CONNECTED VEHICLE APPLICATION PRIORITIZATION PROCESS AND STAKEHOLDER OUTREACH AS PART OF PREPARING A POSSIBLE OREGON ROAD MAP FOR CONNECTED VEHICLE/COOPERATIVE SYSTEMS DEPLOYMENT SCENARIOS

Task 4 Report

SPR 764

Oregon Department of Transportation

Connected Vehicle Application Prioritization Process and Stakeholder Outreach as Part of Preparing a Possible Oregon Road Map for Connected Vehicle/Cooperative Systems Deployment Scenarios

Task 4 Report

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by

Robert L. Bertini, Ph.D., P.E.
Associate Professor
California Polytechnic State University
Department of Civil and Environmental Engineering
1 Grand Avenue
San Luis Obispo, CA 93407

Haizhong Wang, Ph.D.
Assistant Professor
Oregon State University
School of Civil & Construction Engineering
101 Kearney Hall, Corvallis, OR 97331

for

Oregon Department of Transportation
Research Section
555 13th Street NE, Suite 1
Salem OR 97301

and

Federal Highway Administration
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1 Grand Avenue, San Luis Obispo, CA 93407-0353

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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The project team is grateful to the Technical Advisory Committee members and all workshop participants and organizers for their valuable feedback and input. We also appreciate the roles that Myra Sperley and Brooke Jordan played on the project in its earlier stages. Many ODOT staff also contributed their time and ideas to the project, particularly those who responded to the survey, and we owe its success to their input.

DISCLAIMER

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1.0 STAKEHOLDER INVENTORY AND OUTREACH

1.1 INTRODUCTION

The research team has worked with the TAC and ODOT staff to identify an agreed upon set of stakeholders to engage within Oregon on the topic of connected vehicles topic via an in-person workshop. The original concept for this task included the idea of a webinar as an option. However, discussion with the TAC and ODOT staff resulted in the idea to host an internal ODOT workshop with department leadership as part of an internal effort aimed at developing a strategy for connected and automated vehicles (CAV). The research team worked closely with ODOT staff to draft a preliminary set of discussion points for capitalizing on opportunities, advancing and/or responding to potential connected vehicle/cooperative systems applications and technologies. This chapter serves as the Task 4 summary memo/presentation documenting the findings of the task.

There are many stakeholders and stakeholder groups to consider. Even within ODOT (see organization chart in Figure 1.1) there are many organizations that need to be engaged and involved in preparations for connected vehicle systems. In earlier phases of the project (e.g., Task 1), the research team surveyed members of ODOT staff from a wide range of disciplines and divisions for input to the project. The TransPort ITS Advisory Committee was also consulted. Following is a checklist of potential stakeholders to consider as the effort to prepare for connected vehicles and cooperative systems continues. Potential stakeholders include, but are not limited to:

- ☐ Federal Agencies
  - ☐ U.S. Department of Transportation
    - ☐ Federal Highway Administration
    - ☐ National Highway Traffic Safety Administration
    - ☐ Federal Motor Carrier Safety Administration
    - ☐ Federal Transit Administration
    - ☐ Federal Railroad Administration
    - ☐ Office of the Assistant Secretary for Research and Technology
      - ☐ Intelligent Transportation Systems Joint Program Office
    - ☐ Federal Communications Commission
    - ☐ Department of Commerce
      - ☐ National Telecommunications & Information Administration
    - ☐ Department of Energy
- ☐ State Agencies
  - ☐ Oregon Department of Transportation
    - ☐ Driver and Motor Vehicle Services
    - ☐ ITS Opportunities Team (ITOT)

        - ☐ Technical Leadership Team
        - ☐ Planning Business Leadership Team
        - ☐ Traffic Operations Leadership Team
        - ☐ ITS Unit
        - ☐ Research Section
        - ☐ Office of Maintenance and Operations
        - ☐ Transportation Safety Division
    - ☐ Oregon Transportation Commission
    - ☐ Oregon State Police
    - ☐ Governor's Office
    - ☐ Border states: California, Washington, Idaho, Nevada
- ☐ Regional Organizations
    - ☐ Metropolitan transportation organizations (MPOs)
    - ☐ Oregon MPO Consortium
        - ☐ Portland Metro
            - ☐ JPACT
            - ☐ TPAC
            - ☐ TransPort ITS Advisory Committee
        - ☐ Salem-Keizer
        - ☐ Albany
        - ☐ Corvallis Area
        - ☐ Eugene-Springfield
        - ☐ Bend Area
        - ☐ Middle Rogue
        - ☐ Rogue Valley
        - ☐ Southwest Washington Regional Transportation Council (border state MPO)
    - ☐ Area Commissions on Transportation (ACTs)
        - ☐ Northwest Oregon
        - ☐ Mid-Willamette Valley
        - ☐ Cascades West
        - ☐ South West
        - ☐ Rogue Valley
        - ☐ Lower John Day
        - ☐ Central Oregon
        - ☐ South Central Oregon
        - ☐ North East
        - ☐ South East
        - ☐ Lane County
        - ☐ Region 1 ACT
- ☐ Local Agencies

- ☐ Cities
  - ☐ Portland
  - ☐ Salem
  - ☐ Eugene
  - ☐ Gresham
  - ☐ [Smaller cities]
  - ☐ League of Oregon Cities
- ☐ Counties
  - ☐ Association of Oregon Counties
- ☐ Transit agencies
  - ☐ Trimet
  - ☐ Lane Transit District
  - ☐ Salem-Keizer
  - ☐ [Smaller transit agencies]

☐ Citizens/Voters
- ☐ League of Women Voters

☐ National Trade Associations
- ☐ American Association of State Highway and Transportation Officials (AASHTO)
  - ☐ Connected Vehicle Executive Leadership Team (ELT)
- ☐ American Public Transportation Association (APTA)
- ☐ National Association of Counties
- ☐ National League of Cities
- ☐ Association of Metropolitan Planning Organizations (AMPO)
- ☐ Institute of Transportation Engineers (ITE)
- ☐ ITS America
- ☐ Telecommunications Industry Association (TIA)
- ☐ Vehicle to Infrastructure (V2I) Deployment Coalition
- ☐ Consumer Electronics Association (CEA)
- ☐ CTIA The Wireless Association
- ☐ Connected Vehicle Trade Association (CVTA)
- ☐ International Road Federation (IRF)
- ☐ Transportation Research Board (TRB)
- ☐ Society of Automotive Engineers (SAE)
- ☐ American Automobile Association (AAA)
- ☐ Women's Transportation Seminar (WTS)
- ☐ American Society of Civil Engineers (ASCE)
- ☐ American Public Works Association (APWA)
- ☐ National Electrical Manufacturers Association (NEMA)
- ☐ International Municipal Sign Association (IMSA)

☐ Auto manufacturers (OEMs)

- ☐ Auto manufacturing suppliers
- ☐ After market suppliers
- ☐ Insurance companies
- ☐ Banking and financial services
- ☐ Auto dealers
- ☐ Wireless device manufacturers
- ☐ Wireless communications providers
- ☐ Wireless communications network manufacturers/suppliers
- ☐ Electric Vehicle Charging Stations
- ☐ Fuel Stations
- ☐ Emergency response
- ☐ Software/App Developers
- ☐ Consultants
- ☐ Contractors
- ☐ Trucking Industry
  - ☐ Truck Stops
  - ☐ Oregon Trucking Association
- ☐ Taxi Industry
- ☐ Health care
- ☐ Railroads
- ☐ Data providers
- ☐ Parking industry
- ☐ Motorcycle industry
- ☐ Bicycle groups
  - ☐ Bicycle Transportation Alliance
- ☐ Pedestrian advocacy
  - ☐ Oregon Walks
- ☐ Shared mobility providers
- ☐ Infrastructure providers
- ☐ Systems Integrators
- ☐ Standards Development Organizations (SDOs)
  - ☐ International Organization for Standardization (ISO)
    - ☐ Technical Committee 204 (TC204)
  - ☐ International SDOs
    - ☐ European Telecommunications Standards Institute (ETSI)
    - ☐ European Committee for Standardization (CEN)
  - ☐ U.S. SDOs
    - ☐ National Transportation Communications for Intelligent Transportation System Protocol (NTCIP)
    - ☐ IEEE

        - ☐ AASHTO
        - ☐ ITE
        - ☐ ANSI
        - ☐ NEMA
        - ☐ SAE
    - ☐ National ITS Architecture
- ☐ Academia/Research Organizations

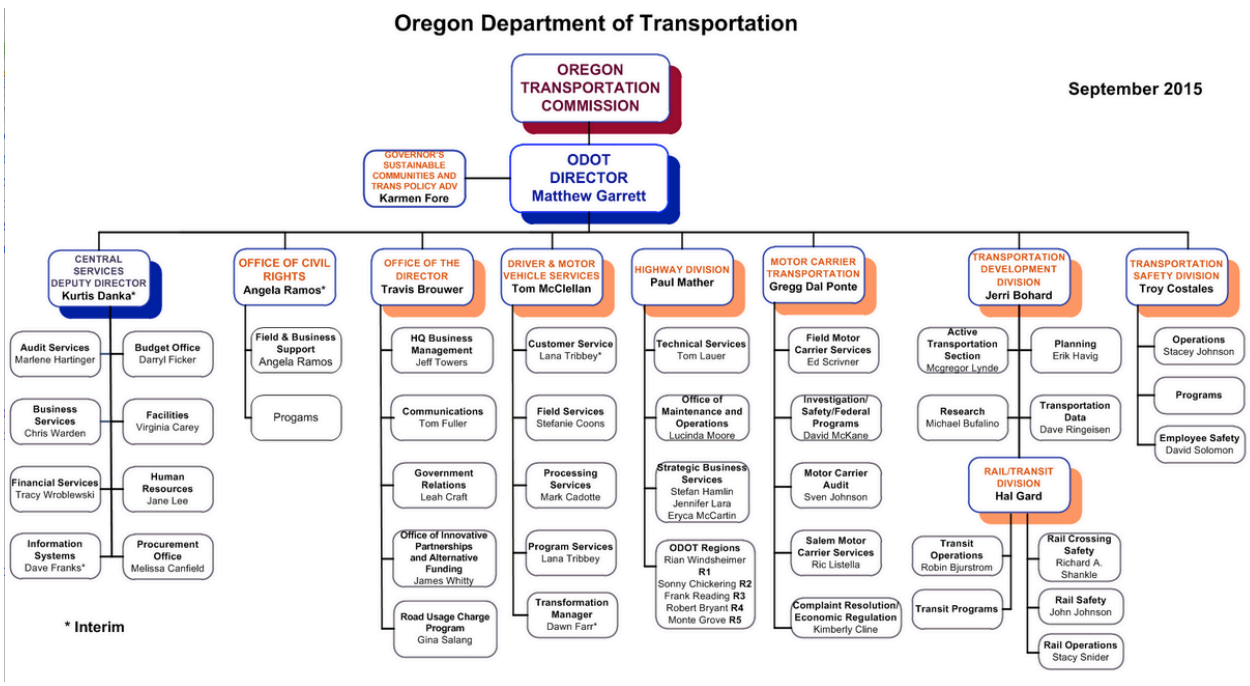


Figure 1.1: Oregon Department of Transportation Organization Chart

2.0 CONNECTED AND AUTOMATED VEHICLE APPLICATION PRIORITIZATION WORKSHOP

2.1 INTRODUCTION

The purpose of this workshop was to link the Oregon Department of Transportation (ODOT) Intermodal Leadership Team (ILT) initiative on connected and automated vehicles (CAV) with the ODOT Research project that is focusing on developing a roadmap for connected vehicle applications. (Table 2.1) The agenda started with a briefing by the research team and quickly turned into a hands-on exercise. (Table 2.2) Our goal was to identify emerging connected vehicle applications that will help ODOT achieve its goals and priorities. The workshop was held on April 13, 2015.

Table 2.1: Workshop Participants

Amanda Pietz, Transportation Development Division, Planning	Mike Kimlinger, Traffic-Roadway Section, Traffic Standards	Jon Maker, Connected and Automated Vehicle Team
*Brooke Jordan, Transportation Development Division, Planning (& Connected and Automated Vehicle Team)	Rich Crossler-Laird, Traffic-Roadway Section, Senior Urban Design Engineer	Eryca McCartin, Connected and Automated Vehicle Team
Brian Dunn, Transportation Development Division, Transportation Planning Analysis Unit	David Fifer, Motor Carrier Division	Nathaniel Price, Federal Highway Administration
Tony Knudson, Research Section	Michele O'Leary, Transportation Safety Division	David Eyerly, Driver and Motor Vehicle (DMV) Services Division
Galen McGill, Intelligent Transportation Systems (ITS) Unit	Chuck Larsen, Road Usage Charge Program	Ron Winterrowd, Information Systems (IS), Central Services Division
Doug Spencer, Intelligent Transportation Systems (ITS) Unit	*Ashley Horvat, Chief Electric Vehicle Officer	Dr. Haizhong Wang, Assistant Professor, Oregon State University
Joel McCarroll, Region 4 Traffic Manager	Jeremiah Griffin, Region 3 District 8 Assistant Manager	Dr. Robert Bertini, Associate Professor, California Polytechnic State University San Luis Obispo
*Paul Mather, Highway Division Administrator, Connected and Automated Vehicle Sponsor	*Troy Costales, Transportation Safety Division Administrator	Bob Bryant, Region 4 Manager

* Unable to attend

Table 2.2: Workshop Agenda

<table>
<tr><th colspan="4">Connected Vehicle Application Prioritization Workshop</th></tr>
<tr>
<td>AGENDA

April 13, 2015
10:00 am
– 4:00 pm
TLC – Diamond Lake Conf. Rm

4040 Fairview Industrial Drive SE
Salem OR</td>
<td>☐ Amanda Pietz, TDD Planning
☐ Brooke Jordan, TDD Planning (& CAV Team)
☐ Brian Dunn, TDD TPAU
☐ Tony Knudson, Research
☐ Galen McGill, ITS
☐ Doug Spencer, ITS
☐ Joel McCarrol, R4 Traffic
☐ Jeremiah Griffin, R3 District</td>
<td>☐ Mike Kimlinger, Technical Services
☐ Rich Crossler-Laird, Technical Services
☐ David Fifer, Motor Carrier Division
☐ Michele O'Leary, Trans Safety Division
☐ Chuck Larsen, RUC
☐ Ashley Horvat, Electric Vehicle</td>
<td>☐ David Eyerly, DMV
☐ Ron Winterrowd, IS
☐ Jon Makler, CAV Team
☐ Eryca McCartin, CAV Team
☐ Paul Mather, Highway Division Administrator
☐ Nathaniel Price, FHWA
☐ Dr. Haizhong Wang, Researcher
☐ Dr. Robert Bertini, Researcher</td>
</tr>
<tr><td colspan="4">Please arrive a few minutes early to check in and get back to the conference room</td></tr>
</table>

Time		Topic	Lead
10:00 – 10:20	1	Welcome and Introductions	All
10:20 – 10:45	2	Mapping ODOT Priorities	Eryca M
10:45 – 11:15	3	Connected Vehicles 101	Robert B, Haizhong W
11:15 – 11:30	4	Word from the Manufacturers	Jon M
11:30 – 12:30		Working Lunch	
	5	Discussion: Technology Adoption	Jon M
12:30 – 1:30	6	Initial Mapping of Goals and Applications	Eryca M
1:30 – 2:30	7	Breakout Discussions: Triage for ODOT Priorities	All
2:30- 4:00	8	Conclusion: a. Which Connected Vehicle application should be ODOT priorities? b. What risks does ODOT face in	Jon M, Eryca M

		pursuing these priorities?	

