected vehicles using mobile communications, instant asset tracking, real time traffic information and, for example, electronic tolling.

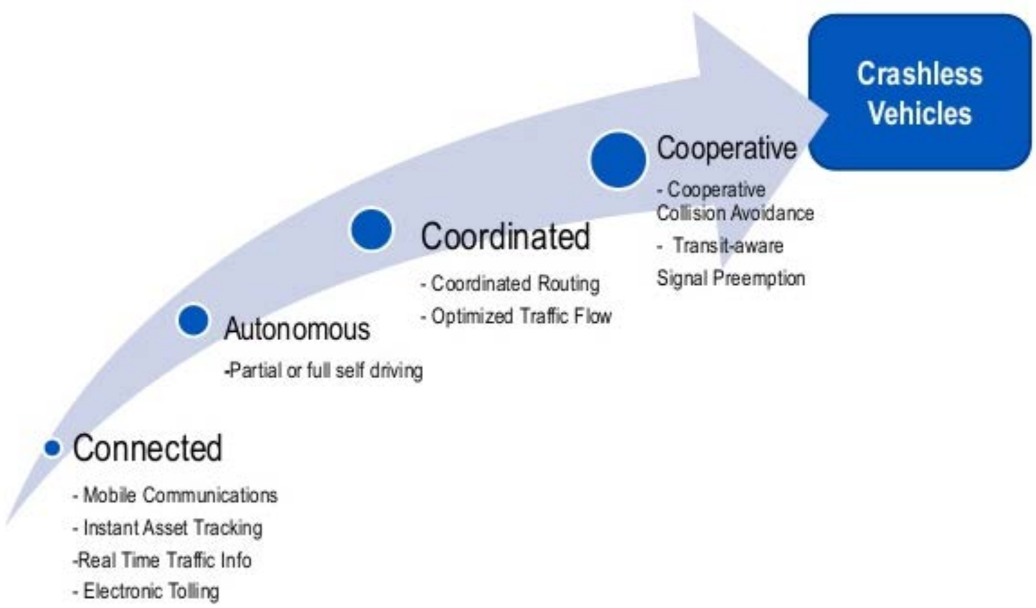

Figure 1.5: U.S. DOT Roadmap Evolution to Crashless Vehicles

Another step along the path to crashless vehicles will likely include increasing levels of automation, with partial or full self-driving. If these two technologies can converge and become coordinated there would be a wide range of advantages. It would be conceivable to provide better coordinated routing and optimized traffic flow if vehicles are able to provide feedback and receive signals from the infrastructure. This may be especially true at intersections with traffic signals.

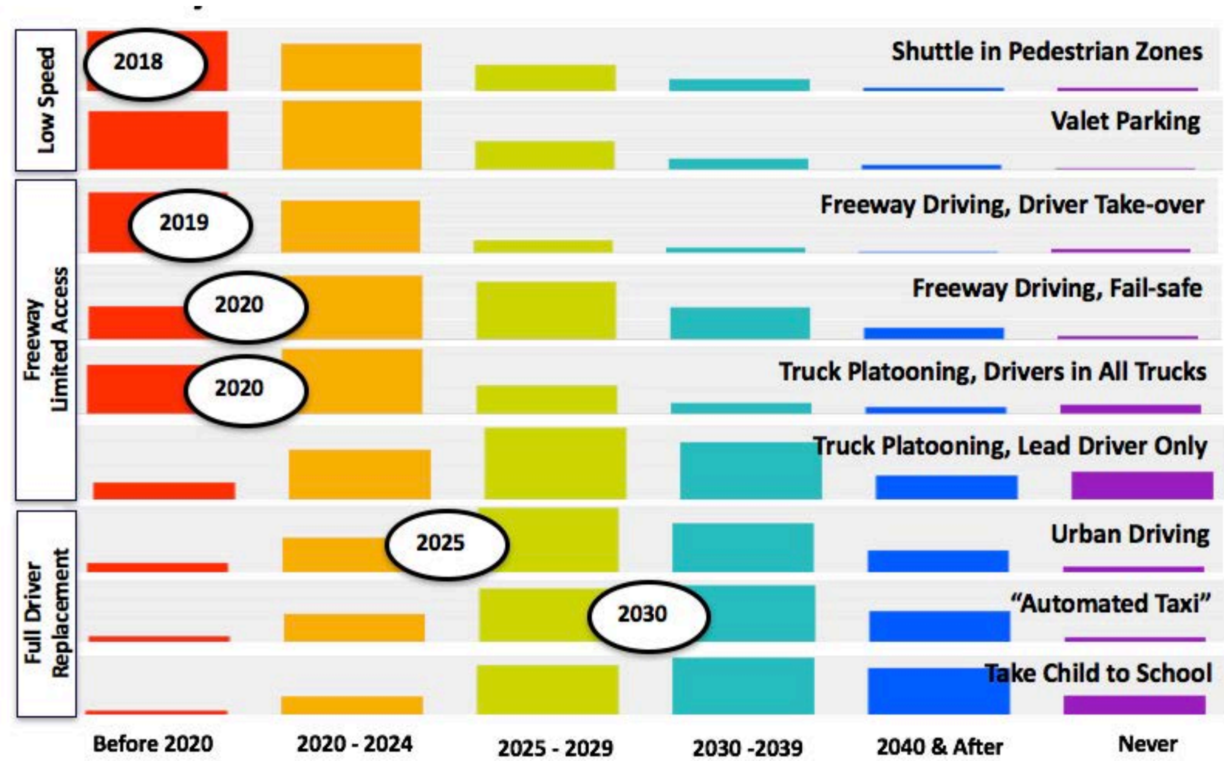

Figure 1.6: Survey of AVS15 Attendees on Market Introduction Dates *(AVS 2015)*

Turning to the potential for deployment of automated/driverless vehicles, Figure 1.6 shows the results from a survey of participants of the seminal Automated Vehicle Symposium (AVS) held in 2015. As shown in the figure, respondents indicate that by 2020 a range of low speed (shuttle and parking) applications, plus freeway driving and truck platooning applications will likely exist. By 2025, participants envision urban driving and by 2030 participants expect an automated taxi concept to be deployed.

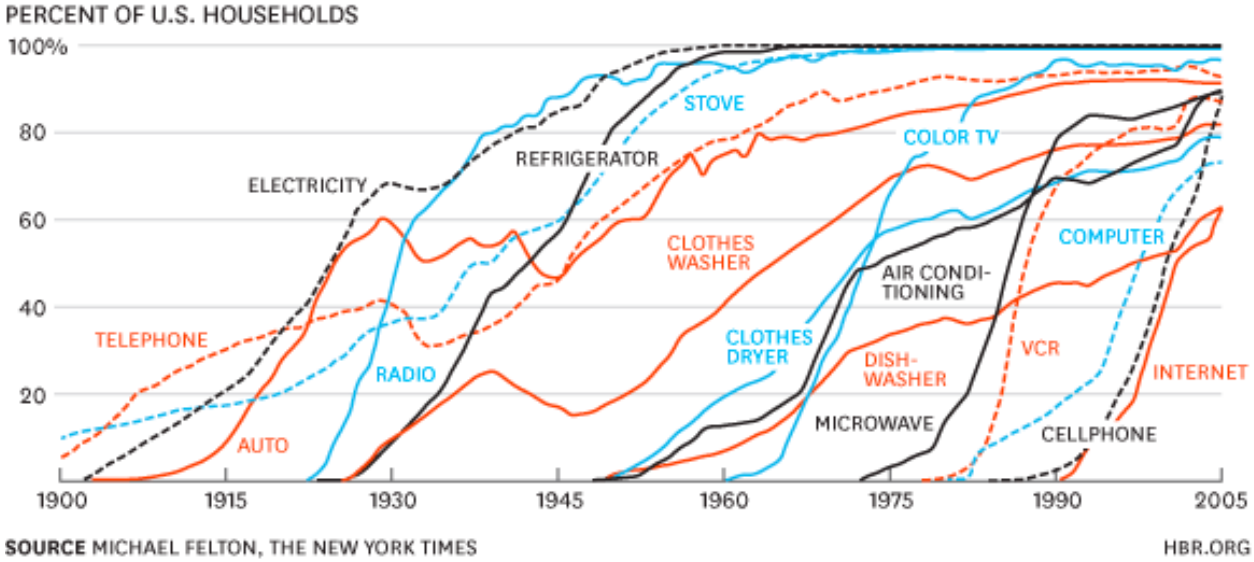

Figure 1.7: Pace of Change Increasing

It is also worth mentioning that we are in an era where the pace of change is increasing, and the uptake rate of technology is faster than in the past. As shown in Figure 1.7 *(McGrath 2013)*. This may indicate that as consumers gain experience with connected and/or automated vehicles, the rate of adoption may be faster than currently imagined.

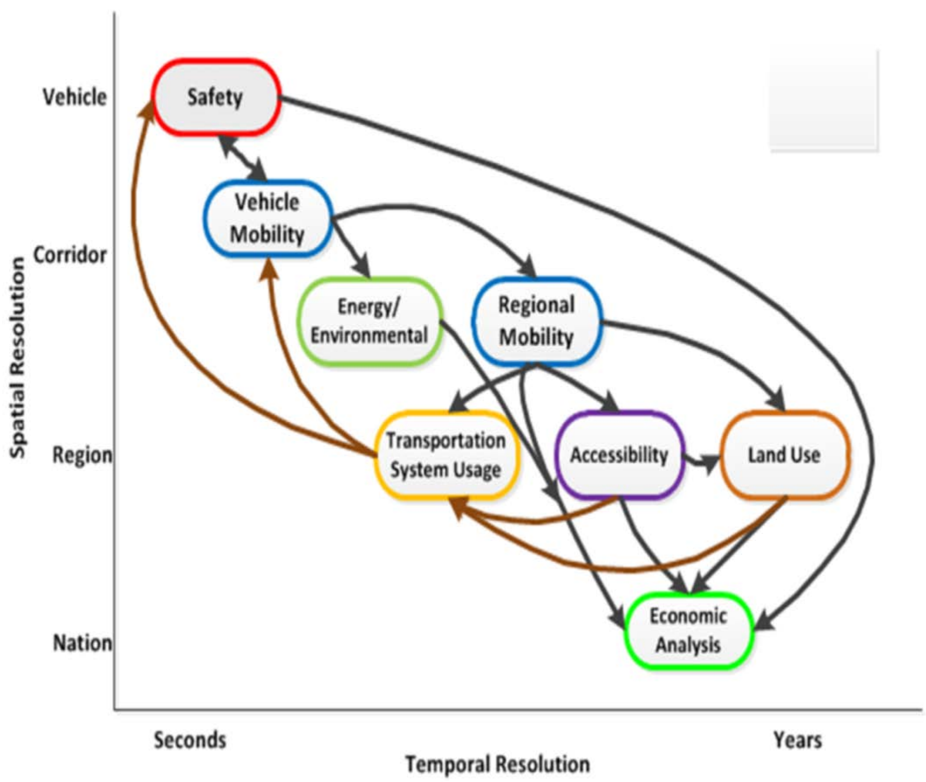

Figure 1.8: U.S. DOT Taxonomy of Data Applications

Data issues continue to emerge as common themes particularly for transportation agencies when contemplating the deployment of connected vehicles for V2I applications. Figure 1.8 shows a taxonomy developed by the U.S. DOT that is informative to the discussion. The *x*-axis provides a scale of temporal resolution from seconds to years, while the *y*-axis shows the spatial resolution from the national level down to the individual vehicle. When thinking of instantaneous or sub-second level safety applications, one starts in the upper left corner. Moving down and to the right, one encounters mobility and environmental applications, and a range of planning issues moving further down and to the right. Many data issues remain to be grappled with. Data sharing, privacy, and ownership issues, as well as archiving, storage, and aggregation are unresolved issues. Furthermore, the question of what entity (that may or may exist yet) would play the role of trusted data broker. These and other issues will be raised in this roadmap.

For the remainder of this volume, Chapter 2 will discuss the ongoing Connected/Automated Vehicle Research Roadmap being pursued by NCHRP on behalf of AASHTO. Chapter 3 provides context for the ODOT connected vehicle roadmap by providing updates on Federal initiatives including work by NHTSA, FHWA and the ITS JPO. Chapter 4 describes the relatively new initiative aimed at strengthening the role of transportation agencies and State DOTs in particular by the Vehicle to Infrastructure Deployment Coalition. Chapter 5 provides further context by describing recent Connected Vehicle activities by several other states, including California, Michigan, Texas and Virginia. Chapter 6 reviews a scenario planning activity conducted in the Netherlands. Chapter 7 presents a spatial analysis of existing Oregon roadside devices as a means of assessing Oregon's "readiness" for deploying V2I Roadside Equipment (RSEs) with necessary power and backhaul. Finally, Chapter 8 presents the roadmap for Oregon to consider for future deployment of systems to support Connected Vehicles for a wide range of applications.

2.0 CONNECTED/AUTOMATED VEHICLE RESEARCH ROADMAP FOR AASHTO

2.1 BACKGROUND

NCHRP has published a Connected/Automated Vehicle Research Roadmap for the American Association of State Highway and Transportation Officials (AASHTO) *(NCHRP 2014)* under project number 20-24(98). The objective of this research was to develop a Connected/Automated Vehicle Research Roadmap addressing the policy, planning, and implementation issues that will face state and local transportation agencies. The roadmap should consider the implications of CV/AV technologies for the various segments of the traveling public (e.g., passenger cars, trucks, transit vehicles, emergency vehicles, bicycles, pedestrians) and for agency fleets. Consideration should be given to CV technologies that are not based on the Dedicated Short Range Communication band.

2.2 ISSUE CLUSTERS

As part of the NCHRP 20-24(98) project, a long list of unresolved issues related to CV/AV was identified and clustered into four categories:

- Institutional and Policy
- Operational
- Legal
- Planning

More than 100 issues were identified and prioritized by the NCHRP panel members. Topics that were supported by more than half of the panel were developed into more complete research project descriptions in four subject clusters:

- Institutional and Policy
- Infrastructure Design and Operations
- Planning
- Modal Applications

There are multiple ways to group research questions, but the following sections describe the current list of 23 research projects, which cover about half of the 100 individual issues identified.

2.2.1 Institutional and Policy Issues

A wide range of issues were identified under the institutional policy issue cluster:

- Business models for infrastructure deployment
- Public policy actions to facilitate implementation
- Implications of AV for motor vehicle codes
- Harmonization of state goals and regulations
- Fed/state/local responsibilities
- Lessons learned from Safety Pilot and CV Pilots
- Lessons learned from other tech rollouts (e.g. 511, Next Gen air traffic control)

Seven research projects were identified under this cluster, as shown in Table 2.1.

Table 2.1: Institutional and Policy Research Projects

Project	High Level Description of Outcomes	Schedule/ budget	Urgency
1.1 Implications of Automation for Motor Vehicle Codes	Recommendations for changes to laws and regulation of motor vehicle codes to address AV technologies	18 months, $500 K	Resolution of major impediment to AV deployment
1.2 Business models for CV/AV infrastructure deployment	Guidelines for investment decisions based on public and private benefits	18 months, $750 K	Resolution of major impediments to CV/AV deployment
1.3 Public agency actions to facilitate CV/AV implementation	Recommendations for policy actions with impact assessment of each	12 months, $500 K	Resolution of major impediments to AV/CV technologies
1.4 Harmonization of state regulations	Compendium of regulatory issues and action plan for resolution	24 months, $500 K	Medium – will provide tools for second-wave states
1.5 Federal-state-local boundaries of responsibility	Recommendations for actions to resolve ambiguities	18 months, $250 K	Medium – higher levels of automation and broader CV penetration will require resolution
1.6 Lessons learned from other transportation technology roll-outs	Recommendations for how to improve upon past lessons learned	12 months, $250 K	Early guidance may help early adopters of CV
1.7 Lessons learned from CV Pilot Deployments	Consolidated lessons from CV pilots to inform other agencies	12 months, $250 K	Pending completion of first wave of CV pilots

2.2.2 Infrastructure Design and Operations

A wide range of issues were identified under the infrastructure design and operations issue cluster:

- Road infrastructure design
- Tools for CV/AV impact assessment
- CV/AV maintenance fleet apps
- Relationships of CV to AV
- Traffic control strategies
- Dedicated lanes for CV/AV
- Roadway geometric design
- Cybersecurity for states and locals
- Workforce capability strategies
- Management of "Big" Data

Ten research projects were identified under this cluster, as shown in Table 2.2.

Table 2.2: Infrastructure Design and Operations Research Projects

Project	High Level Description of Outcomes	Schedule/ budget	Urgency
2.1 Roadway infrastructure design	Recommendations for infrastructure elements to improve AV performance	18 months, $750 K	Resolution of potential impediment to AV deployment
2.2 Tools for predicting AV/CV impacts	Models for use in assessment of AV/CV deployment systems	36 months, $3 M	Foundation for evaluations needed for other projects
2.3 CV/AV applications for maintenance fleets	Agency recommendations for bundle of apps relevant to maintenance fleets	12 months, $100 K	Narrow niche application, but possible "low hanging fruit"
2.4 Relationships of Connected and Automated vehicle systems	Report on how CV infrastructure can support AV operation	12 months, $250 K	Medium – higher levels of automation and broader CV penetration will require resolution
2.5 Traffic control	Concepts for revamping or	36 months,	Needs early start, but later

Project	High Level Description of Outcomes	Schedule/ budget	Urgency
strategies with consideration of AV	enhancing traffic control with AV systems	$1.5 M	phases are linked to tools and model development
2.6 Dedicated lanes for CV/AV operation	Report assessing the B/C analysis	18 months, $500 K	Dedicated lane facilities are high probability early adopters
2.7 Geometric design concepts for AV systems	Recommendations for roadway design modifications facilitating AV	18 months, $500 K	Medium
2.8 Cybersecurity implications of CV/AV on state and local operating agencies	Primer on cybersecurity issues and needed agency actions	12 months, $250 K	Critical
2.9 Workforce capability strategies for state and local agencies	State of the practice summary and recommendations for future staffing	18 months, $150 K	Medium
2.10 Data management strategies for CV/AV applications	Recommendations for agency actions to maintain incoming and outgoing data	24 months, $500 K	Following CV pilot deployments will enhance the quality of the recommendations

2.2.3 Planning Issues

A wide range of issues were identified under the planning issue cluster:

- AVs and regional long-term planning models
- Assessing impacts of CV/AV (applying tools to test cases)
- Modeling effects of AV/CV on land use and travel demand

Three research projects were identified under this cluster, as shown in Table 2.3.

Table 2.3: Planning Research Projects

Project	High Level Description of Outcomes	Schedule/ budget	Urgency
3.1 Including consideration of AV systems in the regional planning process	Algorithms and tools for modifying planning models; sample results	36 months, $1.5 M	Very limited existing tool set for predicting impacts
3.2 Assessing transportation system impacts of CV/AV	Predictions of B/C impacts of CV/AV technology in various environments	24 months, $1.5 M	Important for policy formulation, but depends on new tools
3.3 Effects of AV/CV on land use, travel demand, and traffic impact models	Algorithms and tools for modifying land use and travel demand models; sample results	18 months, $1 M	Follow results of the regional planning model project

2.2.4 Modal Applications (Transit, Trucking)

A wide range of issues were identified under the modal applications issue cluster:

- Impacts of transit regulations on AV/CV tech introduction
- Next steps for AV/CV applications to long-haul freight
- Benefit/cost analysis of AV transit systems

Three research projects were identified under this cluster, as shown in Table 2.4.

Table 2.4: Modal Applications Research Projects

Project	High Level Description of Outcomes	Schedule/ budget	Urgency
4.1 Impacts of transit system regulations and policies on AV/CV technology introduction	Recommendations for changes to regulations to encourage innovation	12 months, $150 K	Foundational to facilitate AV transit projects
4.2 AV/CV applications for Long-haul freight operations	Recommendations and plan of action to address challenges	9 months, $150 K	Foundational to facilitate AV freight projects
4.3 B/C analysis of AV transit systems	Analysis of AV transit scenarios and comparative assessment with traditional transit systems	18 months, $500 K	High probability of AV transit systems in controlled environments to be near-term applications

2.3 CURRENT RESEARCH TASKS

Based on the CV/AV Research Roadmap developed under NCHRP 20-24(98), NCHRP has allocated $2 million ($1 million each for fiscal year (FY) 2015 and 2016)) to fund a set of initial tasks under NCHRP Project 20-102. The aim of this program is to identify issues for state and local transportation agencies that are expected to be faced with the introduction of connected and automated vehicles (CAVs), to perform research related to those issues and also to produce some technology transfer and outreach products related to the issues identified. The initial tasks that will be performed include the following:

- 20-102(01) Policy and Planning Actions to Internalize Societal Impacts of CV and AV Systems into Market Decisions
- 20-102(02) Impacts of Regulations and Policies on CV and AV Technology Introduction in Transit Operations
- 20-102(03) Challenges to CV and AV Application in Truck Freight Operations
- 20-102(05) Strategic Communications Plan for NCHRP Project 20-102
- 20-102(06) Road Markings for Machine Vision
- 20-102(07) Implications of Automation for Motor Vehicle Codes
- 20-102(08) Dedicating Lanes for Priority or Exclusive Use by CVs and AVs

- 20-102(09) Providing Support to the Introduction of CV/AV Impacts into Regional Transportation Planning and Modeling Tools

It is likely that products from these research projects will be of interest to Oregon and to all state, regional and local transportation agencies that are grappling with the advancement of connected vehicle technologies and anticipating development of connected vehicle pilot deployments.

3.0 CONTEXT: RECENT FEDERAL TRANSPORTATION INITIATIVES

3.1 NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION (NHTSA)

The National Highway Traffic Safety Administration (NHTSA) was established in 1970, and is “dedicated to achieving the highest standards of excellence in motor vehicle and highway safety. It works daily to help prevent crashes and their attendant costs, both human and financial.” As one of the operating administrations of the U.S. Department of Transportation (DOT), NHTSA is working closely with other modes and with the ITS JPO to develop policies and regulations related to connected vehicles.

Most notably, based on significant research and analysis, on August 20, 2014, NHTSA released an Advance Notice of Proposed Rulemaking (ANPRM) and a supporting research report *(NHTSA 2014, Harding et al. 2014)* that supports a regulatory process aimed at ultimately requiring Vehicle to Vehicle (V2V) communications technology in new light vehicles. The report contains results on subjects such as technical feasibility, privacy and security and preliminary cost and benefit estimates. The initial findings from that time reported that two safety applications: Left Turn Assist (LTA) and Intersection Movement Assist (IMA) could prevent up to 592,000 crashes and save up to 1,083 lives per year. A total of 948 public comments were received on the ANPRM. Similar efforts are underway for heavy vehicles. The U.S. DOT states that “NHTSA has moved ahead of its public timetable to issue a rulemaking to require V2V communication devices in new vehicles. The Notice of Proposed Rulemaking (NPRM) will be released this spring,” *(Leonard 2016)*, meaning spring of 2016.

In addition, the White House Office of Management and Budget (OMB) Office of Information and Regulatory Affairs (OIRA) announced on January 13, 2016 that it had received a notice of proposed rulemaking (NPRM) from NHTSA. According to the OIRA regulatory agenda, the proposed rule considers the following issues:

> V2V communications uses on-board dedicated short-range radio communication (DSRC) devices to broadcast messages about a vehicle's speed, heading, brake status, and other information to other vehicles and receive the same information from the messages, with extended range and "line-of-sight" capabilities. V2V's enhanced detection distance and ability to "see" around corners or "through" other vehicles helps V2V-equipped vehicles uniquely perceive some threats and warn their drivers accordingly. V2V technology can also be fused with vehicle-resident technologies to potentially provide greater benefits than either approach alone. V2V can augment vehicle-resident systems by acting as a complete system, extending the ability of the overall safety system to address other crash scenarios not covered by V2V communications, such as lane and road departure. Additionally, V2V communication is currently perceived to become a foundational aspect of vehicle automation.

Furthermore, the timetable from OIRA shows May 2016 as the target date for the NPRM. This regulation would complement many public announcements from OEMs indicating that they plan to include V2V capabilities on new vehicles in the near future.

3.2 FEDERAL HIGHWAY ADMINISTRATION (FHWA) VEHICLE TO INFRASTRUCTURE (V2I) GUIDANCE ANTICIPATED

In late 2015, the FHWA released their 2015 Vehicle to Infrastructure Deployment Guidance *(FHWA 2014)*. In 2016, U.S. DOT reported that the FHWA is developing policy positions, guidance, guidelines, whitepapers, and practitioner tools to promote smooth deployment of V2I technology by transportation system owners/operators. Further, U.S. DOT reported that the FHWA plans to issue initial guidance in spring 2016 *(Leonard 2016)*. The initial guidance is intended to assist in planning for future investments and deployment of V2I systems. FHWA has developed the deployment guidance through an open and inclusive process, illustrated in Figure 3.1.

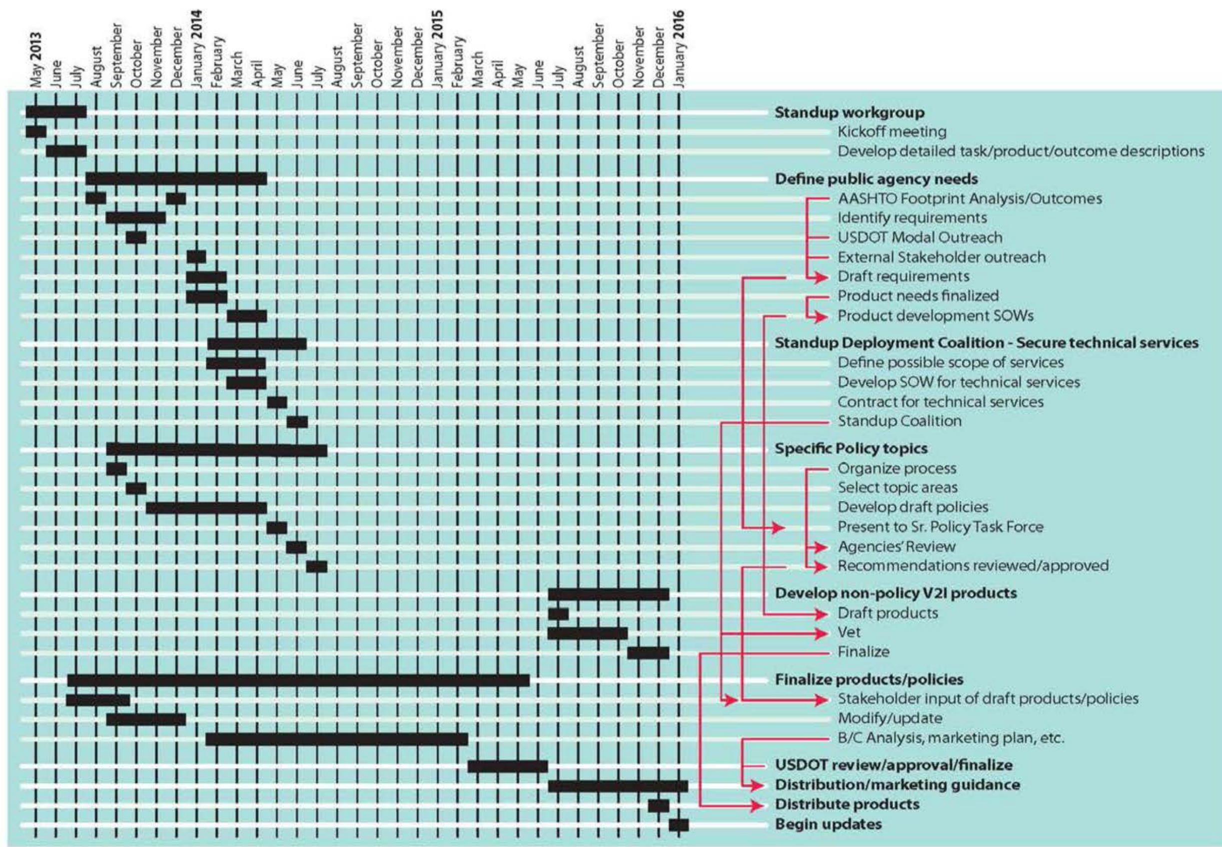

Figure 3.1: FHWA V2I Deployment Guidance Roadmap

Currently the FHWA guidance includes brief discussions of the following topics:

- Planning
- Federal-aid Eligibility of V2I Equipment and Operations

- V2I Deployments and NEPA
- Interoperability
- Evaluation
- ITS Equipment Capability and Compatibility
- Hardware/Software Device Certification
- Reliability
- Use of Right of Way
- Allowance of Private Sector Use
- Design Considerations for Facilities
- Use of Existing Structures and Infrastructure
- Use on Public Sector Fleets
- Procurement
- Legacy Systems/Devices
- Communication Technology
- Dedicated Short Range Communications (DSRC) Service Licensing
- Data Connection and Latency
- Connected Vehicle Privacy Principles
- Connected Vehicle Security
- Data Access
- Manual on Uniform Traffic Control Devices (MUTCD)
- Using Public Private Partnerships (PPP)

Some of the ingredients of this guidance will include the following key products and tools:

- System 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
- Guide to Initial Deployments
- Warrants for Deployment

The U.S. DOT has confirmed that the new guidance will not impose any new requirements on local governments and that the work will be harmonized with related efforts by other U.S. DOT modal administrations. The future guidance updates will also incorporate ITS research findings.

3.3 INTELLIGENT TRANSPORTATION SYSTEMS JOINT PROGRAM OFFICE (ITS JPO)

3.3.1 Safety Pilot

From 2011-2013, the Intelligent Transportation Systems Joint Program Office (ITS JPO) conducted the Connected Vehicle Safety Pilot. The Safety Pilot was designed to support the 2013 NHTSA agency decision by obtaining empirical data on user acceptance and system effectiveness; to demonstrate real-world connected vehicle applications in a data-rich environment; to establish a real-world operating environment for additional safety, mobility and environmental applications development; and archive data for additional research purposes. The outcomes from this research included: documentation and determination of the potential benefits of connected vehicle technologies and evaluation of driver acceptance of vehicle-based safety systems; identification of research gaps and steps necessary to address them; and factual evidence needed to support the 2013 NHTSA agency decision.

The Safety Pilot was conducted in Ann Arbor, Michigan. Nearly 3,000 vehicles were equipped with four different safety devices:

- **Vehicle Awareness Device –** This is an aftermarket electronic device, installed in a vehicle without connection to vehicle systems, that is capable of only sending the basic safety message (BSM) over a DSRC wireless communications link. Vehicle awareness devices do not generate warnings. They may be used in any type of vehicle.
- **Aftermarket Safety Device (ASD) –** This is an aftermarket electronic device, installed in a vehicle, and capable of sending and receiving the safety messages over a DSRC wireless communications link. The device has a driver interface, runs V2V and

V2I safety applications, and issues audible or visual warnings and/or alerts to the driver of the vehicle.

- **Retrofit Safety Device –** This is an electronic device installed in vehicles by an authorized service provider, at a service facility after the vehicle has completed the manufacturing process (retrofit). This type of device is connected to a vehicle databus and can provide highly accurate information from in-vehicle sensors. The integrated device has a working driver interface, both broadcasts and receives BSMs, and can process the content of received messages to provide warnings and/or alerts to the driver of the vehicle in which it is installed. These are being developed for transit vehicles and trucks.

- **Integrated Safety System –** This is an electronic device inserted into vehicles during vehicle production. This type of device is connected to proprietary data busses and can provide highly accurate information using in-vehicle sensors. The integrated system both broadcasts and receives BSMs and can process the content of received messages to provide warnings and/or alerts to the driver of the vehicle in which it is installed. These are being developed for light vehicles, trucks, and transit vehicles. A connected vehicle network can vastly improve system wide safety.

NHTSA research found that V2V and V2I applications could provide solutions for 80% of unimpaired crashes. The top six crash types contributing to these scenarios include:

- Rear End Warning (28%)
- Lane Departure (23%)
- Intersection (25%)
- Lane Change (9%)
- Opposite Direction (2%)
- Backover (2%)

In order to address these scenarios, the Safety Pilot included demonstrations of eight V2V applications and four V2I applications:

- Vehicle to Vehicle (V2V)
    - Forward Collision Warning
    - Emergency Electronic Brake Light
    - Intersection Movement Assist
    - Blind Spot Warning/Lane Change Warning

    - Do Not Pass Warning
    - Left Turn Across Path/Opposite Direction
    - Right Turn in Front
- Vehicle to Infrastructure (V2I)
    - Signal Phase and Timing
    - Curve Speed Warning
    - Railroad Crossing Warning
    - Pedestrian Detection

The Safety Pilot included not only model deployment through a mix of cars, trucks and transit vehicles (also at least one bicycle and one motorcycle), but also included driver clinics with hundreds of real drivers responding to in-vehicle alerts and warnings. Finally, the Safety Pilot has also been undergoing an independent evaluation.

3.3.2 Connected Vehicle Pilot Deployment (CVPD) Program

The U.S. DOT Connected Vehicle Pilot Deployment (CVPD) Program is a multi-modal initiative to enable safe, interoperable, networked wireless communication among vehicles, infrastructure, and personal communications devices. Connected vehicle research is being sponsored by the U.S. DOT and others to leverage the capabilities of wireless technology to make surface transportation safer, smarter, and greener. The CVPD Program will encompass multiple pilot sites over time, with each site having different needs, focus, and applications. Available funding for the CVPD Program is approximately $100 million. On March 12, 2014, the U.S. DOT released a Request for Information (RFI) for the CVPD Program to gather information from the public and private industry about connected vehicle technology and provide notice of anticipated procurements for pilot deployment concepts. A total of 63 responses were received.

The BAA for Wave 1 of the CVPD Program was released on January 30, 2015, with approximately $40 million of funding available. We understand that ODOT participated in a CVPD proposal entitled Open Interoperable Technology Marketplace. On September 14, 2015, the U.S. DOT announced the selection of three connected vehicle deployment sites as Wave 1 participants in the CVPD Program. The three sites collectively envision a broad spectrum of applications enabled by connected vehicle technologies driven by site-specific needs. The three Wave 1 sites include: Wyoming, New York City and Tampa, Florida.

3.3.2.1 Wyoming

The CV Pilot on I-80 in Wyoming includes using connected vehicle technologies to improve safe and efficient truck movement along I-80 in the southern portion of the state (see Figure 3.2). This deployment will utilize connected vehicle technology to improve and monitor performance on Interstate 80 (I-80), which is a freight-intensive corridor with a daily volume of 11,000 to 16,000 vehicles, many of which are heavy-duty trucks (30% to 55%). The I-80 corridor is about 402 miles long and reaches its maximum elevation of 8,640 feet above sea level at Sherman Summit, near Buford (See the figure below). As a result of the high elevation, the corridor is particularly subject to winter weather events, most commonly between the months of October and May. Weather events typical to the corridor are ice and snow covered road surfaces, poor visibility, and high wind events (i.e., wind speeds exceeding 30 mph and wind gusts exceeding 40 mph) that often lead to truck blow-overs. Between 2002 and 2012, more than 3,470 high-wind crashes were observed. This Pilot will develop applications that use vehicle to infrastructure (V2I) and vehicle to vehicle (V2V) connectivity to support a flexible range of services that improves safety and mobility. Information from these applications will be made available directly to the equipped fleets or through data connections to fleet management centers, that will then communicate it to their trucks using their own systems. The applications to be deployed include Road Weather Advisories and Warnings for Motorists and Freight Carriers, Weather-Responsive Variable Speed Limit System, Freight-Specific Dynamic Travel Planning, Spot Weather Impact Warning, Situational Awareness, and others as determined by the user needs of truck drivers, fleet managers in the corridor.