2.2 CONNECTED AND AUTOMATED VEHICLE BUSINESS CASE

The first portion of the meeting presented the business case for connected and automated vehicles. ODOT uses a four stage paradigm in thinking through improvement strategies, as shown in Figure 2.1. The first stage is to define the need, followed by build understanding, then take action and confirm and sustain results. For this program we are in the first stage of "define need." We recognize four important points regarding connected and automated vehicles:

Figure 2.1: **Making the Business Case**

- Connected and automated vehicles are technologies that are advancing rapidly.
- ODOT is unprepared to address the potential future changes to the transportation system.
- Connected and automated vehicles can create safety, mobility, and environmental benefits.
- Failure to act could result in a loss of funding opportunities and political credibility.

Connected vehicles, and the technologies that support them, are emerging as an increasingly viable transport option available to drivers. At the federal level, lawmakers and transportation professionals are examining the implications of connected vehicles to the transportation system and users. Connected vehicle applications have the potential to generate safety, mobility, and environmental benefits for the transportation system and users. Not addressing the future implications of connected vehicles in the near term could result in the loss of key funding opportunities and political credibility. At worst, this could result in a failure of the agency to fully realize its stated mission of providing a safe, efficient transportation system that supports economic opportunity and livable communities for Oregonians. Examining connected vehicles and their implications for Oregon’s transportation system will clarify these issues and support informed decision-making within the agency.

The connected vehicle "road map" research project is addressing some of the future implications of connected vehicles to the transportation system. However, this approach is incomplete because the research project does not address the full suite of issues and challenges that this emerging technology could present. Internally, ODOT has not reached a consensus regarding what this emerging technology could mean for the agency and the transportation system, how to approach future changes to the transportation system, or a preferred course of action to address the first two issues.

Circumstances are conducive for ODOT to address the uncertainties it faces regarding connected vehicles in the near term. The U.S. DOT recently launched a program to fund regional connected vehicle pilot projects in various areas of the country. The program will fund projects in two phases: the first phase will begin in 2015 and the second in 2017. This is an excellent opportunity for ODOT determine the implications of connected vehicles for Oregon's transportation system and users. In addition, there is political pressure to address this issue. The Oregon State Legislature is increasingly curious about which aspects of this issue are within their purview and are require attention.

2.3 CONNECTED AND AUTOMATED VEHICLES ARE AN AGENCY PRIORITY

2.3.1 Background

ODOT has embarked on the following tasks related to connected and automated vehicles:

- The Intermodal Leadership Team (ILT) is ODOT's venue for investing resources to solve priority problems that cut across transportation functions.
- ILT selects projects each year and assigns a team, including a sponsor.
- "Connected and Automated Vehicles Strategic Framework" was selected as a 2014-15 "High Priority" project. Paul Mather is the sponsor.
- Simultaneously, ODOT has a research project underway with a very relevant scope (and a concurrent timeline).
- The ILT effort aims to conclude by the end of summer 2015.

The Connected and Automated Vehicle (CAV) Team was formed with the following members:

- Paul Mather, Sponsor
- Jon Makler, Lead
- **Galen McGill**, Expert Advisor
- **Eryca McCartin**, Change Facilitator

- **Mike Kimlinger**, Tech Services
- Brooke Jordan, Planning
- Tony Knudson, Research
- **Terra Lingley**, staff resource
- Nathaniel Price, FHWA
- **Kelly Kita**, Change Facilitator Support (Pivotal Resources)

The CAV Team has consulted with the following internal resources, including internal stakeholder groups such as:

- Public Transit Policy
- ITS (standards, implications, etc.)
- Technical Services
- Project Delivery
- Safety (Engineering)
- Maintenance & Operations
- Fleet
- DMV
- Transportation Safety
- Information Systems
- MCTD
- Statewide and regional planning
- Director's office, Communications, and Government Relations

2.3.2 Goal and Objectives

The CAV Team intends to identify implications of a changing transportation system that includes connected and automated vehicles to current and projected skills required for ODOT employees.

The CAV Team's intention is to include in the framework changing workforce needs, such as changing job classifications and/or skills in response to evolving technology (e.g. electrician vs. network engineer). This will identify areas for further investigation.

Goal: Develop a **strategic framework** for connected and automated vehicles that builds ODOT's **ability to evolve and respond** to changes in CAVs across business lines and divisions.

- **Objective 1:** Identify connected vehicle applications with greatest benefit to Oregon and **prioritize deployment in the near and long term.**
- **Objective 2:** Identify opportunities to proactively participate in the national conversation in order to **take advantage of early learning opportunities.**
- **Objective 3: Define** prioritized scopes of work and **identify** individuals or groups **responsible for implementation**.

2.3.3 Engagement Strategy

The objectives of the CAV Team's engagement strategy are to:

- Increase awareness of connected and automated vehicles and technology and the CAV Strategic Framework initiative among most ODOT employees by end of 2015.
- Increase understanding of connected and automated vehicles, supporting technologies, and potential impacts to the transportation system among key ODOT staff by the end of 2015.

2.3.4 Goal for workshop: Prioritize Applications

The goal for the workshop was to create a matrix that displays a list of connected vehicle applications that have a combination of expected benefit and level of effort that will make it worthwhile for ODOT to be proactive in the near term deployment. The final workshop product should look something like the tabulation shown in Figure 2.2.

	Application	ODOT Value	Benefit	Effort
1				
2				
3				
4				
5				

Figure 2.2: **Conceptual Vision for Final Product**

3.0 MAPPING ODOT PRIORITIES

There are many ways to assemble the priorities of a large state agency like the Oregon Department of Transportation (ODOT). First there are a number of important source and policy documents to examine:

- Oregon Transportation Plan (2006)
- Oregon Highway Plan (1999 + amendments)
- Oregon Highway Safety Plan
- Intermodal Oregon
- Legislature
- Special Projects (e.g., Office of Innovative Partnerships and Alternative Funding)
- Others?

In addition there are the adopted priorities (goals) of the Oregon Transportation Plan that can contribute to an overall understanding of the agencies direction:

- Mobility and Accessibility
- Management of the System
- Economic Vitality
- Sustainability
- Safety and Security
- Funding the Transportation System
- Coordination, Communication and Cooperation

The Oregon Highway Plan also contains the following vision statements:

> The Oregon Highway Plan envisions a state highway system that is **safe**, **attractive**, **efficient** and **dependable** for Oregonians and visitors. State highways provide transportation for people, goods, services and modes of travel. The highway system

supports state and local goals for economic opportunity, livability and a sustainable environment.

The highway system strikes a balance between local accessibility and through movement of people and goods in urban and rural communities. It respects local and regional differences, as it is developed and operated in partnership with local communities.

Keeping the highway system safe, attractive and well-maintained benefits the state and all highway users. A stable funding system protects the state's investment in its highways, enhances reliability, and provides and efficient use of resources. Long-term funding continues to be based on an equitable user-based system of cost responsibility.

Since many of the applications enabled by connected and automated vehicles, and since the users of the system expect a high degree of safety, it is possible to consider the Transportation Safety Action Plan's 2011 Edition Priority Actions:

- Develop strategies to assure the recruitment and retention of EMS volunteers
- Safety areas of interest should include intersection crashes, roadway departure and pedestrian/bicycle
- Improve and expand the delivery system for driver education in Oregon

Next, Intermodal Oregon is an internal initiative created at ODOT to take a fresh look at structures, processes and policies. The Intermodal Oregon objectives are:

- ODOT staff has a clear understanding of their individual roles and responsibilities along with their connection to the broader vision and objectives of the agency
- Policy direction exists to ensure creation and support of an intermodal system that provides efficient transportation options and modal choices
- Each solution is designed and implemented to support or take advantage of connections between elements of the transportation system and/or avoid inhibiting future connections, whether or not multiple modes are involved in the proposed solution.
- Flexible funding is available to support an intermodal transportation system
- Decisions that cross functions or modes are not made in silos, but through collaboration with appropriate areas of the agency, customers and/or stakeholders
- Sufficient and accessible data exist to identify the consolidated needs of an intermodal system and help to analyze and resolve conflicting priorities
- Problem definition phase is open and considerate to all modes and the preferred solution will be the one(s) best positioned to address a problem or need, whether local, regional or state.

In 2015, Intermodal Oregon has established five key priorities:

- ODOT Strategy for Connected and Automated Vehicles
- Robust Multi-Modal TSPs
- ODOT's Role in Transloading Facilities
- Regional Roles in Transit Project Delivery
- A&E Contracting Improvements

It is also important to consider the state's legislative priorities in the transportation arena. The 2009 Oregon Legislature passed House Bill 2001, also known as the Oregon Jobs and Transportation Act (JTA). The JTA included the following recitals:

- Connect communities
- Economic competitiveness
- Maintenance and modernization (for Economic Development)
- Sustainability
- Statewide need for safety and preservation
- Jobs

Thus, these six elements provide yet another lens through which to view the approach to preparing for connected and automated vehicles. The State of Oregon has also become known for two signature project/programs over the past decade that should also inform its approach to connected and automated vehicles. These programs are:

- **Electric Vehicles**: Petroleum-based transportation is not sustainable in the long run, either environmentally or economically. Our dependency on imported fossil fuels, impacts of global climate change and the introduction of new carbon emission standards have created an urgency to find alternative solutions. ODOT has sustainability as one of its core values, and it is in the best interest of the state to support a growing EV industry. Currently, the biggest limitation for drivers considering EVs is the absence of a reliable network of charging facilities to increase the range of these vehicles and alleviate fears of "running out of juice." Even so, by 2020, plug-in cars could account for as much as 20 percent of new vehicles sold in Oregon. That's why EV charging stations are appearing in key locations around the state.

- **Road Usage Charge Program (OReGo)**: Diminishing fuel tax returns led Oregon decision-makers back to the drawing board to create a fair, reliable source of revenue to fund transportation projects for all Oregonians. The result is OReGO:

- OReGO volunteers will pay a road usage charge for the amount of miles they drive, instead of the fuel tax.

- The OReGO road usage charge is set at 1.5 cents per mile.
- Volunteers will get a credit on their bill to offset the fuel tax they pay at the pump.
- Volunteers will have their choice of secure mileage reporting options offered by OReGO's private-sector partners.
- Volunteers' personal information will be kept secure and private.
- The first phase of OReGO is limited to 5,000 cars and light-duty commercial vehicles.

Table 3.1 shows a possible way to map a range of performance outcomes to existing policy/priority documents with the idea that key themes should emerge. This framework was discussed at the workshop but the mapping was not completed.

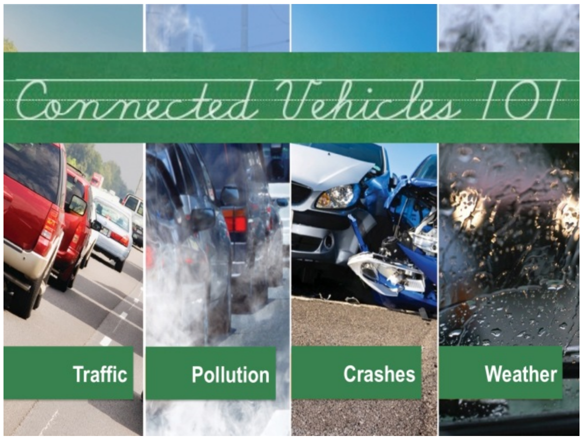
Table 3.1: **Possible Mapping of ODOT Priorities**

	OTP	OHP	JTA	IO										
Mobility	✓	✓												
Accessibility	✓		✓											
TSMO	✓	✓												
Economic Vitality	✓		✓											
Sustainability	✓													
Safety	✓	✓												
Security	✓													
Funding	✓													
Coordination	✓													
Attractive		✓												
Maint & Ops														
Reliability														
Efficiency														
Connectivity														
Performance														
Innovation														
Equity														
(Authority?)														
Cust. Service														
Livability														
(Strategic?)														
Implementability														

4.0 CONNECTED VEHICLES 101

The research team presented a tutorial on connected vehicles with the following basic information:

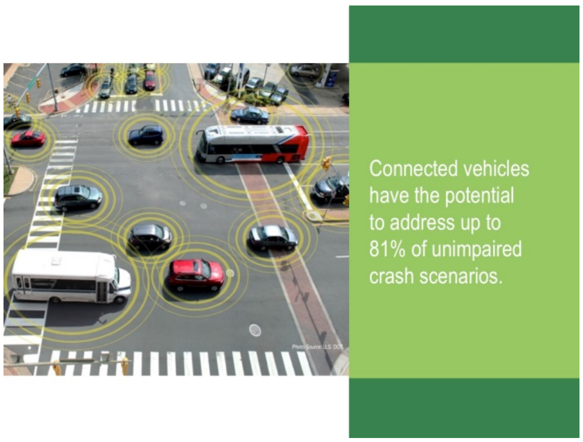
- Dedicated Short Range Communications (DSRC) and Basic Safety Message
- Connected Vehicle Application Definition
- Difference Between Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I)
- Outcome Based Applications



1. In 2010, there were 5.4 million crashes and 32,885 crash fatalities in the U.S. (Source: NHTSA)
2. Crashes are the leading cause of death for people between the ages of 4 and 34. (Source: CDC)
3. Americans spent 4.8 billion hours in traffic in 2010. (Source: TTI)
4. Americans wasted 1.8 billion gallons of fuel in 2010. (Source: TTI)

1. In the future, cars will continuously communicate with each other.
2. Vehicles will also communicate with traffic signals, toll booths, work zones, and specially designed street signs.

1. DSRC is like Wi-Fi for cars.
2. It is fast, reliable, and not impacted by weather and other interference.
3. DSRC devices can be installed in various types of vehicles, from motorcycles to tractor-trailers.
4. Pedestrians with cell phones can also be part of the connected vehicle environment.



1. Recent studies show that connected vehicles have the potential to reduce many types of crashes because the cars of the future will see crashes before they can happen.
2. The cars of the future will see many hazards that drivers won’t even notice.

1. Luxury cars may already seem to have many of these warnings, but connected vehicle technology offers many unique advantages and benefits.
2. All vehicles will have the warnings, regardless of make, model, or price.
3. Connected vehicle technology is cheaper, more effective, and safer than today’s crash avoidance technology.

1. Trucks and buses will receive many of the same safety warnings as light vehicles.
2. Trucks will use connected vehicle technology to send information to weigh stations without stopping.
3. Connected vehicle technology can adjust the phasing of traffic signals to give transit buses priority and help them remain on schedule.
4. Buses will also use wireless technology to send real-time information about their location.

1. The data from connected vehicles is anonymous, and driver privacy is always protected.
2. The connected vehicle system will be totally secure.
3. The data from the vehicles will be housed in a central location and available to anyone who wants to develop applications.

1. In the future, cars and trucks that are miles ahead of you will be able to send data to your car about icy bridges, flooded highways, and heavy snowfall, while informing you of detour options ahead.
2. The data will be in real time, from scores of other vehicles on the same stretch of road that are sharing data based on prevailing road conditions.
3. The highway of the future will change from one where cars travel independently, with each driver trying to navigate safely in bad weather, to a network of vehicles that are constantly sharing weather and road condition data

1. With data from tens of millions of connected vehicles, imagine the potential applications that can be developed.
2. With the addition of traffic signals, parking meters, bus stops, rest areas, toll booths, work zones, HOV lanes, and other infrastructure, the possibilities are even better.
3. Regardless of the device, the new information available will dramatically change how we travel in the future.

1. More and more Americans are concerned about their carbon footprint.
2. Connected vehicles will give them the tools they need to make greener travel choices.
3. Real-time traffic data from connected vehicles can help drivers choose the least-polluting travel route. This would be a totally new concept in transportation.
4. Imagine a city using real-time traffic data to help control the amount of pollution downtown each day.

The vision for a connected future shown in Figure 4.1 includes the following elements:

- Multi-modal surface transportation system—connectivity as its core.
- Vehicles (cars, trucks, buses, fleets of all kinds) ←→ Drivers and operators ←→ Infrastructure ←→ Mobile Devices
- Leverage technology to maximize safety, mobility and the environment—enabled through wireless communications—in all modes.
- First priority is safety: crash and injury prevention (80% of crash scenarios).

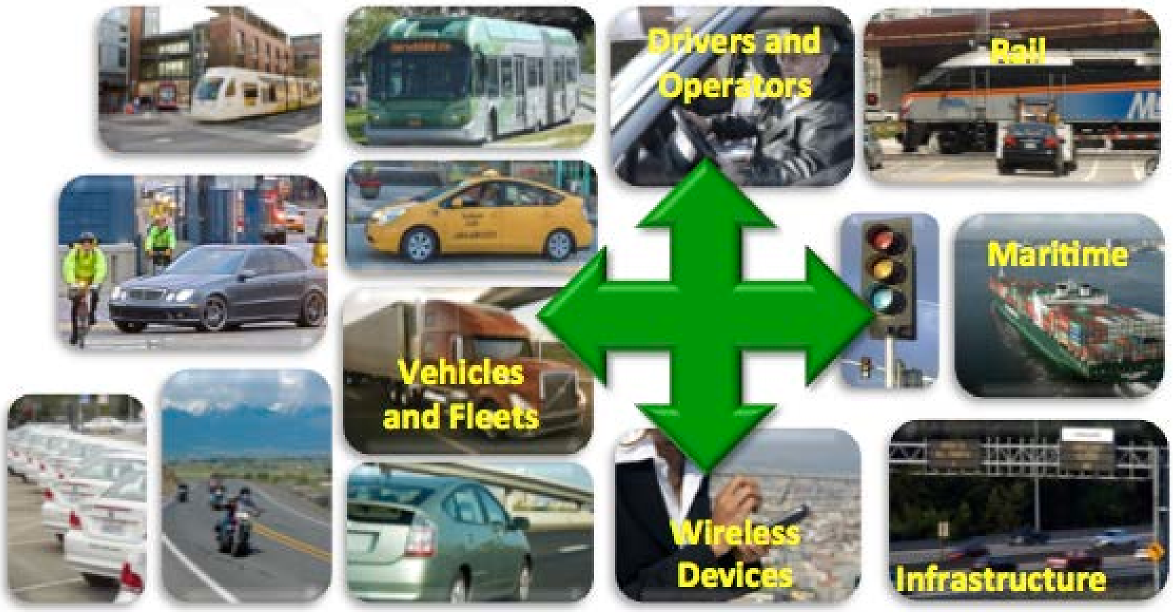


Figure 4.1: Vision for a Multimodal Connected Transportation Environment

4.1 DEFINITION OF CONNECTED VEHICLES

Vehicle or mobile device (platform) equipped with communications and processing allowing equipped platforms to be aware of their location and their status and to communicate with each other and the surrounding infrastructure.

- Connectivity:
  - Among vehicles to enable crash prevention.
  - Between vehicles/infrastructure to enable safety, mobility & environmental benefits.
  - Among vehicles, infrastructure and wireless devices for all system users.
- Safety (DSRC):
  - Increase situational awareness
  - Reduce or eliminate crashes through vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) data communications
- Mobility (DSRC + wide area wireless communications):
  - Connected, data-rich travel environment, including vehicle to device (V2X)
  - Driver advisories, driver warnings, vehicle and/or infrastructure controls

    - Capture real time data from on-board equipment (autos, trucks, buses, etc.) and from within the infrastructure

    - Data are transmitted wirelessly and used by transportation managers in a wide range of dynamic, multi-modal applications to manage the system for optimal performance.

- Environment:

    - Generate and capture environmentally relevant real-time transportation data to support and facilitate green transportation choices, reducing impacts of each trip.

4.2 WHAT IS DEDICATED SHORT RANGE COMMUNICATIONS?

- Dedicated Short Range Communications”

- FCC authorized spectrum at 5.9 GHz for safety applications in 1999 (also Europe and Japan)

- Key ingredients: **standardization** and **interoperability**

- Other applications and other wireless technologies can be accommodated

- Older DSRC systems such as toll tags operate at 900 MH: no standard, several proprietary systems are in place

- Both vehicle to infrastructure and vehicle to vehicle communication environments

- **Complementary** to cellular

- High data transfer rates and **low latency**

- Range up to 1000 m

- Data Rate – 6 to 27 Mbps

- Seven licensed channels

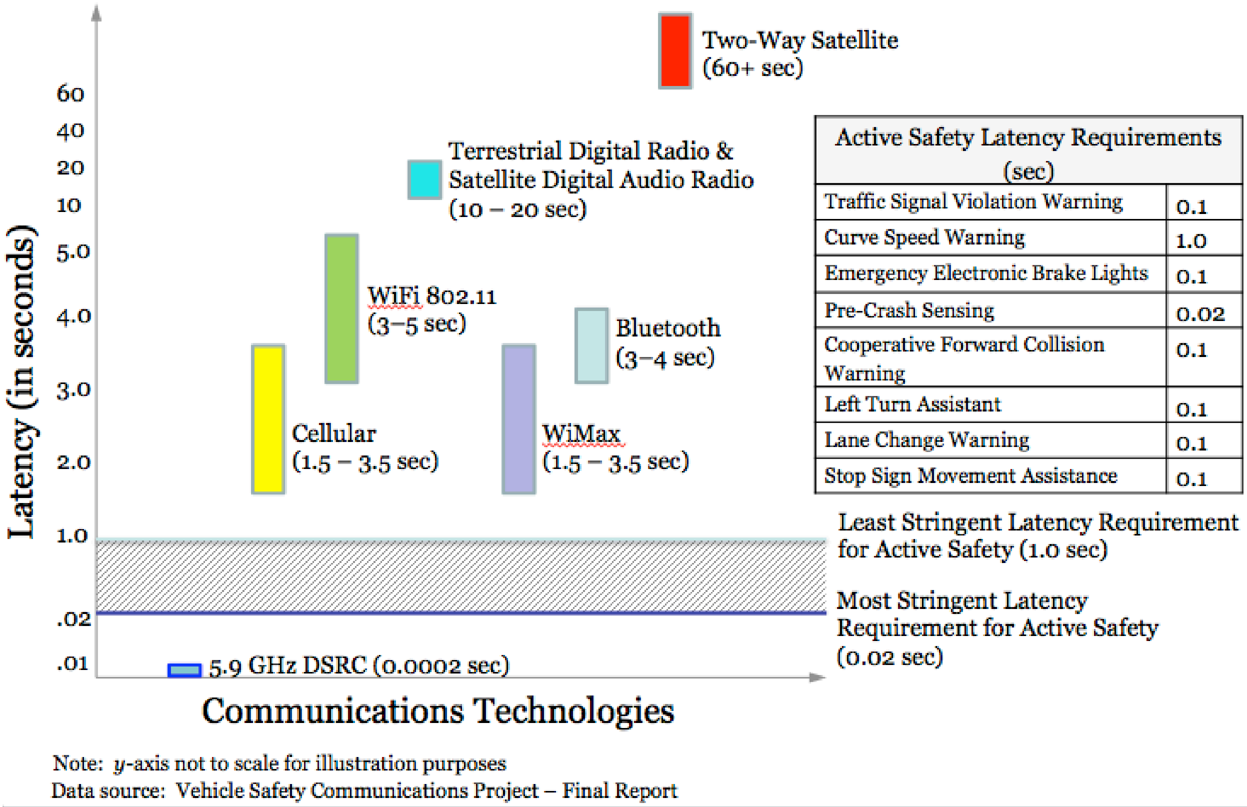


Figure 4.2: Communications Technologies

Figure 4.2 depicts *latency*, a measure of time delay experienced in a system for various communications technologies currently available in the market. The location of 5.9GHz on the vertical (latency) axis at .0002 seconds **dramatically demonstrates** why it is the only candidate that meets or exceeds the **most stringent latency requirement** (at .02 seconds) for active safety.

Think about the seconds it takes for your computer to connect to a wireless network. Even those few seconds are not acceptable in an imminent crash situation. The other technologies (WiFi, Cellular, Bluetooth and Satellite Digital Radio) are easily identified as inadequate to meet even the *least* stringent latency requirement at 1 second.

As shown in Figure 4.3, DSRC is projected to provide solutions for 80% of crash scenarios using the SAEJ2735 Basic Safety Message (BSM).

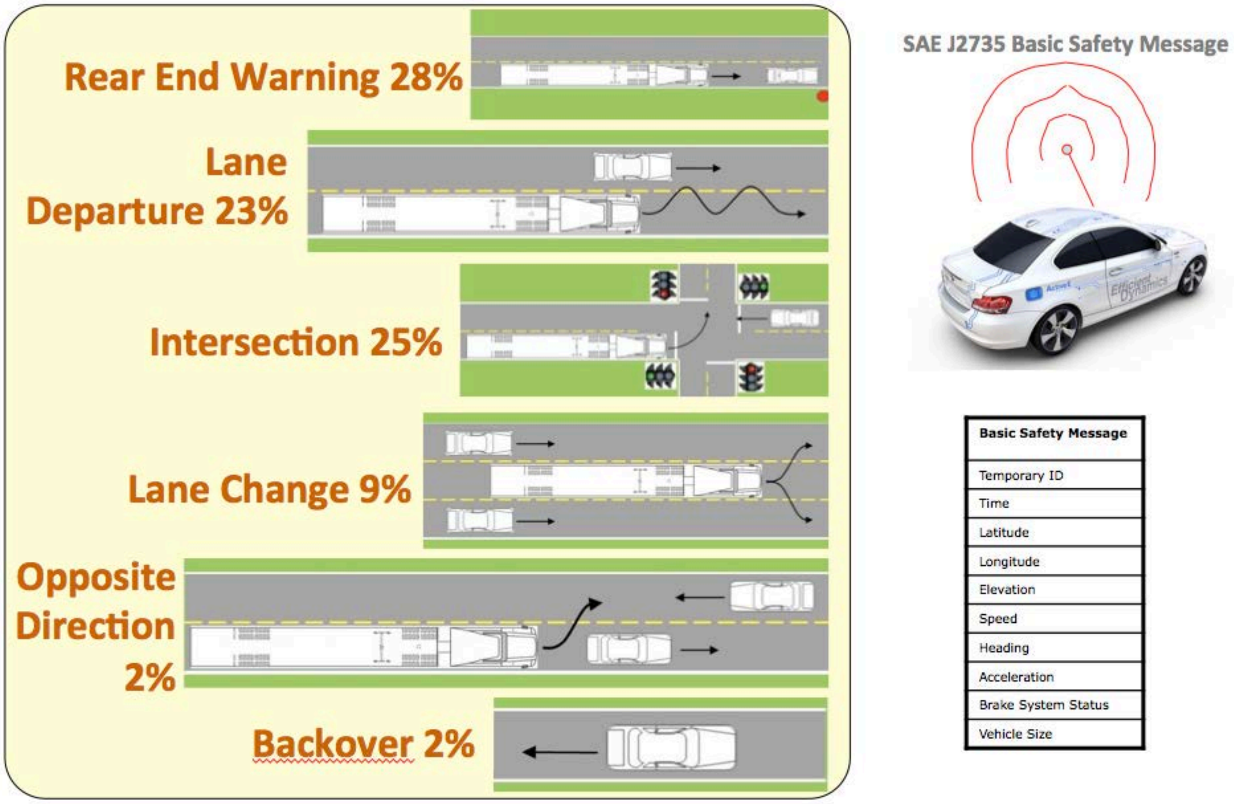


Figure 4.3: V2V Safety Applications and Basic Safety Message

4.3 WHAT IS AN "APPLICATION" OR "USE CASE?"

In the context of connected and automated vehicles, we often speak about applications or use cases. In order to think about what these terms mean, we begin with the general definition of an "app," in the context of computer applications (see Figure 4.4):

> *a self-contained program or piece of software designed to fulfill a particular purpose; an application, especially as downloaded by a user to a mobile device.*

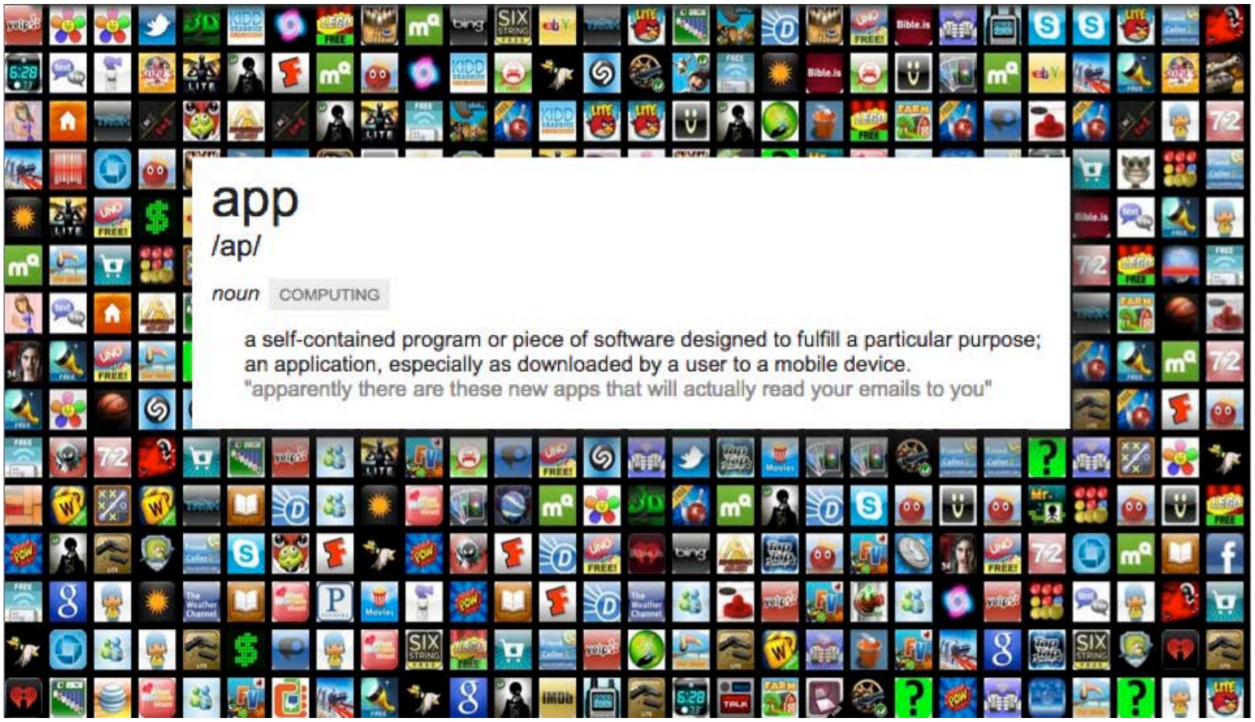


Figure 4.4: Definition of Applications

4.3.1 Components of a Smartphone Application

Many people are familiar with smartphone applications, which can be thought of as analogous to future connected vehicle applications. Some of the characteristics of a smartphone app include:

- Need/Benefits/Relevance/Customers
- Interface (screen, buttons…)
- Communications/Connectivity (networks, cellular, wi-fi…)
- Computing Power and Storage (hardware)
- Location/GPS
- Backbone (the “cloud,” aggregation of user data….)
- Institutional Structure (app store, etc.)
- Sensors (accelerometer….)
- Software/Operating System (security…)

- Integration/Interoperability (other devices, countries, languages….)
- Lifecycle/Updates/Certainty

4.3.2 Definition of Connected Vehicle Application

- One or more pieces of software designed to perform some specific function.
- Configuration of interacting Engineering Objects.
- A computer software program with an interface, enabling people to use a computer as a tool to accomplish a specific task.
- Provide an accessible, service-oriented perspective to the Connected Vehicle Reference Implementation Architecture (CVRIA), as illustrated in Figure 4.5.
- Tailored to fit, separately or in combination, real world transportation problems and needs.
- Defined by various connected vehicle programs.
- Sources: Concepts of Operations (ConOps), Requirements Specifications, or existing Standards and Architectures.
- Four types: Environmental, Mobility, Safety, and Support.
- Four architectural views: Enterprise, Functional, Physical, and Communications.

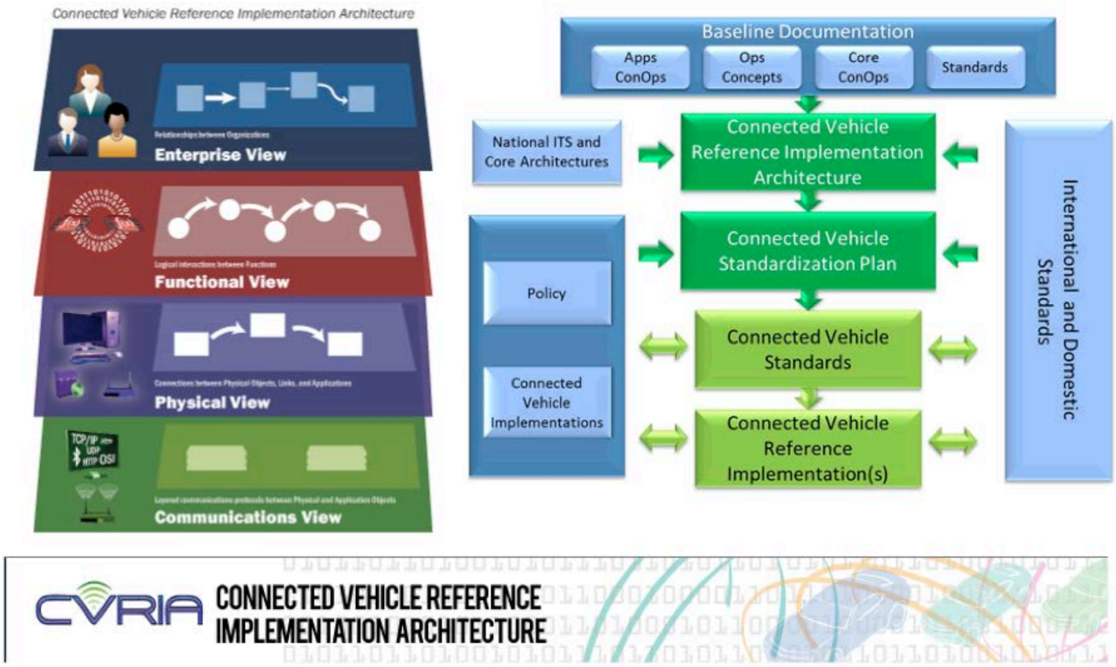


Figure 4.5: Connected Vehicle Reference Implementation Architecture

4.3.3 Traditional Intelligent Transportation Systems

Historically we have thought about traditional intelligent transportation systems (ITS) as consisting of three key components (see Figure 4.6):

- **Technology**: the transportation industry has been able to take advantage of innovations in four primary fields:
  - **Location/GPS**
  - **Sensors**
  - **Computing**
  - **Communication**
- **Proactive Management:** technology alone is not enough. ITS has included from its inception the idea that the technological developments provide a platform upon which proactive management approaches are needed including:
  - **Management Strategies**
  - **Brainpower/Collaboration**
  - **Integration**
- **Functional Areas and Applications**:
  - In the early implementations of ITS specific functional areas and associated applications were realized, including:
    - Advanced Traveler Information Systems (ATIS)
    - Advanced Traffic Management Systems (ATMS)

    - Advanced Vehicle Control Systems (AVCS)
    - Advanced Rural Transportation Systems (ARTS)
    - Advanced Public Transportation Systems (APTS)
    - Commercial Vehicle Operations (CVO)
- These included a wide range of projects and programs including but not limited to:
    - Ramp Metering
    - Dynamic Freeway and Arterial Message Signs
    - Incident Response
    - Variable Speed Limit Systems
    - Closed Circuit Television Surveillance Systems
    - Traffic Management Centers
    - Transit Information Systems
    - Commercial Vehicle Weigh Station Baypass
    - Dynamic Curve Warning Systems
    - Ice Warning Systems
- The systematic and individual implementations of technologies and systems resulted in a key set of measurable benefits that were sometimes summarized as "lives time and resources:"
    - Safety
    - Efficiency
    - Sustainability

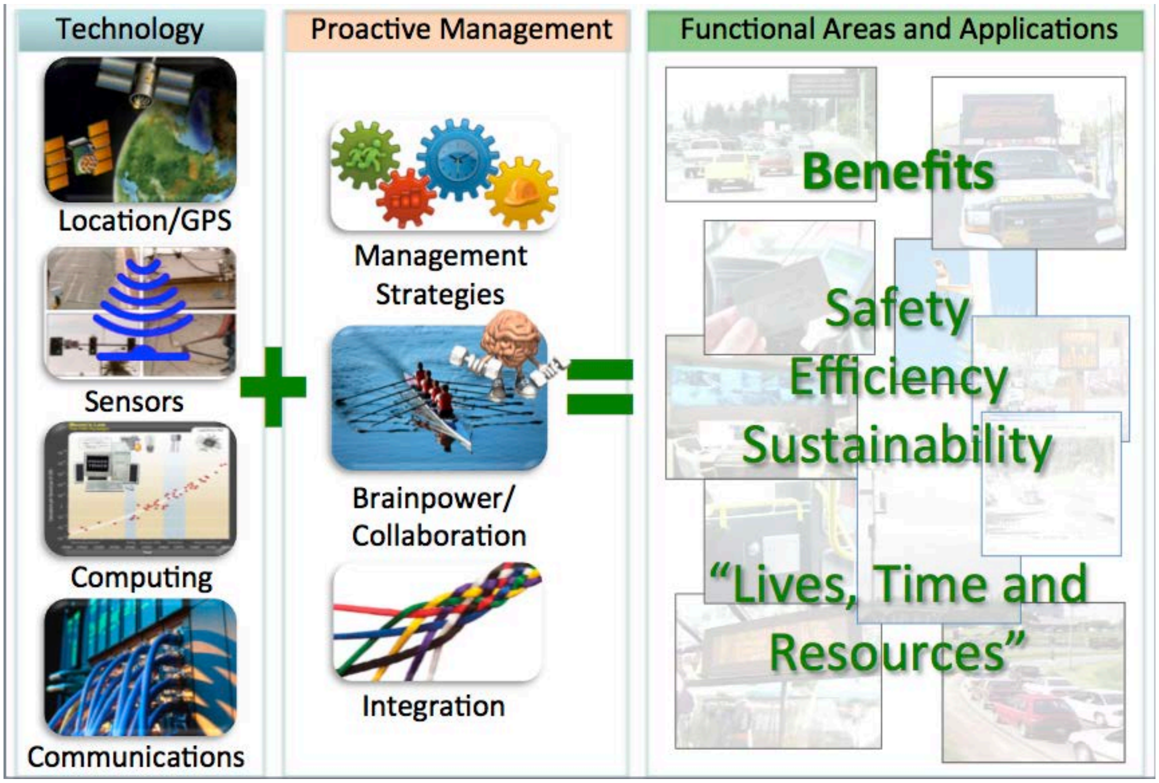


Figure 4.6: Traditional ITS

4.3.4 Connected Vehicle Infrastructure Deployment

The vision for a system with vehicles that are connected to one another and to the infrastructure requires a range of infrastructure elements for it to be fully enabled (see Figure 4.7):

- Roadside communications equipment (for DSRC or other wireless services), enclosures, mountings, power and network backhaul.
- Traffic signal controller interfaces for applications that require signal phase and timing (SPaT).
- Systems and processes required to support management of security credentials and ensure a trusted network.
- Mapping services that provide highly detailed roadway geometries, signage and asset locations for the various CV applications.
- Positioning services for resolving vehicle locations to high accuracy and precision.
- Data servers for collecting and processing data provided by vehicles and for distributing information, advisories and alerts to users.

In parallel with the spirit of traditional ITS, a connected vehicle environment also consists of developments in:

- **Technology**
  - DSRC + Wireless
  - Roadside
  - Vehicle/On-Board Unit
  - Security Layer
  - Location/GPS
- **Management**
  - Data Environment
  - Management Strategies
  - Application "Engine"
- **Applications**
  - Safety
  - Mobility
  - Environmental

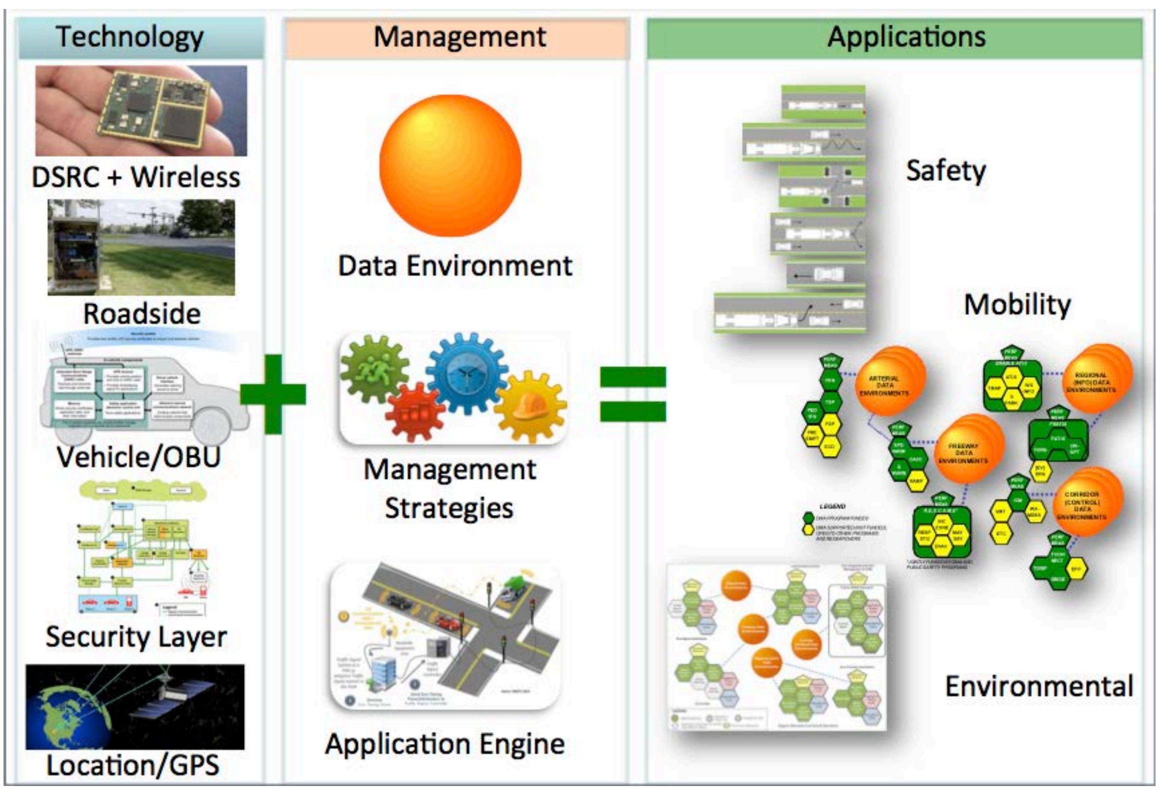


Figure 4.7: Connected Vehicle Environment Developments

4.4 CURRENT STATE OF NATIONAL CONNECTED VEHICLE PROGRAM

4.4.1 Safety Pilot and NHTSA Rulemaking

In 2010 the U.S. DOT launched its Connected Vehicle Safety Pilot in Ann Arbor Michigan, as shown in Figure 4.8, consisting of 2,836 vehicles and 11 applications:

Figure 4.8: Safety Pilot

- Vehicle to Vehicle
    - Forward Collision Warning
    - Emergency Electronic Brake Light
    - Intersection Movement Assist

    - Blind Spot Warning/Lane Change Warning
    - Left Turn Across Path/Opposite Direction
    - Right Turn in Front
  - Vehicle to Infrastructure
    - Signal Phase and Timing
    - Curve Speed Warning
    - Railroad Crossing Warning
    - Pedestrian Detection.

The primary vehicle type was automobile, but several commercial trucks, buses, motorcycles and bicycles were also included in the model deployment. The primary goal of the pilot was to inform a decision announced by the National Highway Traffic Safety Administration (NHTSA) in February 2014. NHTSA is currently working on a rulemaking effort that will likely be announced in early 2016, with a possible regulation to require all new light vehicles in the U.S. to include DSRC communications capabilities.