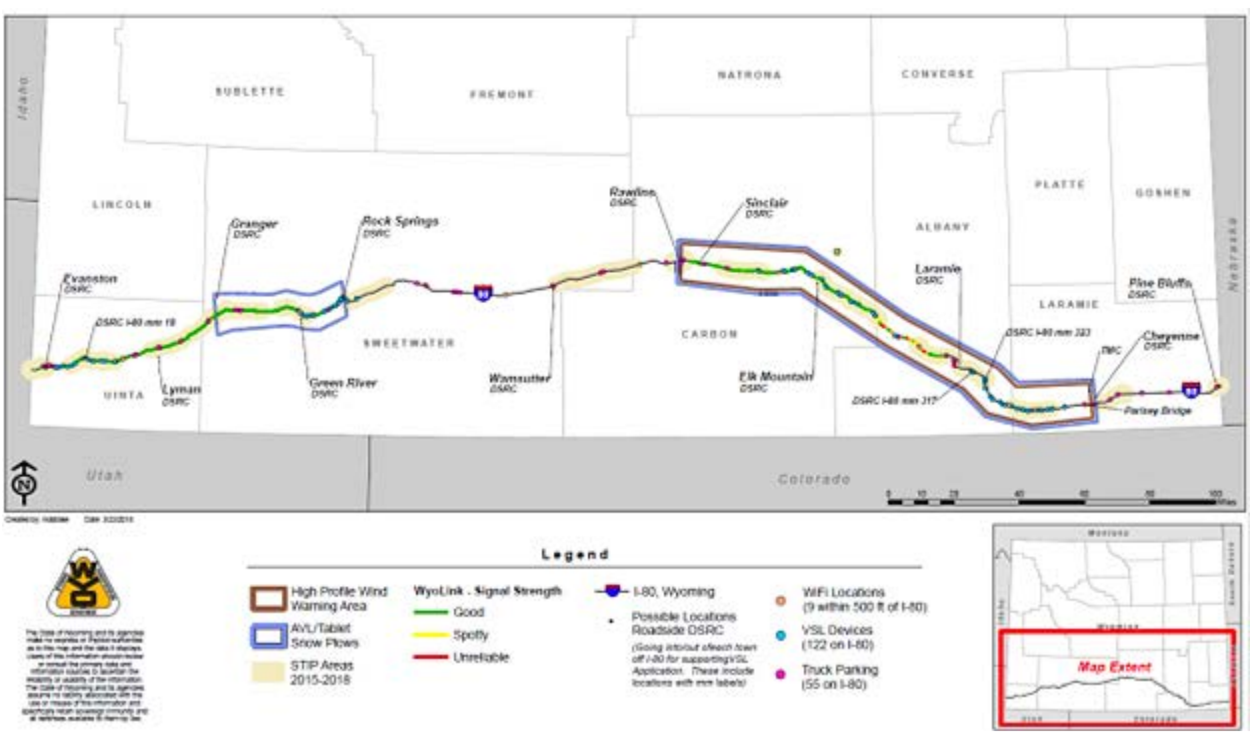

Figure 3.2: Wyoming I-80 Corridor Map
http://www.its.dot.gov/pilots/pdf/04_CVPilots_Wyoming.pdf

3.3.2.2 New York City

The primary objective of the CV Pilot NYC pilot deployment site (see Figure 3.3) is to improve the safety of travelers and pedestrians in New York City through connected vehicle technologies. This objective of the CV Pilot NYC is directly aligned with the New York City's Vision Zero initiative, which seeks to reduce pedestrian fatalities and make the City's streets safer for travelers in all modes of transportation. This NYC site provides an ideal opportunity to evaluate the CV technology and applications in tightly-spaced intersections typical in a dense urban transportation system. Connected vehicle technologies and associated applications will be deployed along heavily traveled high accident rate arterials in Manhattan and Brooklyn (as shown in the figure below) to provide a comparative sample that can be used to verify benefits against those for locations that are not instrumented. The NYC pilot deployment will feature the installation and utilization of vehicle to vehicle (V2V) technology in up to 10,000 city-owned and other fleet vehicles. Traffic signals in the high-priority corridors in Manhattan and Brooklyn will be upgraded with vehicle to infrastructure (V2I) communications capabilities. Applications to be deployed include Red Light Violation Warning, Pedestrian in Signalized Crosswalk Warning, Vehicle Turning Right in Front, Mobile Accessible Pedestrian Signal System (PED-SIG), and Freight-Specific Dynamic Travel Demand and Performance, to help reduce congestion and control speeds, enhance intersection and pedestrian safety, and optimize truck freight operations. The New York City Department of Transportation leads this deployment effort.

Figure 3.3: New York City Pilot Deployment Site Map
http://www.its.dot.gov/pilots/pdf/02_CVPilots_NYC.pdf

3.3.2.3 Tampa

The Tampa pilot deployment effort, headed by the Tampa-Hillsborough Expressway Authority (THEA), will deploy a variety of connected vehicle technologies on and within the vicinity of the Lee Roy Selmon Expressway reversible express lanes in downtown Tampa (see Figure 3.4). In addition to the Expressway, the deployment area contains bus and trolley services, high pedestrian densities, special event trip generators and highly variable traffic demand over the course of a typical day. These diverse travel demand environments in a single concentrated deployment area create a wide variety of dynamic traffic conditions. Drivers within the deployment area experience significant delays (especially on the Selmon Expressway) during the morning peak hour resulting in, and often caused by, a correspondingly large number of rear-end crashes and red light running collisions. The deployment area also experiences transit signal delays, pedestrian conflicts, red light running and signal coordination issues. Hence, the primary objective of this deployment is to alleviate congestion on the roadway during morning commuting hours. In addition, the project team will deploy a variety of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) safety, mobility, and agency data applications to create reinforcing benefits for motorists, pedestrians, and transit operation. Some of the applications to be deployed include Curve Speed Warning, Intelligent Traffic Signal System, Intersection Movement Assist, Mobile Accessible Pedestrian Signal, and Transit Signal Priority.

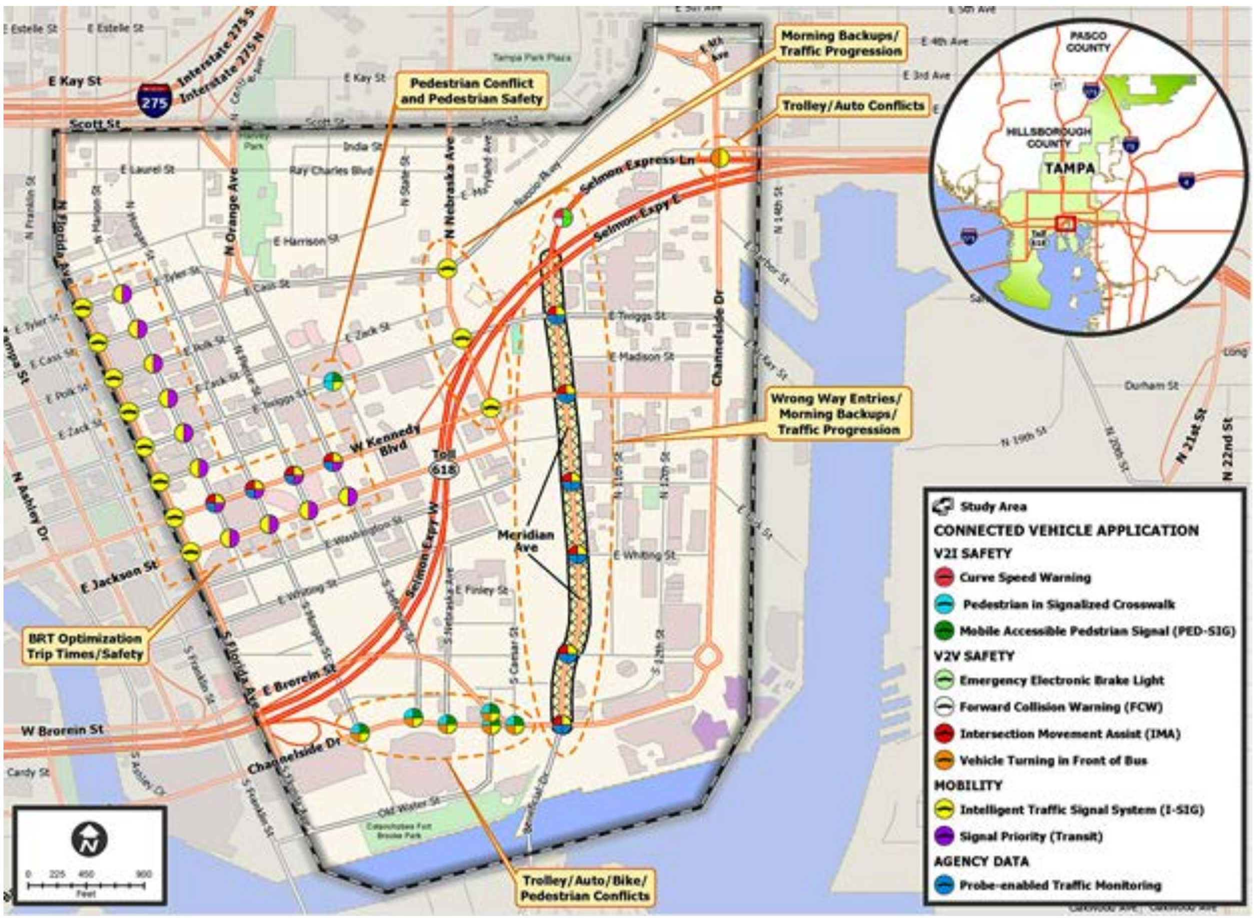

Figure 3.4: Downtown Tampa Connected Vehicle Pilot Deployment
http://www.its.dot.gov/pilots/pdf/03_CVPilots_Tampa.pdf

3.3.3 Connected Vehicle Pilot Deployment Program Roadmap

Figure 3.5 shows the high level roadmap for the Connected Vehicle Pilot Deployment Program. A second wave of pilots are anticipated in the future, where Oregon may want to consider submitting a proposal.

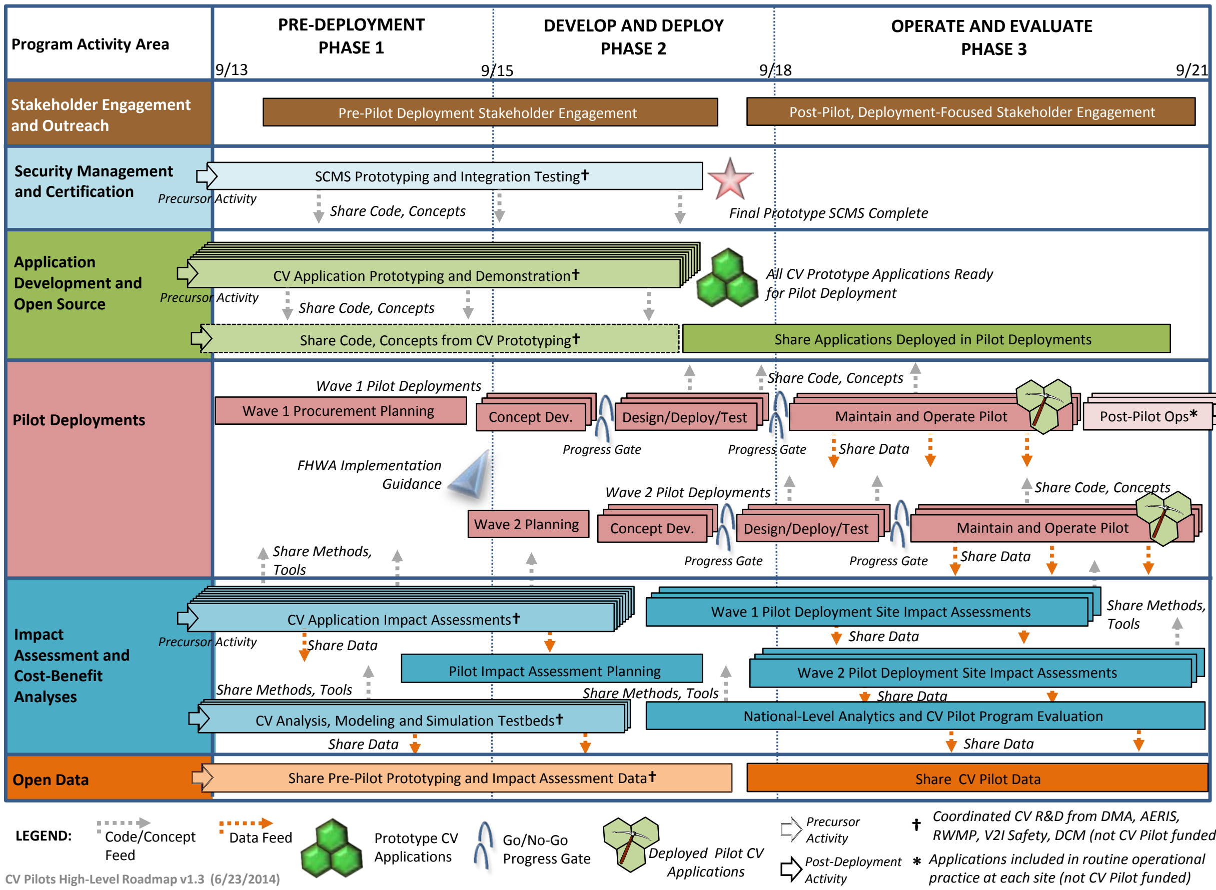

Figure 3.5: Connected Vehicle Pilot Deployment Program: High-Level Roadmap

3.3.4 Smart City Challenge

On December 7, 2015, the U.S. DOT issued "Beyond Traffic: The Smart City Challenge," making up to $40 million in federal funding available to a mid-sized city to conduct a smart city demonstration *(U.S. DOT 2015)*. The Smart Cities Council defines a smart city as "city that uses information and communications technology to enhance its livability, workability and sustainability." *(Leonard 2016)*. The program is asking cities to demonstrate how advanced data and intelligent transportation systems (ITS) technologies and applications can be used to reduce congestion, keep travelers safe, protect the environment, respond to climate change, connect underserved communities, and support economic vitality.

The U.S. DOT has identified a set of ideal characteristics for a Smart City:

- Population between approximately 200,000 and 850,000 people within city limits as of the 2010 Census;
- A dense urban population typical for a mid-sized American city;
- Represents a significant portion (more than 15%) of the overall population of its urbanized area using 2010 Census data;

- An existing public transportation system;
- An environment that is conducive to demonstrating proposed strategies;
- Continuity of committed leadership and capacity to carry out the demonstration throughout the period of performance;
- A commitment to integrating with the sharing economy; and
- A clear commitment to making open, machine-readable data accessible, discoverable and usable by the public to fuel entrepreneurship and innovation.

In addition, the DOT has identified some example elements in the categories of technology, Smart City and innovative approaches to urban transportation that are desirable:

- **Technology Elements**
  - Urban automation
  - Connected vehicles
  - Intelligent, sensor-based infrastructure
- **Smart City Elements**
  - Architecture and standards
  - Low cost, efficient, secure, and resilient Information and Communications Technology
  - Smart land use
- **Innovative Approaches to Urban Transportation Elements**
  - Urban analytics
  - User-focused mobility services and choices
  - Urban delivery and logistics
  - Strategic business models and partnering opportunities
  - Smart grid, roadway electrification, and electric vehicles
  - Connected, involved citizens

As shown in Figure 3.6, the U.S. DOT received 78 applications including one from the City of Portland, Oregon. A total of 1,400 local officials, companies, academics and non-profits participated in Smart City Challenge webinars, 800 people participated in the Smart City Forum, and 300 companies express interest in partnering. Seven finalists were announced on March 12, 2016 at the South by Southwest (SXSW) event in Austin, Texas. Portland, Oregon is one of the seven finalists, along with Austin, Texas; Columbus, Ohio; Kansas City, Missouri; Pittsburgh, Pennsylvania; San Francisco, California; and Denver, Colorado (shown in Figure 3.6). Each finalist will receive $100,000, technical assistance and guidance from the U.S. DOT and Vulcan. The winner of the $50 million program will be announced in June 2016. This program and its components also provide opportunities for Oregon moving forward.

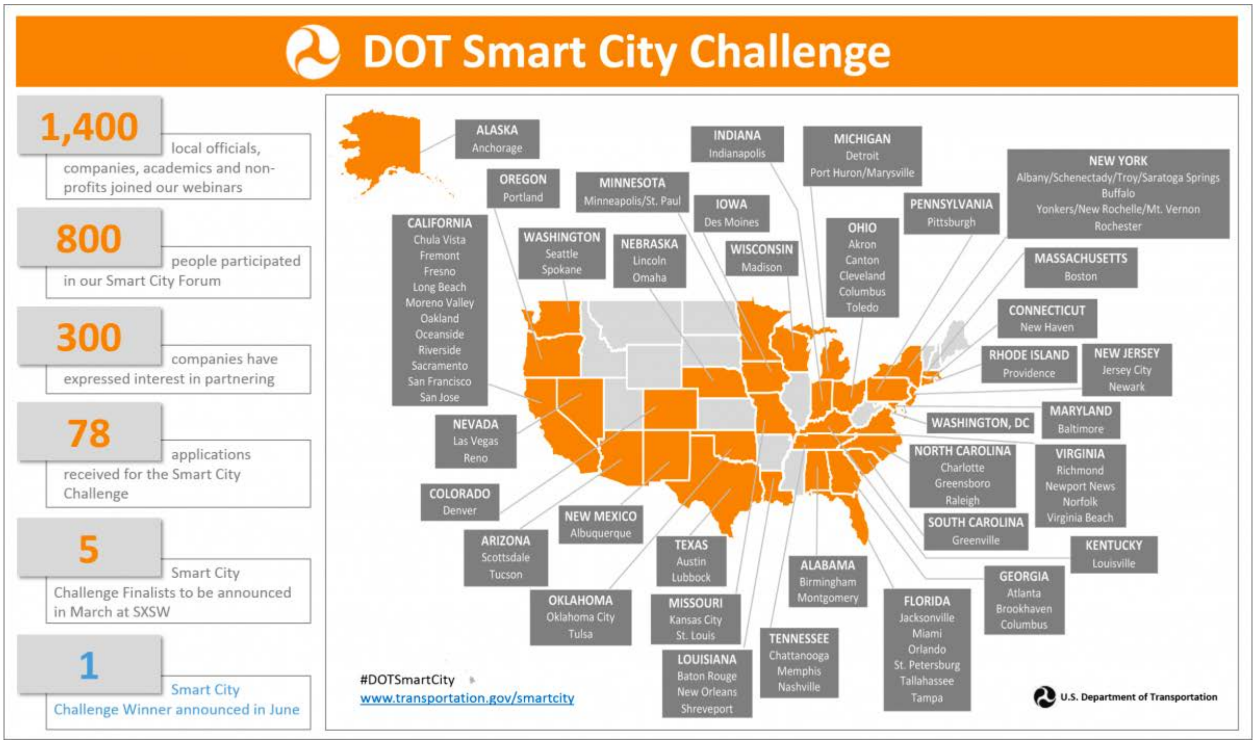

Figure 3.6: U.S. DOT Smart City Challenge
https://www.transportation.gov/smartcity

3.4 CONNECTED VEHICLE REFERENCE IMPLEMENTATION ARCHITECTURE (CVRIA)

The U.S. DOT has released Version 2.1 of the Connected Vehicle Reference Implementation Architecture (CVRIA), which falls under the National ITS Architecture umbrella. The CVRIA provides the basis for identifying key interfaces across the connected vehicle environment and supports analyses to identify and prioritize USDOT support for standards development activities. The first phase of the CVRIA project was completed in 2014, and includes a website that hosts the architecture viewpoints for 88 connected vehicle safety, mobility, environmental, and support applications. The site is at: http://www.iteris.com/cvria and includes the complete set of drawings and detailed descriptions that make up the physical, functional, enterprise, and communications views of the CVRIA (see Figure 3.7).

CVRIA also supports policy considerations for certification, standards, core system implementation, and other elements of the connected vehicle environment. This new version of the CVRIA provides Physical, Functional, Enterprise and Communication viewpoint enhancements, as well as covering international applications. In addition, the Systems Engineering Tool for Intelligent Transportation (SET-IT) is new software that integrates drawing and database tools with the CVRIA so that users can develop project architectures for pilots, test beds and early deployments.

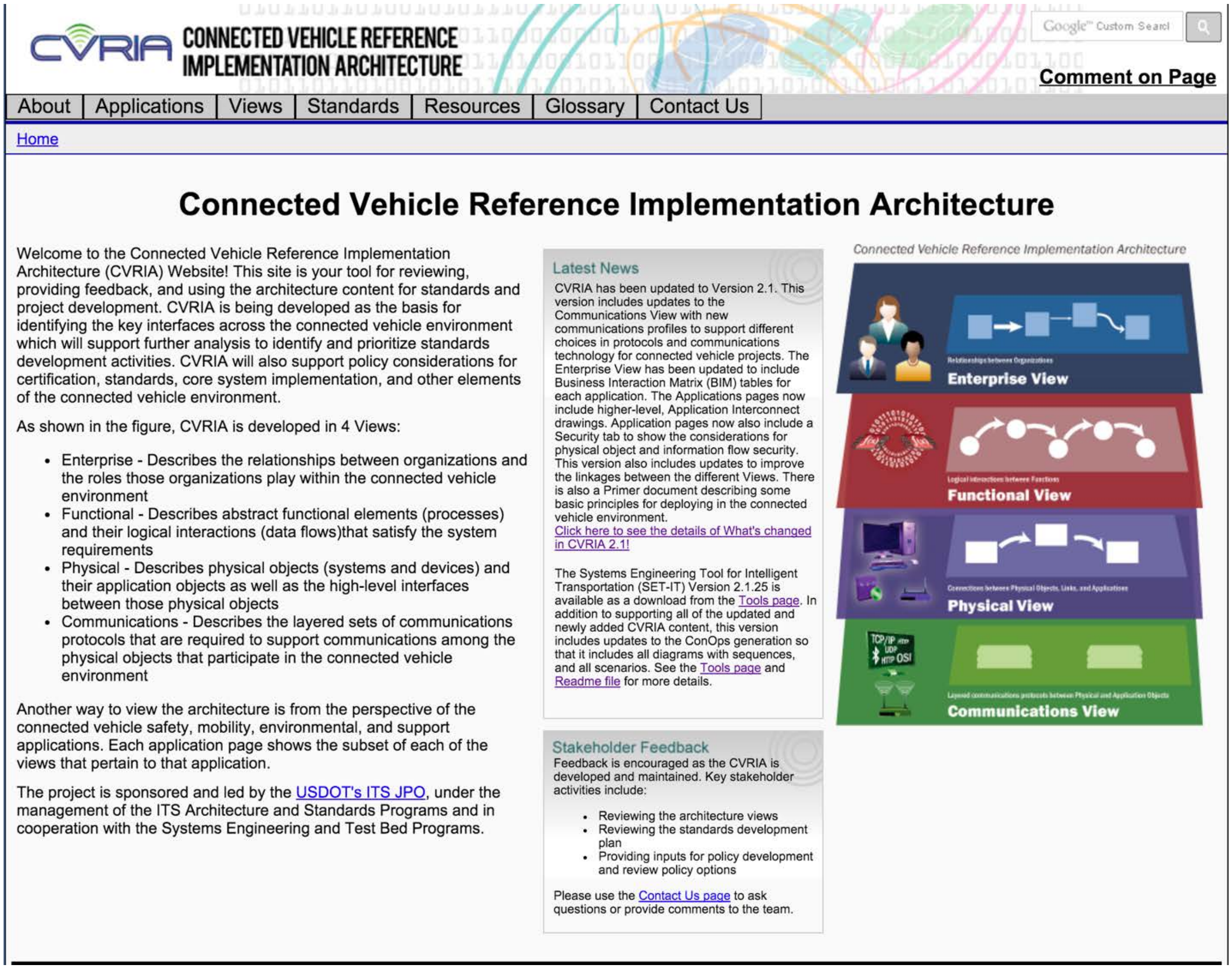

Figure 3.7: CVRIA Website

3.5 COST OVERVIEW FOR PLANNING IDEAS AND LOGICAL ORGANIZATION TOOL (COPILOT)

The U.S. DOT has launched Cost Overview for Planning Ideas and Logical Organization Tool (COPILOT). COPILOT is a high-level cost estimation planning tool designed to facilitate the development of cost estimates for the Connected Vehicle Pilot Deployments. Through its user interface, COPILOT allows users to generate deployment cost estimates for 56 applications drawn from the following program areas:

- Vehicle-to-Vehicle Safety
- Vehicle-to-Infrastructure Safety
- Mobility
- Environment
- Road Weather

- Smart Roadside
- Agency Data

After selecting their desired application(s), users then input the estimated number of "building blocks" that their deployments will feature. These 16 building blocks encompass the system elements of each deployment, such as signalized intersections, transit vehicles, and freight terminals. COPILOT then allows users to assign relevant selected applications to each program building block. COPILOT produces three possible outputs. An Excel spreadsheet provides a line-item breakdown of deployment costs. A pie chart displays the percentages of costs associated with each deployment building block. Finally, a cost probability distribution graph displays the projected deployment costs. COPILOT also provides users with the flexibility to alter unit cost data to suit local needs, as well as to add additional cost elements. As shown in Figure 3.8, CO-PILOT is available at https://co-pilot.noblis.org/CVP_CET/.

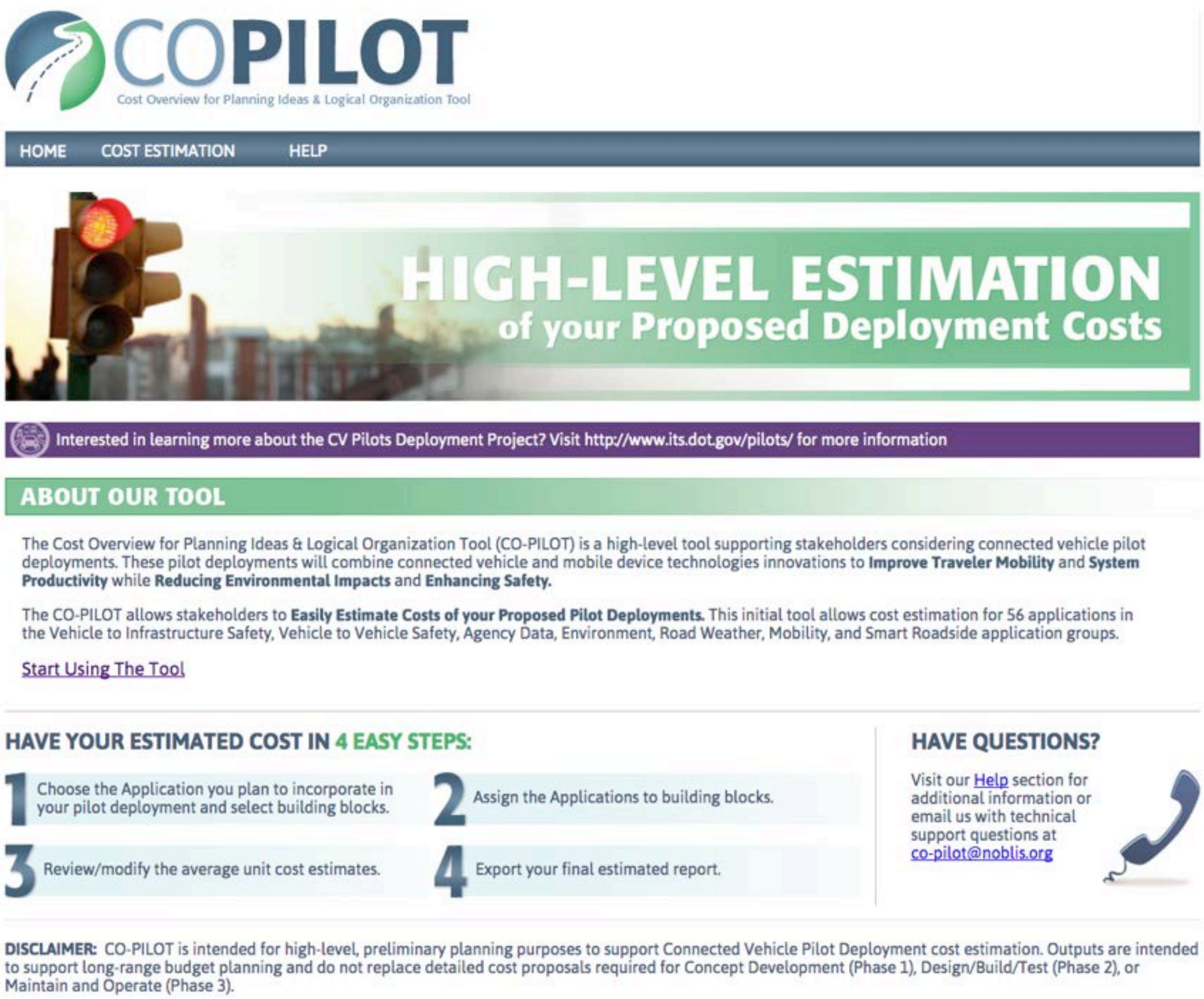

Figure 3.8: CVRIA Website

3.6 FIXING AMERICA'S SURFACE TRANSPORTATION (FAST) ACT

Since this research project began in 2014, the MAP21 legislation expired and the Fixing America's Surface Transportation (FAST) Act, a five-year, $305 billion surface transportation reauthorization bill, was signed into law on December 4, 2015. The legislation includes an Innovation Title, known as the Transportation for Tomorrow Act of 2015, which will fund critical research and accelerate the adoption of technologies to address highway and vehicle safety, traffic congestion, mobility, infrastructure condition, and other current and future transportation challenges.

ITS America has summarized 20 FAST Act provisions that are designed to encourage innovation and accelerate the research and deployment of Intelligent Transportation Systems (ITS America, 2015). Several of these provisions refer explicitly to connected vehicle technology, including the new Advanced Transportation and Congestion Management Technologies Deployment Program (2) and explicit funding eligibility for V2I equipment within all major highway formula programs:

- $100 million per year for Intelligent Transportation Systems (ITS) research, with an expanded role to enhance the national freight system and assist in developing cybersecurity standards to help prevent hacking, spoofing, and disruption of connected and automated transportation vehicles. In a joint explanatory statement, the conferees state their belief that "federal, state, and local agencies must be prepared for the future growth and adoption of innovative technologies such as autonomous vehicles and that the ITS program should support research initiatives that are engaged in the research, development, testing, and validation of autonomous vehicle technologies."

- A new $60 million per year Advanced Transportation and Congestion Management Technologies Deployment Program to provide competitive grants to develop model deployment sites for large scale installation and operation of advanced transportation technologies to improve safety, efficiency, system performance, and infrastructure return on investment. Between 5-10 grants per year will be awarded to deploy advanced traveler information systems; advanced transportation management technologies; infrastructure maintenance, monitoring, and condition assessment; advanced public transportation systems; system performance data collection, analysis, and dissemination; advanced safety systems including vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, technologies associated with autonomous vehicles, and other collision avoidance technologies; integration of ITS with the Smart Grid and other energy distribution and charging systems; electronic pricing and payment systems; or advanced mobility and access technologies, such as dynamic ridesharing and information systems to support human services for elderly and disabled individuals.

- $67.5 million per year for a Technology and Innovation Deployment Program designed to accelerate the deployment of new technology and innovations and analyze Federal, State, and local cost savings, project delivery time improvements, reduced fatalities, and congestion impacts.

- $15-20 million per year to establish a Surface Transportation System Funding Alternatives Program to provide grants to states to demonstrate user-based alternative revenue mechanisms to maintain the long-term solvency of the Highway Trust Fund.

- Funding eligibility for ITS projects within core highway formula programs including the revised Surface Transportation Block Grant Program which specifies eligibility for infrastructure-based ITS capital improvements, operational improvements, capital and operating costs for traffic monitoring, management, and control facilities and programs, development and implementation of State asset management plans and performance-based management programs, highway and transit research and technology transfer programs, projects designed to support congestion pricing including electronic toll collection and travel demand management, and state offices to support eligible public private partnerships (PPP).

- Explicit funding eligibility for installation of V2I communication equipment within all major highway formula programs including the National Highway Performance Program (NHPP), Surface Transportation Block Grant Program (STP), Highway Safety Improvement Program (HSIP), and Congestion Mitigation and Air Quality (CMAQ) Improvement program.

- Creation of a Nationally Significant Freight and Highway Projects competitive grant program funded at $4.5 billion over five years and a National Highway Freight program providing $6.3 billion in formula funding to states for projects including "intelligent transportation systems and other technology to improve the flow of freight, including intelligent freight transportation systems. Other ITS projects specifically listed as being eligible for funding include real-time traffic, truck parking, roadway condition, and multimodal information systems; electronic screening and credentialing systems including weigh-in-motion truck inspection technologies; traffic signal optimization, including synchronized and adaptive signals; work zone management and information systems; highway ramp meters; electronic cargo and border security technologies; and ITS technologies that would increase truck freight efficiencies inside the boundaries of intermodal facilities. The bill also requires development of a multimodal freight policy which, among other goals, will use innovation and advance technology to improve the safety, efficiency, and reliability of the National Multimodal Freight Network.

- An Innovative Technology Deployment discretionary grant program to promote the deployment of ITS in commercial vehicle operations, link Federal and State commercial vehicle information systems and networks, improve the safety and productivity of commercial vehicles and drivers, and reduce costs associated with commercial motor vehicle operations and regulations.

- A Beyond Compliance initiative requiring the Federal Motor Carrier Safety Administration (FMCSA) to incorporate a methodology into the Compliance, Safety, Accountability (CSA) program or establish a safety BASIC in the Safety Measurement System (SMS) to allow recognition for motor carriers that install advanced safety equipment, use enhanced driver fitness measures, adapt fleet safety management tools, technologies and programs, or satisfy other standards as determined by the Administrator.

- Promulgation of a rule by the National Highway Traffic Safety Administration (NHTSA) to require that information on collision avoidance technologies be indicated next to crashworthiness information on stickers placed on motor vehicles by their manufacturers.

- $72.5-77.5 million per year for the University Transportation Centers (UTC) program, including selection of at least one Regional UTC focused on comprehensive transportation safety, congestion, connected vehicles, connected infrastructure, and autonomous vehicles.

- A directive that federal transportation research planning be multimodal whenever possible and coordinated by the Secretary's office to prevent duplication of effort and identify opportunities to apply research across modes, which will include submission of annual modal research plans, publication of a comprehensive database of U.S. DOT research projects, and development of a Transportation Research and Development 5-Year Strategic Plan to guide future research activities.

- A Future Interstate Study to examine the actions needed to upgrade and restore the Dwight D. Eisenhower National System of Interstate and Defense Highways to its role as a premier system that meets the growing and shifting demands of the 21st century.

- A Government Accountability Office assessment of autonomous transportation technology policy developed by public entities in the U.S., an assessment of the organizational readiness of U.S. DOT to address autonomous vehicle technology challenges including consumer privacy protections, and recommended implementation paths for autonomous technology, applications, and policies.

- Traffic congestion research to accelerate the adoption of transportation management systems that allow traffic to flow in the safest and most efficient manner possible while alleviating current and future traffic congestion.

- A Smart Cities Transportation Planning Study to examine how digital and information technologies, including shared mobility, data, transportation network companies, and on-demand transportation services, are being adopted by cities and used to influence transportation planning and investment. The study would provide best practices to plan for smart cities in which information and technology are used to improve city operations, grow the local economy, improve response in times of emergencies and natural disasters, and improve the lives of city residents.

- Establishment of a Performance Management Data Support program to develop, use, and maintain data sets and data analysis tools to assist states and metropolitan planning organizations in carrying out performance management analyses, including collection and distribution of vehicle probe data; collection of household travel data; enhancement of existing data collection and analysis tools to accommodate performance measures, targets, and related data to better understand trip origin and destination, trip time, and mode; improved performance predictions and travel models; and evaluation of the effects of project investments on performance.

- A reduced cost threshold of $10 million for ITS, rural, and transit-oriented development projects to qualify for Transportation Infrastructure Finance and Innovation Act (TIFIA) loan assistance.

- Continuation of FHWA's Every Day Counts initiative to work with States, local agencies, and industry stakeholders to identify and deploy proven innovative practices and products that accelerate innovation deployment, shorten the project delivery process, improve environmental sustainability, enhance roadway safety, and reduce congestion.

- A Motorcyclist Advisory Council to coordinate with and advise the Federal Highway Administrator on infrastructure issues including barrier and road design, construction, and maintenance practices, and the architecture and implementation of ITS technologies.

3.7 NEW ADMINISTRATION BUDGET PROPOSAL 2016

On February 9, 2016, President Obama released his FY 2017 Budget Request *(U.S. DOT 2016)*. One of the provisions includes a proposal for $200 million in FY 2017 and nearly $3.9 billion over 10 years in pilot deployments of safe and climate-smart autonomous vehicles to create better, faster, cleaner urban and corridor transportation networks. This initiative would accelerate the development and adoption of autonomous vehicles, this program would fund large-scale deployment pilots to test connected vehicle systems in designated corridors throughout the country; and work with industry to ensure a common multi-state interoperability framework for connected and autonomous vehicles. It's not likely that this plan will move forward but it is worth being aware of the administration's proposal in this area.

3.8 NHTSA RESPONSE TO GOOGLE

In February 2016, the National Highway Traffic Safety Administration (NHTSA) posted a letter responding to Google's request for interpretation of several federal safety standards as they apply to self-driving vehicles *(NHTSA 2016)*. The key premise was: "NHTSA will interpret 'driver' in the context of Google's described motor vehicle design as referring to the [self-driving system], and not to any of the vehicle occupants," Chief Counsel Paul Hemmersbaugh said in the letter. "We agree with Google its [self-driving vehicle] will not have a driver in the traditional sense that vehicles have had drivers during the last more than 100 years.” The U.S. DOT intends to provide additional guidance regarding self-driving vehicles later in 2016.

3.9 REPORT TO CONGRESS ON THE STATUS OF THE DEDICATED SHORT RANGE COMMUNICATIONS TECHNOLOGY AND APPLICATIONS

Pursuant to requirements in MAP-21, the U.S. DOT reported to Congress on the the Status of the Dedicated Short Range Communications Technology and Applications in July 2015 *(U.S. DOT 2015)*. Just to include a short update of this situation, the following primary conclusions were included in the report:

- 5.9 GHz DSRC remains a foundational requirement for enabling safety-critical V2V and V2I applications
- Operations that use DSRC—test beds, operational sites, and emerging pilot sites—are demonstrating how the spectrum is used
- DSRC is ready for wider-scale implementation
- With regard to calls for spectrum sharing—completion of analysis, testing, and simulation modeling in 2016/2017 will provide details necessary to further inform the FCC’s exploration of sharing technologies

4.0 VEHICLE TO INFRASTRUCTURE (V2I) DEPLOYMENT COALITION

4.1 ABOUT THE V2I DEPLOYMENT COALITION

The Vehicle to Infrastructure Deployment Coalition (V2I DC) began as a concept to create a single point of reference for stakeholders to meet and discuss V2I deployment related issues. The initial emphasis was on capacity building for state departments of transportation (DOTs) and other public agency stakeholders. Nationwide deployment, operations, and maintenance of V2I applications will require long-term cooperation, partnership, and interdependence between the infrastructure owners and operators (state, county, and local level transportation agencies); the automobile industry original equipment manufacturers (OEMs), and aftermarket manufacturers; and a variety of other stakeholders.

For these reasons, the U.S. DOT asked the American Association of State Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the Intelligent Transportation Society of America (ITS America) to collaborate on organizing and managing the V2I DC. The V2I DC Project Team (consisting of members from AASHTO, ITE and ITS America) then created a vision, mission, and set of objectives that would guide the coalition.

4.1.1 V2I DC Vision, Mission and Objectives

The **vision** of the V2I Deployment Coalition is defined as:

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

The **mission** of the V2I Deployment Coalition is to:

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

The **objectives** of the V2I Deployment Coalition are to:

- Provide leadership on Connected Vehicle (CV) Program deployment efforts
- Establish CV deployment strategies
- Lead and provide support on continued technical research for CV

- Support CV standards development
- Provide input to and refinement of CV guidance

A website for the V2I DC was established at: http://www.transportationops.org/V2I/V2I-overview

This original concept was presented to U.S. DOT for input and guidance leading to the formation of the coalition. The V2I DC was organized in the spring of 2015, with a series of webinars that helped define the coalition. The initial in-person meeting occurred in June, 2015 in Pittsburgh, Pennsylvania. Since then, the individual Technical Working Groups (TWGs) have met regularly to conduct technical work.

4.1.2 V2I DC Leadership and Focus Areas

As shown in Figure 4.1, the V2I DC leadership is provided by the V2I DC Executive Committee (V2I DC EC). The V2I DC EC consists of executives and senior technical staff from a combination of public and private sector organizations that represent a wide range of V2I stakeholders. The V2I DC EC formally met for the first time in September, 2015.

During the September V2I DC EC meeting, it was agreed by members of the Executive Committee that *the role of the V2I DC is to help accelerate consistent and effective deployments of Connected Vehicle technologies that address passenger vehicles, freight, and transit operations in both urban and rural areas.*

To accomplish this role, the V2I DC EC has established its initial goals to be:

- **Goal 1:** Help to accelerate the deployment of V2I technologies at *Intersections* where the majority of crashes and/or congestion occur [note that this corresponds to a suite of ODOT applications related to intersections, including: 1 (SPAT), 2 (Red Light), 4 (Stop Sign), 6 (Pedestrian), 7 (Railroad Crossing), 23 Eco-Approach/Departure Intersections, 24 Eco-Traffic Signal Timing, 25 Eco-Traffic Signal Priority, 47 (I-SIG), 48 (Signal Priority) and 49 (PED-SIG)].

- **Goal 2:** Help to accelerate the deployment of V2I technologies to support *End of Queue Warnings* in locations with high rates of rear-end collisions [note that this corresponds to ODOT application 52. Q-WARN, and 51. Dynamic Speed Harmonization (SPD-HARM) in the suite of freeway traffic management applications]

- **Goal 3:** Help to accelerate the deployment of V2I technologies for *Work Zone Management* [this corresponds to several ODOT applications related to work zones, including 22. Work Zone Traveler Information, 39. Motorist Advisories and Warnings (MAW) and 56. Incident Scene Work Zone Alerts (INC-ZONE).]

- **Goal 4:** Help to accelerate the deployment of V2I technologies for *Curve Speed Warning Systems*. [this matches ODOT application 3. Curve Speed Warning]

For Oregon, this prioritization action taken by the V2I DC EC is generally consistent with several of the Near Term Focus Applications chosen, including:

- 1. Signal Phase and Timing and applications enabled by this feature for *Intersections*.
- 51. Dynamic Speed Harmonization (SPD-HARM), very similar in concept and details required for 52. *End of Queue Warnings*.
- 23. Motorist Advisories and Warnings (MAW), similar to *Work Zone Management*
- 3. *Curve Speed Warning Systems*

In summary, the actions of ODOT and the V2I DC EC are consistent and mutually reinforcing.

4.1.3 V2I DC Structure and Management

The V2I DC Project Team, consisting of staff and support members of AASHTO, ITE, and ITS America, manage the coalition, and provide technical support to technical working groups (TWGs) made up of volunteers. As shown in Figure 4.1, the coalition technical work is accomplished through five TWGs, identified below:

- **TWG 1**: Deployment Initiatives
- **TWG 2:** Deployment Research
- **TWG 3:** Infrastructure Operator, OEM, and Supplier Partnerships
- **TWG 4:** Deployment Guidance
- **TWG 5:** Deployment Standards

Participation in TWGs is voluntary and open to anyone. Additional details (including contact information to be used to request participation) about each TWG are available on the V2I DC website.

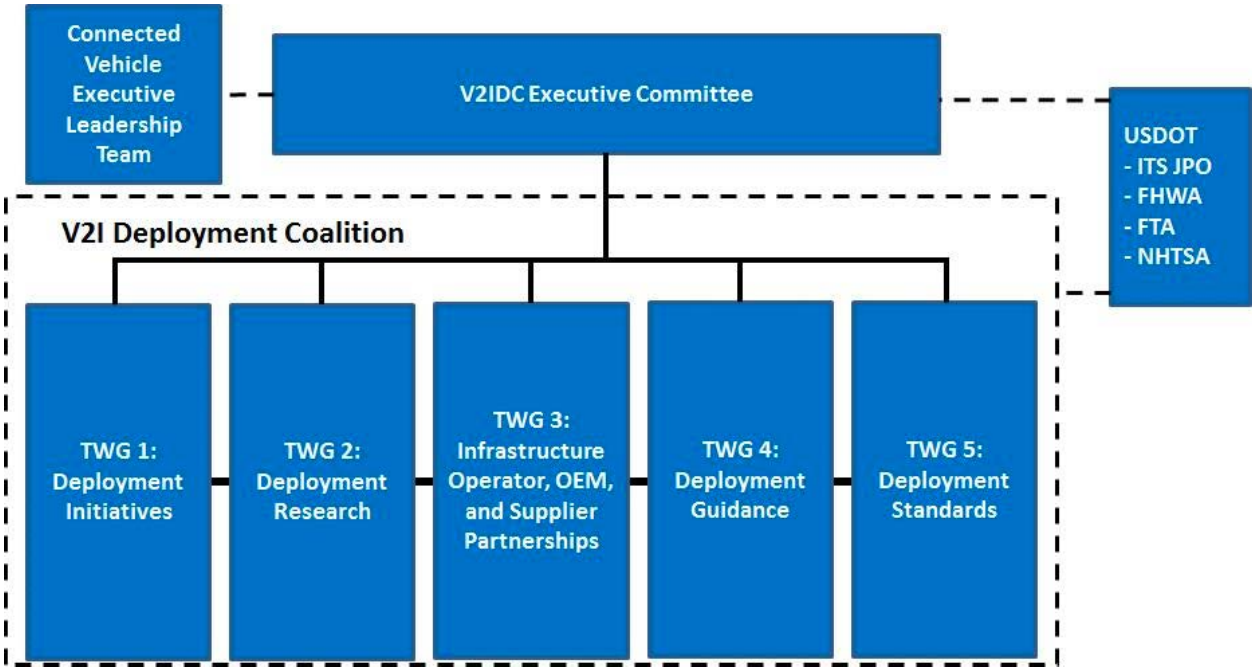

Figure 4.1: V2I Deployment Coalition Organization Chart

4.1.4 V2I DC Schedule and Deliverables

The V2I DC concept originated in early 2015 with an 18-month schedule for initial activities. The initial 18-month schedule will end in July 2016, however discussions and planning are underway to extend the V2I DC beyond the initial 18 months.

During the initial 18-month period of the V2I DC, four Technical Memoranda will be developed to document progress of the coalition. Additional deliverables will be produced by individual TWGs. Coalition deliverables will be posted to the V2I DC website, as they are finalized and available for circulation.

4.1.5 Connected Vehicle Applications Survey

One of the main activities of the V2I DC thus far has been to conduct a connected vehicle (CV) applications survey *(V2I Deployment Coalition 2016)*. This effort has been led by TWG 1. In 2015, the U.S. DOT selected three sites as part of its Connected Vehicle Pilot deployment program:

- **New York City**: V2V capabilities in up to 10,000 city-owned vehicles and V2I technology in the Midtown area. V2I capabilities will be added to traffic signals on avenues between 14th Street and 66th Street Street in Manhattan. Brooklyn will also have updates throughout the borough. Roadside units on FDR Drive between 50th Street and 90th Street will also have connected vehicle capabilities added.

- **Wyoming**: Efficient and safe movement of freight on the Interstate 80 corridor, where between 11,000 and 16,000 vehicles travel daily. The Wyoming Department of Transportation will be using V2V and V2I to collect and disseminate the data it collects to vehicles not equipped with the technology.

- **Tampa**: Plans to work on ways of providing connected technology being put into vehicles to pedestrians' smartphones. This is an effort to protect pedestrians and solve peak rush hour congestion in the downtown area.

In addition to these three sites, the V2I DC knows that dozens of other agencies submitted (unsuccessful) proposals, and members are very interested to learn what specific applications were included in these proposals. Because the U.S. DOT did not make the proposal contents available, the V2I DC decided to launch a survey of agencies who submitted CV Pilot proposals. The survey results included responses from 25 organizations through an online survey and 2 responses through a telephone based survey. Agencies responding included:

- Arizona DOT, TSMO Division
- California DOT (Caltrans)
- California PATH/UC Berkeley
- Carnegie Mellon University Traffic21 Institute
- City of Alexandria, VA
- City of Chattanooga, TN
- City of Palo Alto, CA
- City of Walnut Creek, CA
- King Count Metro Transit, WA
- Louisiana DOTD
- Metropolitan Transportation Commission (MTC), CA
- Michigan DOT
- Minnesota DOT
- NYCDOT
- NYSDOT
- Oregon DOT

- Pennsylvania DOT
- Prospect Silicon Valley, CA
- Santa Clara County, CA Road and Airports Department
- The Ohio State University Mobility Research and Business Development
- THEA Connected Vehicle Pilot Deployment
- Utah DOT
- Virginia DOT
- Virginia Tech Transportation Institute (VTTI)
- Washington State DOT
- Wisconsin DOT

Some discussion with surveyed participants included points that success will be a measure of the penetration and the acceptance of roadside deployments and vehicle applications, which is consistent with discussions by ODOT staff through this project. Toward the objective of identifying specific applications, the survey asked respondents to identify the CV applications that were included in the agency's plan or proposal for CV deployment, or that have already been deployed. The agencies were also asked which five applications would be the most beneficial to deploy.

For the survey, the 72 V2I Applications from the CVRIA Website were presented in eight categories:

- 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)

From the survey (21 responses to this question), Figure 4.2 shows the results indicating how many different applications were included in agency plans or proposals for deployments. As indicated the larger numbers of applications were from the traffic network/traffic signals categories. Figure 4.3 shows the top 11 applications that were chosen; the selections are related to traffic signals and intersections (EV preemption, SPAT, and I-SIG), advanced traffic management (queue warning and speed harmonization), spot warnings (curve speed warnings), and incidents/work zones (INC-ZONE, work zone traveler information, warnings about hazards in a work zone, road weather motorist alert and warning) and agency data (vehicle data for traffic operations). These are consistent with the V2I DC EC priorities and those Near Term Focus for ODOT applications.

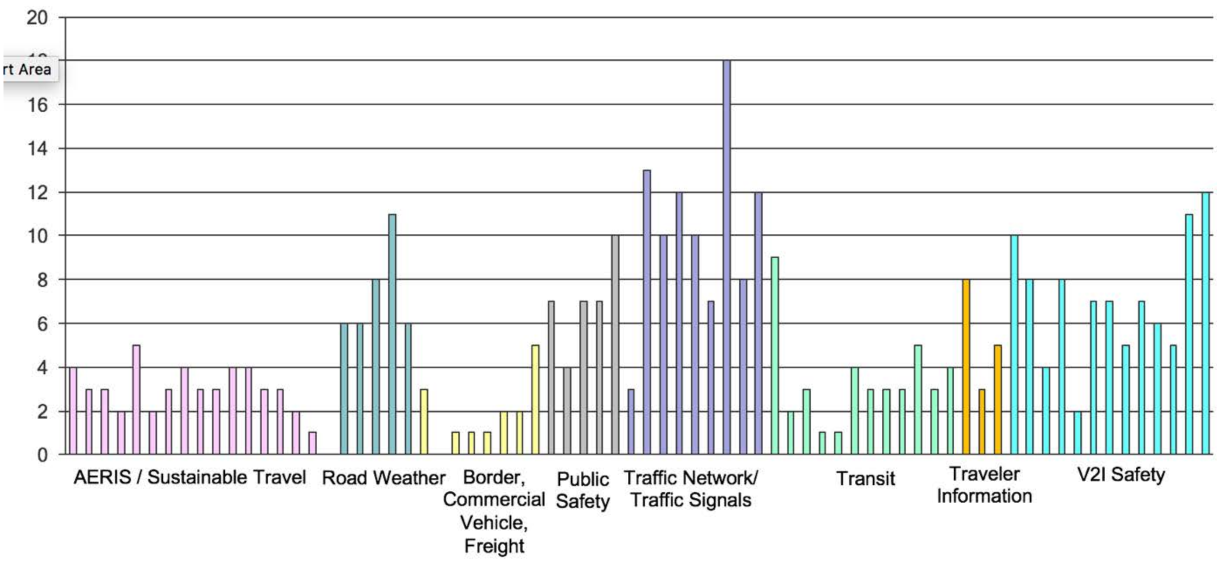

Figure 4.2: CV Applications Included in Agency Plans or Proposals

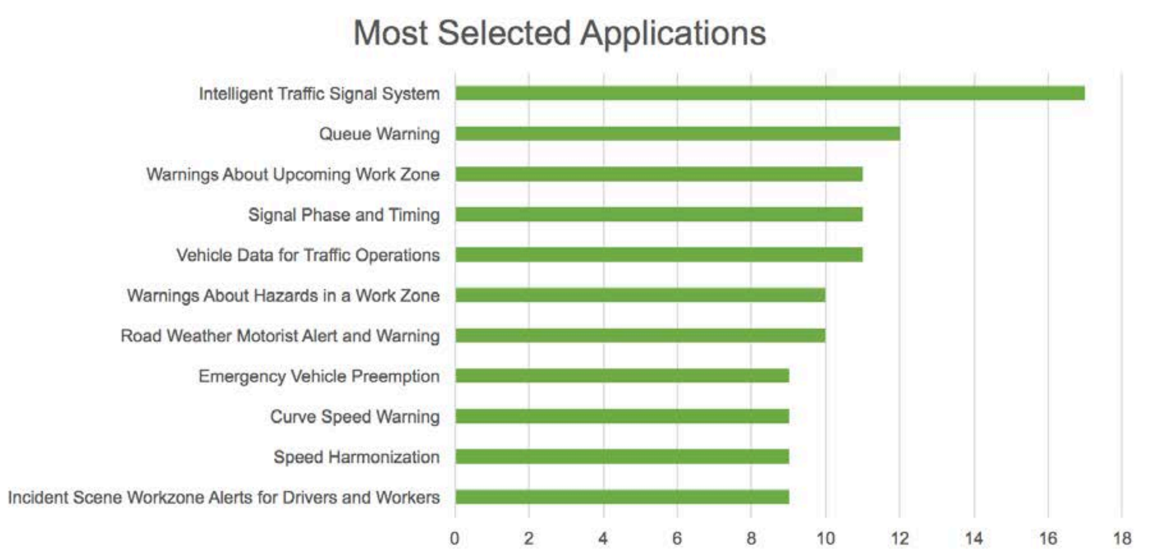

Figure 4.3: Most Selected CV Applications Included in Agency Plans or Proposals

The next line of questioning aimed at identifying the most beneficial applications to deploy (each respondent was asked to select the five most beneficial applications for their agency. Figure 4.4 shows the results, which indicate that most respondents found traveler information and traffic network/traffic signal related applications to be most beneficial. Figure 4.5 shows the list of the top 11 applications in terms of their prospective benefits. This list is also generally consistent with the V2I DC EC priorities and the ODOT Near Term Focus applications. Specifically, applications related to traffic signals (I-SIG, SPAT, Red Light Violation Warning, Pedestrian in Signalized Crosswalk Warning, Transit Signal Priority), agency data (Vehicle Data for Traffic Operations), traffic management (Queue Warning), incidents/work zones (Road Weather Motorist Alert and Warning, Warnings About Upcoming Work Zone), traveler information (Advanced Traveler Information Systems) and spot warnings (In-Vehicle Signage). These are also generally consistent with the applications prioritized by the V2I DC EC and the ODOT Near Term Focus applications. Figure 4.6 illustrates the overlap between the set of applications that survey respondents have proposed vs. those that they feel would be most beneficial.

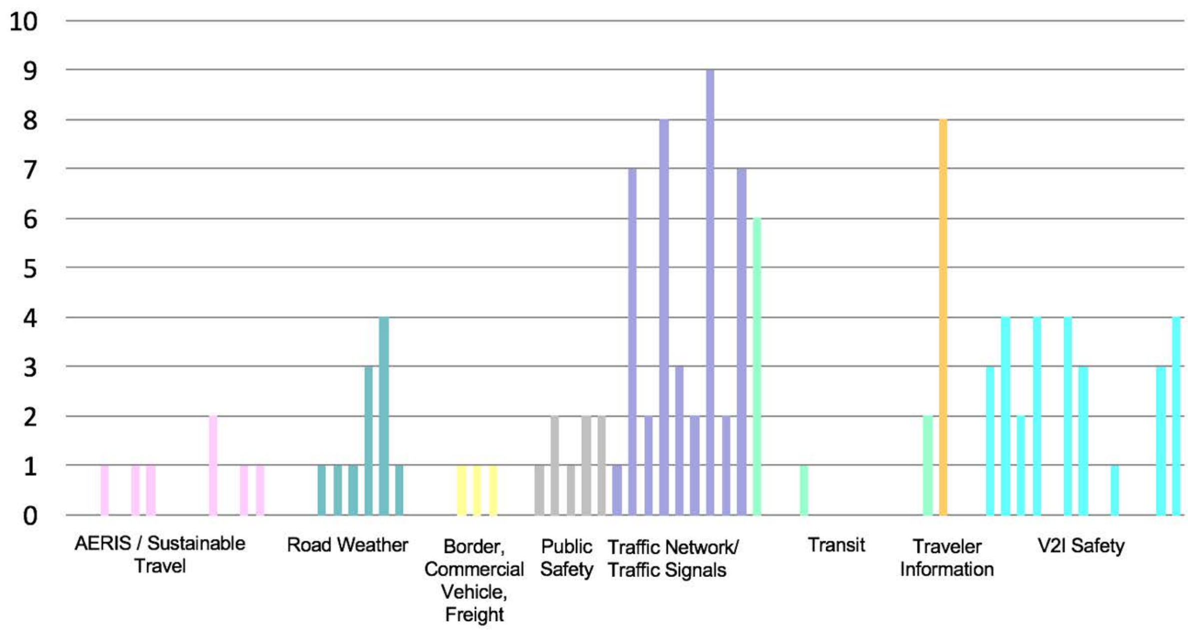

Figure 4.4: Most Beneficial CV Applications to Deploy

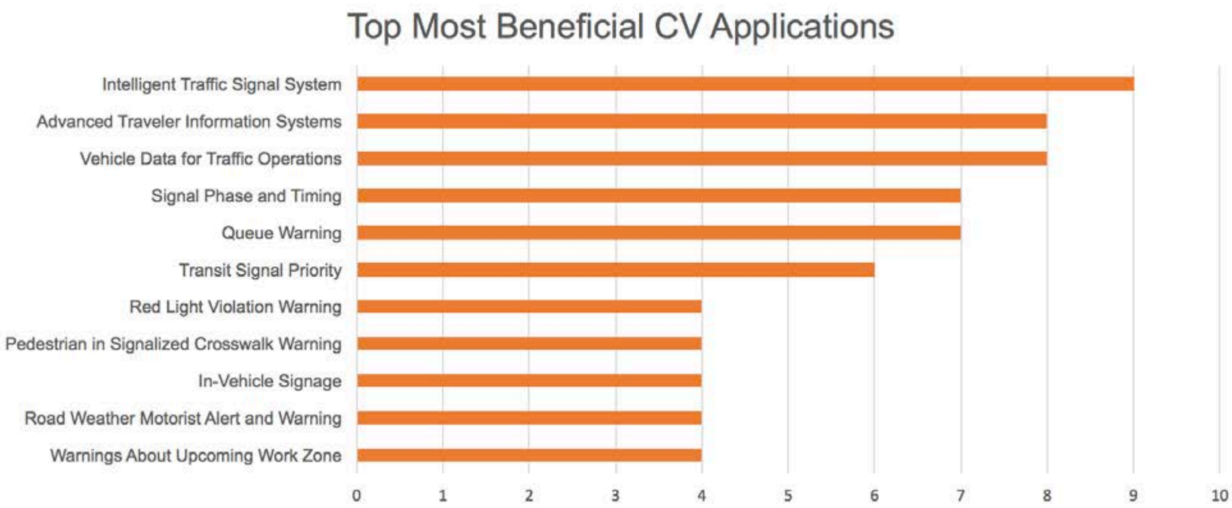

Figure 4.5: Most Selected Most Beneficial CV Applications

Figure 4.6: Overlap Between Proposed Applications and Most Beneficial CV Applications

The next question explored the CV applications that have already been deployed. Figure 4.7 shows the applications that have been deployed by two or more agencies. As indicated, the most popular applications again relate to intersections (SPAT, transit signal priority, emergency vehicle preemption, and Eco-Approach and Departure at Signalized Intersections), traveler information (ATIS), and agency data (performance monitoring, road weather information for maintenance and fleet management systems and planning and enhanced maintenance decision support system). Other applications including electric charging stations management, roadside lighting, and electronic toll collection have not appeared in responses to earlier questions for this survey.

The survey contained several open-ended questions as well. Agencies mentioned several other applications that were not included in deployment plans up until now:

- Transit
- Applications that require a high saturation of DSRC enable vehicles
- Public transportation connection protection (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

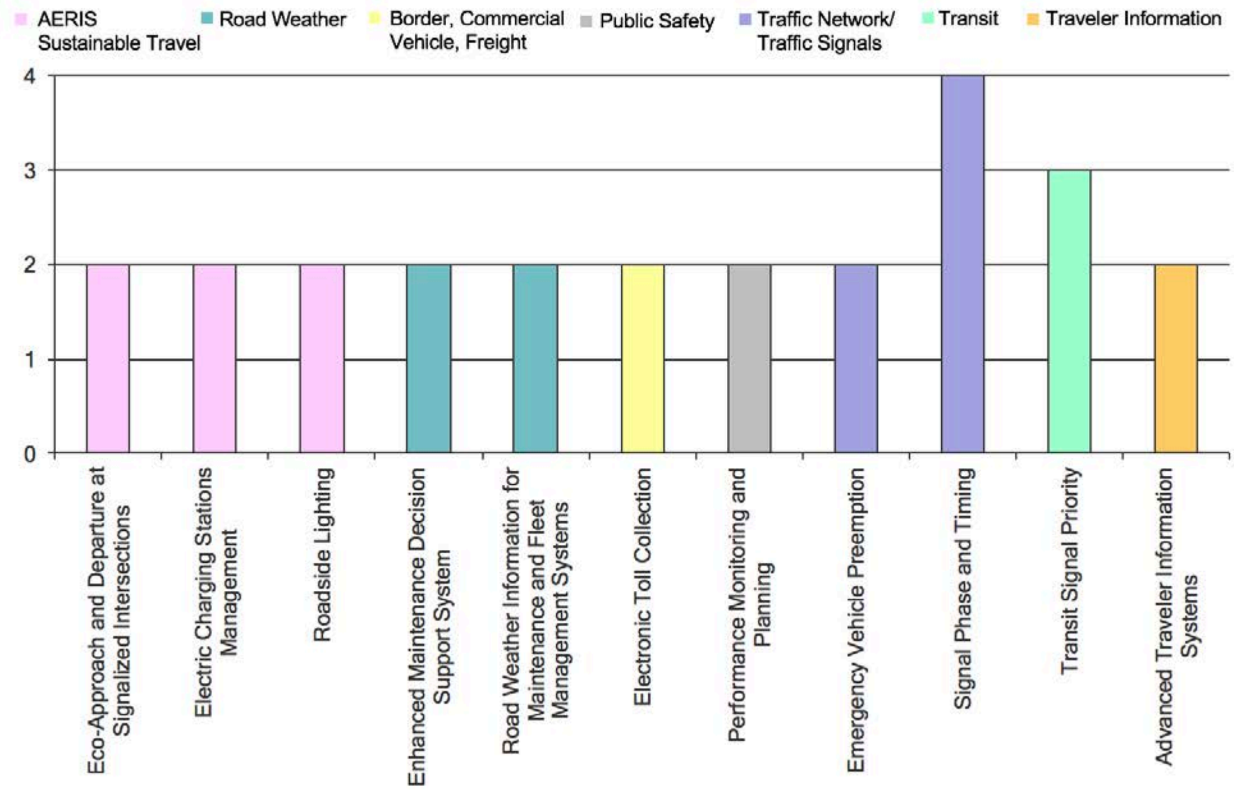

Figure 4.7: Most Selected Most Beneficial CV Applications

Toward identifying potential barriers to CV application deployment, surveyed agencies were asked to identify challenges that might prevent or hinder CV infrastructure deployment. Some of the open-ended responses included:

- DSRC Security
- IT security – lack of guidance
- Existing Patents
- 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

These comments included issues with security, intellectual property, specific issues related to the applications themselves (combining applications, lack of readiness, lack of documentation, lack of supporting research), policy/legislation (rulemaking), terminology, institutional differences/barriers and communications network limitations (lack of backhaul).

One of the aims of this survey was to solicit lessons learned from agencies that have gained some experience in planning and/or actually implementing CV applications. The last question asked for respondents to provide two important or surprising lessons learned that might be helpful for other organizations. A summary of the responses is listed below:

- 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.
- 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.
- Rate of Change
  - The rapid development of automated vehicle technology and the projection of these vehicles operating on roadways in the near future.
  - It is incredible how quickly the field is advancing right now.
- Coordination/Communication
  - Having a good relationship between IT and Operations is key.

    - There is a lack of common vision between local agencies and State DOTs. That gap needs to be closed.

    - It is difficult at this point to gain tremendous public input on this process. I feel it is a lack of understanding.

    - Successful CV will be highly dependent on partnerships across many modes to fully leverage regional benefits.

- Deployment Decisions

    - Listening to the conversations of other submitting agencies, there appears to be a 'pick-and-choose' approach to application lists, rather than concentrating on transitioning existing job functions/responsibilities to new infrastructure.

    - Transit agencies are very interested in deploying CV to improve transit operations.

    - Deploying CV at this point is risky. Agency access to private vehicle CV data is still undefined.

5.0 CONTEXT: STATE DOT ACTIONS

5.1 CONNECTED VEHICLE POOLED FUND STUDY

The Connected Vehicle Pooled Fund Study (http://www.cts.virginia.edu/cvpfs/) began in 2009. The project currently involves 12 states plus Maricopa County AZ, with Virginia as the lead state. The aim is to aid transportation agencies in justifying and promoting the deployment of cooperative transportation systems through modeling, development, engineering, and planning activities.

With an annual membership fee of $50,000, through a set of pooled fund studies, the Virginia Department of Transportation is working with Federal, State, and local departments of transportation to establish a multiphase program to facilitate the development, field demonstration, and deployment of connected vehicle infrastructure applications. The participants in this program will complete applied research to create deployable connected vehicle infrastructure applications. The purpose of this program is to provide a means to conduct the work necessary for infrastructure providers to play a leading role in connected vehicles, as described in the American Association of State Highway and Transportation Officials strategic plan. All efforts will be coordinated with the partners currently engaged in the Connected Vehicles program, namely the U.S. Department of Transportation and automobile manufacturers.

Pooled fund members include 12 states, one county, the FHWA and the University of Virginia:

1. California Department of Transportation (Caltrans)
2. Federal Highway Administration (FHWA)
3. Florida DOT
4. Maricopa County in Arizona
5. Michigan DOT
6. Minnesota DOT
7. New Jersey DOT
8. New York DOT
9. Pennsylvania DOT
10. Texas DOT
11. Utah DOT

12. Washington DOT
13. Wisconsin DOT
14. Virginia DOT, lead agency
15. University of Virginia Center for Transportation Studies, technical leadership provider

The pooled fund program is currently undertaking two notable projects:

5.1.1 Multi-Modal Intelligent Traffic Signal System – Phase II: System Development, Deployment and Field Test

The University of Arizona has teamed with California PATH of the University of California at Berkeley (UCB) to design, develop, deploy, and field test a multi-modal intelligent traffic signal system that will operate in a connected vehicle environment. The team is supported by technical experts from a connected vehicle system equipment manufacturer (Savari) and a traffic signal control system supplier (Econolite). The objectives of this project are to develop a detailed design, construct the software and hardware system, and conduct a field test of a comprehensive traffic signal system that services multiple modes of transportation, including general vehicles, transit, emergency vehicles, freight fleets and pedestrians.

5.1.2 Best Practices for Surveying/Mapping Roadways and Intersections for Connected Vehicle Applications

Conducted by University of California, Riverside, the goal of this project is to analyze and document the surveying and mapping requirements for expected connected vehicle applications, and to determine the best practices that should be used to satisfy them. An emphasis will be placed on efficiency, particularly with respect to lowering the costs and time required. Here are some additional considerations:

- Safety of personnel performing the work
- Accuracy of the measurements
- Minimal/no lane closures needed
- Minimal time required to complete the work
- Creation of maps that are easy to update as aspects of the location change

In addition, eight prior projects were completed through the pooled fund program:

- 5.9 GHz Dedicated Short Range Communication Vehicle-Based Road and Weather Condition Applications

- Multi-Modal Intelligent Traffic Signal System – Phase I: Development of Concept of Operations, System Requirements, System Design and a Test Plan
- Traffic Management Centers in a Connected Vehicle Environment
- Aftermarket On-Board Equipment for Cooperative Transportation Systems: Enabling Accelerated Installation of Aftermarket On-Board Equipment for Cooperative Transportation Systems
- Certification Program for Cooperative Transportation Systems: Preparing to Develop a Standards Compliance and Interoperability Certification Program for Cooperative Transportation Systems Hardware and Software
- IntelliDrive Traffic Signal Control Algorithms
- Investigation of Pavement Maintenance Support Applications of IntelliDrive
- Investigating the Potential Benefits of Broadcasted Signal Phase and Timing (SPAT) Data under IntelliDrive

Additional projects are currently being scoped for future selection, and Oregon should stay tuned for potential future participation.

5.2 AASHTO FOOTPRINT ANALYSIS

Another important effort has been the National Connected Vehicle Field Infrastructure Footprint Analysis, conducted by AASHTO *(AASHTO 2014)*. The fundamental premise of the connected vehicle initiative is that enabling wireless connectivity among vehicles, the infrastructure, and mobile devices will bring about transformative changes in safety, mobility, and the environmental impacts in the transportation system. Key federal policy decisions relating to connected vehicle safety needs are currently moving forward. In particular, the work of the National Highway Traffic Safety Administration (NHTSA) to consider a rulemaking for vehicle-to-vehicle (V2V) communications in light vehicles has received significant national attention. While the future actions of NHTSA and the state and local transportation agencies are independent, and the NHTSA decision does not require agencies to deploy any connected vehicle infrastructure, it is important for the state and local agencies to understand what this action will mean to them, what they need to know to prepare for an emerging connected vehicle environment, and what investments may need to be made to leverage a nationwide fleet of equipped vehicles in support of their own policy and operational objectives.

The American Association of State Highway and Transportation Officials (AASHTO), with the support of United States Department of Transportation (USDOT) and Transport Canada, has undertaken a Connected Vehicle Field Infrastructure Footprint Analysis to provide supporting information to agency decision-makers. AASHTO’s work in this analysis has been performed through its Connected Vehicle Deployment Coalition, a group comprising representatives from a number of state and local transportation agencies, and the findings and recommendations in this report represent the opinions of this AASHTO community. In addition, the development of connected vehicle deployment scenarios engaged a broader group of state and local agency participants. This work consists of a vision for a national footprint; a description of the background for and current research on connected vehicle deployments; a set of assumptions underlying the infrastructure footprint analysis; the applications analysis; the deployment concepts, the preliminary national footprint, including the value proposition, deployment objectives, context, scenarios, and experience to date; and a preliminary deployment and operations cost estimation.