4.4.2 Mobility Program

As illustrated in Figure 4.9, data from vehicles are made available via DSRC. They are all interoperable and this permits the formation of a data environment, which can be a client-server architecture, ad hoc peer to peer, or something we haven't thought of yet. These data can be consumed by a broad spectrum of devices. There is a vision for multi-source data fusion with the following objectives:

- Enable systematic data capture from connected vehicles (automobiles, transit, trucks), mobile devices, and infrastructure

- Develop data environments that enable integration of data from multiple sources for use in transportation management and performance measurement

- Reduce costs of data management and eliminate technical and institutional barriers to the capture, management, and sharing of data

The wide range of data merged via the envisioned data environment, a range of connected vehicle applications are enabled with the following objectives:

- Create applications enablers using frequently collected and rapidly disseminated multi-source data from connected travelers, vehicles (automobiles, transit, freight) and infrastructure

- Develop and assess applications showing potential to improve nature, accuracy, precision and/or speed of dynamic decision making by system managers and system users

- Demonstrate promising applications predicted to significantly improve capability of transportation system to provide safe, reliable, and secure movement of goods and people

Several years ago an open call for transformative mobility application concepts resulted in 93 ideas being submitted, with a set of 33 consolidated applications being formulated. These have been bundled into six key categories as shown in Figure 4.10:

- Enable Advanced Traveler Information Systems (Enable ATIS)
- Response Emergency Staging & Communication Uniform Management & Evacuation (RESCUME)
- Multimodal Intelligent Traffic Signal Systems (MMITSS)
- Freight Advanced Traveler Information System (FRATIS)
- Integrated Dynamic Transit Operations (IDTO)
- Intelligent Network Flow Optimization (INFLO)

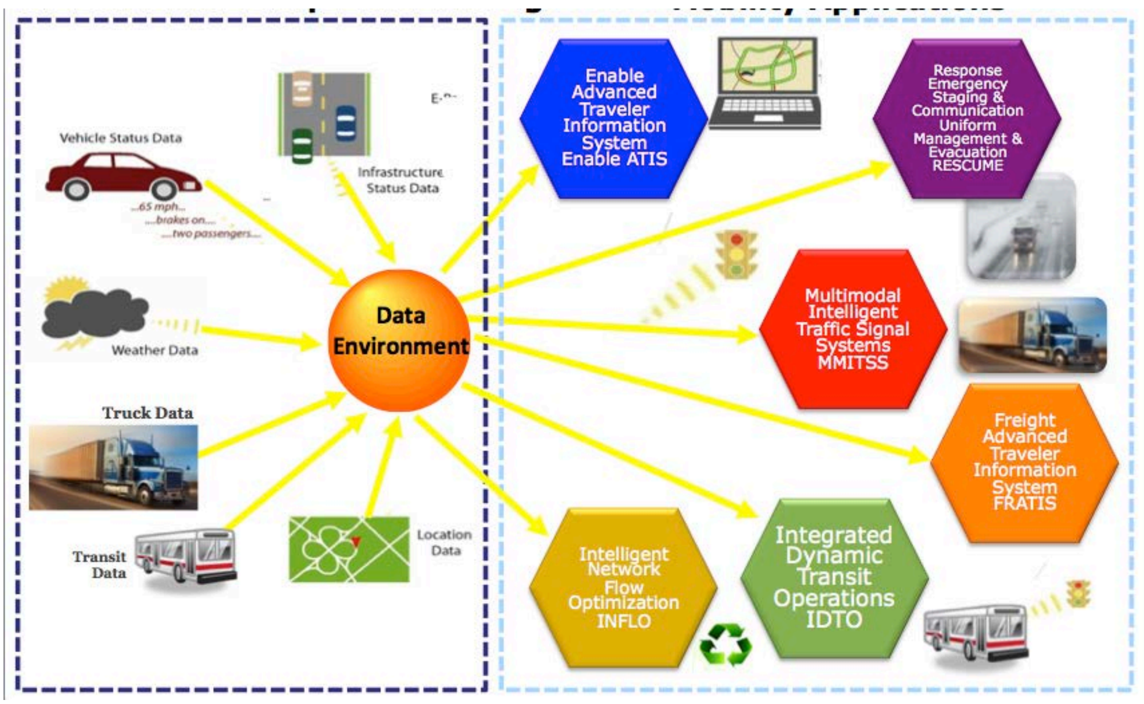


Figure 4.9: Mobility Program Real Time Data Capture and Management and Mobility Applications

On September 14, 2015, the U.S. DOT announced the selection of three sites for the National Connected Vehicle Pilot Deployment Program:

- **New York City, New York**: vehicle to vehicle (V2V) technology will be installed in 10,000 city-owned vehicles; including cars, buses, and limousines, that frequently travel in Midtown Manhattan, as well as vehicle to infrastructure (V2I) technology throughout Midtown. This includes upgrading traffic signals with V2I technology along avenues between 14th Street and 66th Street in Manhattan and throughout Brooklyn. Additionally, roadside units will be equipped with connected vehicle technology along the FDR Drive between 50th Street and 90th Street.

- **Tampa, Florida**: connected vehicle technology will solve peak rush hour congestion in downtown Tampa and protect the city's pedestrians by equipping their smartphones with the same connected technology being put into the vehicles. Tampa also committed to measuring the environmental benefits of using this technology.

- **Wyoming**: focus is on the efficient and safe movement of freight through the I-80 east-west corridor, which is critical to commercial heavy-duty vehicles moving across the northern portion of our country. Approximately 11,000 to 16,000 vehicles travel this corridor every day, and by using V2V and V2I, Wyoming DOT will both collect information and disseminate it to vehicles not equipped with the new technologies.

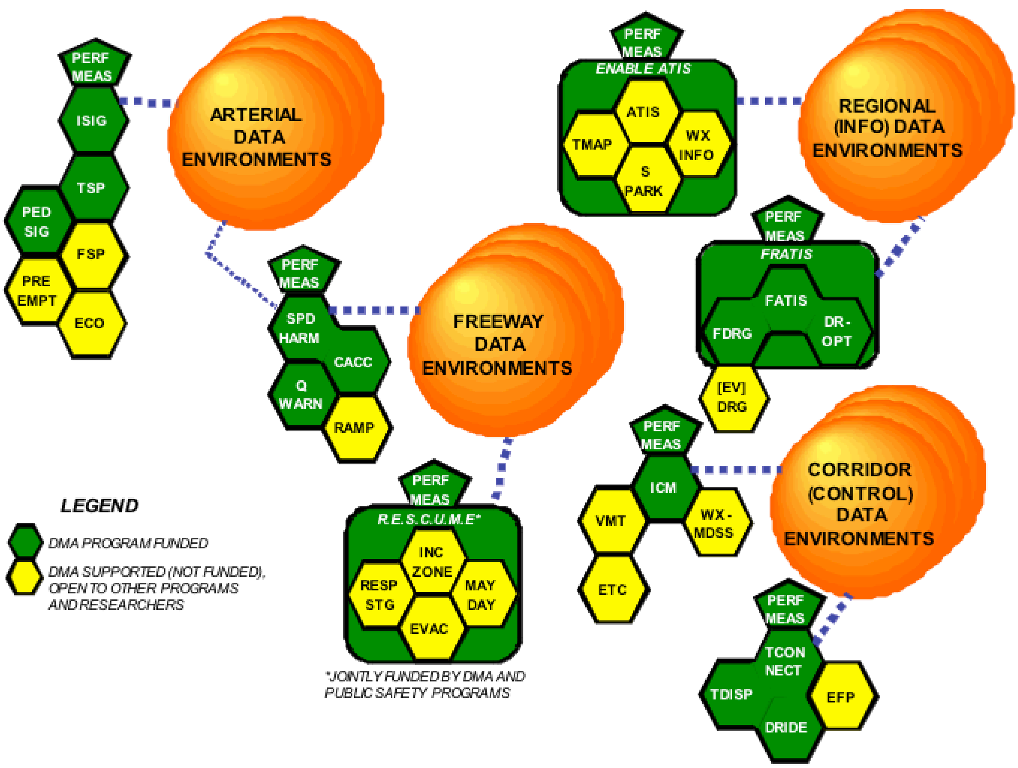


Figure 4.10: High Priority Mobility Applications

4.4.3 Environmental Program

The environmental program for connected vehicles is known Applications for the Environment: Real-Time Information Synthesis (AERIS). The objective of the AERIS research program is to generate and acquire environmentally-relevant real-time transportation data, and use these data to create actionable information that support and facilitate "green" transportation choices by transportation system users and operators. Employing a multi-modal approach, the AERIS Research Program aims to encourage the development of technologies and applications that support a more sustainable relationship between transportation and the environment chiefly through fuel use reductions and resulting emissions reductions. As shown in Figure 4.11, the six primary areas under AERIS include:

- Low Emission Zone
- Eco-integrated Corridor Management
- Eco-Signal Operations
- Eco-Lanes
- Support Alternative Fuel Vehicle Operations
- Eco-Traveler Information

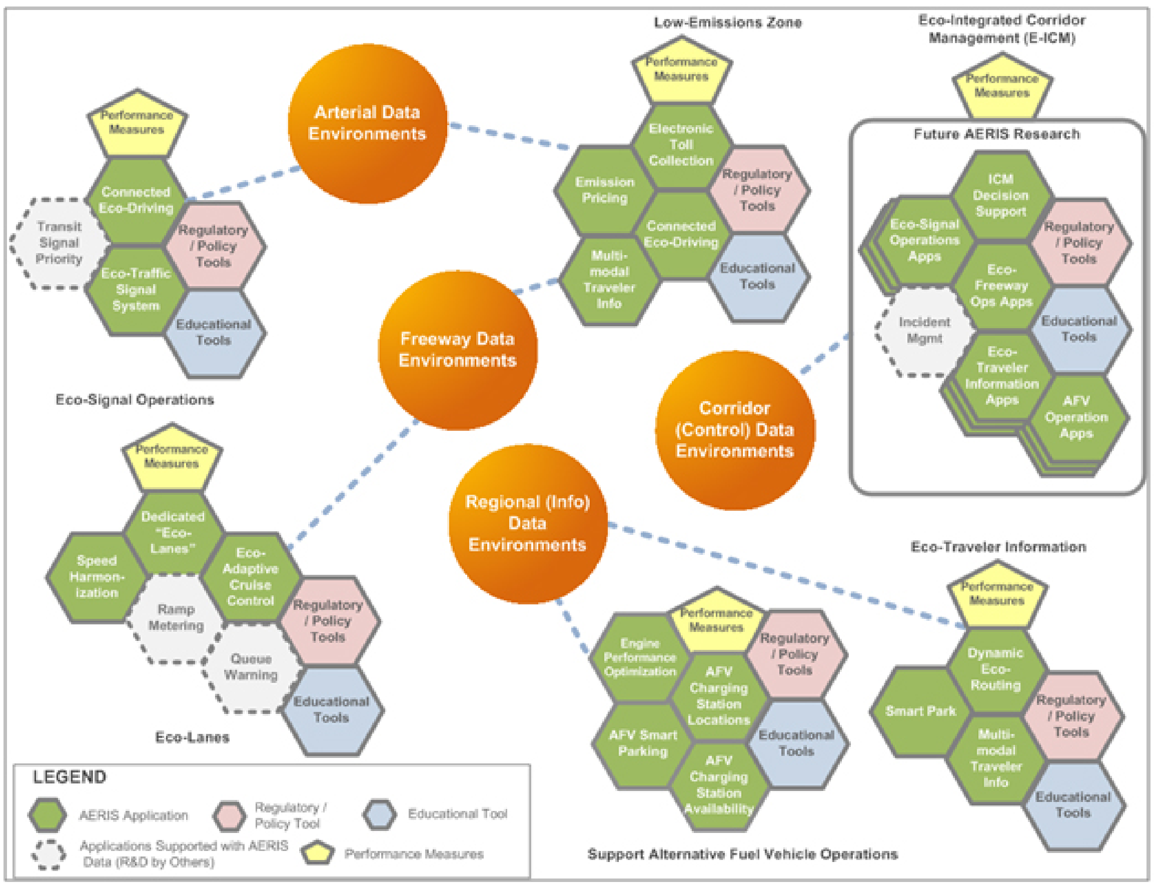


Figure 4.11: AERIS Program

5.0 INITIAL MAPPING OF GOALS AND APPLICATIONS

The most significant effort as part of the stakeholder outreach for this project has been the sifting and sorting of connected vehicle applications as described next. (Figures 5.1 through 5.14) There are multiple ways to break up the array of applications into logical groupings. The U.S. DOT categorizations fall into V2V and V2I and across outcomes, such as mobility, safety, environment, agency data, road weather, and smart roadside. Another way of categorizing the applications that is relevant for an infrastructure provide like ODOT is whether the application focuses on a node or along a link in the transportation network.

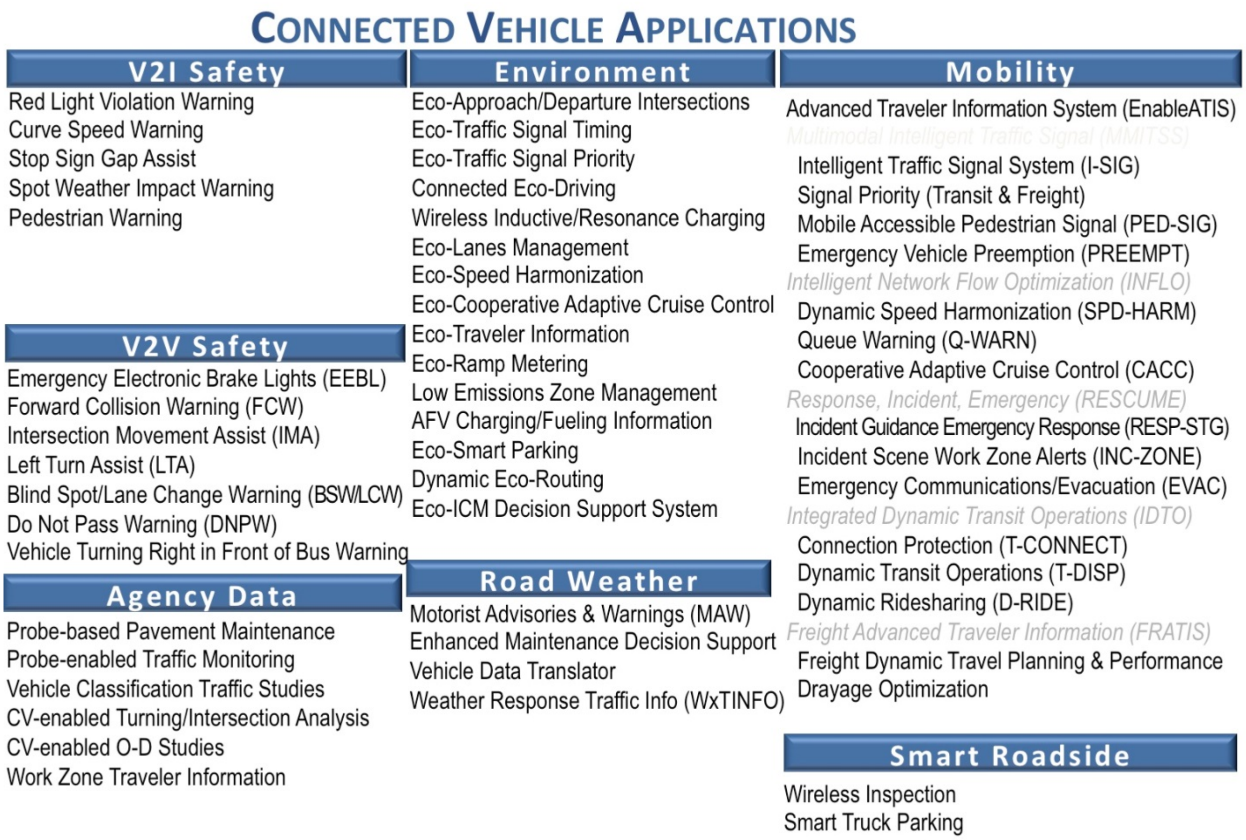


Figure 5.1: Initial Connected Vehicle Application Listing from U.S. DOT

We begin with the U.S. DOT's list of connected vehicle applications. A total of 55 applications are listed in Figure 5.1.