The footprint analysis consists of detailed deployment concepts for nine scenarios:

- Rural Roadway
- Urban Highway
- Urban Intersection
- Urban Corridor
- International Land Border Crossing
- Freight Intermodal Facility
- Smart Roadside Freight Corridor
- DOT Operations and Maintenance
- Fee Payment

Within the analysis of these deployment concepts, the footprint analysis also identifies and explores the following nine considerations that are common to all deployment concepts:

- Connected Vehicle System Architectures
- Connected Vehicle Data Needs and Standards
- Mobile Element Components
- V2I Communications
- Communications Security
- Backhaul
- Mapping Support
- Siting and Installation
- Power Considerations

Table 5.1 shows the list of application groups and bundles that are considered in the footprint analysis.

Table 5.1: Application Groups and Bundles

Application Group	Application Bundle
Vehicle to Infrastructure Safety	Intersection Applications
	Speed Applications
	Vulnerable Road Users
	Transit Safety
Mobility	Enable ATIS (Advanced Traveler Information Systems)
	Integrated Network Flow Optimization (INFLO)
	Freight Advanced Traveler Information Systems (FRATIS)
	Multimodal Intelligent Traffic Signal Systems (M-ISIG)
	Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.)
	Integrated Dynamic Transit Operations (IDTO)
	Next Generation Integrated Corridor Management (ICM)
	Information for Maintenance and Fleet Management Systems
	Information and Routing Support for Emergency Responders
	Smart Roadside
Applications for the Environment: Real-Time Information Synthesis (AERIS)	Eco-Signal Operations
	Dynamic Eco-Lanes
	Dynamic Low Emissions Zones
	Support for Alternative Fuel Vehicle Operations
	Eco-Traveler Information
	Eco-Integrated Corridor Management Decision Support System
Road Weather	Road Weather
International Border Crossings	International Border Crossings

Application Group	Application Bundle
Fee Payments	Fee Payments
Agency Data Applications	Performance Measures
	Connected Vehicle-enabled Traffic Studies
	Probe Data Applications

The footprint analysis includes a discussion of whether it would be possible to equip signalized intersections with connected vehicle infrastructure as a starting point for establishing a nationwide footprint. For the analysis, some basic cost estimates were included (2013 data):

- The average direct DSRC RSU equipment and installation 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 depending on an agency's existing investments, at an estimated national average of $30,800.

- The typical cost of signal controller upgrades for interfacing with a DSRC RSU is estimated to be $3,200.

- The annual operations and maintenance cost for a DSRC RSU site is estimated to be $3,050.

AASHTO recommends that state and local agencies develop their own deployment strategies. This project has been one step toward that end for Oregon. AASHTO sets out a list of tasks for developing statewide strategies, including:

- Convene public sector stakeholders from appropriate state and local transportation agencies, as well as potentially from public transportation providers, law enforcement, and public safety agencies depending on applications under consideration. Metropolitan and regional planning agencies may also participate, and could be responsible for this activity within the bounds of the conventional transportation planning processes.

- Identify connected vehicle concepts and applications that are of interest to the stakeholders and create scenarios under which these applications are realized.

- Review and update relevant plans and other documents to reflect potential connected vehicle deployments. Documents to be revisited could include regional ITS architectures, Sec. 1201 plans, and Strategic Highway Safety Plans.

- Identify the specific locations at which connected vehicle infrastructure deployments will take place and the scope of the deployment, which may include consideration of the need for a pilot or prototype demonstration initially.

- Consider funding options for deployment, and address needs for inclusion of connected vehicle activities in long-range transportation plans and subsequently in statewide TIPs (STIPs) or local TIPs.

- Develop procurement documents, which must be consistent with future federal deployment guidance, the Connected Vehicle Reference Implementation Architecture (CVRIA), and federal decisions on the Security Credential Management System (SCMS).

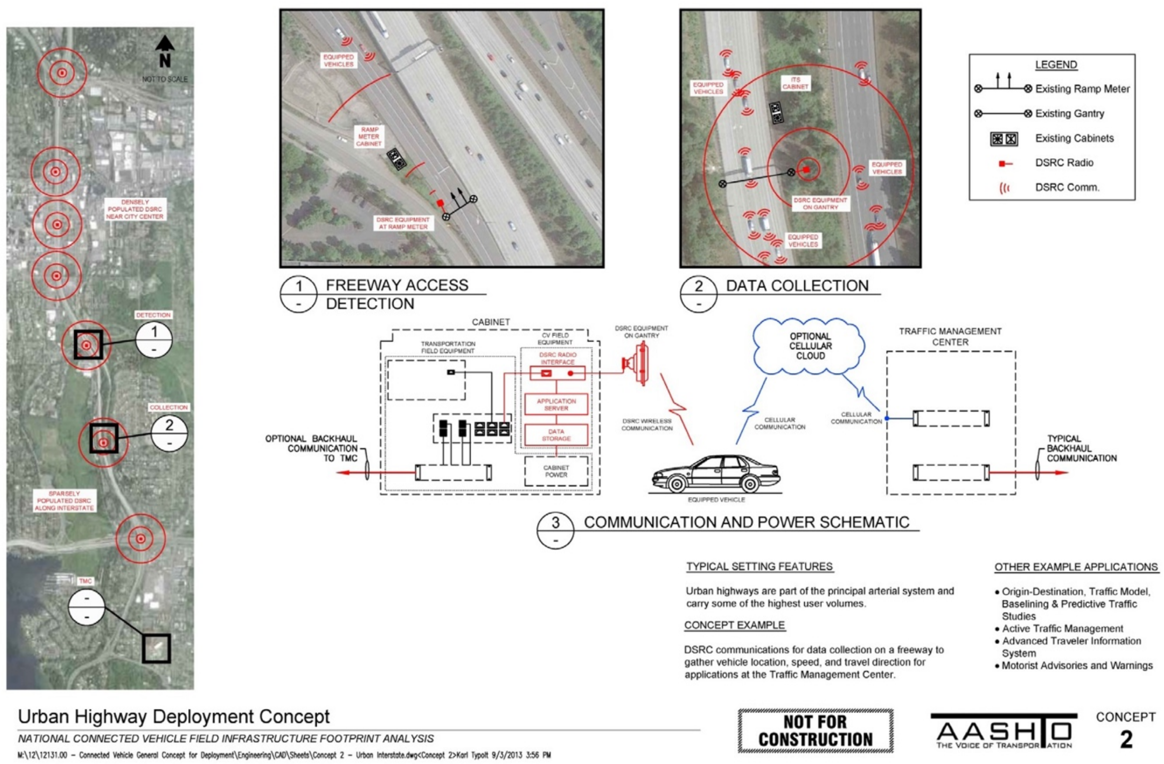

Figure 5.1: Urban Highway Deployment Concept

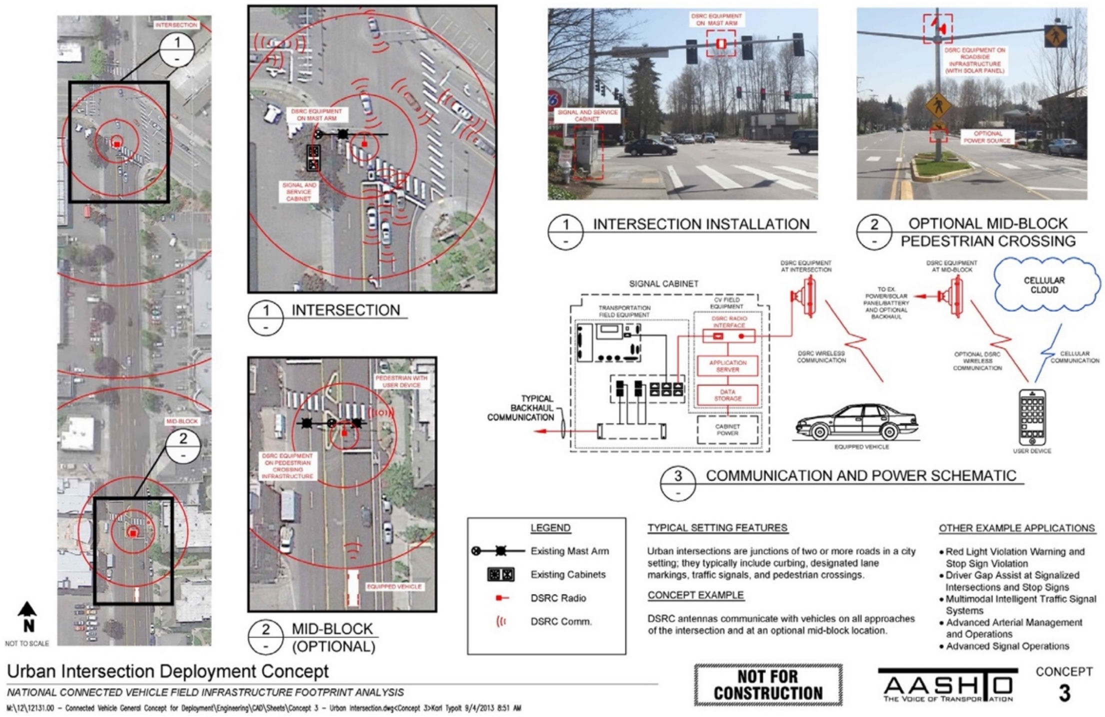

Figure 5.2: Urban Intersection Deployment Concept

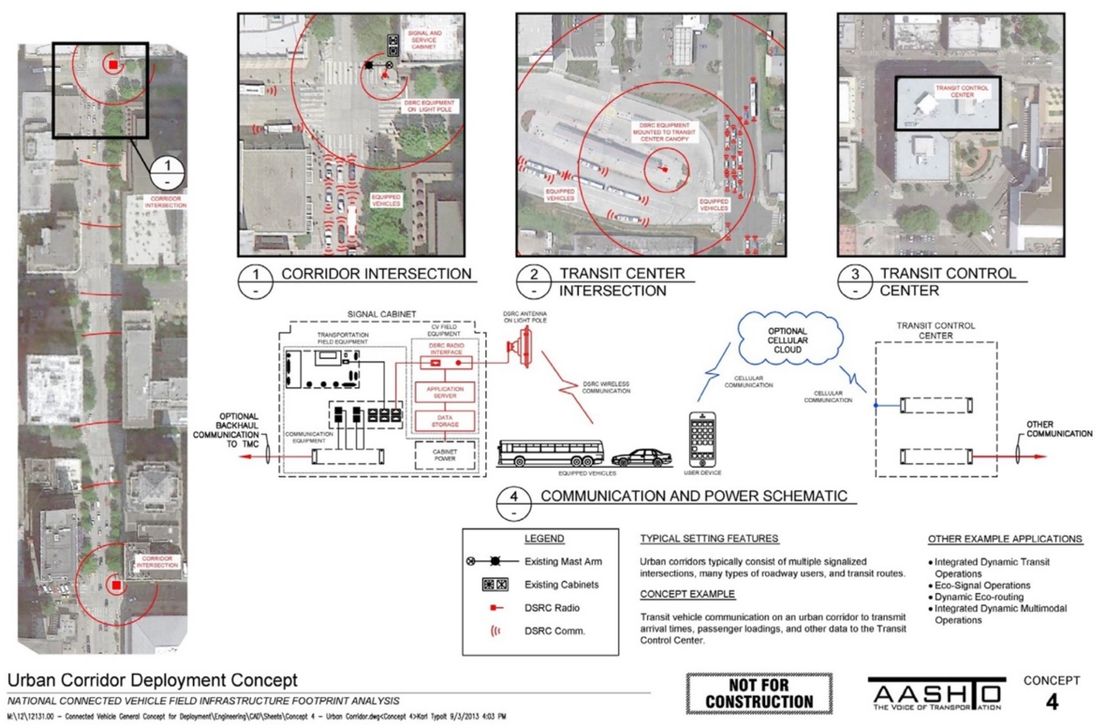

Figure 5.3: Urban Corridor Deployment Concept

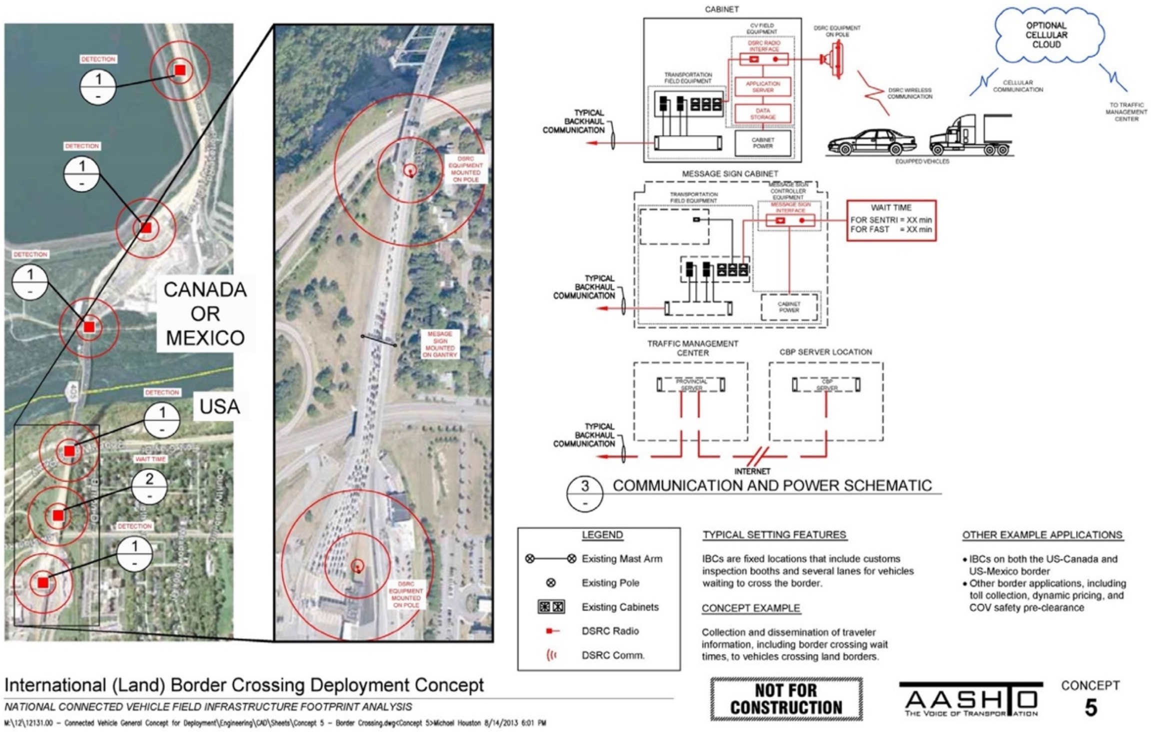

Figure 5.4: International (Land) Border Crossing Concept

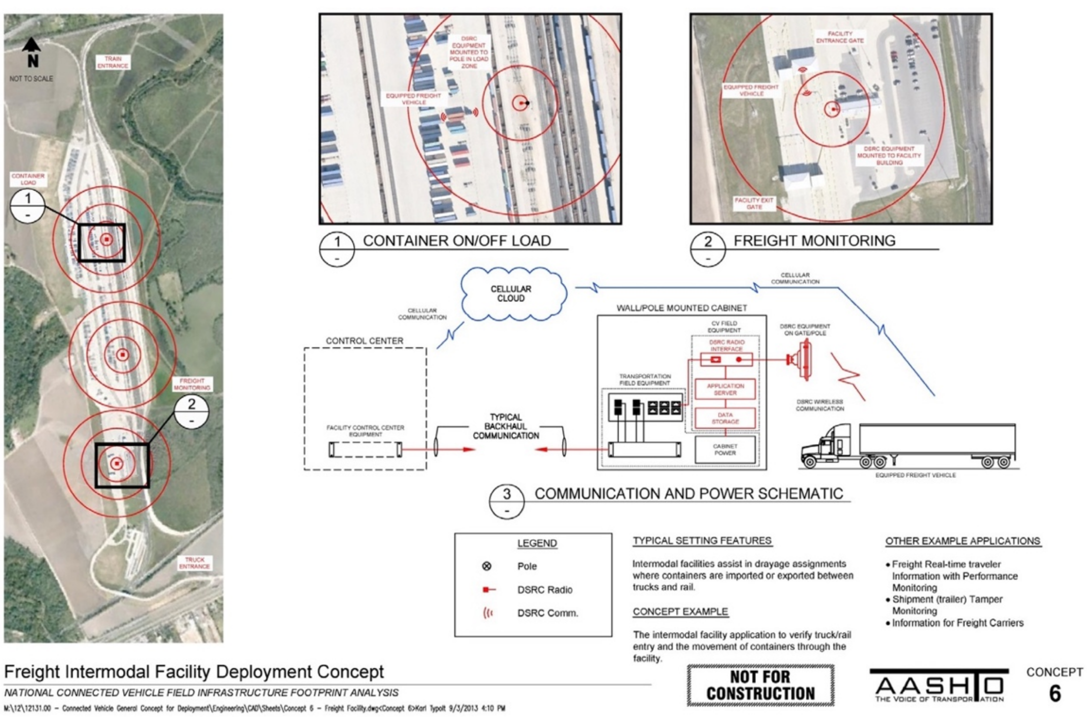

Figure 5.5: Freight Intermodal Facility Deployment Concept

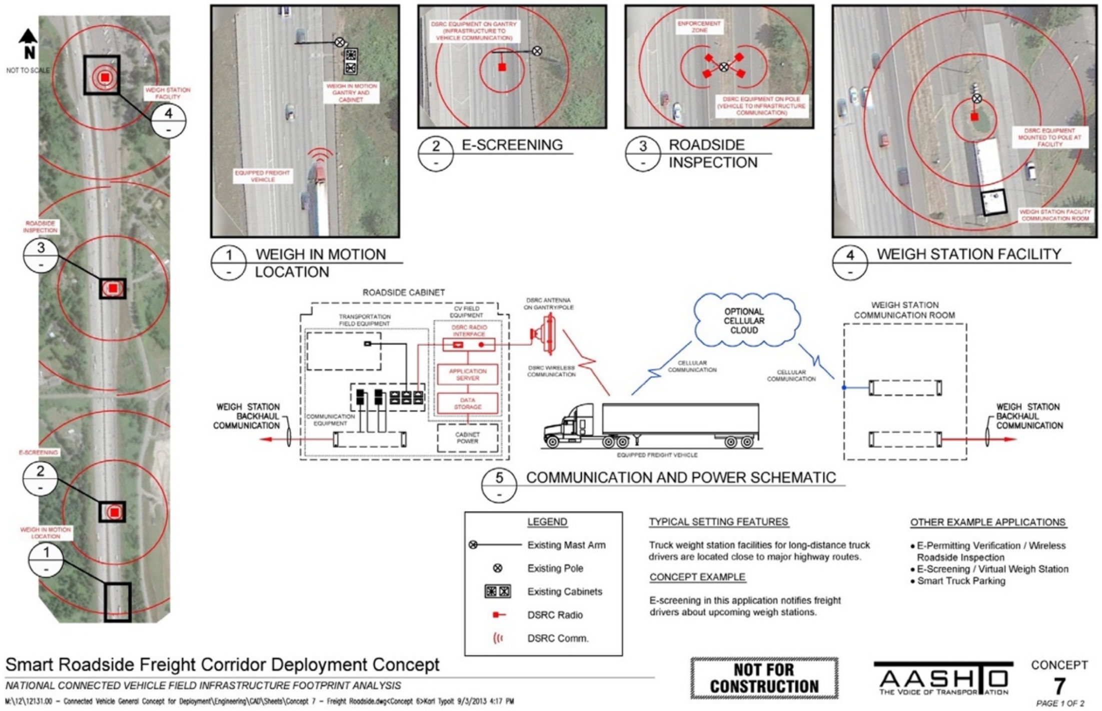

Figure 5.6: Smart Roadside Freight Deployment Concept – Weigh Station

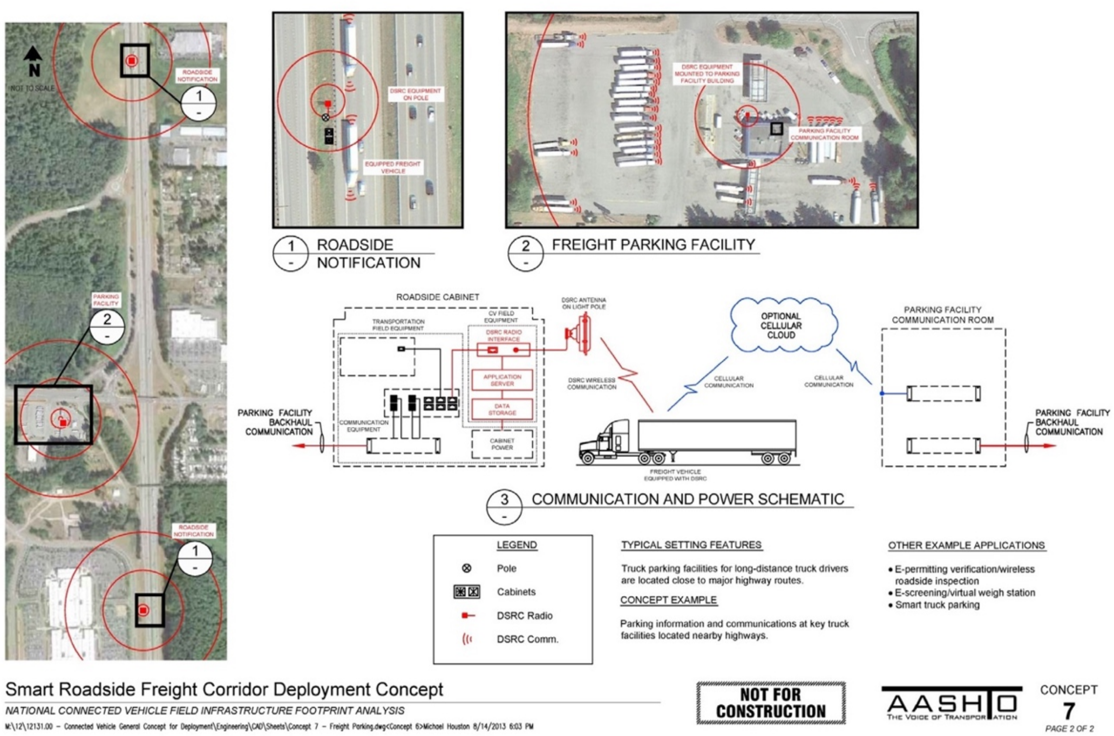

Figure 5.7: Smart Roadside Freight Deployment Concept – Parking

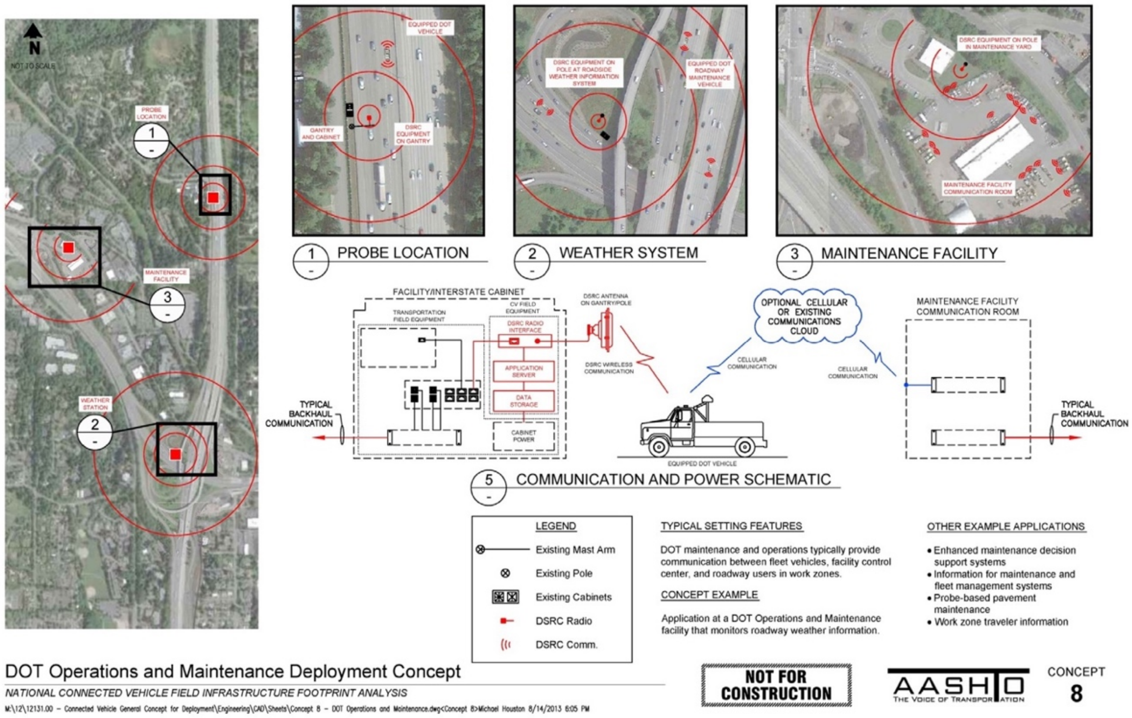

Figure 5.8: DOT Operations and Maintenance Deployment Concept

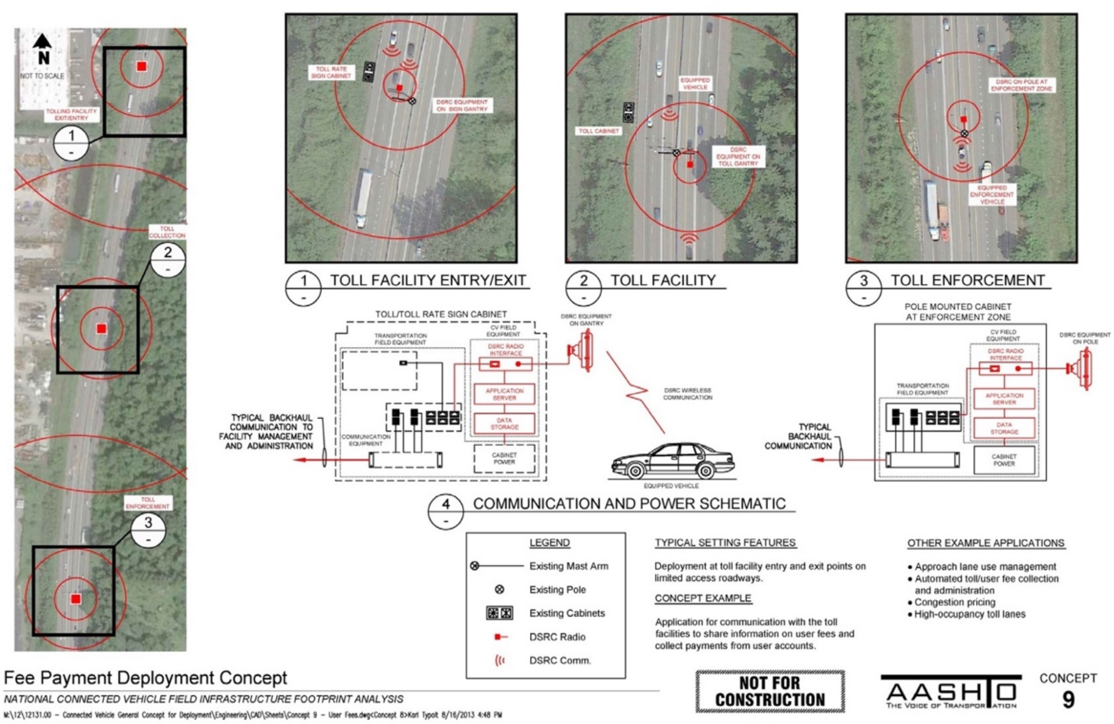

Figure 5.9: Fee Payment Deployment Concept

5.3 CALIFORNIA

5.3.1 Connected Vehicle Efforts

There are opportunities for Oregon to collaborate with neighboring states. California, with its academic partners at U.C. Berkeley, U.C. Riverside and others, has been one of the leading states in developing and deploying CV applications. Figure 5.10 shows the set of CV applications that was proposed *(Caltrans 2015)*. The One California proposal includes a comprehensive approach to CV deployment, submitted by the California Department of Transportation (Caltrans) and combining the skills and expertise of transportation agencies from three of the most progressive regions in the United States, namely the Metropolitan Transportation Commission (MTC) of the San Francisco Bay Area, the Los Angeles County Metropolitan Transportation Authority (METRO), and the San Diego Association of Governments (SANDAG).

The team defined the transportation needs and challenges affecting California's urban regions with growing populations during stakeholder meetings held in the three deployment regions, and then examined U.S. DOT defined and new CV technology applicable to these needs and challenges across four categories: mobility, environment, safety, and agency efficiency. Lending support to the team is the County of Los Angeles Department of Public Works (LADPW) and Caltrans' academic partners at the University of California (UC), Berkeley's Partners for Advanced Transportation Technology (CA PATH) and UC Riverside's Bourns College of Engineering-Center for Environmental Research and Technology (CE CERT). These academic partners have worked with Caltrans for more than 25 years, performing technical research in CV-related areas, including the implementation and operation of the existing California CV Test Bed, located in Palo Alto, CA.

Figure 5.10: Proposed One California CV Pilot Deployment Applications

Figure 5.11 shows a schematic indicating the scope, applications and locations that are proposed for California. Many of the proposed applications are in line with ODOT's priorities.

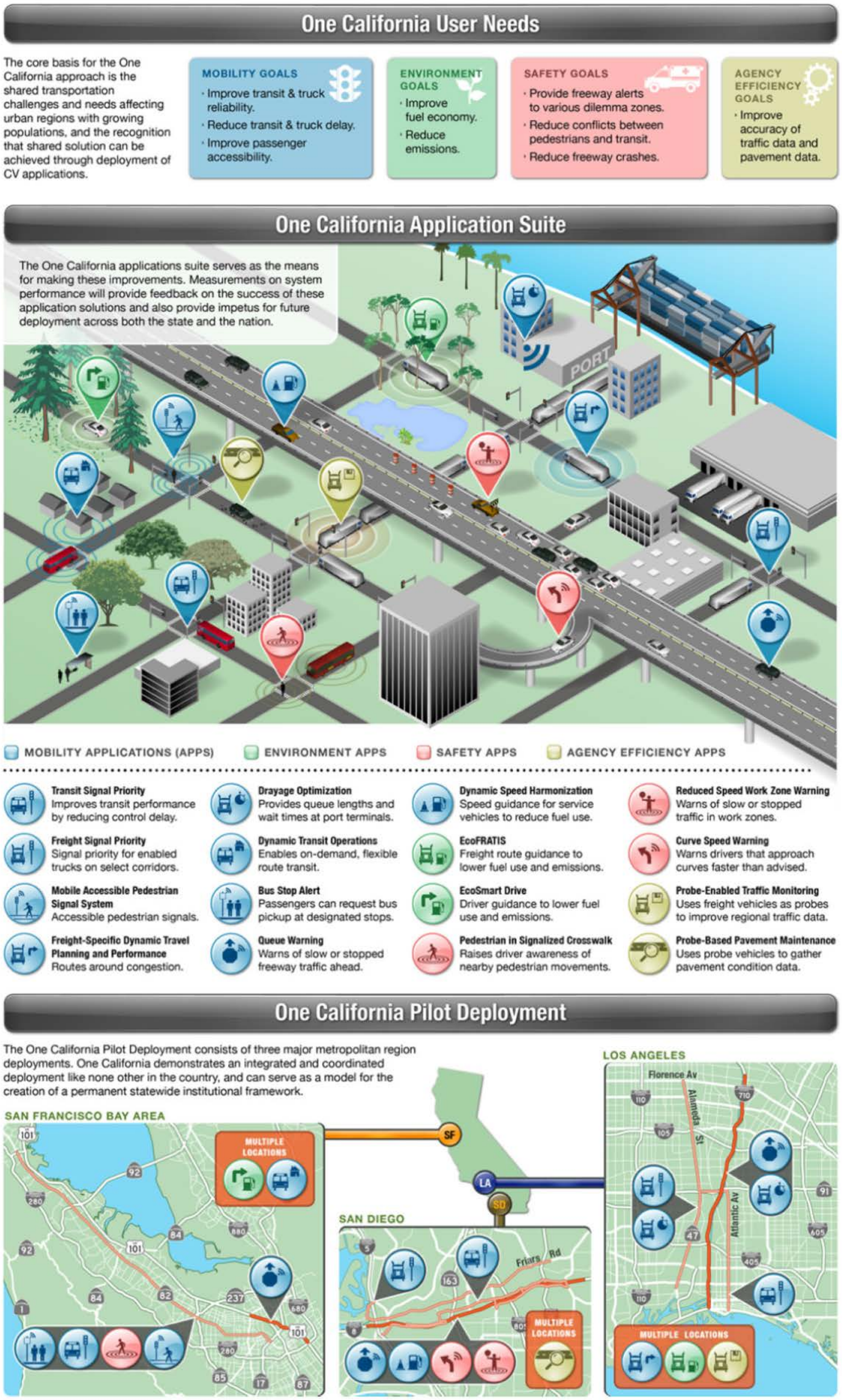

Figure 5.11: Proposed One California CV Pilot Deployment

5.3.2 Automated Vehicle Efforts

The state of California is one of a handful of states allowing automated vehicles on its roadway for research purposes. The California Department of Motor Vehicles (DMV) has released draft autonomous vehicle deployment regulations for public comment *(California DMV 2015)*. This is the next step toward allowing the public to operate self-driving vehicles on California roadways in the future (see http://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/auto).

The draft regulations are intended to promote the continued development of autonomous vehicle technology in California, while transitioning manufacturers from testing to deployment of self-driving cars. Upcoming public workshops are intended to gather input from industry, consumer and public interest groups, academics, as well as the public, to help improve the quality of the regulations that will eventually be adopted for the operation of self-driving vehicles.

Senate Bill 1298 *(Chapter 570; Statutes of 2012)* required the DMV to adopt regulations governing both the testing and the use of autonomous vehicles on public roadways. SB 1298 established several definitions that will guide the department's development of regulations.

- "Autonomous technology" means technology that has the capability to drive a vehicle without the active physical control or monitoring by a human operator.
- "Autonomous vehicle" means any vehicle equipped with autonomous technology that has been integrated into that vehicle. An autonomous vehicle does not include a vehicle that is equipped with one or more collision avoidance systems, such as electronic blind spot assistance, automated emergency braking systems, park assist, adaptive cruise control, lane keep assist, lane departure warning, and traffic jam and queuing assist.
- An "operator" of an autonomous vehicle is the person who is seated in the driver's seat, or if there is no person in the driver's seat, causes the autonomous technology to engage.
- A "manufacturer" of autonomous technology is the person that originally manufactures a vehicle and equips autonomous technology on an originally completed vehicle or, in the case of a vehicle not originally equipped with autonomous technology by the manufacturer, the person that modifies the vehicle by installing autonomous technology to convert it to an autonomous vehicle after the vehicle was originally manufactured.

In September 2014, DMV announced the regulations for manufacturers to test the vehicles. As of December 2015, DMV has issued Autonomous Vehicle Testing Permits to eleven entities:

- Volkswagen Group of America
- Mercedes Benz
- Google

- Delphi Automotive
- Tesla Motors
- Bosch
- Nissan
- Cruise Automation
- BMW
- Honda
- Ford

DMV's new draft regulations address the future use of autonomous vehicles by the public. The new draft regulations are designed to address complex questions related to vehicle safety, certification, operator responsibilities, licensing and registration, privacy, and cyber-security. Key aspects of the draft regulations include:

- **Manufacturer Certification/Third Party Testing:** Manufacturers will certify to their compliance with specific autonomous vehicle safety and performance requirements. In addition, a third-party testing organization will be required to conduct a vehicle demonstration test to provide an independent performance verification of the vehicle.

- **Licensed Driver Required in Vehicle:** A licensed operator will be required to be present inside the vehicle and be capable of taking control in the event of a technology failure or other emergency. Driverless vehicles are initially excluded from deployment. The department will address the unique safety, performance, and equipment requirements associated with fully autonomous vehicles in subsequent regulatory packages.

- **Three-Year Deployment Permit:** Manufacturers will be approved for a three-year deployment permit, which will require them to regularly report on the performance, safety, and usage of autonomous vehicles. This provisional permit is a critical first step towards the full deployment of autonomous vehicles in California. Data collected throughout the permit term will provide an opportunity to evaluate the safety and real-world performance of autonomous vehicles and inform subsequent regulatory actions by the department.

- **Privacy and Cyber-Security Requirements:** Manufacturers must disclose to the operator if information is collected, other than the information needed to safely operate the vehicle. Manufacturers will be required to obtain approval to collect this additional information. Autonomous vehicles will be equipped with self-diagnostic capabilities that detect and respond to cyber-attacks or other unauthorized intrusions, alert the operator, and allow for an operator override.

5.4 MICHIGAN

In addition to hosting the U.S. DOT Safety Pilot, as well as the new Mobility Transformation Center (MTC), the Michigan Department of Transportation (MDOT) has focused on developing possible data applications related to their five key areas of activity:

- Planning and asset management
- Design
- Construction
- Maintenance
- Operations

Given that CVs produce high volumes of data from fixed and mobile sources, MDOT has been developing a Data Use Analysis and Processing (DUAP) system *(Dion and Robinson 2010)* which focuses on using CV data and other mobile observations, in conjunction with traditional MDOT data sets, to populate a series of applications addressing the safety, mobility and asset management goals of MDOT. The initial set of DUAP applications was selected through a department-wide needs analysis. DUAP has identified approximately 124 potential applications for using CV data, as shown in Figure 5.12. The DUAP system aims to use CV and AV data, to increase data sharing and to support performance management. Data applications fall under the five activity areas mentioned above.

Planning & Asset Management	Design	Construction	Maintenance	Operations
Potential Applications to Enhance Performance Management and Data Sharing				
Pavement Conditions • IRI • PASER sufficiency ratings • Accelerometry	Pavement Conditions • Measure Rutting (traction control?) • Pavement Roughness vs. Fuel Consumption	Pavement Performance Correlation with environment • Long term pavement performance and cracking • Tracking pavement conditions for verification of reported vehicle damage • Cure time in environmental conditions • Trending data for cost/benefit analysis	Pavement Conditions • Friction • Ride Quality • Defect Type and Location • IRI PASER • Accelerometry	Pavement Conditions • Ice Forming • Tracking pavement conditions for verification of reported vehicle damage • Friction • Markings • Load Restrictions • Subsurface Impact

Traffic Planning
• Volume Distribution
• Volume Growth
• Congestion Relief
• Roadway System Planning
	Intelligent Construction Probes for comprehensive As-builds
	• Determine actual subgrade compaction state
	• Environmental conditions at time of placement
		Weather/Environment Information
		• Monitoring weather parameters
		• Frost depth
		• Best paving Conditions monitoring
		• Work Conditions Monitoring, i.e. Rain Delays
		• Greenhouse gas emissions
			Weather
			• Winter Weather Maintenance
			  • Response Times
			  • Analyzing & Tracking weather systems
			  • Winter maintenance activities
			• General Year-round Maintenance
				Traffic Management
				• Volume
				• Occupancy
				• Speed
				• Travel Time
				• Seasonal Volume Changes
				• Route Guidance
				• Incident Notification
				• User Delay Cost

HPMS & TMS • Asset Location • Current Conditions • Systems Performance	Weather stations • Ongoing environmental monitoring • Impact on life of pavement • Rate of degradation of pavement • Winter weather maintenance	Work Zone • Traffic Conditions, i.e. speed, volume, queue lengths • Lane Departures • Worker Safety • Monitor when Active	Incident Management • Time of Occurrence • Pinpoint locations • Damage tracking on infrastructure • Incident Cause • Time to repair • Damage Log • High Incident Locations	Incident Management • Incident Report • First Responders Times • First Responders Guidance • Incident Locations • High Incident Locations • User Delay Cost

Reporting:
• Volume
• Speed
• Occupancy
• Classification
• Travel Time
• Origin & Destination Planning
	Mechanistic Empirical Pavement Design
	• Weather impact
	• Fixed Station Placement
		Site Monitoring
		• Real time site monitoring
		• Utility Location for Construction Equipment (DSRC), i.e. Overhead Power Lines
		• High precision as built mapping
			Signals
			• Cost to Operate
			• Phase Analysis
			• Volume
			• Incident Analysis
			  • Vehicle Location
			  • Signal Phasing
			  • Signal Delay
				Weather Management
				• Treatment Status
				• Driving Conditions Status

Counts Path • Pedestrian • Bike	Traffic monitoring • Impact of traffic on pavement over time • Classification, Load cell	Contractor Management • Conditions of Temporary Pavement (Ride Quality) • Monitor Road/Lane Closures • Work Progress for Incentive Payments	Rest areas • Vehicles Pulling in • Time spent • Parking availability	
Truck Tracking • Freight • Light		Topological Analysis • Channel Systems Migration • Land Erosions • Water levels		

Figure 5.12: Michigan DOT CV Data Applications

The DUAP applications were screened according to several criteria including:

- Public benefits
- Agency benefits
- Industry needs and use
- Application readiness
- Data availability

As a result, five key CV applications were selected as top priorities (Smith, 2015):

- **Red Light Violation Warning** (similar to Oregon application 2): application will communicate with vehicles approaching an intersection, providing a warning that, if the current speed the vehicle was maintained, the vehicle would run a red light. Future functionality of this application could warn vehicles on the cross street of a pending vehicle entering the intersection on a red light.

- **Work Zone Warning/**Management (22, 56): application will provide real-time information to drivers on the location of lane closures due to road construction and maintenance activities. Information on additional related hazards, such as queuing due to lane closures and slow or stopped vehicles within the work zone is also expected to be provided. An initial test should be in operation in the spring of 2016.

- **Border Wait Time**: MDOT is partnering with the Ontario Ministry of Transport to implement the border wait time system for travelers and truck operators crossing the international borders between Michigan and Canada. This is being installed on the Blue Water Bridge International Crossing to Canada. A combination of Blue Tooth and fiber-optic technologies are being used, with information disseminated to motorists and commercial vehicle operators through roadside DMS, the MiDrive traveler information website, and smartphone applications.

- **Road Weather Management** (39, 42): MDOT is participating in the Weather Responsive Traveler Information (WxTINFO) project, which brings together near-time environmental and weather-related data collected from both fixed and mobile data sources, and provides this information directly to travelers. The DUAP system will perform the back-end data processing to automatically generate location-specific, real-time weather information and provide it to motorists via roadside Dynamic Message Signs (DMS), and the MiDrive traveler information website.

- **Pavement Condition** (16): application uses a suite of off-the-shelf sensors and MDOT vehicles to measure and detect pavement conditions. The application supports maintenance (performance-based maintenance and pavement defect detection), design (pavement warranties and pavement life cycle analysis), and asset management (surface conditions and ride quality).

MDOT is also using its fleet vehicles as CVs. Working with partners, MDOT has developed a suite of off-the-shelf components for use in MDOT vehicles. As of 2015, 5 MDOT vehicles have been instrumented to date, with another 15 vehicles programmed and 80 more planned for the future. MDOT's high priority applications are similar to several selected by ODOT for Near Term Focus. MDOT could be a partner for Oregon on some of these applications.

5.5 TEXAS

The Texas A&M Transportation Institute (TTI) *(Zmud et al. 2015, 2015a)* conducted a study in order to assess the implications of AV and CV deployments for state and local governments. The project developed scenarios for AV and CV deployments and then generated a set of strategies that may help public agencies prepare for potential issues that may arise in the future. Figure 5.13 shows a conceptual outline of the study process.

In order to lay the groundwork for the study, it was assumed that automated vehicles would consist of vehicles equipped with internal sensors, cameras, global positioning systems (GPS) and advanced processing and control software. The researchers used the NHTSA five levels of automation (0 No Automation, 1 Function-specific Automation, 2 Combined Function Automation, 3 Limited Self-driving Automation, and 4 Full Self-driving Automation). For the scenario, automated vehicles included personal vehicles, public transportation, and interurban and urban freight.

The connected vehicle concept included dedicated short range communications (DSRC) plus Wi-Fi and cellular communications. Data gathering and information exchange for CVs would occur through vehicle to infrastructure (V2I) and vehicle to vehicle (V2V).

The TTI researchers conducted interviews with state and local agency officials. The interviews revealed three primary reactions to the implementation of CVs:

- **Private**: agency staff assume that OEMs and the private sector will deploy V2V, so there is little incentive to get engaged.
- **Funding**: agency staff are uncertain about V2I implementation especially related to the business model for deployment, training for staff, ongoing technical staff, implementation costs, and maintaining and updating databases and detailed mapping.
- **Excitement**: despite the concerns mentioned, agency staff are excited particularly about the data that will be available from the CV applications. Data ownership and data sharing were raised as important concerns to be addressed.

The results included four primary reactions regarding AV deployment:

- **Sidelined**: agency staff feel sidelined since AV developments are being driven by OEMs and the private sector.
- **Disruptive**: agency officials are concerned about disruptive technologies and do not know what is expected from their agencies.
- **Uncertainty**: staff are uncertain about their roles and responsibilities particularly relating to AVs operating in mixed traffic with dynamic conditions.
- **Confusion**: there is confusion about how traffic signage, and striping will need to evolve in the future.

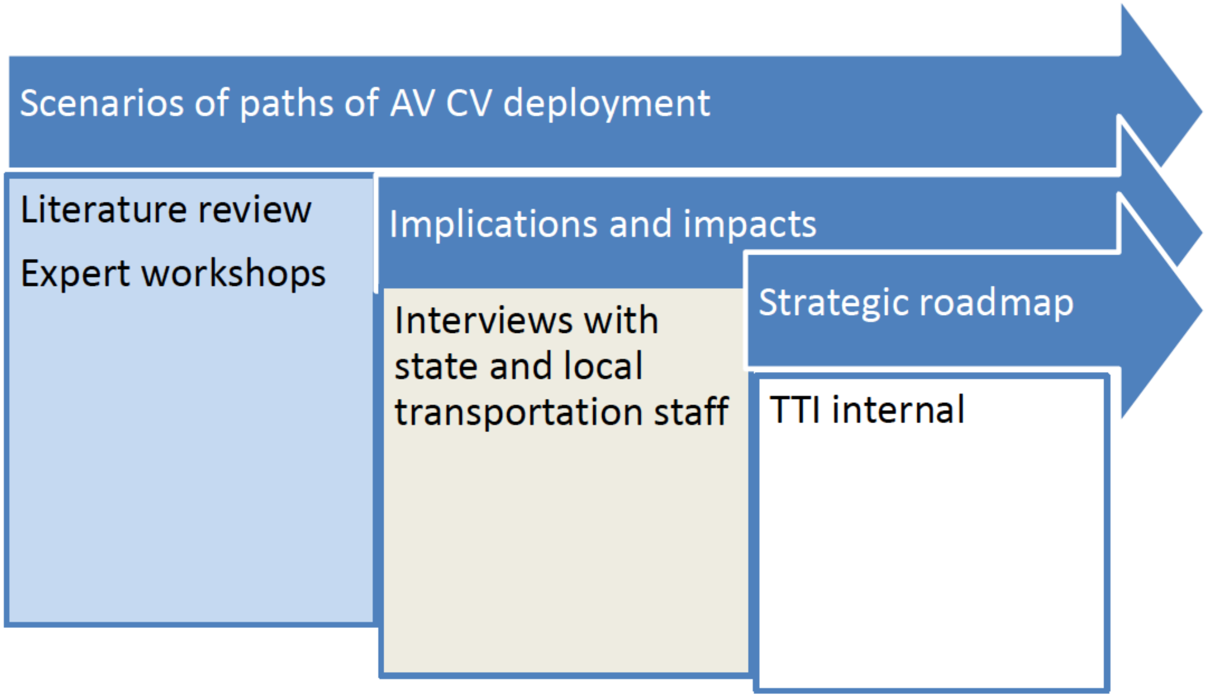

Figure 5.13: TTI Scenario-Based Roadmapping

Two distinct scenarios were scoped and used in interviews with state, MPO, local and toll authority staff to identify possible impacts and implications. The scenarios were conceived to be plausible but extreme. This allowed participants to focus on the potential impacts of two significantly different future outcomes, and provided bounds on the potential actual future realizations of CVs and AVs. To set up the scenarios, four influencing factors were considered: society, technology, economy and policy (see Table 5.2). The societal influence included market demand, consumer acceptance, auto ownership, operating environments and data privacy. The technology influence factors included driver/vehicle interface, cybersecurity, sensor technology and vehicle decision-making. The economic factors were consumer buying power, sectoral disruption, cost of technology and infrastructure investment. Policy factors focused on market-driven or prescriptive policies, V2V mandates, and liability issues.

Table 5.2: Factors by Influencing Areas

Influencing Area	**Factors**	**Projection Metric**
Society	Market demand for AVs	Degree to which consumers embrace fully automated vehicles
	Consumer acceptance of V2V and V2I	Degree to which consumers accept V2V and V2I applications
	Auto ownership trend	Rate of auto ownership
	Operating environments	Locations of early adoption (type of

Influencing Area	Factors	Projection Metric
		operating environment)
	Data privacy	Concerns over privacy and data collection
Technology	Interface between driver and vehicle	Ability to seamlessly and safely use vehicle in fully automated or manual modes
	Cybersecurity	Vulnerabilities adequately addressed
	Sensor technology	Speed of accuracy improvements for safety- critical functions (high, moderate, low)
	Vehicles' decision making under uncertainty	Capabilities for artificial intelligence (AI) decisions under unexpected traffic situations
Economy	Consumers' buying power	Ability to afford AVs
	Sectorial disruption	Extinction versus increase in jobs or industries
	Supportive infrastructure investment	Capacity of state to invest in supporting infrastructure for AV and CV
	Cost of self-driving technology	Additional cost to MSRP
Policy	Public policy perspective	Type of regulatory approach—precautionary or market-based
	NHTSA mandate on V2V technology	Year in which NHTSA mandates V2V
	Liability concerns from industry	Changes or shifts in insurance model

The results of this analysis were two scenarios: revolutionary (Figure 5.14) and evolutionary (Figure 5.15). As shown in Figure 5.14, the revolutionary scenario begins with a V2V mandate in 2016, and assumed that there would be a significant number of self-driving vehicles in use by 2025, which is consistent with some announcements from manufacturers. It was assumed that OEMs and technology companies would conduct significant research and development, leading to disruptive technologies being introduced to consumers quickly. The policy framework was assumed to be supportive of these developments.

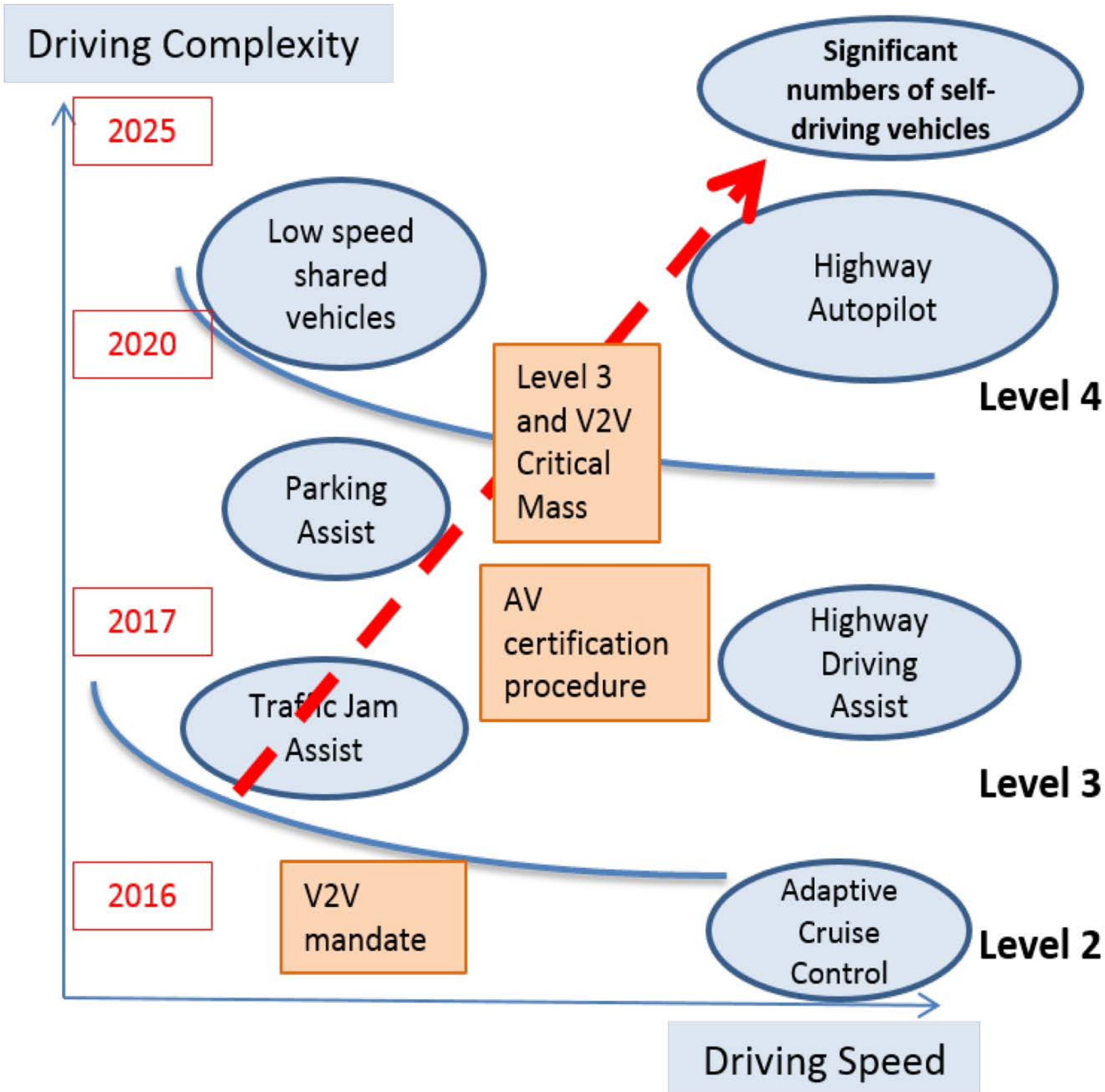

Figure 5.14: TTI Revolutionary Scenario

The evolutionary scenario is also assumed to include the V2V mandate in 2016, but sees a slower proliferation of self-driving vehicles, with a significant number appearing by 2050. The scenario assumes that technology and regulatory issues would cause friction and delay deployment. As shown in Figure 5.16, generally, the revolutionary scenario arose due to disruptive innovation and consumer demand, compared to precautionary and partisan policy making and technical issues for the evolutionary scenario. A strong economy, demand from Baby Boomers and young adults and timely support from federal, state and local legislation would also drive the revolutionary scenario. A sluggish economy, slower vehicle fleet turnover, costs, negative media and more cautious legislative actions would drive the evolutionary scenario.

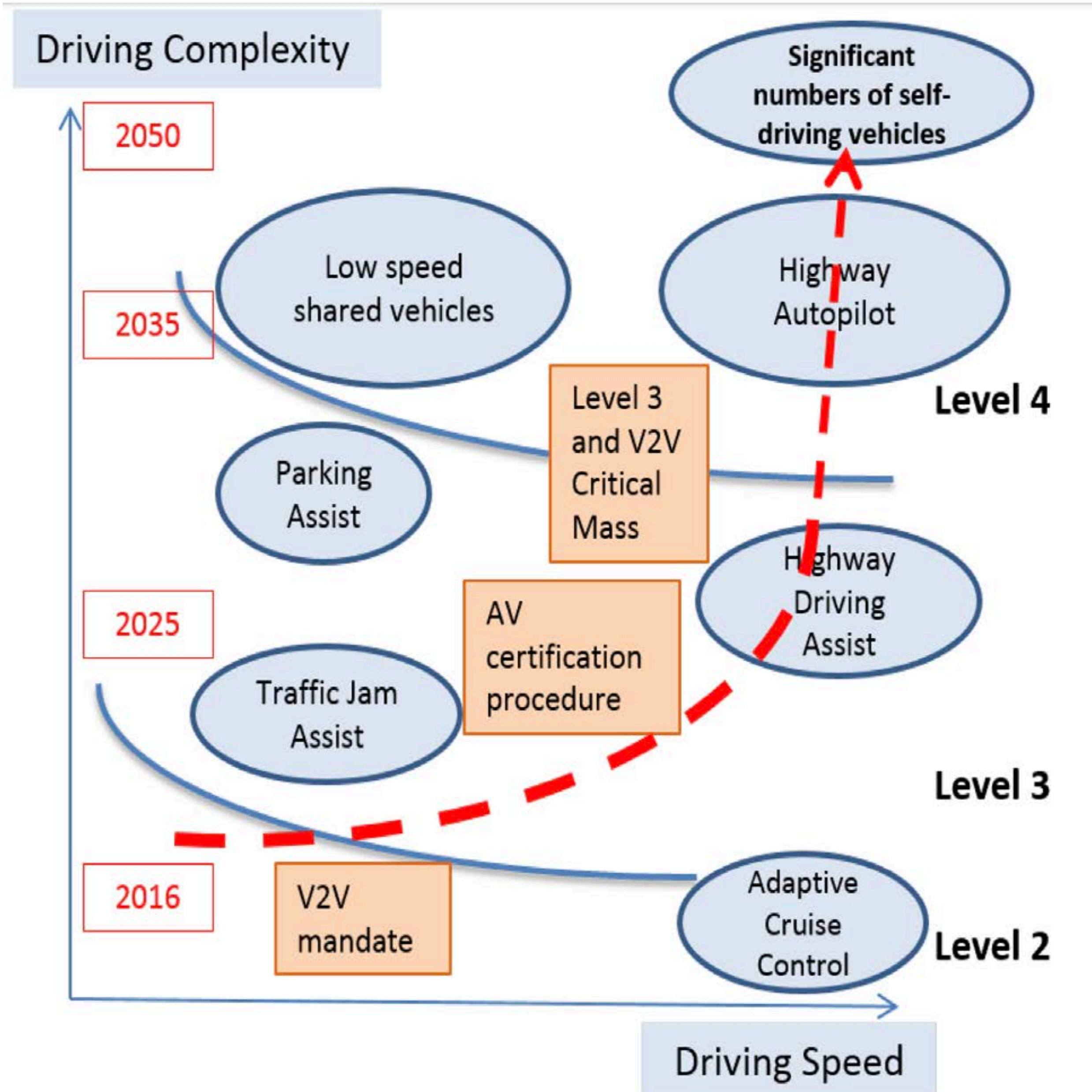

Figure 5.15: TTI Evolutionary Scenario

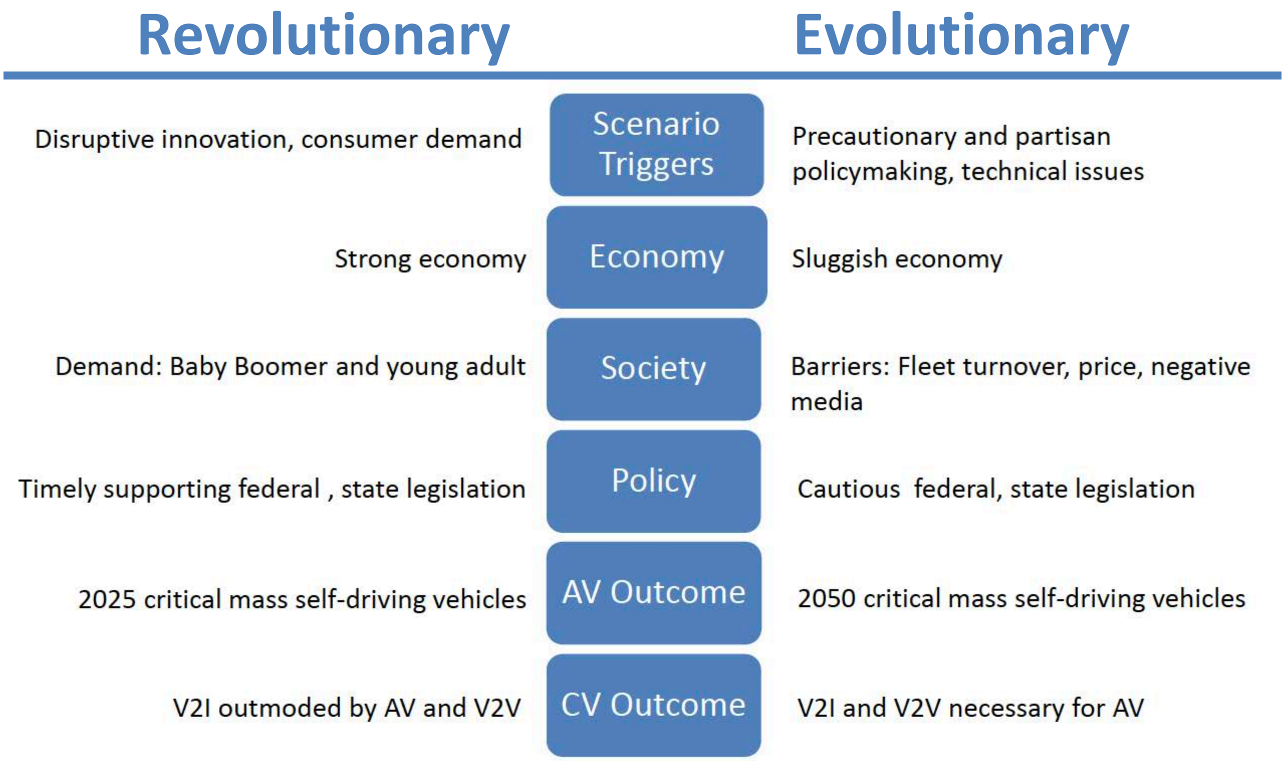

Figure 5.16: TTI Scenario Drivers

After establishing the scenarios, TTI interviewed 30 professionals from the public and private transportation sectors. As shown in Table 5.3 there were roughly even predictions and preferences for each of the scenarios (slightly higher likelihood and preference for the revolutionary scenario. Interview subjects indicated the following potential changes for their organizations based on the two scenarios:

- **Mission**: no change.
- **Responsibilities**: increased responsibilities for maintenance, operations, data management and analysis. Lower responsibility for construction, safety, human services transportation, traditional ITS and parking management.
- **Structure**: agency requires larger operations group and specific section for CV/AV.

Table 5.3: Reactions to Scenarios

Scenario	Likelihood	Preference
Evolutionary	Regulatory change and fleet turnover slow even though technology changes fast 47%	Easier to adapt, less stressful, More time to evolve the enabling infrastructure 43%
Revolutionary	AV – OEMs pushing, Consumers buying Quick use cases: Trucking, shared ride, package delivery 53%	Private sector push brings capital resources to make it happen Benefits evident and should be realized as quickly as safety to do so 57%

Agency interviewees also indicated a set of potential policy or planning actions may be necessary to prepare for CV/AV deployment, including:

- Review current legislation and policies that could impact the implementation of AV/CV technologies
- Designate a specific individual within an organization be responsible for AV/CV
- Participate in the national discussion on AV/CV
- Establish a working relationship with resources in state/region with useful expertise
- Outreach to state and local policy makers to familiarize and educate regarding AV/CV
- Develop plan for workforce development
- Formulate strategy to address financial challenges of implementation

The final element of the TTI study includes a set of research questions, including:

- What is the business case for V2I?
- To what degree is V2I technology necessary for AV deployment?
- What can we start monitoring now to understand future market development (i.e., private vehicle ownership or vehicle-on-demand fleets)?
- How do regulatory issues for AVs differ between models of private vehicle ownership or vehicle-on-demand fleets?
- What role will after-market play in AV deployment?

Many of these issues are relevant for Oregon in the context of CV deployment and should be considered as part of this roadmap.

5.6 VIRGINIA

Virginia has been active in the connected vehicle arena for many years, and leads the Connected Vehicle Pooled Fund study. Virginia is pursuing its Virginia Connected Corridors (VCC) program (see Figure 5.17). In that program they aim to facilitate deployment and integration of connected vehicle data and applications into Virginia DOT operations *(Gustafson 2015)*. The VCC program has prioritized 12 Tier 1 CV applications:

- Advanced Traveler Information [Oregon application 46.]
- Work Zone Alerts for Drivers and Workers [56.]
- Incident Scene Alerts for Drivers [22., 56]
- Red Light Violation Warning System [2.]
- Queue Warning [52.]
- V2V – Forward Collision Warning [10.]
- V2V – Emergency Electronic Brake Light [9.]
- Parking Availability
- Probe Enabled Traffic Monitoring [17.]
- Integrated Traffic Signal System [1., 47.]
- Transit Signal Priority [48.]
- Emergency Vehicle Preemption [50.]

As indicated in brackets, most of the VCC applications were also considered by ODOT. In addition, the VCC includes support for third-party application development, data services, Application Program Interfaces (APIs), reference applications and a corridor visualization application.

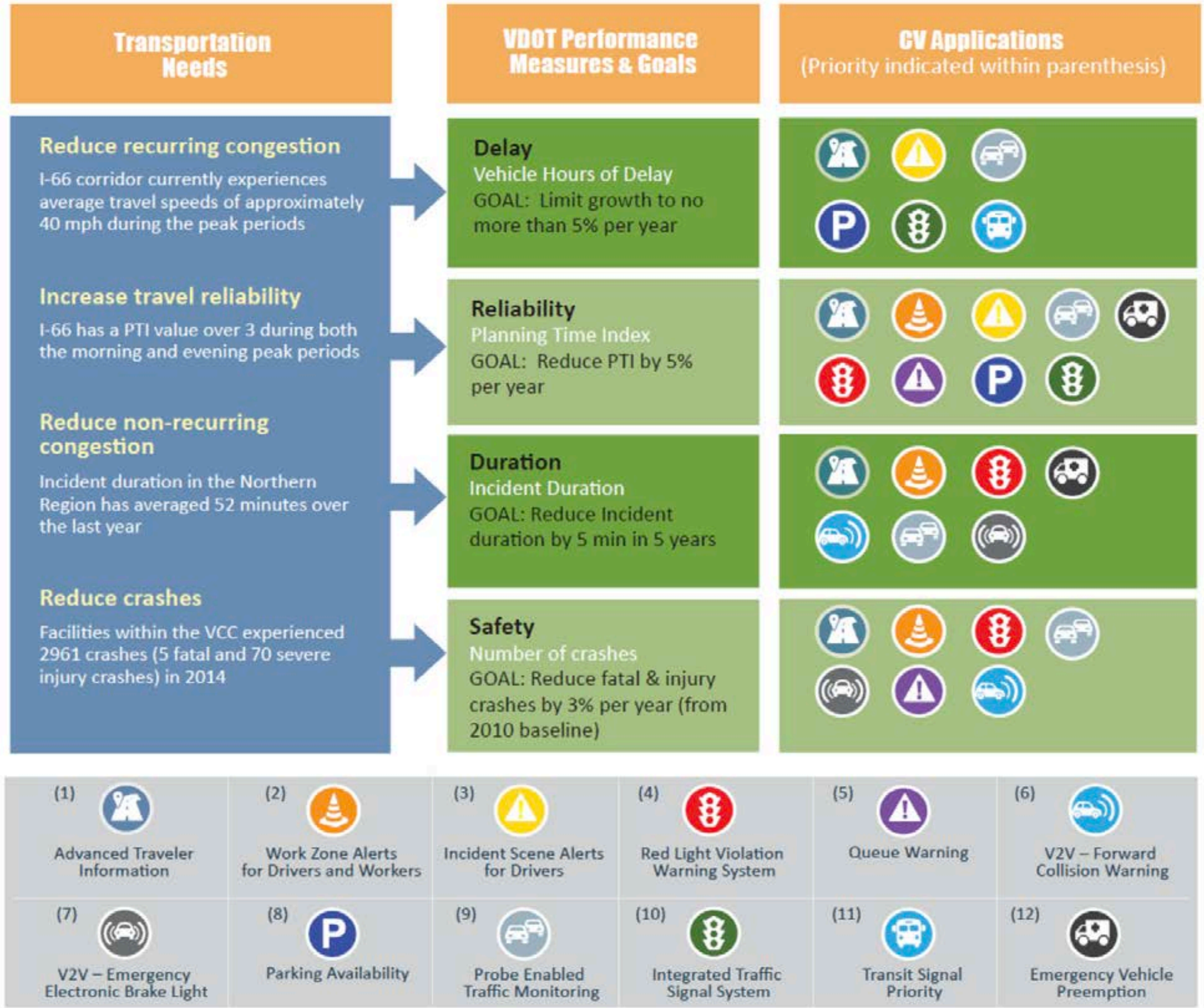

Figure 5.17: Virginia Connected Corridors

Virginia has also launched the Virginia Automated Corridors (VAC), led by the Virginia Tech Transportation Institute (VTTI) with VDOT, Transurban and HERE. The testbed includes real world environments and builds on the VCC program. The VAC includes the I-95 Express Lanes, I-66, I-495 and other primary and secondary routes in Northern Virginia.

6.0 SCENARIO PLANNING

In the Netherlands, the Delft University of Technology conducted an exploratory scenario planning exercise for the introduction of automated vehicles in that country *(Milakis et al. 2015b)* following a procedure outlined in Figure 6.1. For the purposes of this report, an extrapolation of that process for connected vehicles is presented here. There are different dimensions of uncertainties in the transportation and technology development fields. As shown in Figures 6.2 and 6.3 (shown here for CVs), it's possible to consider two axes: one for technological development (low to high), and one for the strength of support or restrictions for connected vehicles through policy actions. The resulting four "quadrants" of the matrix range from (clockwise from upper left) corresponded with four distinct scenarios:

- 1 - AVs in standby
- 2 - AVs in bloom,
- 3 - AVs in demand
- 4 - AVs in doubt

Figure 6.1: Scenario Planning Method *(Milakis et al. 2015b)*

The Dutch scenario analysis aimed to identify plausible future development paths for AVs, and to estimate potential impacts on traffic, travel behavior and transportation planning for 2030 and 2050. Using three workshops and experts from planning, technology and research organizations, the experts identified ranges of likelihood for each scenario. Scenario 2 was deemed to be most likely (41-45% certain), while scenario 4 was thought to be least likely (25% certain). Experts also explored the idea that people's value of time would be dropping with the advent of automated vehicles, with reductions of up to about 30% possible under scenario 2 by 2050. The experts also aimed to forecast the percent of AVs in the vehicle fleet, with estimates for scenario 2 of 11% by 2030 and 61% by 2050.

From this exercise, it was found that AVs would be available commercially between 2025 and 2045 and penetrate the market quickly after their introduction. The complexity of the urban environment and unexpected events could influence the development path of AVs. The impacts of AV introduction would certainly have implications for mobility but there is a high level of variation of those impacts (including fleet penetration and vehicle miles traveled). The study concluded by stating that measures aimed at curbing VMT growth and related externalities would be necessary in three out of the four scenarios.