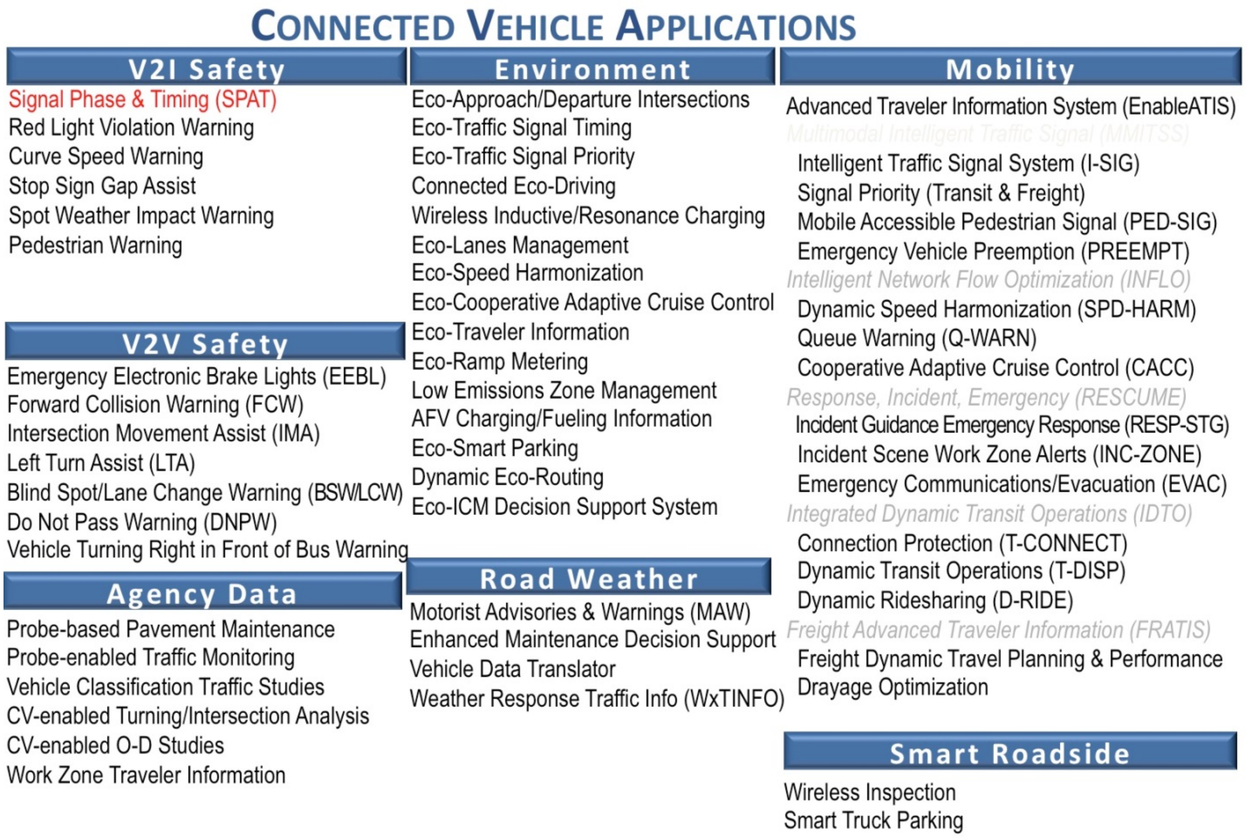


Figure 5.2: Addition of Signal Phase & Timing (SPAT) Application

The U.S. DOT CV listing did not include the signal phase & timing application (SPAT) listed under V2I Safety, so this listing now includes 56 applications as shown in Figure 5.2.

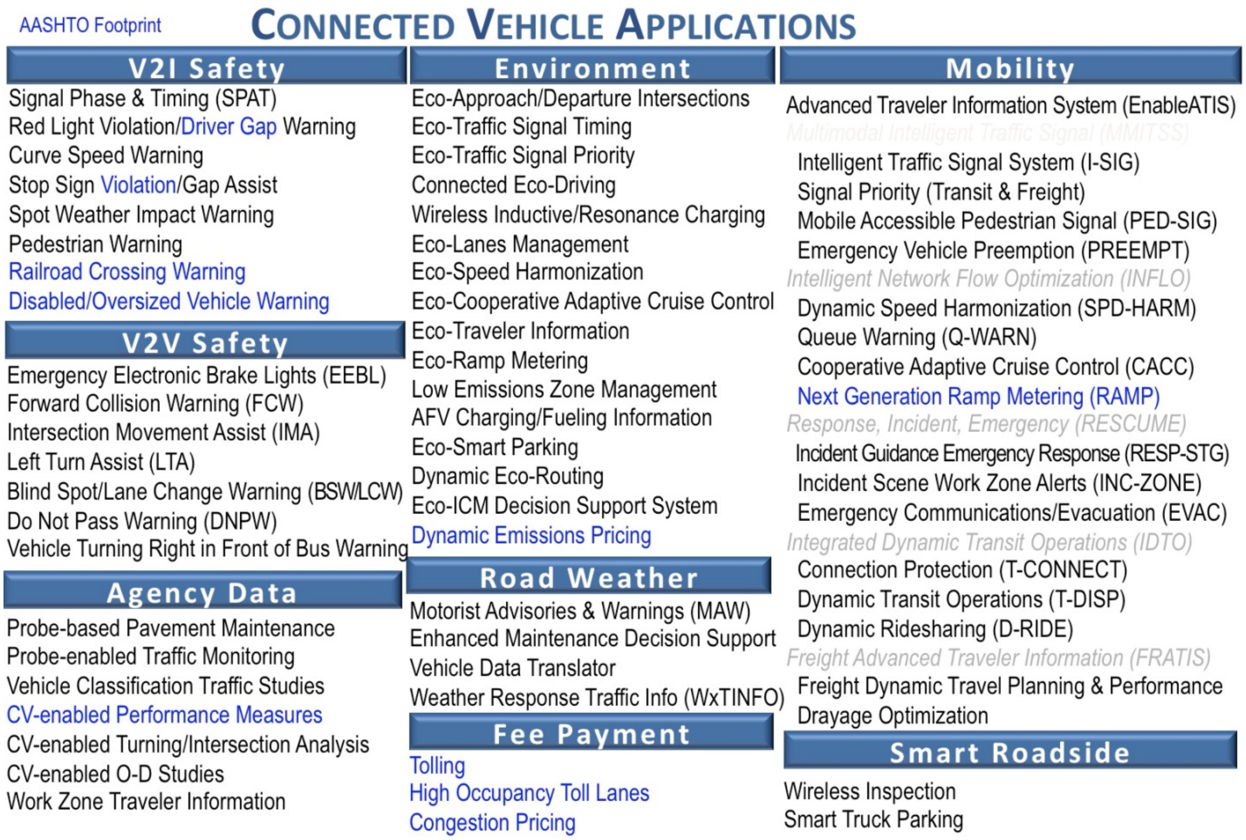


Figure 5.3: Addition of AASHTO Footprint Analysis Applications

The AASHTO Footprint Analysis included several additional applications as shown in this figure, including Railroad Crossing Warning, Disabled/Oversized Vehicle Warning, CV-enabled Performance Measures, Dynamic Emissions Pricing, Tolling, High Occupancy Toll Lanes, Congestion Pricing and Next Generation Ramp Metering. These applications are important for Oregon and make the total number of applications at 64, see Figure 5.3.

Connected Vehicle Applications

V2I Safety
1. Signal Phase & Timing (SPAT)
2. Red Light Violation/Driver Gap Warning
3. Curve Speed Warning
4. Stop Sign Violation/Gap Assist
5. Spot Weather Impact Warning
6. Pedestrian Warning
7. Railroad Crossing Warning
8. Disabled/Oversized Vehicle Warning

V2V Safety
9. Emergency Electronic Brake Lights (EEBL)
10. Forward Collision Warning (FCW)
11. Intersection Movement Assist (IMA)
12. Left Turn Assist (LTA)
13. Blind Spot/Lane Change Warning (BSW/LCW)
14. Do Not Pass Warning (DNPW)
15. Vehicle Turning Right in Front of Bus Warning

Agency Data
16. Probe-based Pavement Maintenance
17. Probe-enabled Traffic Monitoring
18. Vehicle Classification Traffic Studies
19. CV-enabled Performance Measures
20. CV-enabled Turning/Intersection Analysis
21. CV-enabled O-D Studies
22. Work Zone Traveler Information

Environment
23. Eco-Approach/Departure Intersections
24. Eco-Traffic Signal Timing
25. Eco-Traffic Signal Priority
26. Connected Eco-Driving
27. Wireless Inductive/Resonance Charging
28. Eco-Lanes Management
29. Eco-Speed Harmonization
30. Eco-Cooperative Adaptive Cruise Control
31. Eco-Traveler Information
32. Eco-Ramp Metering
33. Low Emissions Zone Management
34. AFV Charging/Fueling Information
35. Eco-Smart Parking
36. Dynamic Eco-Routing
37. Eco-ICM Decision Support System
38. Dynamic Emissions Pricing

Road Weather
39. Motorist Advisories & Warnings (MAW)
40. Enhanced Maintenance Decision Support
41. Vehicle Data Translator
42. Weather Response Traffic Info

Fee Payment
43. Tolling
44. High Occupancy Toll Lanes
45. Congestion Pricing

Mobility
46. Advanced Traveler Information System (EnableATIS)

Multimodal Intelligent Traffic Signal (MMITSS)

47. Intelligent Traffic Signal System (I-SIG)
48. Signal Priority (Transit & Freight)
49. Mobile Accessible Pedestrian Signal (PED-SIG)
50. Emergency Vehicle Preemption (PREEMPT)

Intelligent Network Flow Optimization (INFLO)

51. Dynamic Speed Harmonization (SPD-HARM)
52. Queue Warning (Q-WARN)
53. Cooperative Adaptive Cruise Control (CACC)
54. Next Generation Ramp Metering (RAMP)

Response, Incident, Emergency (RESCUME)

55. Incident Guidance Emergency Response (RESP-STG)
56. Incident Scene Work Zone Alerts (INC-ZONE)
57. Emergency Communications/Evacuation (EVAC)

Integrated Dynamic Transit Operations (IDTO)

58. Connection Protection (T-CONNECT)
59. Dynamic Transit Operations (T-DISP)
60. Dynamic Ridesharing (D-RIDE)

Freight Advanced Traveler Information (FRATIS)

61. Freight Dynamic Travel Planning & Performance
62. Drayage Optimization

Smart Roadside
63. Wireless Inspection
64. Smart Truck Parking

Figure 5.4: Final List of 64 Applications

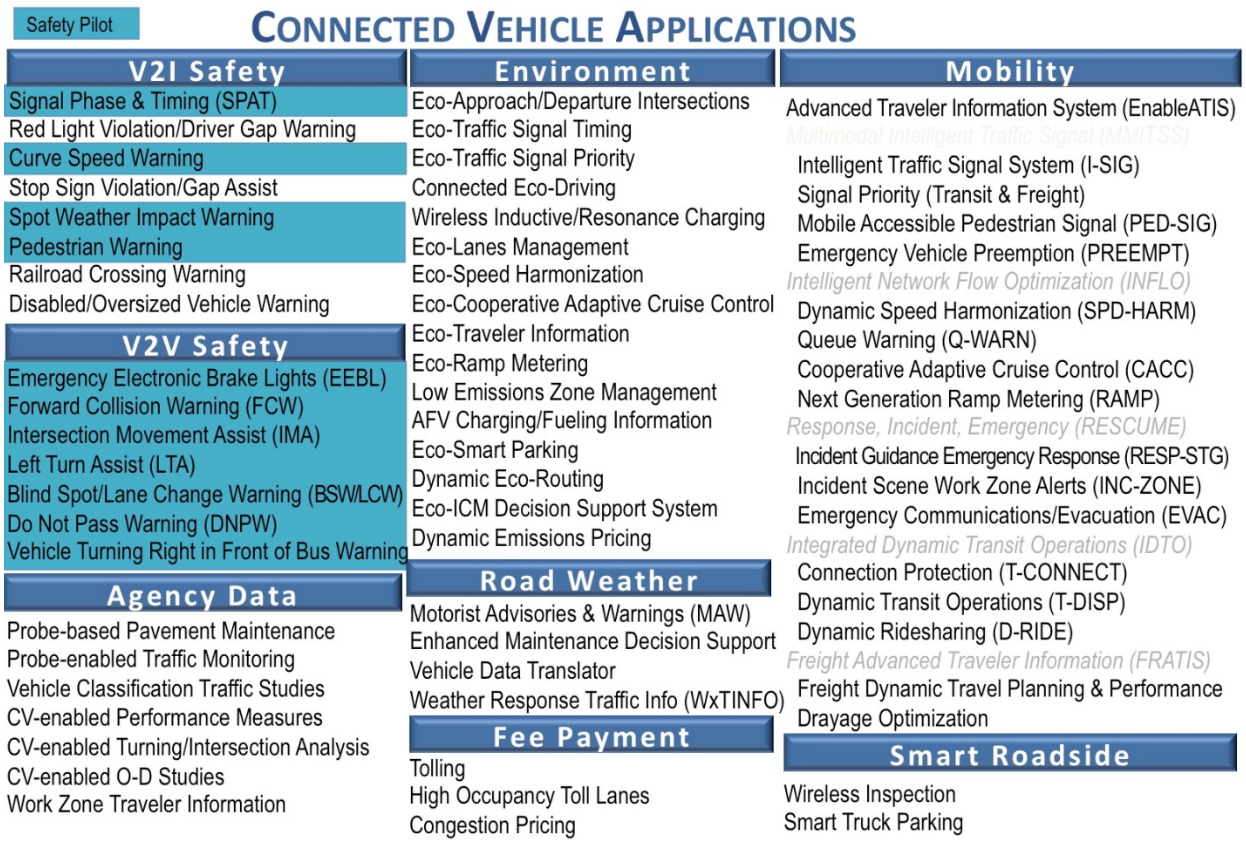


Figure 5.5: Identification of U.S. DOT Safety Pilot V2I and V2V Safety Applications

The U.S. DOT deployed a total of 11 safety applications in Ann Arbor, Michigan. Four of these focused on V2I Safety and seven focused on V2V Safety. We recognize that the V2V applications do not significantly affect the ODOT prioritization process since auto manufacturers are planning to deploy these systems independent of what government agencies decide to do. These are highlighted in Figure 5.5.