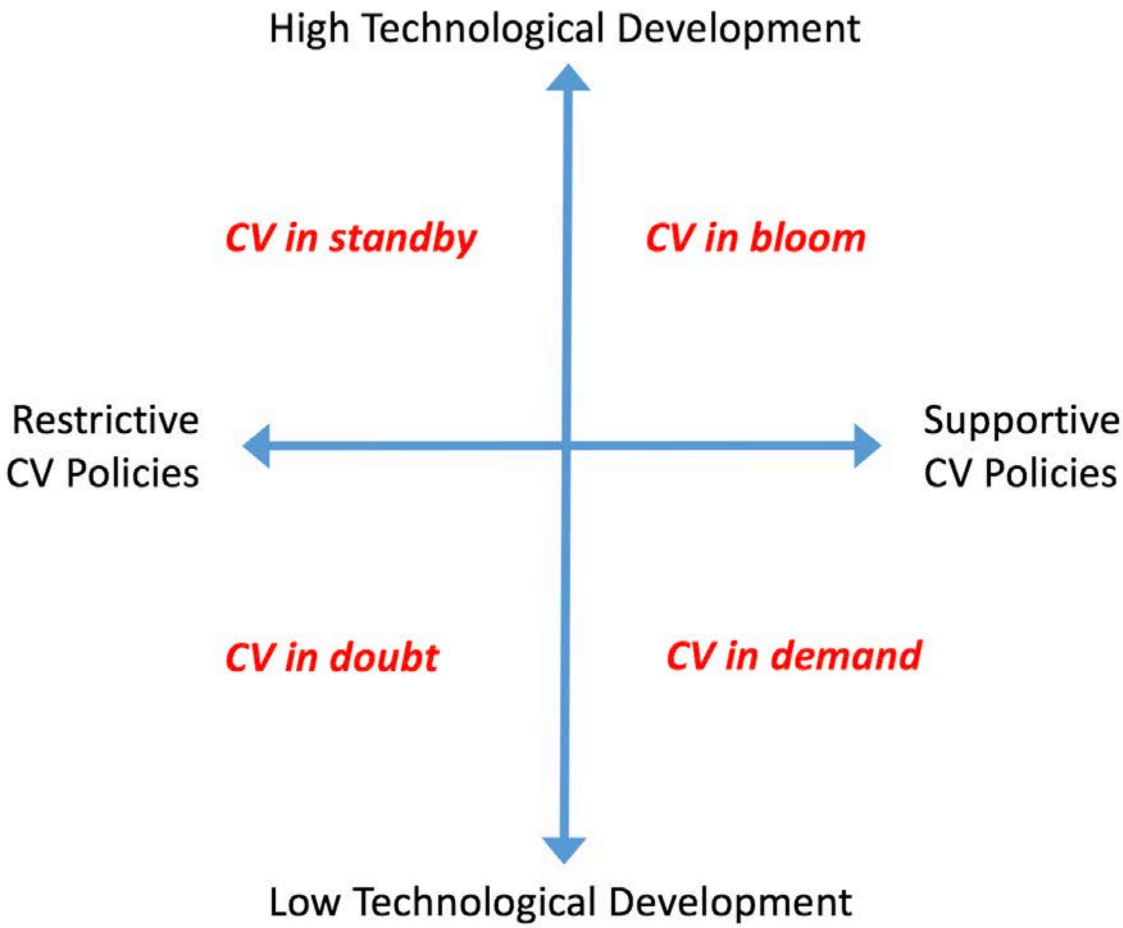

Figure 6.2: *(Milakis et al. 2015a)*

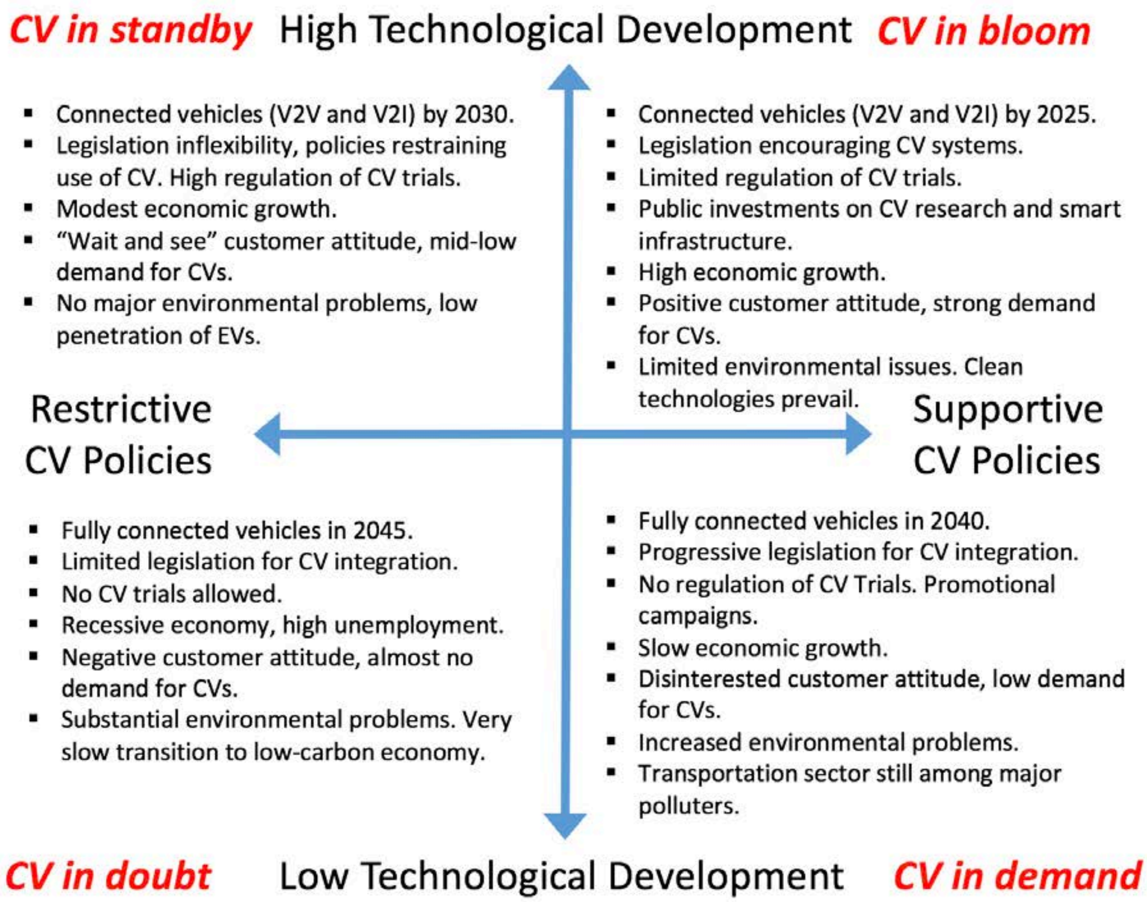

Figure 6.3: *(Milakis et al. 2015a)*

7.0 SPATIAL ANALYSIS OF OREGON ROADSIDE DEVICES FOR POTENTIAL V2I ADAPTATION

7.1 OREGON HIGHWAY NETWORK OVERVIEW

A future with connected vehicles will certainly consist of both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) applications. According to AASHTO *(AASHTO 2011)*, future V2I deployment will require some level of infrastructure investment including installation and maintenance of roadside equipment (RSE) and roadside units (RSU). Some electrical power and wired or wireless communications will be needed. For the Oregon Department of Transportation (ODOT) to be prepared for future V2I applications, it was possible to conduct a spatial analysis of the existing state-maintained roadway system and explore the locations and distribution of existing roadside devices that include electrical power and wired or wireless communications capabilities (referred to as backhaul). This section uses data and mapping retrieved from ODOT's TransGIS website (https://gis.odot.state.or.us/transgis/), which is a rich resource of spatial data regarding the transportation network. Generally speaking, ODOT is responsible for the following inventory:

- 8,300 Miles of Highway (2013)
- 55 Million Vehicle Miles Traveled Daily (2012)
- 805 Intelligent Transportation System (ITS) Assets (2014), including:
  - CCTV
  - Collision Warning System
  - Detector Station
  - Highway Advisory Radio Sign
  - Highway Advisory Radio Beacon
  - Ramp Meter
  - Ramp Gate
  - Road Weather Information System
  - Sensor
  - Snow Zone Sign

- Vehicle Alert System
- Variable Message Sign
- Variable Speed Limit Sign
- Flood Sensor

- 1,955 Traffic Signal Assets (2013)
- 25 Weigh in Motion (WIM) Sites [not used in this analysis]
- 191 Automatic Traffic Recorder (ATR) Stations [not used in this analysis]
- 2,371 Rail Crossings [not used in this analysis]
- 101 ODOT Maintenance Stations [not used in this analysis]
- 5,500 ODOT Fleet Vehicles/Equipment [not considered in this analysis]

As shown in Figure 7.1, about half of the ITS devices are located in Region 1 (50%) with smaller proportions located in the other regions. Figure 7.2 shows that the largest numbers of ITS devices are closed circuit television (CCTV), ramp meters and variable message signs. Figure 7.3 shows the spatial arrangement of all ITS assets throughout the state of Oregon. As indicated, most of the devices are concentrated in the Portland metropolitan region, with other clusters in the Eugene area, along major interstates and state highways and near the California border. Figure 7.4 shows the distribution of ITS assets by type across the state. Most ITS assets have both power and communications backhaul. Many of the ITS assets are already located where there are traveler information, weather, safety or traffic management needs. Upgrading these to include DSRC to enable V2I applications may make sense in the future, and may allow for increased benefits to traveler safety, mobility and sustainability.

Figure 7.5 shows the distribution of traffic signal assets owned and maintained by ODOT. All signal installations have power but only about half have communications backhaul. Intersections are key opportunity areas for V2I applications and so it makes sense to take advantage of existing traffic signal installations as locations for early deployment of DSRC and V2I capabilities.

With nearly 3,000 “spots” on the Oregon highway network with power and most with communications backhaul, the next step of this analysis will assess what proportion of the road network and what proportion of the VMT would be “covered” by V2I installations at these sites. Of course, a full statewide deployment of V2I RSUs would require an assessment of other sites for specific applications but this analysis provides a baseline for such a next step.

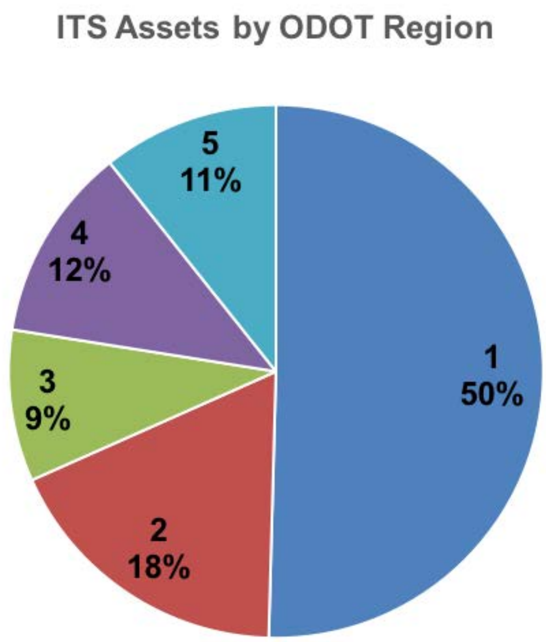

Figure 7.1: **ITS Assets by ODOT Region**

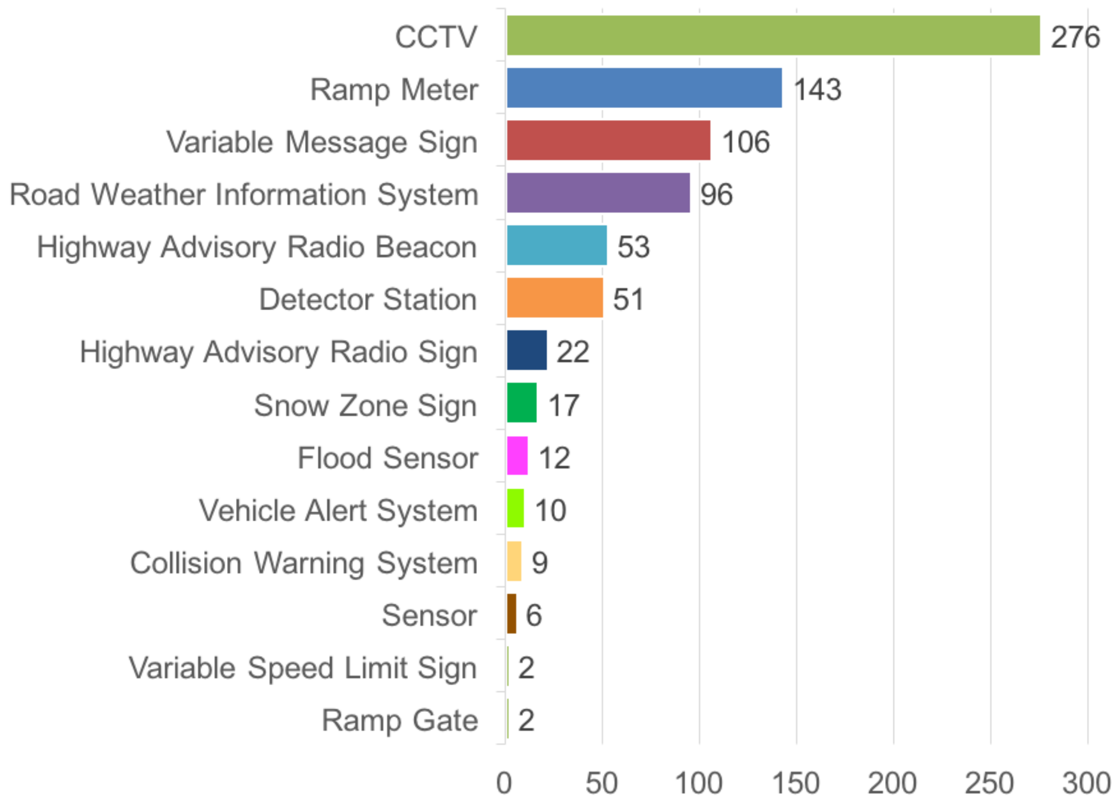

Figure 7.2: ITS Assets By Type

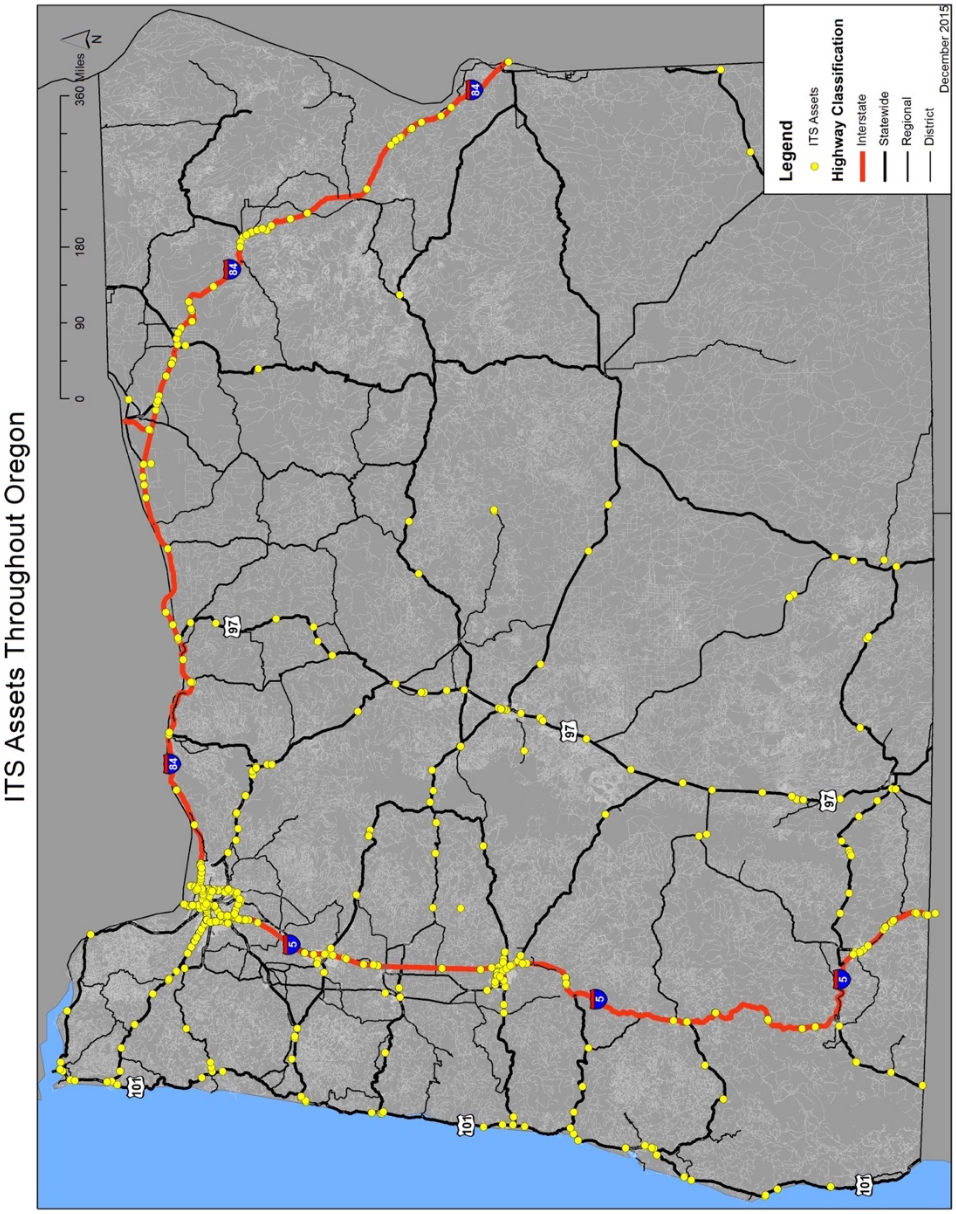

Figure 7.3: ITS Assets Throughout Oregon

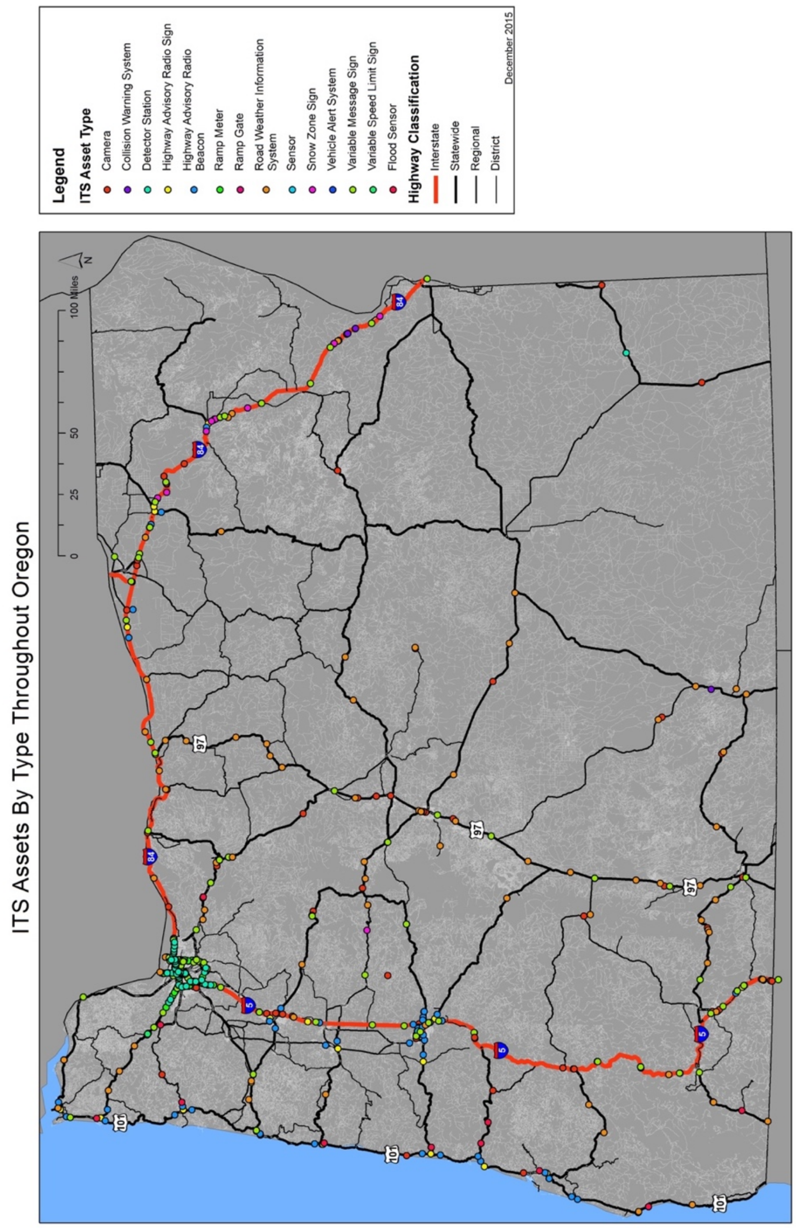

Figure 7.4: ITS Assets By Type Throughout Oregon

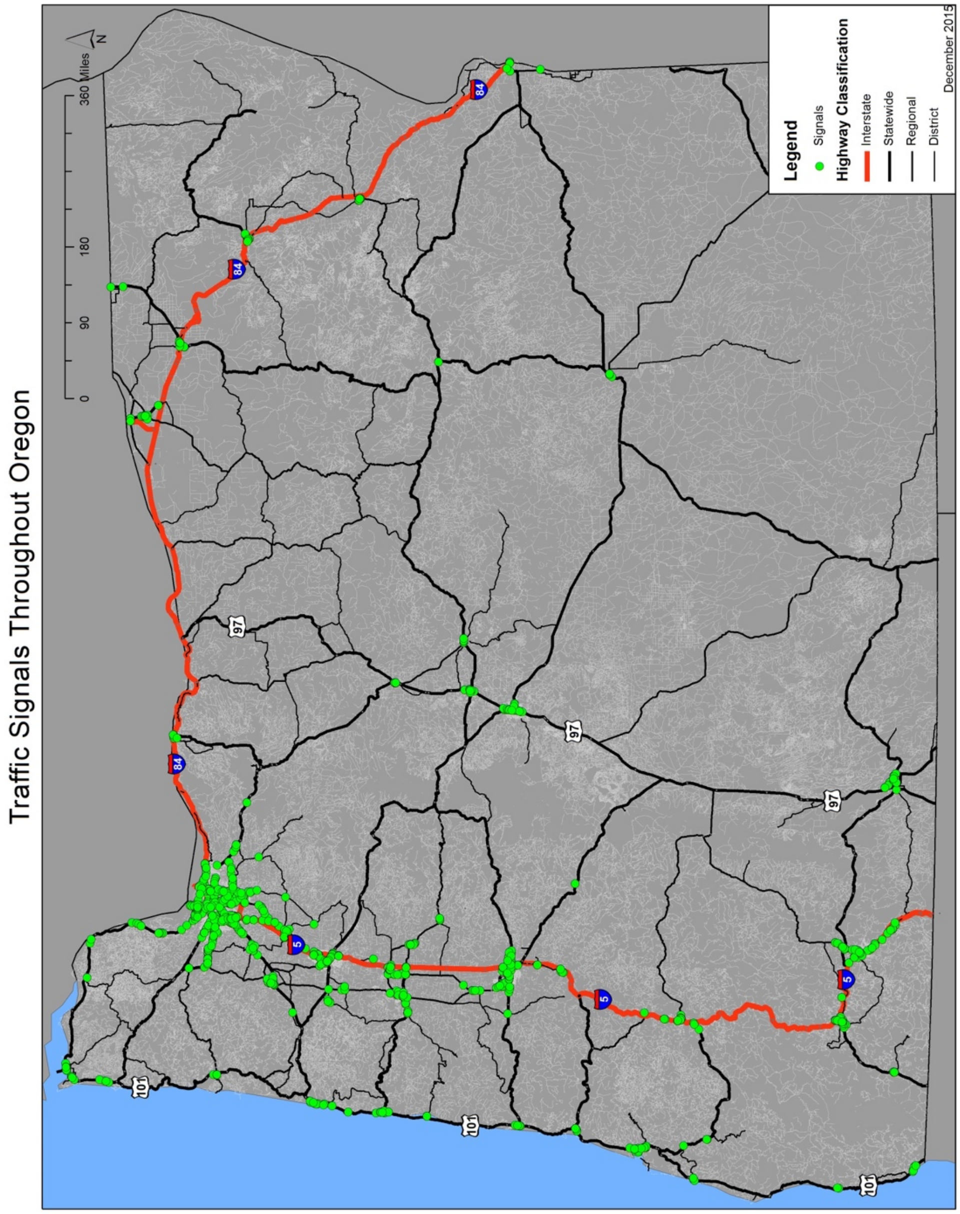

Figure 7.5: Traffic Signals Throughout Oregon

7.2 NETWORK ANALYSIS

The objective of this section is to analyze the spatial coverage of the existing roadside devices on the Oregon state highway network. For future deployment of V2V applications, the notion is that Oregon could take advantage of existing spots with electrical power and communications backhaul as an initial set of RSU installations. If an RSU can be installed in an existing cabinet, taking advantage of power and communications linkages already in place, this can help accelerate and reduce the overall cost of these deployments. An “early” deployment opportunity can be taken advantage of leading to the potential for greater benefits being realized sooner.

As shown in the figures above, there are more than 800 ITS assets and nearly 2,000 traffic signal assets distributed around the highway network in Oregon

The issue of defining the range of a DSRC radio is complex and depends on the purpose, location and many other factors *(CAMP 2004; Meier 2005)*. However, it is usually assumed that DSRC communications will work in a 300-meter radius, so for this purpose a radius of 1000 feet was used as the upper end. Since some applications require shorter ranges for communications, a 500-foot radius was also analyzed. There are other requirements in the IEEE standards for DSRC that use a 1000-meter range/radius distance *(Meier 2005)* which translates to about 3,000 feet, so this analysis can be considered to be conservative. For this analysis, first for just the ITS assets, we examined 500-foot and 1000-foot radius buffers around each spot on the network. Figure 7.6 shows an example of the buffer analysis that aimed to measure the coverage of DSRC signals emanating from existing locations of ITS assets.

Using ArcGIS, the methodology was to buffer 500 feet and then 1000 feet (diameters of the buffer). The buffers were all merged so that any overlap was merged together and was not double counted. The analysis then measured the cumulative distance along the Oregon highway network that was "covered" by these buffers. The results will indicate the total length (and percent) of the Oregon highway system that would be reached by DSRC devices placed at existing ITS sites, as well as at all existing ITS sites plus traffic signal sites. Table 7.1 contains the results of this analysis.

Figure 7.6: **Example of Buffers around ITS Assets and Signal Sites**

Table 7.1: Statewide Network Analysis Results for Coverage

	Buffer Distance (ft)	**Highway Miles**	**Network Coverage** (%)	**Daily VMT**	**Percent of Daily VMT**
ITS Assets	500	216	2.7%	6,526,800	11.7%
ITS Assets	1000	383	4.7%	10,926,400	19.5%
ITS & Signals	500	498	6.1%	12,363,000	22.1%
ITS & Signals	1000	871	10.7%	21,434,700	38.3%

As showing in Table 7.1, using the 1000-foot buffer distance, a total of 871 miles of state highway would be "covered" by DSRC signals. This means that 10.7% of the entire state highway mileage would be covered. While this does not sound like much at first glance, these segments account for more than 38% of the daily vehicle miles traveled (VMT) across the state, so not surprisingly a significant portion of the state's traffic would be exposed to potential future V2I communications if the existing ITS assets and traffic signals were to be used as initial deployment sites.

Further research and analysis could be done with this as a starting point. Using the highway network, plus ITS Assets and Traffic Signal locations as a starting point, an initial layout optimizing locations of DSRC devices could be presented, with an effort aimed at minimizing the number (and thus cost) of devices while maximizing coverage and exposure to Oregon traffic.

7.3 CONSIDERING SAFETY PRIORITY INDEX SYSTEM (SPIS) SITES

The analysis in the previous section takes the (non-optimized) locations of ITS assets and traffic signals as "given," and computes the coverage of the highway network that would result from adding DSRC capability to these power and communications equipped spots. Many of the V2I enabled connected vehicle (CV) applications are aimed at improving safety. ODOT has an excellent safety data system so that it is possible to assess the degree to which enabling existing ITS assets and traffic signals with DSRC could reach high priority safety locations on the highway network. The idea is that based on historical knowledge of crash locations, it would be possible to deploy V2I safety applications to address the highest priority sites.

The Safety Priority Index System (SPIS is a method developed by ODOT for identifying potential safety problems on state highways. SPIS is a tool used to identify crash history in 0.10 mile or variable length segments on state highways. SPIS scores are developed based upon crash frequency, severity, and rate. Each indicator is weighted and summed to yield a SPIS score:

- Crash Frequency is weighted 25%
- Crash Rate is weighted 25%
- Crash Severity is weighted 50%

A prioritized list is created for each region (the top 10 percent of statewide SPIS sites) and is provided to regions annually for analysis and possible corrective action. Figure 7.7 shows the Statewide SPIS map from 2014, which includes 14,936 SPIS sites (crash data from 2011-2013), while 7.8 shows the SPIS sites in a GIS framework.

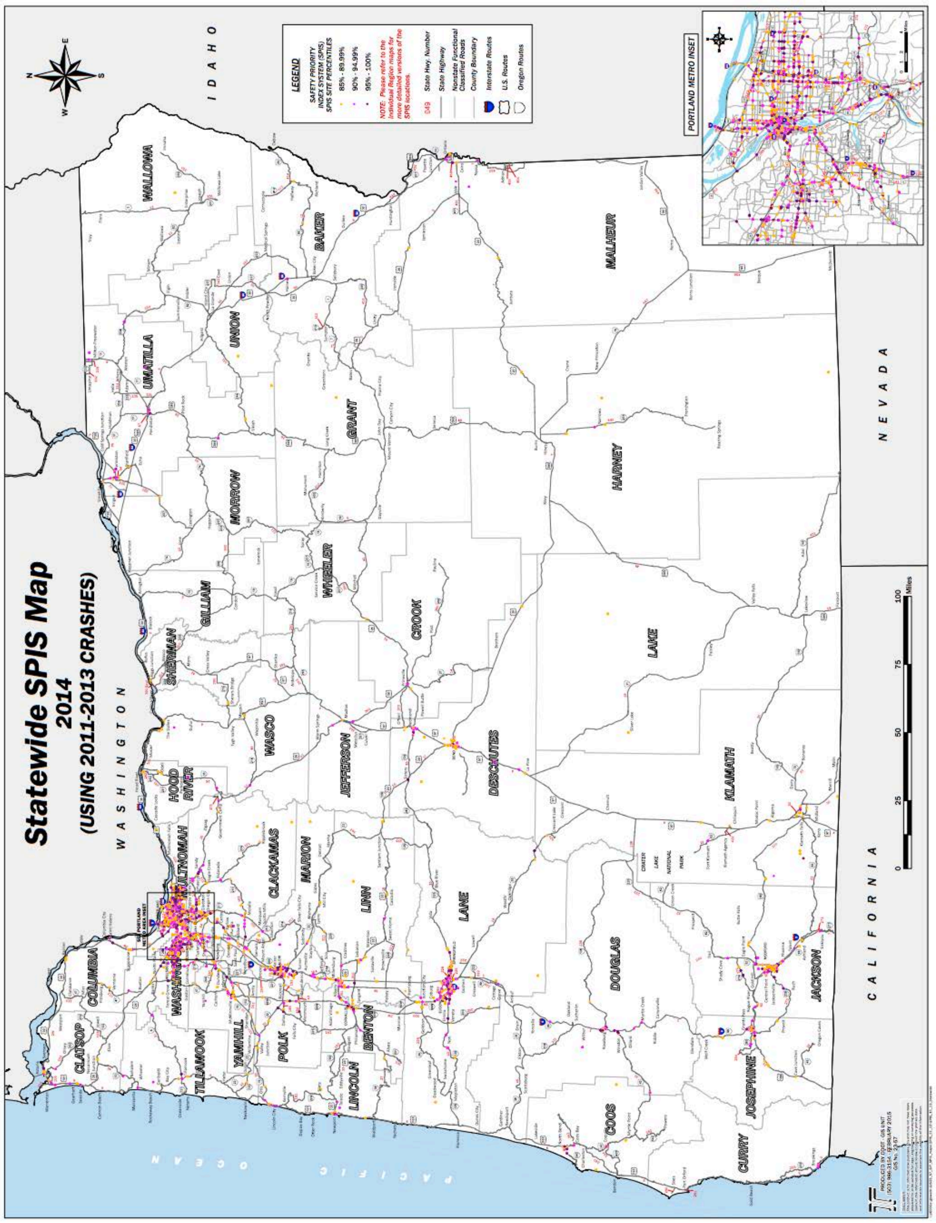

Figure 7.7: Statewide SPIS Map

2011-2013 SPIS Sites Throughout Oregon

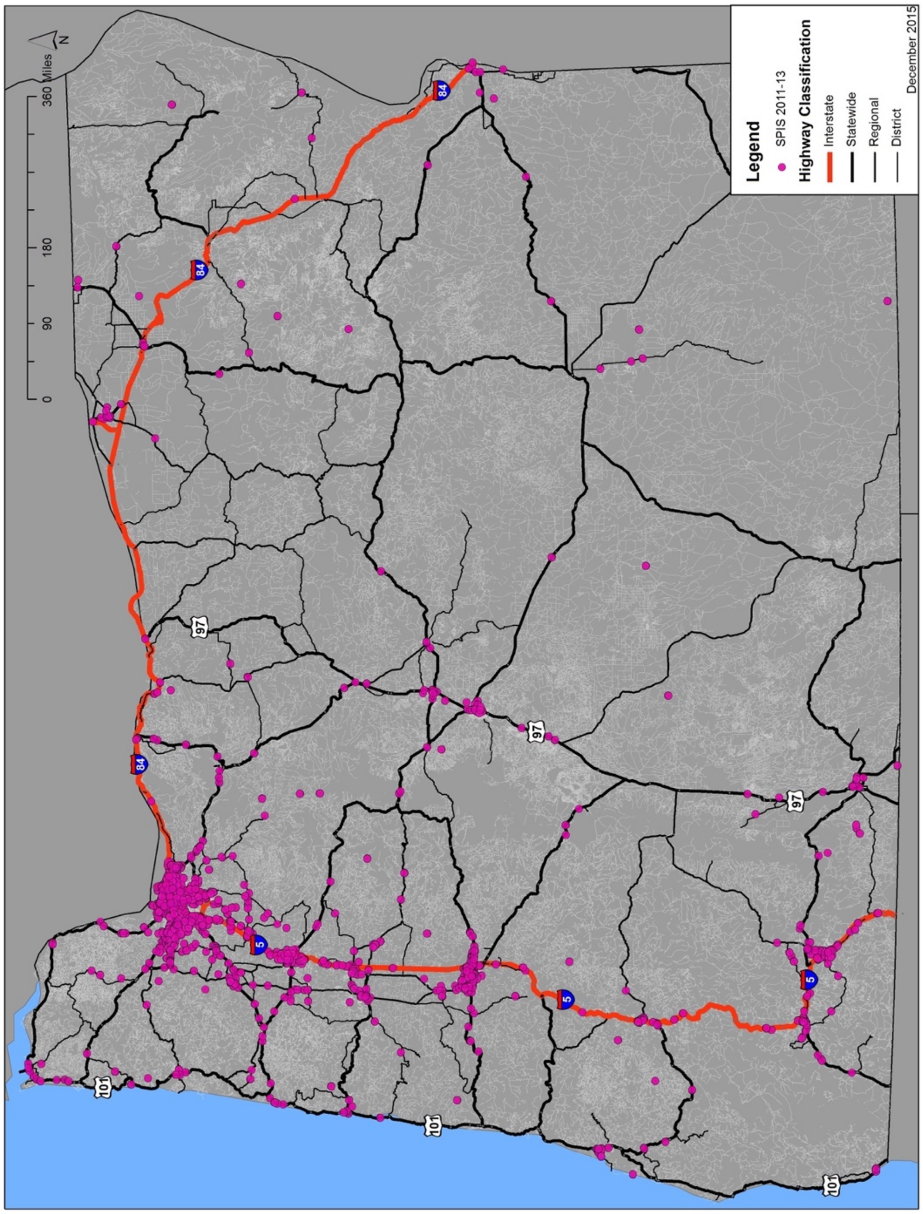

Figure 7.8: 2011-2013 SPIS Sites Throughout Oregon

Following a similar procedure as in the previous section, a buffer analysis was conducted in order to assess what proportion of the SPIS sites were within 500 foot or 1000 foot range of existing ITS Asset locations. Figure 7.9 shows the map of the 543 SPIS sites within a 500 foot range of ITS assets for the entire state, and Figure 7.10 shows the map of the 1,019 SPIS sites within a 1,000 foot range of ITS assets. Because it’s difficult to see the buffers at the statewide scale, Figure 7.11 shows a zoomed in map of both the 500-foot and 1,000-foot buffers around the ITS assets just for the Portland metropolitan region.

SPIS Sites Within Range of ITS Assets

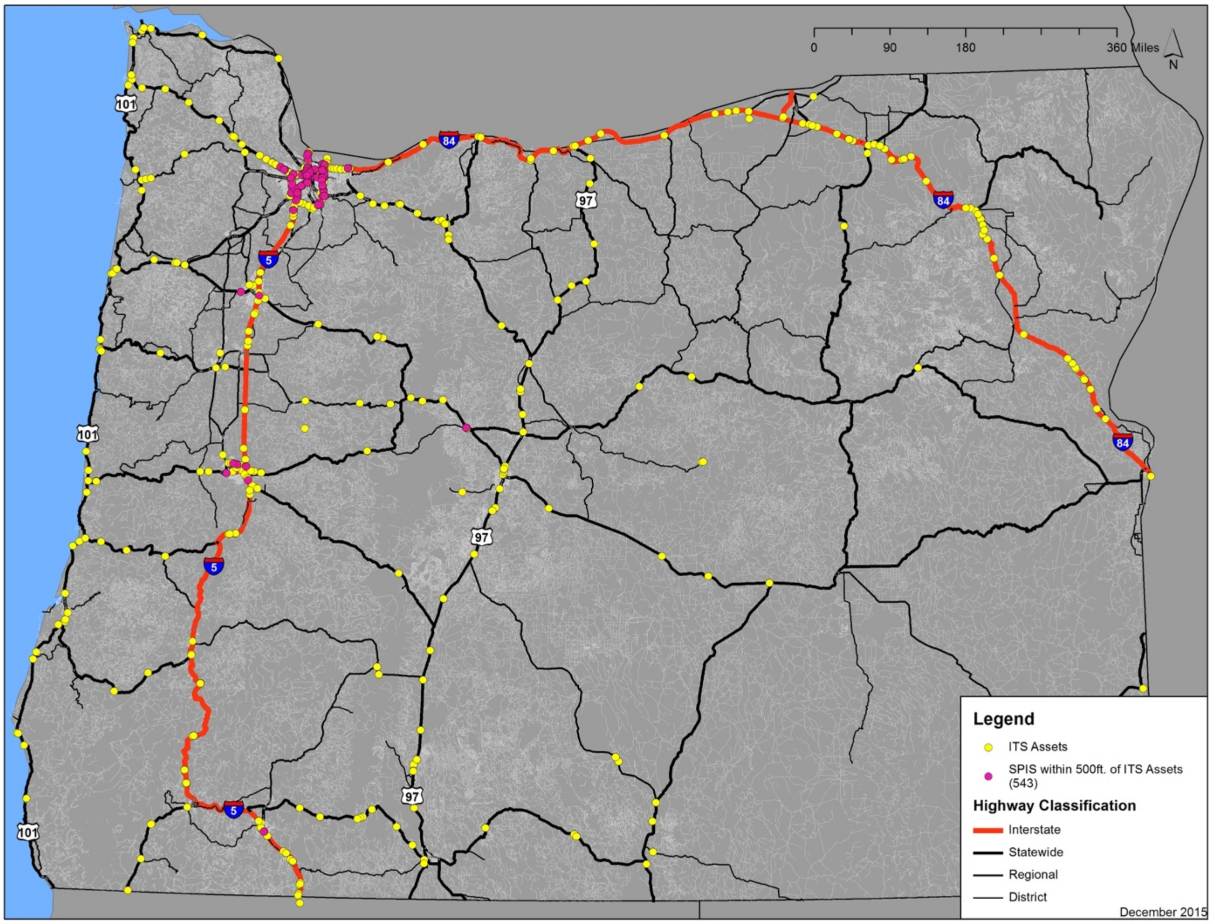

Figure 7.9: SPIS Sites Within 500 Foot Range of ITS Assets

SPIS Sites Within Range of ITS Assets

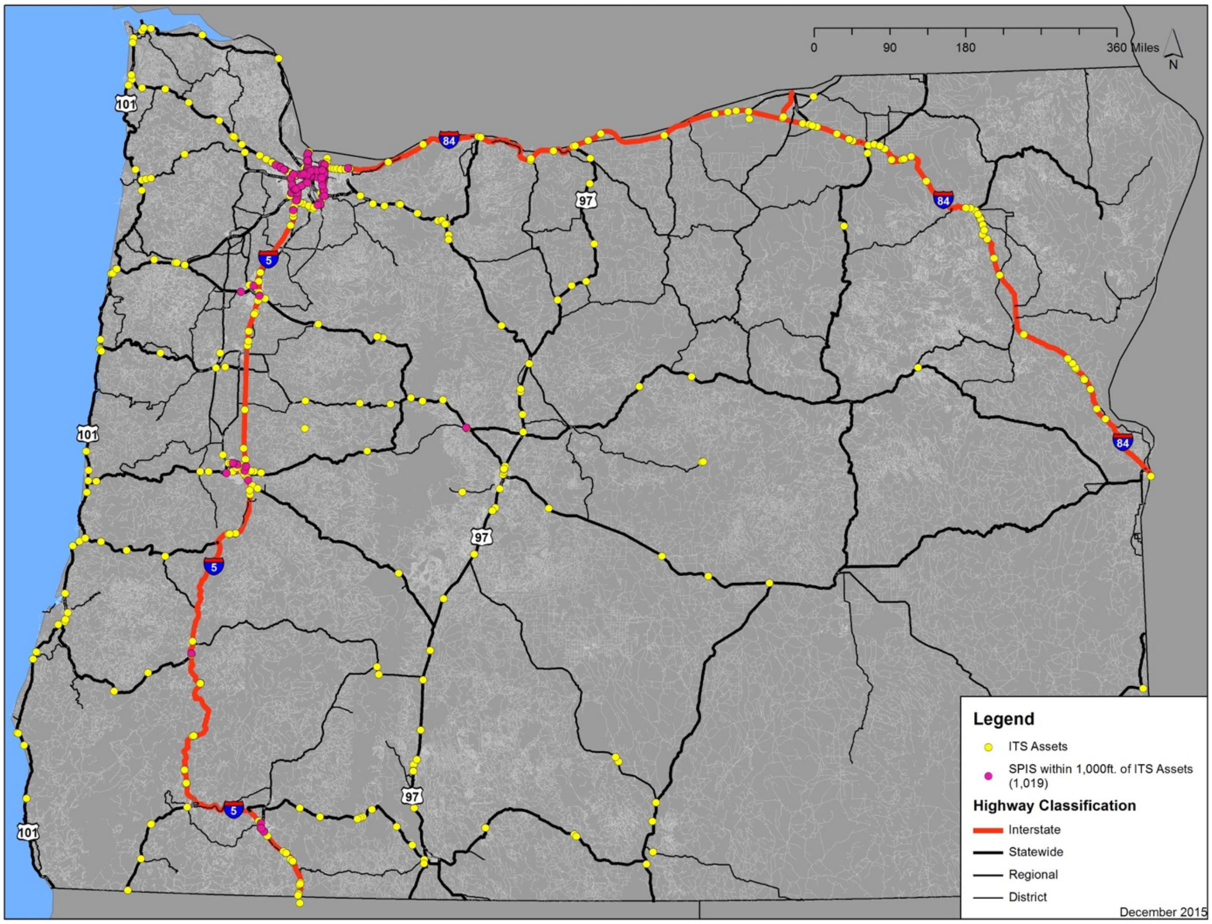

Figure 7.10: SPIS Sites Within 1000 Foot Range of ITS Assets

SPIS Sites Within Range of ITS Assets (Portland, OR)

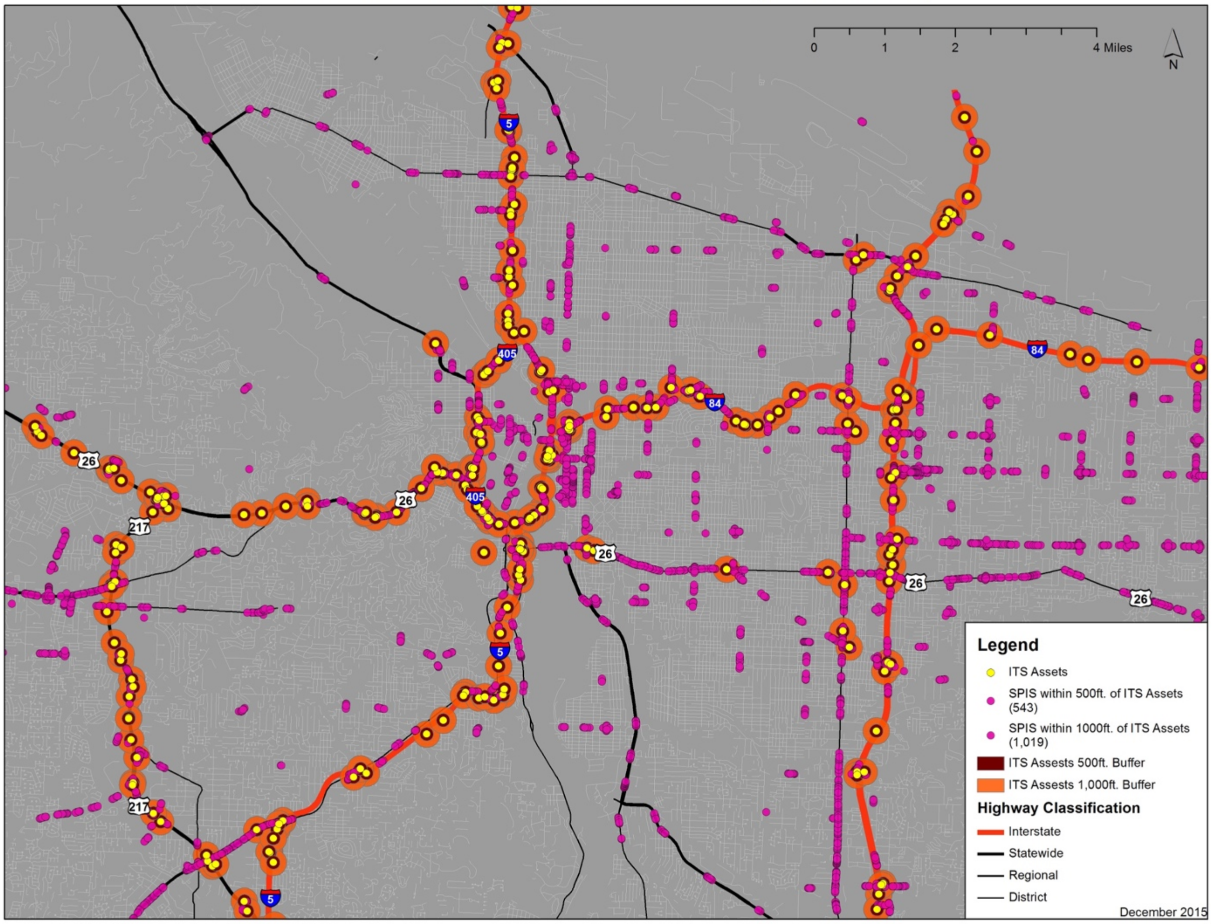

Figure 7.11: SPIS Sites Within Range of ITS Assets (Portland, OR)

Following a similar procedure as in the previous section, a buffer analysis was conducted in order to assess what proportion of the SPIS sites were within 500 foot or 1000 foot range of existing traffic signal locations. Figure 7.12 shows the map of the 1,934 SPIS sites within a 500 foot range of traffic signals for the entire state, and Figure 7.13 showemphasis in Oregon is shown in Figure 8.2 s the 2,222 SPIS sites within 1,000 feet of traffic signal sites, again for the entire state. Because it is difficult to see the buffers at the statewide level, Figure 7.14 shows a zoomed in map of the 500-foot and 1,000-foot buffers for just the Portland metropolitan region.

SPIS Sites Within Range of Traffic Signals

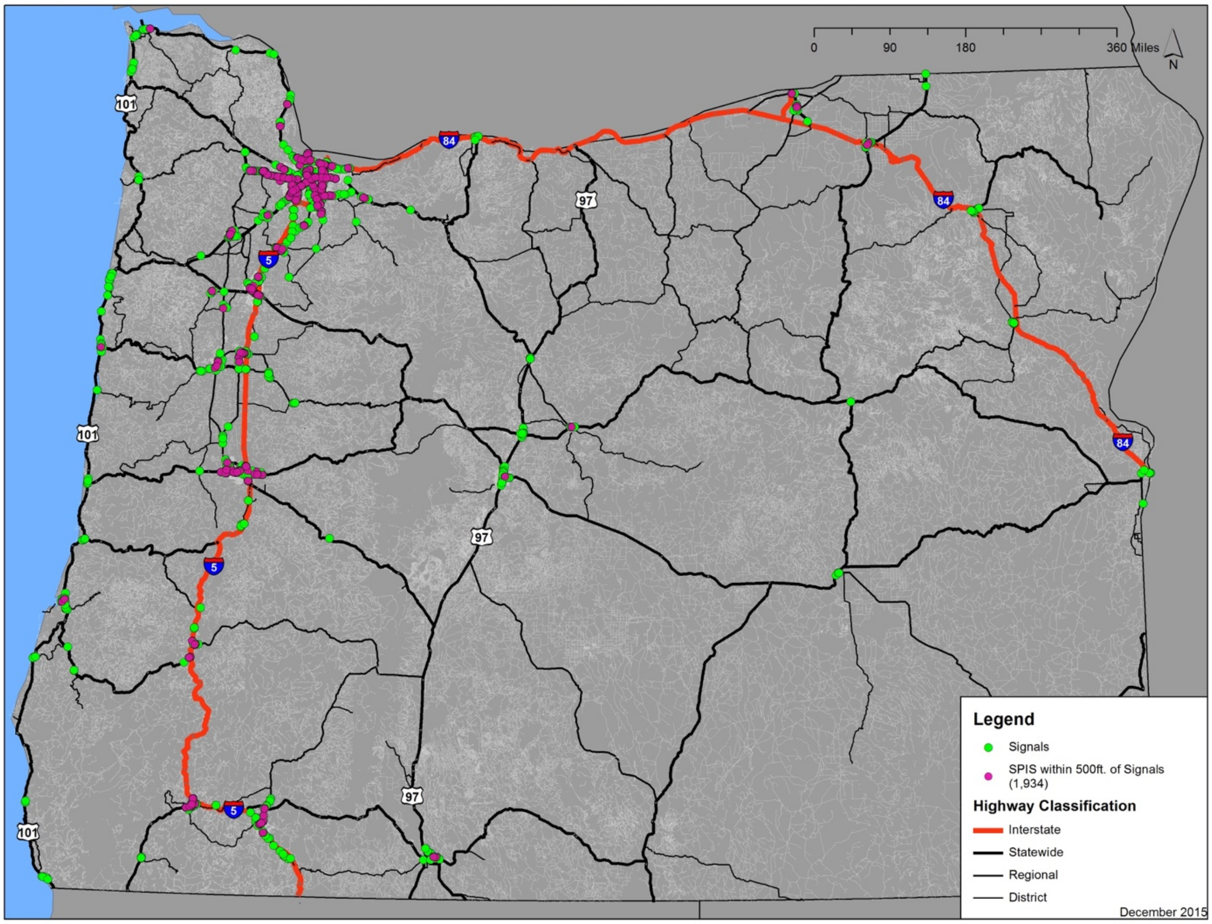

Figure 7.12: SPIS Sites Within 500 Foot Range of Traffic Signals

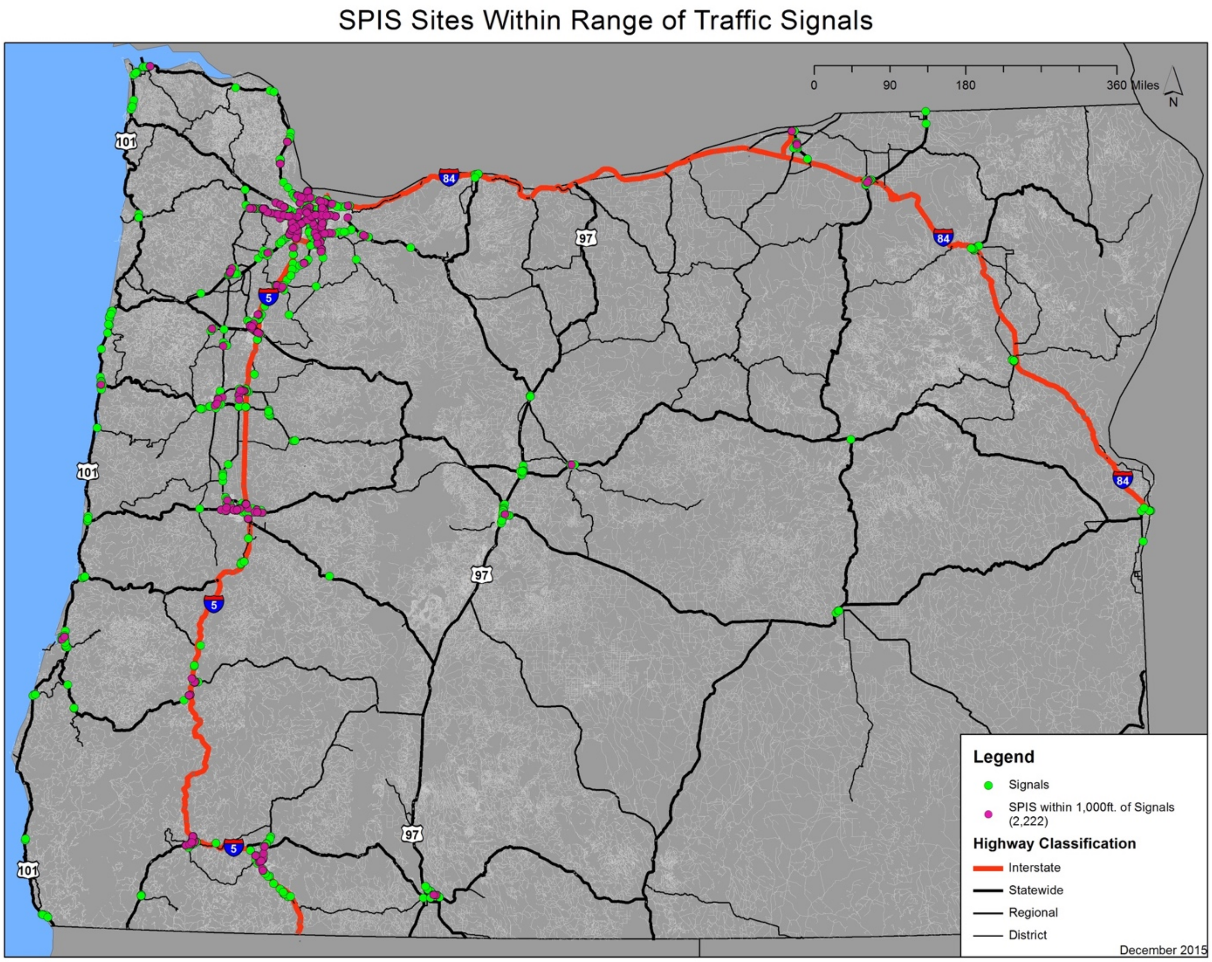

Figure 7.13: SPIS Sites Within 1,000 Foot Range of Traffic Signals

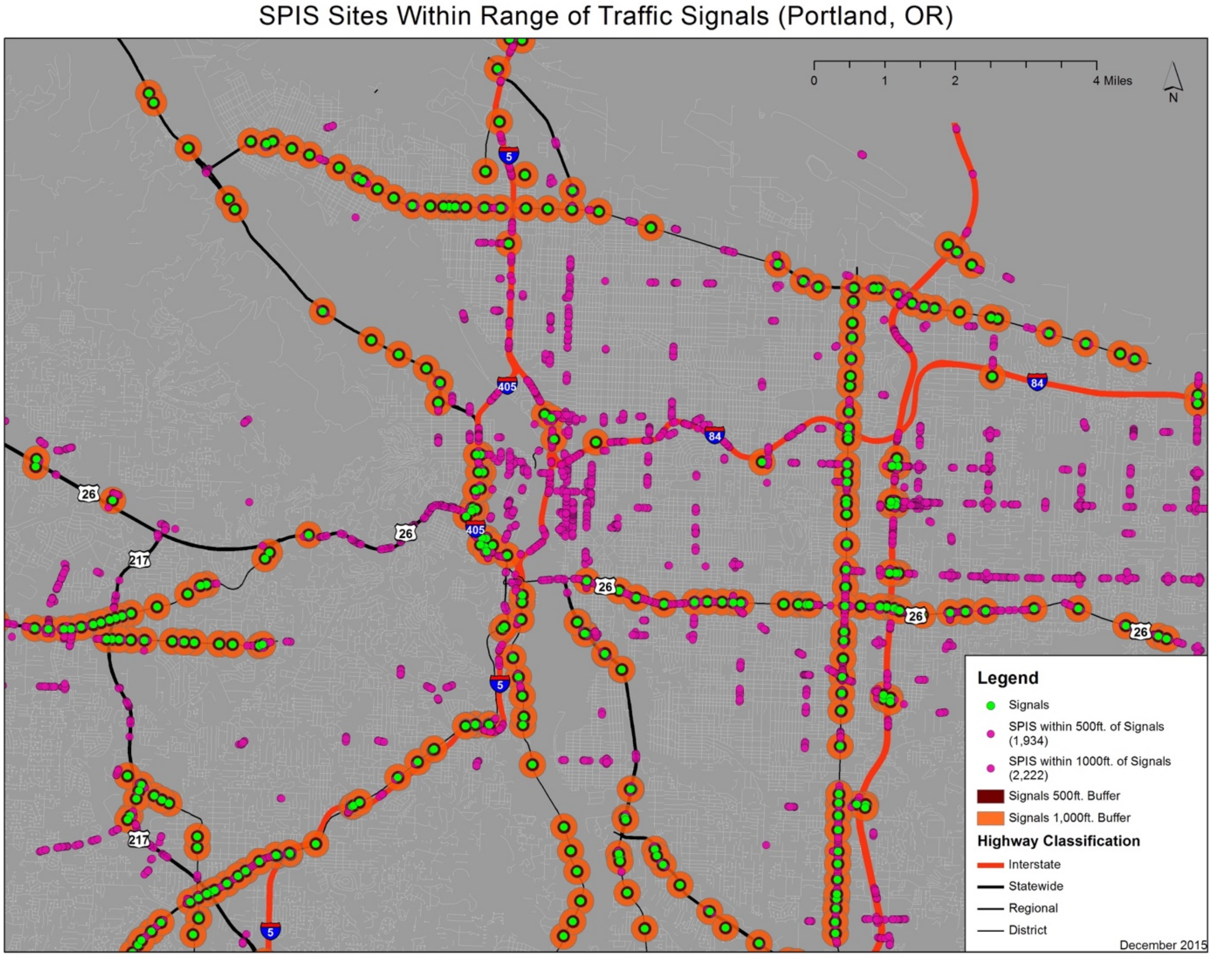

Figure 7.14: SPIS Sites Within Range of Traffic Signals (Portland, OR)

Now combining the results from the buffer analysis of SPIS sites in relation to the ITS assets and traffic signals, a buffer analysis was conducted in order to assess what proportion of the SPIS sites were within 500 foot or 1000 foot range of existing ITS asset and traffic signal locations. Figure 7.15 shows the map of the 2,108 SPIS sites within a 500 foot range of ITS assets and traffic signals for the entire state, and the 2,521 SPIS sites within 1,000 feet of ITS assets and traffic signal sites, again for the entire state. Because it is difficult to see the buffers at the statewide level, Figure 7.16 shows a zoomed in map of the 500-foot and 1,000-foot buffers for just the Portland metropolitan region.

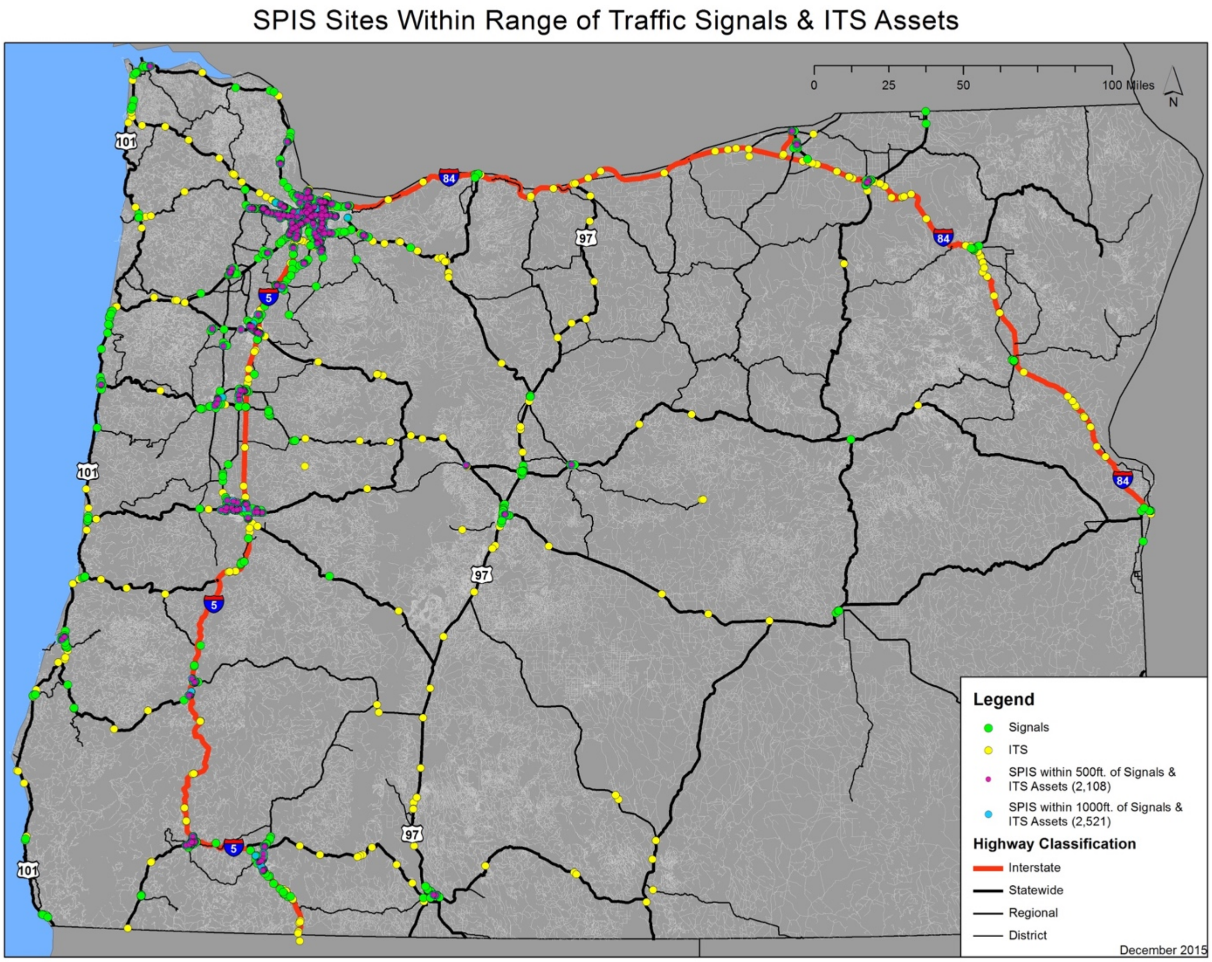

Figure 7.15: SPIS Sites Within 500 and 1,000 Foot Range of Traffic Signals & ITS Assets

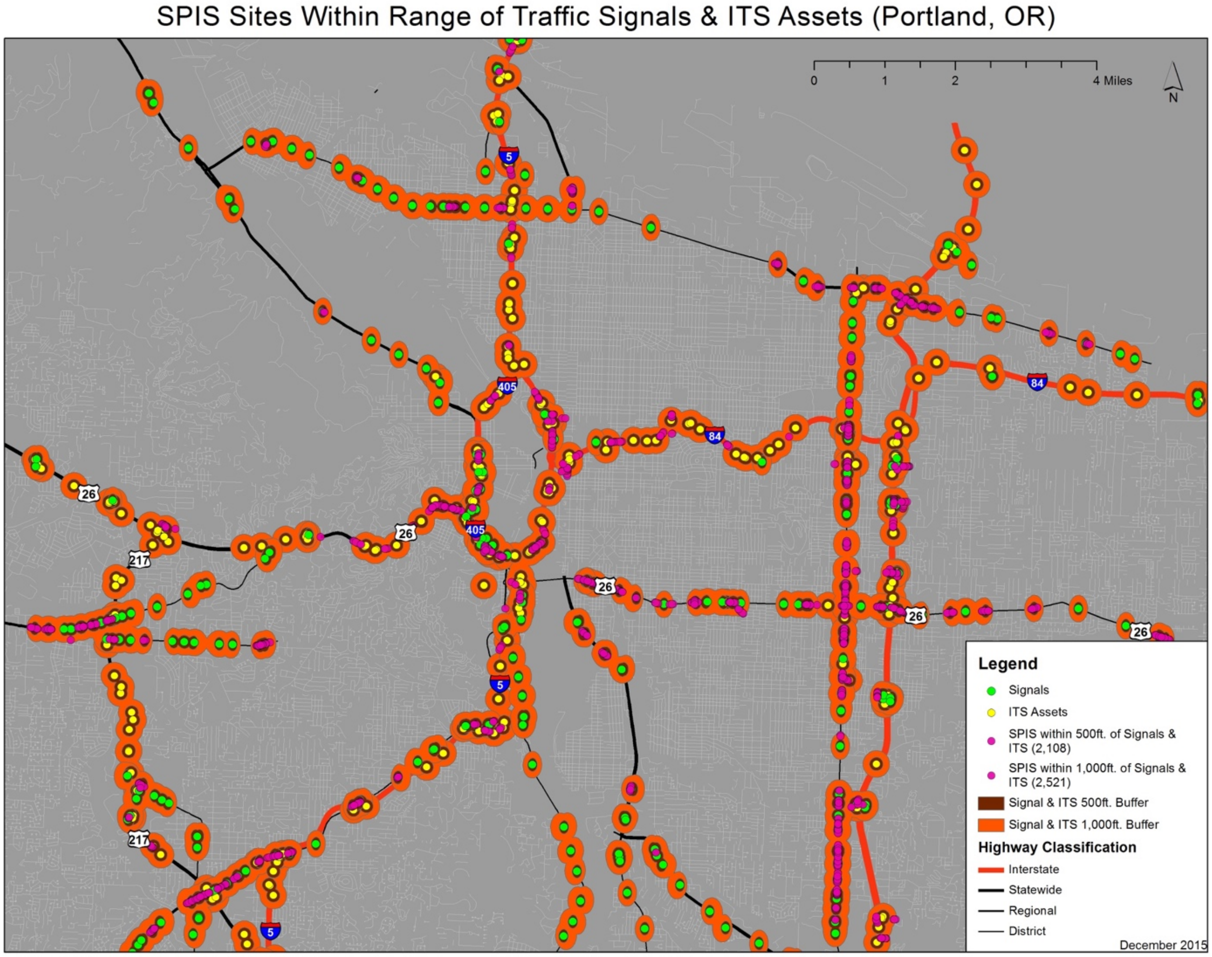

Figure 7.16: SPIS Sites Within Range of Traffic Signals & ITS Assets (Portland, OR)

Table 7.2: Statewide Network Analysis Results for SPIS

		All SPIS		95-100 SPIS		90-95 SPIS		85-90 SPIS	
	Buffer (ft)	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
ITS Assets	500	1,371	9%	543	12%	409	9%	419	7%
ITS Assets	1,000	2,612	17%	1,019	22%	765	16%	828	15%
Signals	500	4,879	33%	2,108	47%	1,569	33%	1,376	24%
Signals	1,000	6,040	40%	2,521	56%	1,943	41%	1,875	33%
ITS & Signals	500	5,361	36%	2,651	58%	1,710	36%	1,543	27%
ITS & Signals	1,000	6,841	46%	3,540	78%	2,156	45%	2,164	38%
TOTAL SPIS		14,936	100%	4,532	30%	4,748	32%	5,656	38%

Table 7.2 contains the spatial analysis results for the Oregon SPIS sites, in relationship to the 500-foot and 1,000-foot buffers around ITS assets, traffic signals and their combination. The table shows the number of all SPIS sites falling within the buffers. Of the total of 14,936 SPIS sites, nearly half (46%) are within 1,000 feet of the combined ITS assets and signal locations. The table also separates out the three percentile classes of SPIS locations within the top 15% of sites:

- Very High (top 5% SPIS scores, between 95% - 100%)
- Medium High (next 5% SPIS scores, between 90% - 94.99%)
- High (next 5% SPIS scores, between 85% - 89.99%)

When, for example, considering the most severe SPIS sites (top 5%), it is evident that 78% of those sites are within 1,000 feet of the ITS assets and signals. This indicates that a sizable majority of sites with safety concerns would be in the vicinity of DSRC equipped V2I capabilities if the existing assets were used for initial deployment.

Additional analysis could be conducted by investigating the relationship between certain crash types and the potential for V2I applications to address them. For example, intersection related crashes, curve or ice/weather related crashes could be assessed based on the potential for ITS asset or traffic signal location based V2I warnings to address them. Further analysis could also consider using weigh stations, maintenance facilities, automatic traffic recorders, railroad grade crossings and other fixed roadside facilities as CV data hubs. ODOT fleet vehicles could also be assessed as future potential CV probes.

8.0 ROADMAP

8.1 ODOT CV APPLICATION EMPHASIS

Toward the development of a roadmap for the deployment of connected vehicles (CVs), the Oregon Department of Transportation (ODOT) has considered the applications listed in Figure 8.1. Through a sorting procedure, the shorter list of potential applications for emphasis in Oregon is shown in Figure 8.2. Through a stakeholder workshop, these applications were ranked along the two axes shown in Figure 8.3, and were placed in the four quadrants shown in the figure. The x-axis tracks the level of effort and the degree to which the applications are manageable. The y-axis focuses on the meaningful level of benefits and impact that would be derived by implementing each application. Figure 8.3 indicates that the seven applications located in the upper right corner of the matrix (most meaningful and most manageable/least effort) were selected for additional near term focus.