In the next several pages, a summary of the current priority coding of applications by risk and reward as follows:

- Priority 1 **(GREEN):** Near Term Focus for ODOT
- Priority 2 **(YELLOW):** ODOT Should Monitor, Possibly Collaborate, Leadership by Others
- Priority 3 **(RED):** Leadership by Others, ODOT Monitor

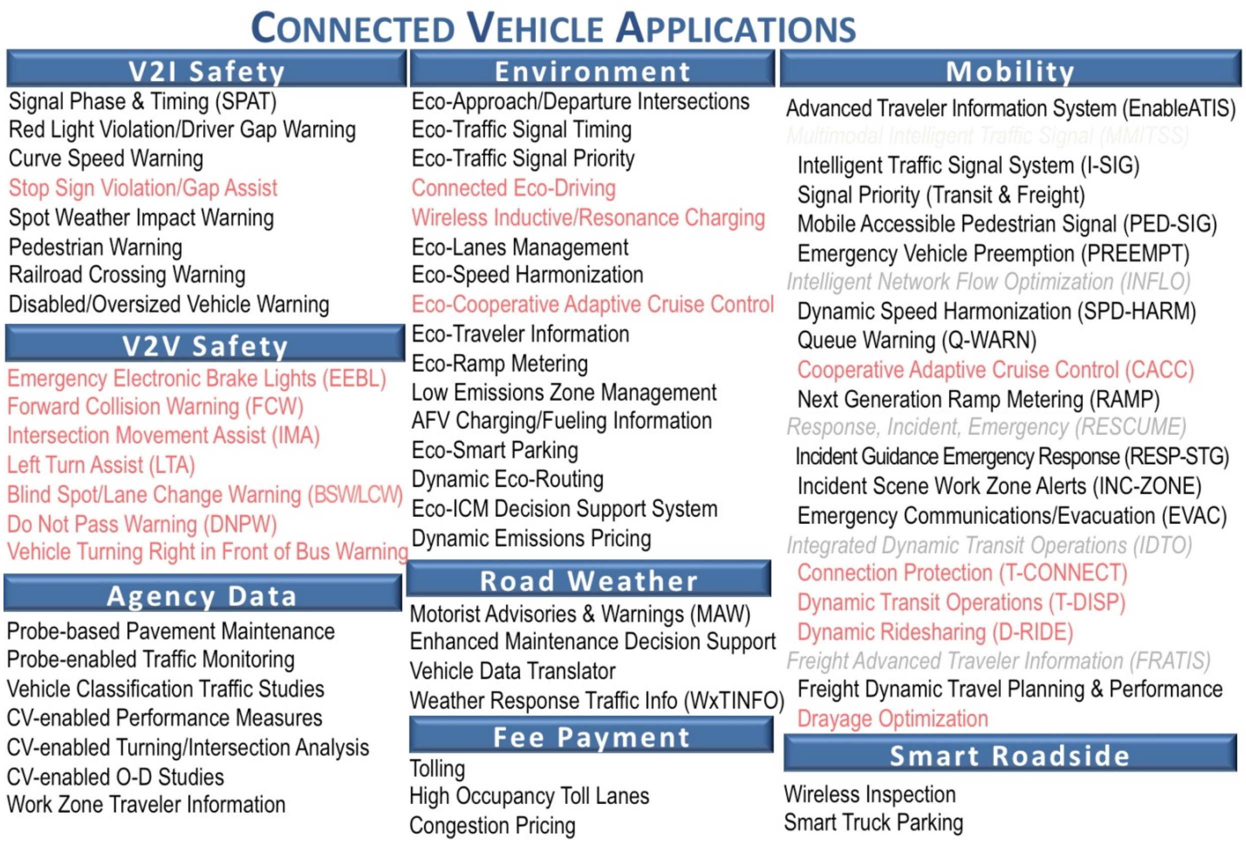


Figure 5.6: Identification of Priority 3 Applications

In this step, the seven V2V Safety applications were put into Priority 3, as shown in red in Figure 5.6. In addition, other applications that do not require a connection to the infrastructure provider, including: Stop sign Violation/Gap Assist, Connected Eco-Driving, Wireless Inductive/Resonance Charging, Eco-Cooperative Adaptive Cruise Control, Cooperative Adaptive Cruise Control and Drayage Optimization were also placed in Priority 3. For transit operations, since ODOT is not a provider of transit, the three applications: Connection Protection, Dynamic Transit Operations and Dynamic Ridesharing were also placed in Priority 3. This does not mean that these are not important areas for ODOT but just not the highest on an operational level.

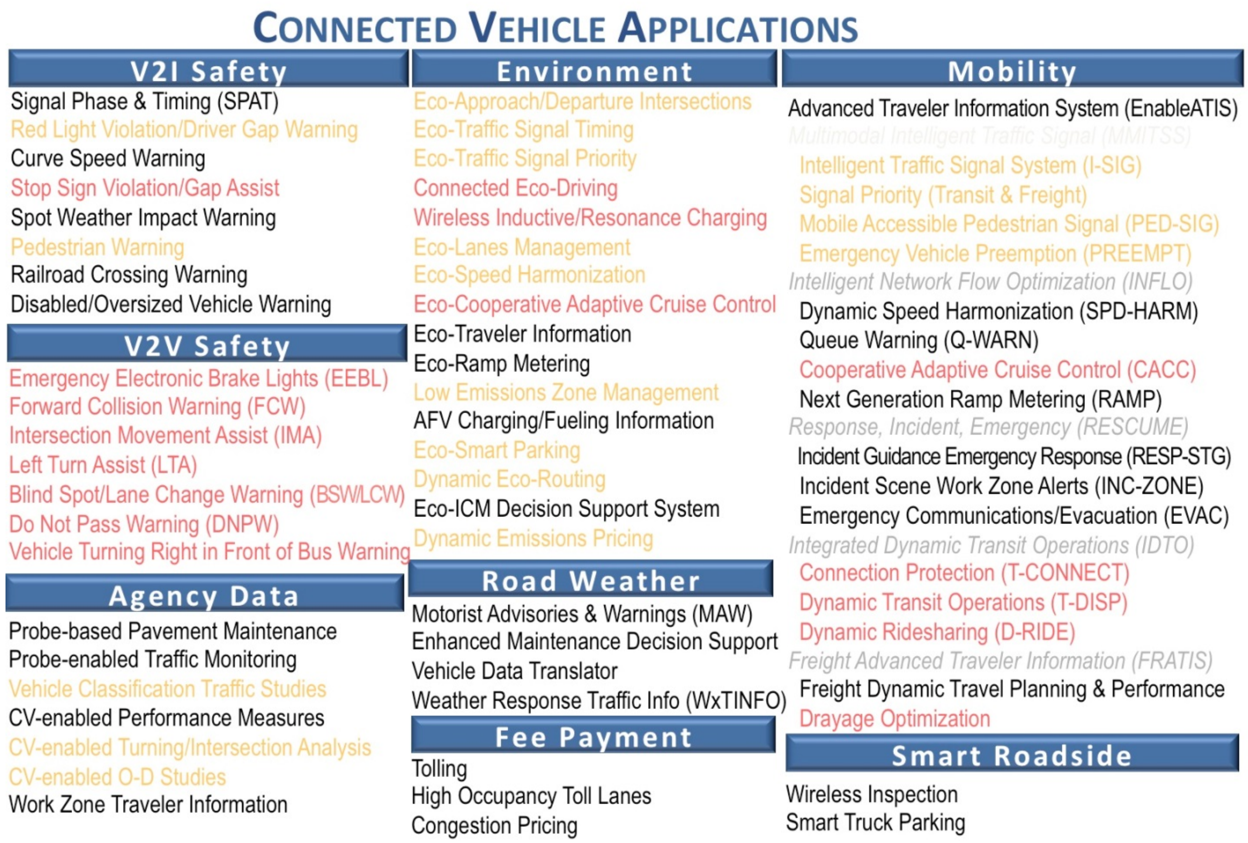


Figure 5.7: Identification of Priority 2 Applications

Through discussion with the Technical Advisory Committee (TAC) a second tier of applications were placed (initially) in Priority 2. Under V2I Safety, the Pedestrian Warning and Red Light Violation/Driver Gap Warning applications were moved into Priority 2 since it is envisioned that city agencies may be more focused on these issues. Under Agency Data, while all applications are valuable, three were placed in Priority 2 that seemed more relevant for cities and MPOs. Under the Environment, applications that overlapped with similar Mobility applications were put in Priority 2 since the Mobility goals would also result in Environmental improvements. Under mobility several ATIS applications were also moved to Priority 2 that are more focused on transit agencies or cities. Figure 5.7 shows the Priority 1 and Priority 2 applications.

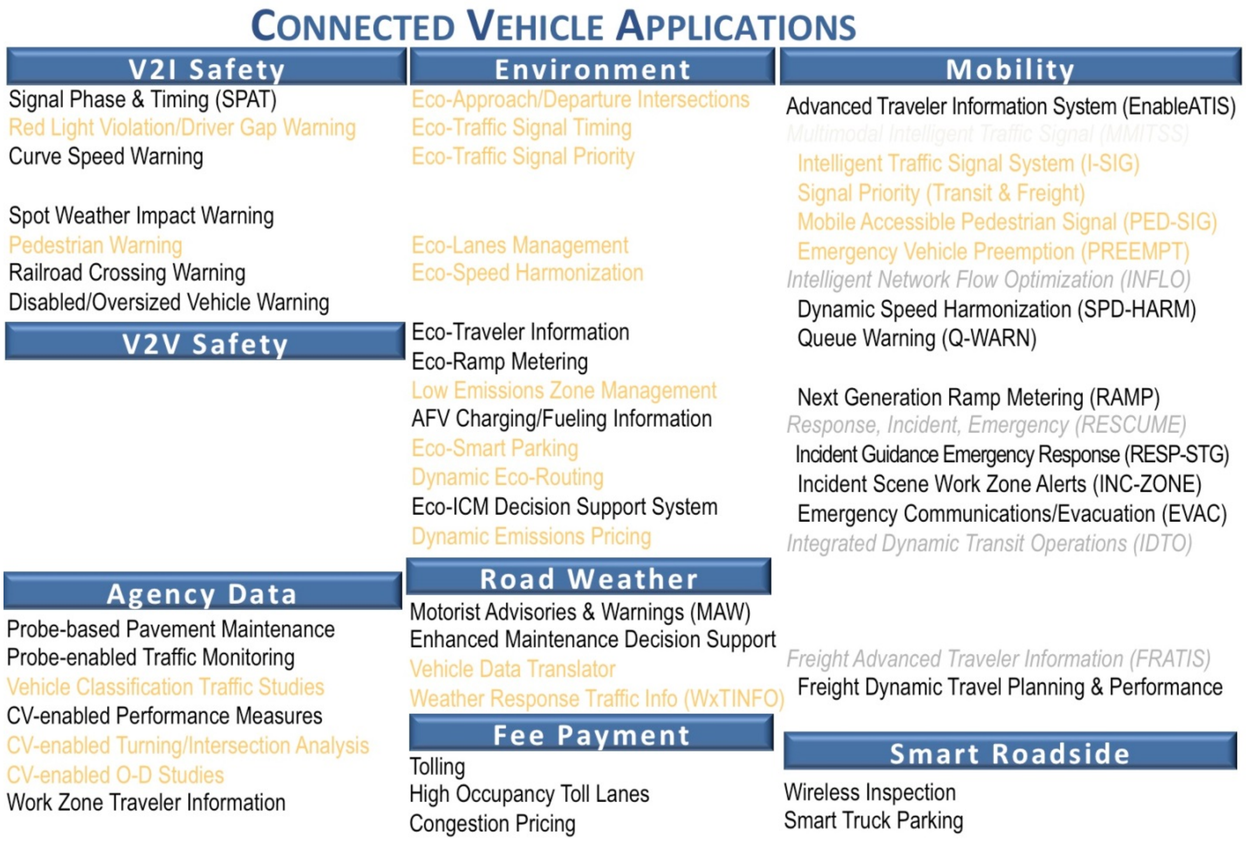


Figure 5.8: Identification of Priority 2 Applications

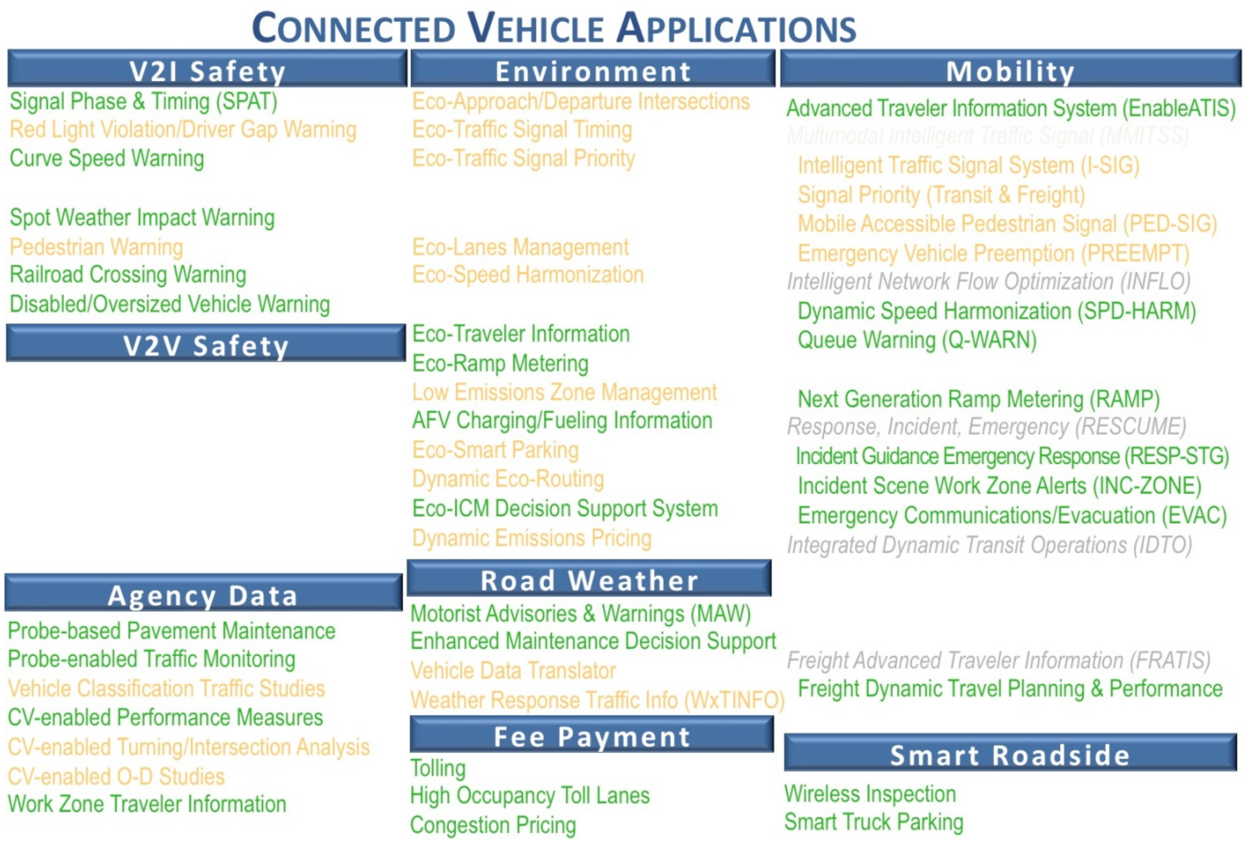


Figure 5.9: Identification of Priority 1 Applications

The sorting process results in a total of 28 Applications as candidates for Priority 1, shown in green in Figure 5.9.