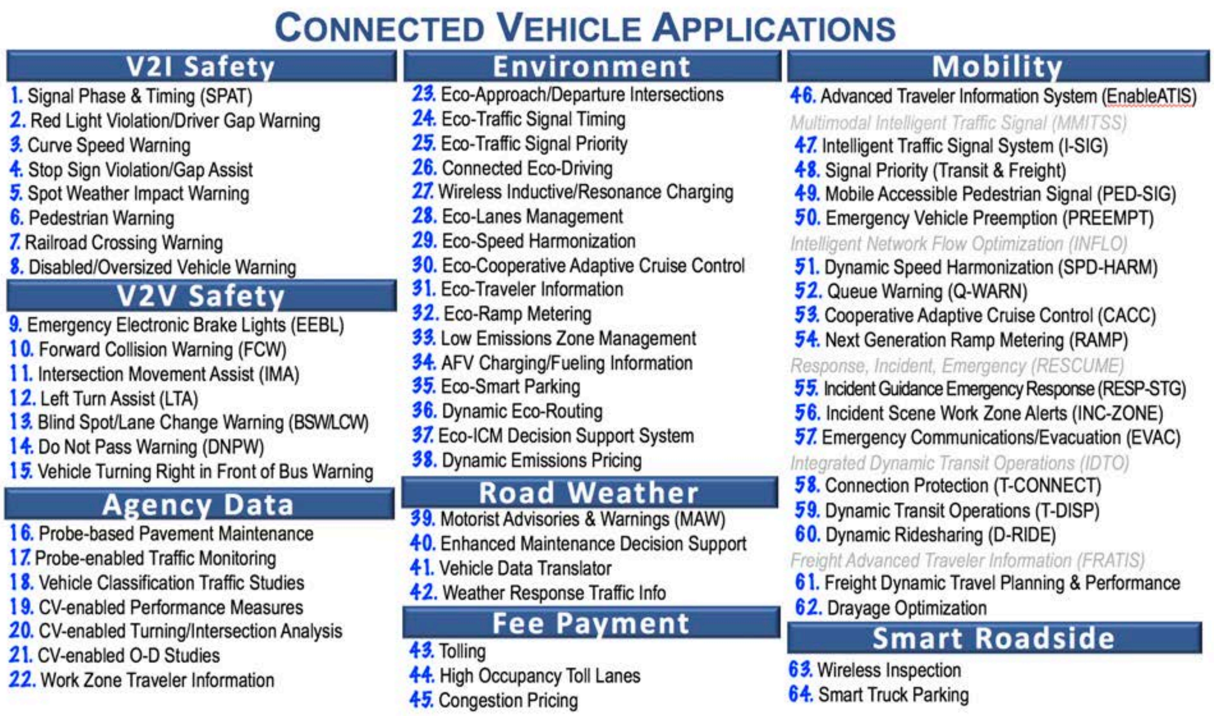

Figure 8.1: Connected Vehicle Applications

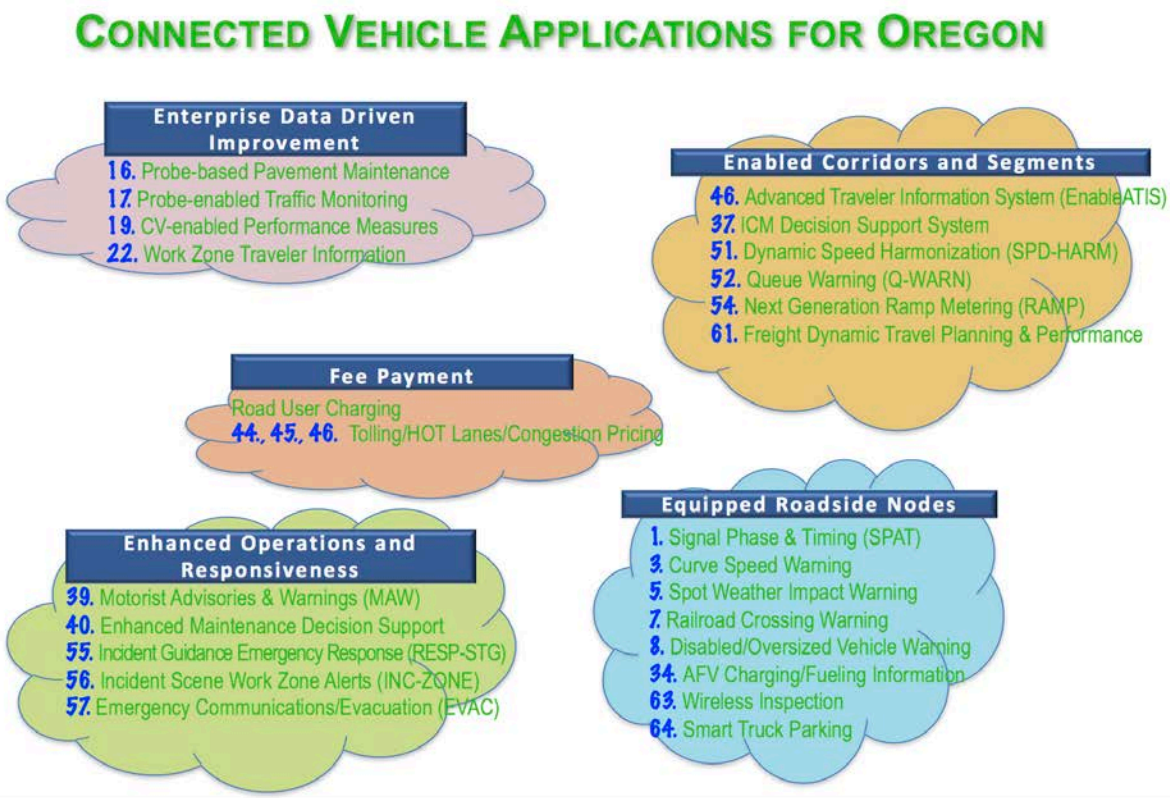

Figure 8.2: Connected Vehicle Applications for Oregon

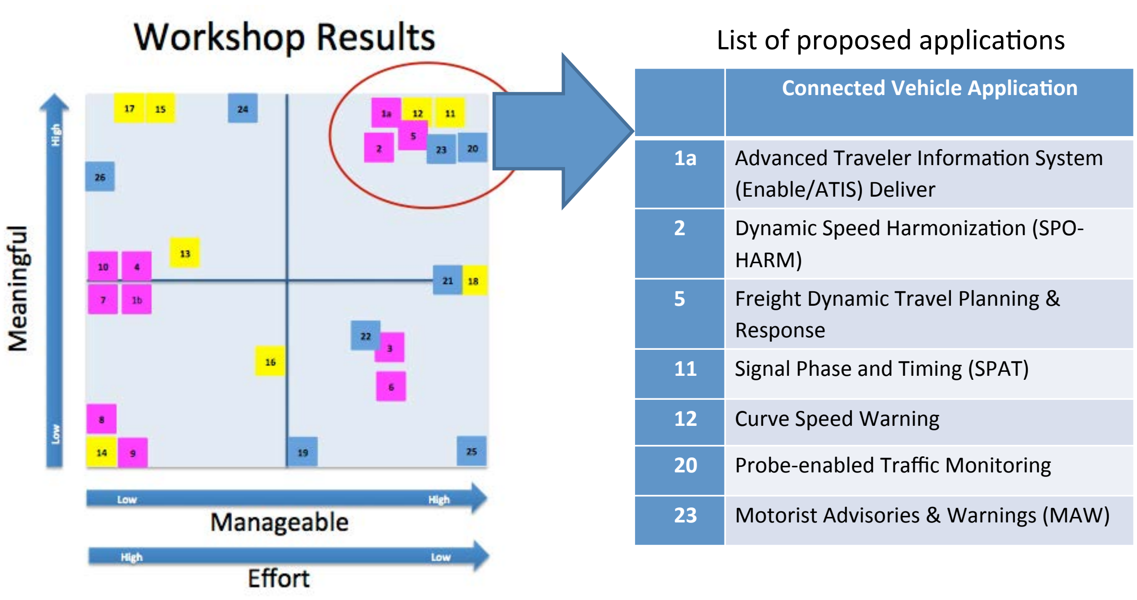

Figure 8.3: Workshop Results

Table 8.1 shows the list of CV applications selected for near term focus for ODOT, while Table 8.2 lists the applications that ODOT should monitor and consider collaboration with partner organizations. The columns titled Impact/Benefit and Effort use a numerical scale between 1 and

5, where 1 is low and 5 is high. Table 8.3 lists the applications where ODOT has determined that other entities should lead, but ODOT should monitor. There was also discussion that the work zone related applications could be moved up in the priority ranking since workzone safety is a priority for ODOT. The applications related to bicycle and pedestrian safety were also discussed as potentially higher priorities for communities in Oregon.

Table 8.1: Near Term Focus for ODOT

Number	Connected Vehicle Application	Impact/ Benefit	Effort
1a	Advanced Traveler Information System (Enable/ATIS)	5	5
2	Dynamic Speed Harmonization (SPO-HARM)	4	4
5	Freight Dynamic Travel Planning & Response	5	5
11	Signal Phase and Timing (SPAT)	5	5
12	Curve Speed Warning	5	5
20	Probe-enabled Traffic Monitoring	5	5
23	Motorist Advisories & Warnings (MAW)	5	4

Table 8.2: ODOT Should Monitor, Possibly Collaborate

Number	Connected Vehicle Application	Impact/ Benefit	Effort
1b	Advanced Traveler Information System (Enable/ATIS)	3	1
4	Next Generation Ramp Metering (RAMP)	3	1
7	Eco-ICM Decision Support System	3	1
10	Congestion Pricing (with road user charge)	3	1
13	SPOT Weather Impact Warning	4	2
15	Disable/Oversized Vehicle Warning	5	2
17	Incident Scene Work Zone Alerts (INC-ZONE)	5	2
18	Emergency Communications/Evacuation	3	5
19	Probe-based Pavement Maintenance	1	3
22	Work Zone Traveler Information	2	4
24	Enhanced Maintenance Decision Support	5	2
26	Smart Truck Parking	4	2

Table 8.3: Leadership by Others, ODOT Monitor

Number	Connected Vehicle Application	Impact/ Benefit	Effort
3	Queue Warning (Q-WARN)	2	4
6	AFV Charging/Fueling Information	2	4
8	Tolling	1	1
9	HOT Lanes	1	1
14	Railroad Crossing Warning	1	1
16	Incident Guidance Emergency Response	2	3
21	CV-enabled Performance Measures	3	5
25	Wireless Inspection	1	5

8.2 ROADMAP PRIORITIES

This section includes a "roadmap" for preparing for connected vehicles (CVs) from the perspective of the Oregon Department of Transportation. Proposed/considered actions are grouped according to the following 12 categories:

- DSRC and Backhaul Communications (Table 8.5)
- Education and Outreach (Table 8.6)
- Policy and Communications/Collaboration (Table 8.7)
- Benefits/Business Case (Table 8.8)
- Data Management and Strategies (Table 8.9)
- Applications (Table 8.10)
- Try Things (Table 8.11)
- Research Questions/Challenges (Table 8.12)
- Planning and Equity (Table 8.13)
- Multimodal (Table 8.14)
- Design and Construction (Table 8.15)
- Operations and Maintenance (Table 8.16)

Each strategy or action is scored according to three primary criteria shown in Table 8.4.

Table 8.4: Connected Vehicle Roadmap Criteria

	Lower	Medium	Higher
Priority	○	◑	●
	Shorter-term	**Medium-term**	**Longer-term**
Timing	■▶	■■▶	■■■▶
	Lower	**Medium**	**Higher**
Cost	$	$$	$$$

Table 8.5:DSRC and Backhaul Communications

DSRC and Backhaul Communications	Priority	Timing	Cost
▪ **Communications Plan**: Identify CV communication needs for V2I priorities that will ensure robust communications, in the context of existing statewide communications network (including ITS, traffic signals and other ODOT assets). Identify gaps, needs and costs.	●	■▶	$
▪ **Communication and Network Management**: Identify and plan needs assessment for management of robust statewide communications network. Work with partners to develop vision for redundancy and back up capabilities. Integrate with existing communications network and build into planning, design and construction activities.	●	■■▶	$$
▪ **DSRC Spectrum**: Work with U.S. DOT, AASHTO, and other stakeholders to protect DSRC band for V2I. Address spectrum uncertainties.	◑	■■▶	$
▪ **DSRC Leverage**: Work with partners to explore whether a shared DSRC spectrum could be monetized to pay for future V2I investment. Consider what the optimum usage of allocated DSRC spectrum would/should be. Seek recommendations on use of DSRC band and related channels within the band for V2I	◑	■■■▶	$

Table 8.6: Education and Outreach

Education and Outreach	Priority	Timing	Cost
▪ **CV Education**: Aim to stay educated on continuing development of CV deployment progress. Educate internal and external stakeholders. Partner with associations and	●	■▶	$

Education and Outreach

	Priority	Timing	Cost
universities.			
▪ **Public Outreach**: Provide accurate information to the public about CV deployment, and counteract some of the “hype” and misperceptions. Expand upon scenario approach for public involvement.	◑	■■▶	$$
▪ **ODOT Workforce**: Develop plan for workforce development to bring more cross functional skillsets to the hiring process in support of CV deployment. Identify what kind of workforce to be developed. Strengthen technical capabilities of staff.	●	■▶	$
▪ **Elected and Appointed Officials**: Conduct CV related outreach, training and education to state and local policy makers to familiarize and educate regarding CV. Provide accurate information to counteract hype and misperceptions. Include city, county, regional, and statewide elected and appointed officials. Cooperate with League of Oregon Cities, Association of Oregon Counties, Oregon Trucking Association, Oregon MPO Consortium, Oregon Transit Association, Oregon Chapter of the American Planning Association. Include training for city planning commissioners.	●	■▶	$
▪ **Workforce Issues**: identify long term workforce needs, consider whether jobs will be eliminated in the future through CV deployment, and determine how to retrain workers for this possibility.	◑	■■■▶	$$
▪ **Professional Development**: Support and encourage staff to participate (as speakers, panelists, and attendees) in TRB Annual and Midyear Meetings (ITS Committee and Vehicle Highway Automation Committee); ITS America Annual Meetings or World Congresses; ITE Conferences; and Automated Vehicles Symposium. *(Arnold 2015)*	●	■▶	$$
▪ **Exchanges**: Support and encourage in-person peer exchanges and virtual peer exchanges related to CV applications and deployment. Consider states such as: Michigan, California, Virginia, Florida, Texas.	●	■▶	$
▪ **Leverage National Expertise**: Consider launching program to invite experts to seminar/webinar series and conferences/events such as the Northwest Transportation	◑	■■▶	$

Education and Outreach	Priority	Timing	Cost
Conference (NWTC) and other regular transportation related conferences. Partner with universities and professional organizations.			
▪ **ODOT Convening Leadership**: Consider convening regular forums for discussing CVs and related technology issues, and educating external stakeholders including Cities, Counties, MPOs, Transit Agencies, Ports, Railroads, and the Freight/Trucking Communities.	◑	■■▶	$
▪ **NCHRP CV Related Research**: Encourage/nominate ODOT staff to serve on NCHRP Panels for CV related research.	◑	■■■▶	$$
▪ **International Developments**: Stay abreast of European Commission CV activities and European Commission High Level Group on Automotive Industry (GEAR 2030)	◑	■■■▶	$$

Table 8.7: Policy and Communictions/Collaboration

Policy and Communications/Collaboration	Priority	Timing	Cost
▪ **Internal Coordination:** Establish internal ODOT working group to focus on CV policy and deployment issues. ▪ **Success:** ODOT Formed CAV Steering Committee in 2015.	●	■▶	$$
▪ **Staffing**: Designate a specific individual within ODOT to be responsible for CV. **Success:** ODOT hired Connected, Automated, and Electric Vehicle (CAEV) Program Manager (Operations and Policy Analyst 3) in 2016 to serve as the agency's subject matter expert on connected and autonomous vehicle (CAV) policy and legislation. Among other things, this position will coordinate the flow of information within ODOT, including leading the CAV agency steering committee, make recommendations on CAV policy and legislation for Oregon, and manage implementation of the agency's strategic framework implementation for connected and autonomous vehicles, including tracking and reporting on progress.	●	■▶	$$
▪ **Staffing**: Add technical CV staff in addition to program manager/policy analyst.	●	■■▶	$$

Policy and Communications/Collaboration

	Priority	Timing	Cost
▪ **Agency Culture**: Continue to evolve ODOT culture to prepare staff, programs and policies for future CV deployment, including training for cross functional skill sets.	●	■■▶	$$
▪ **National CV Discussion**: Participate in national discussion on CV deployment. Consider Oregon's role in determining whether we need a national strategy for CV deployment.	●	■■■▶	$$
▪ **NHTSA and FHWA Actions**: Consider impacts of NHTSA rulemaking on DSRC *(NHTSA 2016)* and FHWA V2I Guidance that will be released during the first quarter of 2016. V2I Deployment will be encouraged by FHWA but public agencies will not be required to implement V2I technology. Nevertheless, state, regional, and local agencies will have guidance and products available to ensure efficiency and interoperability.	●	■▶	$$
▪ **Participate in National V2I Deployment Coalition**: Encourage ODOT staff to participate in V2I Deployment Coalition (DC), being led by AASHTO, ITE and ITS America. The V2I DC serves as a single point of reference for stakeholders to meet and discuss V2I deployment related issues. The V2I DC houses five working groups: Deployment Initiatives, Deployment Research, Infrastructure Operator, OEM and Supplier Partnerships, Deployment Guidance and Deployment Standards.	●	■▶	$$
▪ **Crash Avoidance Metrics Partnership (CAMP)**: Engage with CAMP, the consortium that consists of Ford Motor Company, General Motors LLC., Honda R&D Americas, Inc., Hyundai-Kia America Technical Center, Inc., Mercedes-Benz Research and Development North America, Inc., Nissan Technical Center North America, Inc., Toyota Motor Engineering & Manufacturing North America, Inc. and Volkswagen Group of America.	◑	■■■▶	$
▪ **Legislation**: Review current legislation and policies that could impact the implementation the implementation of CV technologies. Determine whether labor issues may emerge, and consider related legislation. Develop sample legislation for local agencies if necessary. Participate in national efforts to	◑	■■■▶	$

Policy and Communications/Collaboration			
	Priority	Timing	Cost
develop sample state level legislation. Solicit experiences from U.S. and international pilot deployments to guide possible legislative changes (example of CityMobil2 program for automated vehicles in Europe).			
▪ **Decision Making Tools**: Participate in use of national level decision making tools based on benefits/costs, including the, the Cost Overview for Planning Ideas and Logical Organization Tool (CO-PILOT).	◑	■■■▶	$$
▪ **Regional Collaboration**: ODOT should establish working relationships with resources in state/region with useful expertise and should consider partnering with neighboring states. Consider regular communications or formation of a statewide coalition with CV stakeholders.	◑	■■▶	$
▪ **Crash Reporting**: ODOT should consider whether to add relevant CV fields to the crash reporting procedures and regulations in order to track safety issues in the future.	◑	■▶	$
▪ **Liability Implications:** Develop policy statement on potential liability implications of CVs.	◑	■■■▶	$
▪ **Incentives**: Where possible consider incentivizing funding programs to encourage use of DSRC (e.g. transit vehicle and other fleet vehicle procurements).	●	■▶	$$
▪ **Driver and Motor Vehicle Services Division (DMV)**: DMV should continue participation in American Association of Motor Vehicle Administrators (AAMVA) Best Practices Working Group. Assess needed changes in driver training/education, licensing and registration for CVs.	●	■■▶	$
▪ **Privacy:** Develop CV privacy commitment statement.	●	■▶	$

Table 8.8: Benefits/Business Case

Benefits/Business Case			
	Priority	Timing	Cost
▪ **V2I Business Model**: Participate in and/or lead statewide and national discussions on developing a clear business case for V2I. Consider whether V2I investment will pay back, and who pays for that investment. Develop strategy to address financial	◑	■■▶	$$

challenges of implementation. Are there private business models? When should public agencies begin to invest in infrastructure changes?			
▪ **CV/V2I Benefits**: Advocate for and participate in expansion of availability of benefit and cost information to support deployment decisions. Include consideration of public benefit vs. agency benefit. How do benefits accrue with low market penetration?	●	■▶	$
▪ **Benefits Beyond Safety and Mobility**: Encourage continuing development of metrics for CV impacts on energy, emissions and health.	◑	■■▶	$$
▪ **Forecasting**: Develop plans for assessing investment decisions regarding these emerging technologies and applications in the absence of experiential data.	○	■■■▶	$
▪ **Links to Tolling/Payment Systems**: Assess how payment systems fit in with new V2I business models.	●	■▶	$
▪ **Aftermarket Devices**: Determine how the role of aftermarket devices can increase the rate of growth toward critical mass, in support of infrastructure investment.	◑	■■▶	$$
▪ **Customer Acceptance**: Link outreach toward enhancing customer acceptance and understanding including value proposition and overcoming fear of loss of privacy.	◑	■■▶	$$

Table 8.9: Data Management and Strategies

Data Management and Strategies	Priority	Timing	Cost
▪ **Statewide Data Strategy**: Develop V2I data strategy for ODOT and other partners, taking existing data streams (e.g., TripCheck) into account. Identify existing and future data needs and availability for V2I applications. Address data access, data ownership and support needs. Identify unaddressed data needs of public agencies. Encourage open data sharing.	●	■▶	$$
▪ **Data Leadership**: Appoint transportation data "czar" to assemble and integrate agency-wide data sources, databases, data streams and uses from across ODOT. Utilize the Michigan Data Use Analysis and Processing (DUAP) system data uses as	●	■■▶	$$

Data Management and Strategies

	Priority	Timing	Cost
a starting point. Identify existing data streams, sources or sets that can be leveraged with new CV data. Strengthen data management capabilities (collect, transmit, store, aggregate, analyze, disseminate, report). **Note**: ODOT has begun a strategic data business plan to consolidate data sources.			
▪ **Probes for Performance**: Using existing fleet vehicles, plan for beginning pilot collection and use of basic system performance/vehicle probe information for basic performance measures as well as: ▪ Traffic signal control strategies ▪ Corridor management ▪ Active traffic management ▪ Weather and event management	◑	■▶	$$
▪ **Data Archiving**: Identify what CV/V2I data should be stored on a CV or within the system to aid in determination of root cause of crashes/malfunction. Design research/deployment projects from the beginning to support and feed ODOT CV research data to the U.S. DOT Research Data Exchange (RDE) https://www.its-rde.net/	◑	■■■▶	$$
▪ **Data Privacy**: Develop and publish data privacy/anonymity commitment.	●	■▶	$
▪ **Mobile/Stationary Data Fusion**: Assess methods for “fusing” fixed sensor and mobile/probe data to determine how “occasional” DSRC messages can be used to reduce sensing uncertainty.	◑	■■■▶	$$
▪ **Trusted Broker**: Conduct needs assessment and feasibility analysis (with statewide and national level input) for receiving, managing, combining, and disseminating data from multiple vehicles/manufacturers and across multiple applications and platforms.	◑	■■■▶	$$
▪ **Maps and Geographic Information Systems (GIS)**: Build on existing ODOT TransGIS to continue analysis described in chapter 7 of this report. Expand analysis across point locations with power and communications backhaul to include ITS devices, traffic signals, SPIS Sites, weigh stations, railroad crossings, intersections, ATRs, and maintenance facilities.	●	■▶	$$

Data Management and Strategies	Priority	Timing	Cost
Expand intersection mapping capabilities to support V2I intersection applications.			
▪ **ODOT Fleet**: Develop plans and procurement strategy to begin using the ODOT fleet as probes using DSRC for operational and maintenance applications.	●	■▶	$$
▪ **Collaborate with Road Usage Charge Program**: Establish links to ORe*GO*, Oregon's pay by the mile system to leverage data and technology.	●	■▶	$$
▪ **Cybersecurity:** Establish policies and programs for enhancing and managing cybersecurity of CVs and infrastructure. Data/communications networks across ODOT and state government should utilize state-of-the-art security management principles.	●	■■▶	$$
▪ **Standards:** ODOT should participate in and follow/require the use of the Connected Vehicle Reference Implementation Architecture (CVRIA) developed by the U.S. DOT. Consider assigning a representative to participate in national and international standards discussions. Emphasize interoperability and standards in procurement, planning and deployment.	◑	■■▶	$

Table 8.10: Applications

Applications	Priority	Timing	Cost
▪ **Near Term Application Readiness**: Continue development of application details for Near Term Focus Applications (Table 8.1). Determine data flows, infrastructure needs and other agency issues to be resolved. Identify implementation and support challenges. Encourage deployment of "street ready" applications.	●	■▶	$$
▪ **Medium Term Application Readiness**: Pursue additional V2I safety/mobility applications including those identified as "ODOT Should Monitor, Possibly Collaborate" in Table 8.2. Identify implementation and support challenges.	◑	■■▶	$$
▪ **Longer Term Application Readiness**: Monitor the "Leadership by Others" applications listed in Table 8.3.	○	■■▶	$$

Applications			
	Priority	Timing	Cost
Identify implementation and support challenges.			
▪ **Aftermarket Devices**: Explore safe delivery of V2I warnings to drivers through high-quality vehicle retrofit/aftermarket devices. Determine what the design and functional requirements of a high-quality vehicle retrofit device would be.	◑	■■■▶	$$
▪ **Commercial Vehicles**: Expand upon Oregon Green Light program using DSRC for broader integration with commercial vehicle systems. Focus on safety and efficiency applications.	●	■■■▶	$$
▪ **AASHTO Deployment Footprint**: Work with AASHTO, U.S. DOT and other states to develop an AASHTO Deployment Footprint specifically for Oregon. Engage public agency (city, county, MPO, transit agency) and private sector (OEM, suppliers) stakeholders.	●	■▶	$$
▪ **CV Application Harmonization**: ODOT should contribute toward leading an effort to harmonize the names and definitions of CV applications (e.g., see U.S. DOT list of CV application which differ from those in the CVRIA). This could include an international harmonization effort to develop a single dictionary of CV applications.	●	■▶	$

Table 8.11: Try Things

Try Things			
	Priority	Timing	Cost
▪ **Future U.S. DOT Pilot Projects**: ODOT should consider participating in future U.S. DOT CV Pilot Projects by submitting proposals through that program. These activities should support ODOT initiatives and priorities and should be coordinated through the CAV Steering Committee. **Success:** ODOT supported a U.S. DOT Connected Vehicle Pilot Deployment Program proposal, "Open Interoperable Technology Marketplace (submitted by Portland State University and CH2M on March 27, 2015)	◑	■▶	$$
▪ **Support Testing and Pilot Deployments**: ODOT should support testing and pilot CV deployments by other partners in Oregon.	◑	■■▶	$

Try Things	Priority	Timing	Cost
▪ **U.S. DOT Smart City Challenge**: ODOT should support U.S. DOT Smart City Challenge concepts and proposals. **Success:** The City of Portland was one of 78 cities submitting a Smart City Challenge proposal in early 2016, and was selected as one of the Challenge Finalists announced in March 2016 at SXSW. The Smart City Challenge Winner will be announced in June 2016.	◑	■▶	$
▪ **Oregon Pilot**: ODOT should consider leading or participating in a CV pilot that does not necessarily wait for federal funding. Emphasis can be on leveraging partner investments and attracting research and evaluation partners to the state.	●	■■▶	$$
▪ **ODOT/DAS Fleet**: ODOT should consider working with agency partners to plan for deployment of DSRC communications capabilities in existing and future fleet purchases.	◑	■■■▶	$$
▪ **Oregon CV Test Bed**: ODOT should consider working with partners to establish an officially certified CV test bed under the U.S. DOT Test Bed program.	◑	■■▶	$

Table 8.12: Research Questions/Challenges

Research Questions/Challenges	Priority	Timing	Cost
▪ **NCHRP CV Research Road Map**: ODOT should monitor the results of the NCHRP CV Research Road Map projects, and should consider nominating ODOT staff to serve on project panels.	●◑○		$$$
▪ **ODOT Research Road Map**: ODOT Research Unit should consider framing and promoting an Oregon-specific CV research road map based on results and gaps from the NCHRP Research Road Map. Partnerships with universities and private sector partners would leverage limited research funding.	●◑○		$$$
▪ **CV Pooled Fund Project**: ODOT should consider the benefits of becoming a participant in the national CV pooled fund project organized through the University of Virginia: http://www.cts.virginia.edu/cvpfs/	●◑○		$$

Research Questions/Challenges	Priority	Timing	Cost
▪ **CV Application Harmonization**: ODOT should contribute toward leading an effort to harmonize the names and definitions of CV applications (e.g., see U.S. DOT list of CV application which differ from those in the CVRIA). This could include an international harmonization effort to develop a single dictionary of CV applications.	●◑○		$$$
▪ **CV Deployment Readiness**: Consider conducting a comprehensive deployment readiness research project, including business processes, systems and technology and performance measurement. Examine agency culture, organization and staffing and commitment to collaboration.	●◑○		$$$
▪ **Truck Platooning**: Consider an evaluation of the impacts of truck platooning and the implications of connected vehicle technologies for highway freight corridors in Oregon.	●◑○		$$$
▪ **Aftermarket V2I Devices**: Consider conducting an assessment and evaluation of the potential for aftermarket devices to support fleet management and acceleration of V2I deployment.	●◑○		$$$
▪ **AASHTO/TRB Participation**: Continue to support the AASHTO Subcommittee on Transportation Systems Management and Operations (TSM&O) Research Working Group and relevant TRB Committees (Regional Transportation Systems Management and Operations, Freeway Operations, Intelligent Transportation Systems and Vehicle Highway Automation).	●◑○		$$$

Table 8.13: Planning and Equity

Planning and Equity	Priority	Timing	Cost
▪ **Statewide Plans**: ODOT should consider working to add a minimum of a mention of CVs and their deployment to all statewide plans, through the planning process, including, as applicable: ▪ Oregon Transportation Plan ▪ Oregon Aviation Plan ▪ Oregon Bicycle/Pedestrian Plan	●	■▶	$

Planning and Equity

	Priority	Timing	Cost
▪ Oregon Freight Plan ▪ Oregon Highway Plan ▪ Oregon Public Transportation Plan ▪ Oregon Rail Plan ▪ Oregon Transportation Options Plan ▪ Oregon Transportation Safety Action Plan ▪ Public Involvement Policy and Procedures ▪ Tolling and Pricing Policy ▪ Passive Electronic Data Collection Policy			
▪ **MPO Leadership**: ODOT should consider working through the Oregon MPO Consortium (OMPOC) and via the Association of Metropolitan Planning Organizations (AMPO) to incentivize/require the addition of CVs to all regional transportation plans in the state. What will MPOs need to know about CVs in the next 5 years to inform their planning?	●	■■▶	$
▪ **City, County, Port and Transit Agency Leadership**: ODOT should work with cities, the League of Oregon Cities, the National League of Cities, the National Association of City Transportation Officials, counties, the Association of Oregon Counties, the National Association of Counties, ports, the Oregon Public Ports Association, the American Association of Port Authorities, transit agencies, the Oregon Transit Association and the American Public Transportation Association to incentivize/require the incorporation of CVs into their planning and procurement efforts.	●	■■▶	$
▪ **Travel Demand Forecasting**: ODOT should work with and leverage the Oregon Model Steering Committee (OMSC) to begin addressing how to modify traffic models and forecasting tools to include future CV deployment.	◑	■■▶	$$
▪ **Planning for Uncertainty**: ODOT should consider taking a leadership role in beginning to address (with partners) uncertainties that will impact the future of transportation demand and supply. This effort should aim to improve the robustness of transportation plans. Initial issues to consider include: ▪ Shorter term: daily mobility choices and activity-travel	◑	■■■▶	$$

Planning and Equity	Priority	Timing	Cost
patterns choices ▪ Medium term: vehicle ownership and usual mode choices and household level choices ▪ Longer term: lifestyle, residential and work locations, and business location ▪ Auto ownership ▪ Demographic changes ▪ VMT ▪ Fleet age/CV penetration			
▪ **Future Organizational Needs**: ODOT should evaluate whether current planning and policy organizations are sufficient to handle future CV deployments.	◑	■■■▶	$
▪ **Freight Planning**: ODOT should consider focusing in planning for CV deployment in the freight and goods movement industries. Logistics companies and fleet owners may be some of the early adopters.	●	■▶	$$
▪ **Scenario Planning**: ODOT should consider adopting a scenario planning approach in order to consider the impacts that CVs, other transportation technologies and innovations and their uncertainty, will have on the transportation system.	●	■■▶	$$
▪ **Vulnerable Road Users**: Consider conducting an assessment to gauge how vulnerable road users would benefit from connected vehicle technology.	◑	■■▶	$

Table 8.14: Multimodal

Multimodal	Priority	Timing	Cost
▪ **Public Transportation**: ODOT should consider incorporating a statewide assessment of the future roles of transit into its CV planning processes (see TCRP Project H-51 results). This should include considerations of first mile/last mile issues, accessibility for urban, suburban and rural residents, and Paratransit. Issues relating to incorporating DSRC communications into transit and paratransit vehicle procurements should also be emphasized. Other fleets	◑	■■▶	$$

Multimodal	Priority	Timing	Cost
including taxis and Transportation Network Companies (TNCs) should also be involved in these activities.			
▪ **Freight**: ODOT should consider a statewide effort to incorporate CV technologies into its freight planning and programming efforts. Multimodal funding programs such as *Connect*Oregon should consider incentivizing CV technology into its funding streams and projects. Commercial vehicles may be among the first to move toward DSRC and CV technologies due to their standardized data streams. ODOT can collaborate with Oregon's 23 ports to assess where CV technologies and DSRC communications make sense for incentivizing installation.	●	■▶	$$
▪ **Rail:** ODOT should partner with its railroads and local agencies to develop a standard for incorporating DSRC communications and CV technologies into all railroad grade crossings, in support of the Railroad Crossing Warning CV Application. Next generation grade crossings should incorporate the new level of safety enabled by this CV application.	◑	■▶	$$
▪ **Air and Maritime**: Airports and River/Ocean Ports may also be locations on the transportation network where DSRC and CV Applications can be explored.	○	■■■▶	$

Table 8.15: Design and Construction

Design and Construction	Priority	Timing	Cost
▪ **Design Standards**: ODOT should assess along with partners what new highway design standards for CV deployments will be required and when they will be necessary. Partnerships may include AASHTO, NACTO, TRB, ITE, IMSA and others.	○	■■▶	$$
▪ **Roadside Hardware Procurement and Construction**: ODOT should consider adopting a policy to include space for future DSRC/CV device installation, plus power and communications needs, in all roadside hardware construction activities.	●	■▶	$$
▪ **Expanded Data Communications Backhaul Needs**: ODOT	●	■■▶	$$$

should consider incorporating construction of conduit and other elements to support future data backhaul needs.			
▪ **Roadside Equipment (RSE) Standards**: ODOT should consider developing RSE standard plans and specifications, and explore appropriate vendors/suppliers, and incentivize/require development and construction projects and programs to incorporate RSE installation as an incremental component.	●	■▶	$

Table 8.16: Operations and Maintenance

Operations and Maintenance	Priority	Timing	Cost
▪ Operational Analysis: determine and plan for how highways will perform with an increasing level of CV proportion of the fleet. Determine whether capacity will increase.	◑	■■▶	$
▪ Safety Analysis/SPIS: Expand safety culture to incorporate safety assessment of spots on the network (e.g. curves, intersections and railroad crossings) that will benefit from CV RSE installation.	●	■▶	$
▪ Strategy for Technical Obsolescence: Plan for deployment of DSRC/CV equipment in sufficiently long timeframe to avoid other, more robust or advanced technologies that may emerge	◑	■■■▶	$$
▪ Maintenance: incorporate planning for future maintenance issues into CV deployment strategy. Prepare requirements for deploying, operating and maintaining V2I equipment	◑	■■■▶	$$
▪ Statewide Data Hubs: Consider designating weigh stations, maintenance stations, RWIS installations and other roadway installations as CV/DSRC hubs.	◑	■■▶	$$
▪ Maintenance and Operations Culture: ODOT should include maintenance and operations staff in planning and workforce development efforts in preparation for CV deployments.	●	■▶	$

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