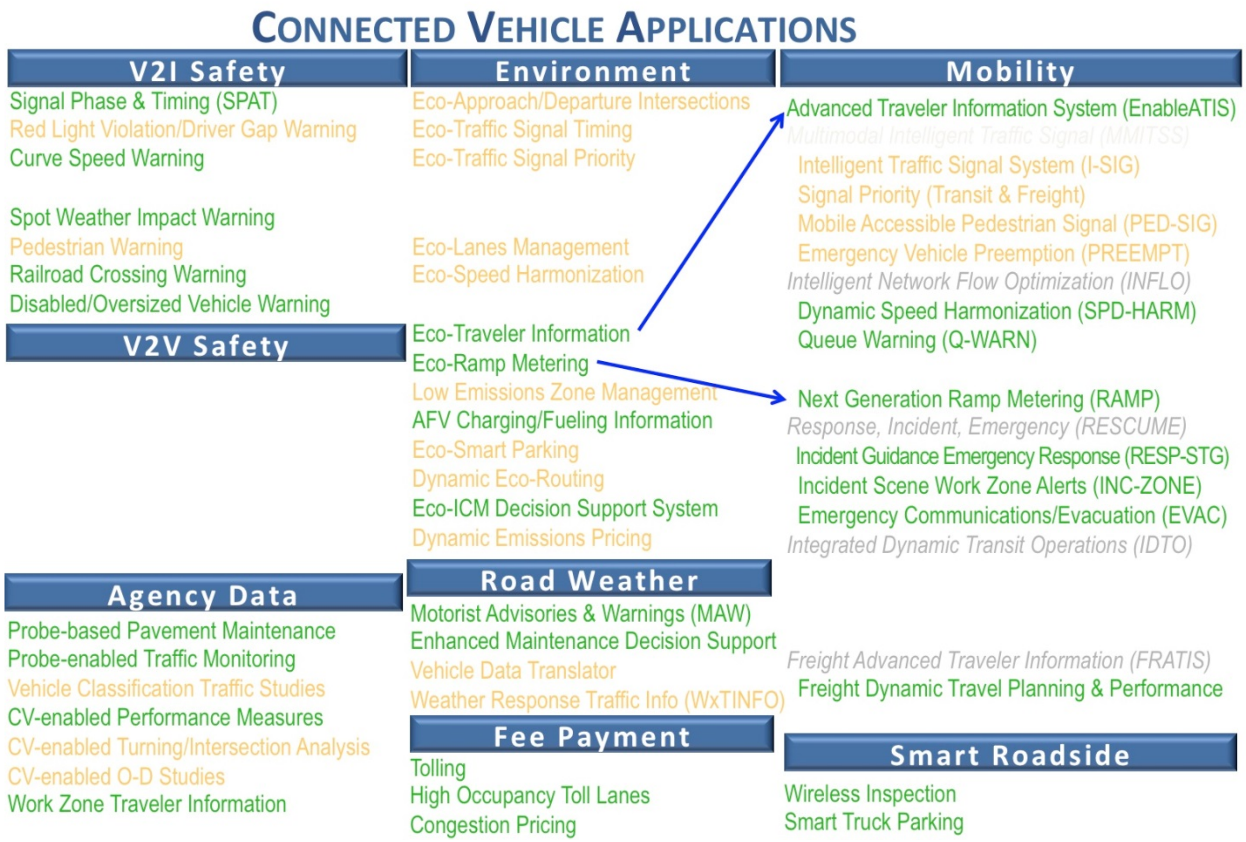


Figure 5.10: Identification of Priority 1 Applications

Eco-Traveler Information and Eco-Ramp Metering were moved to Priority 2 since they are covered under Mobility, as illustrated in Figure 5.10.

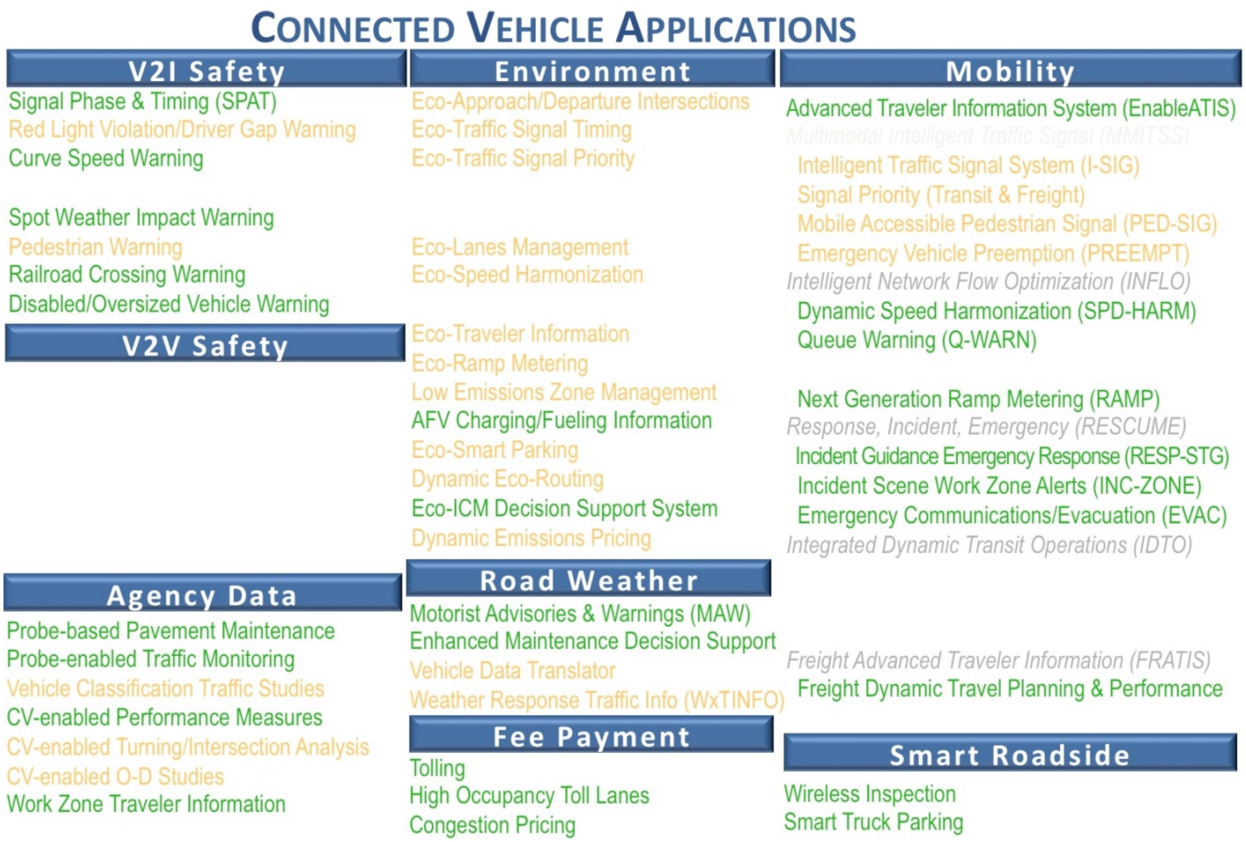


Figure 5.11: Identification of Priority 1 Applications

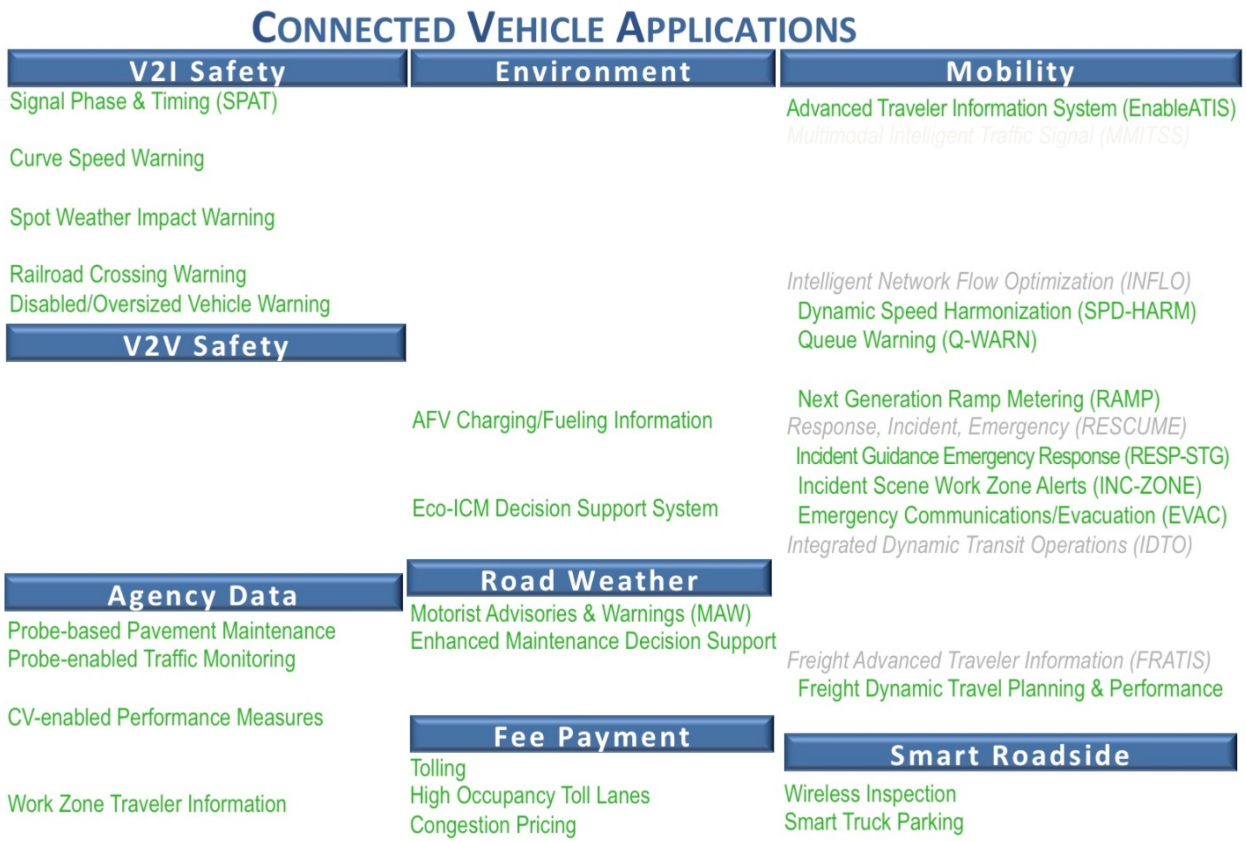


Figure 5.12: Identification of Priority 1 Applications

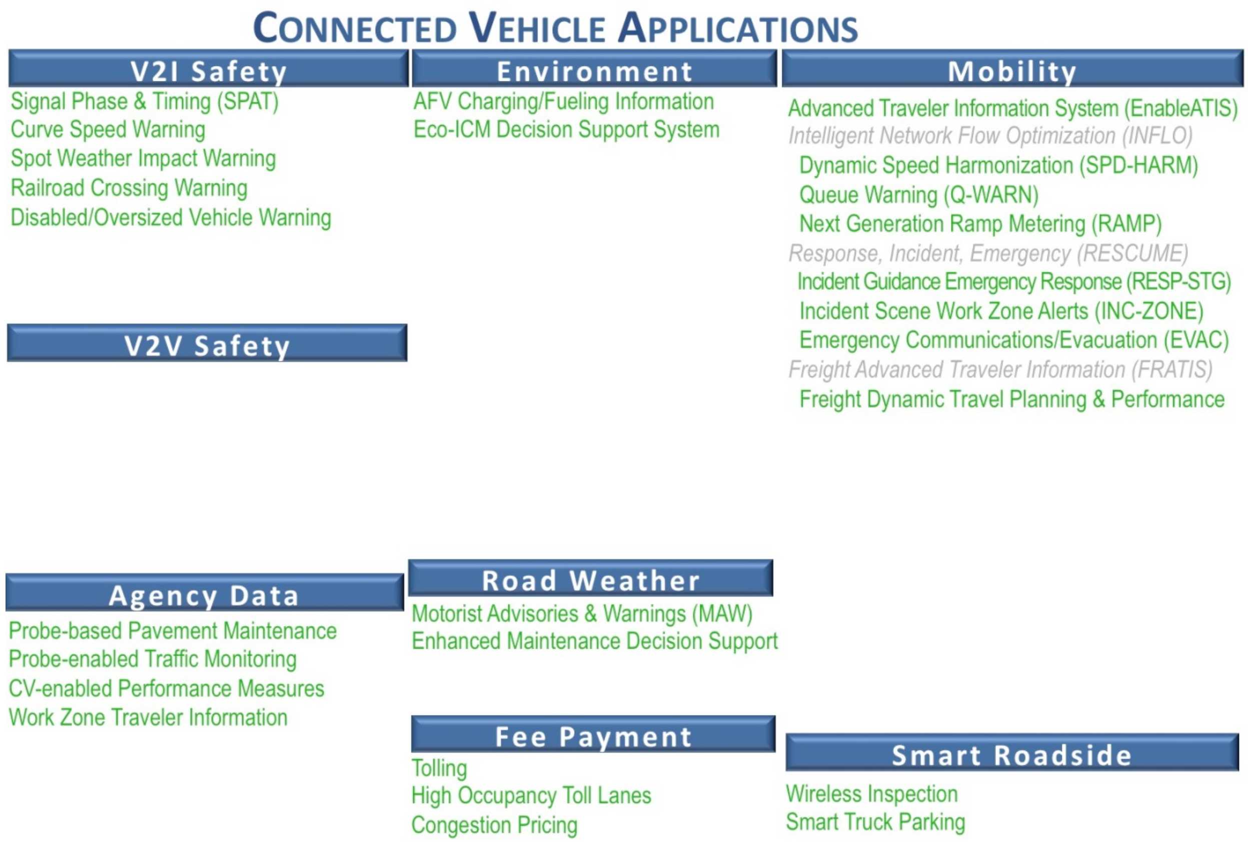


Figure 5.13: Identification of Priority 1 Applications

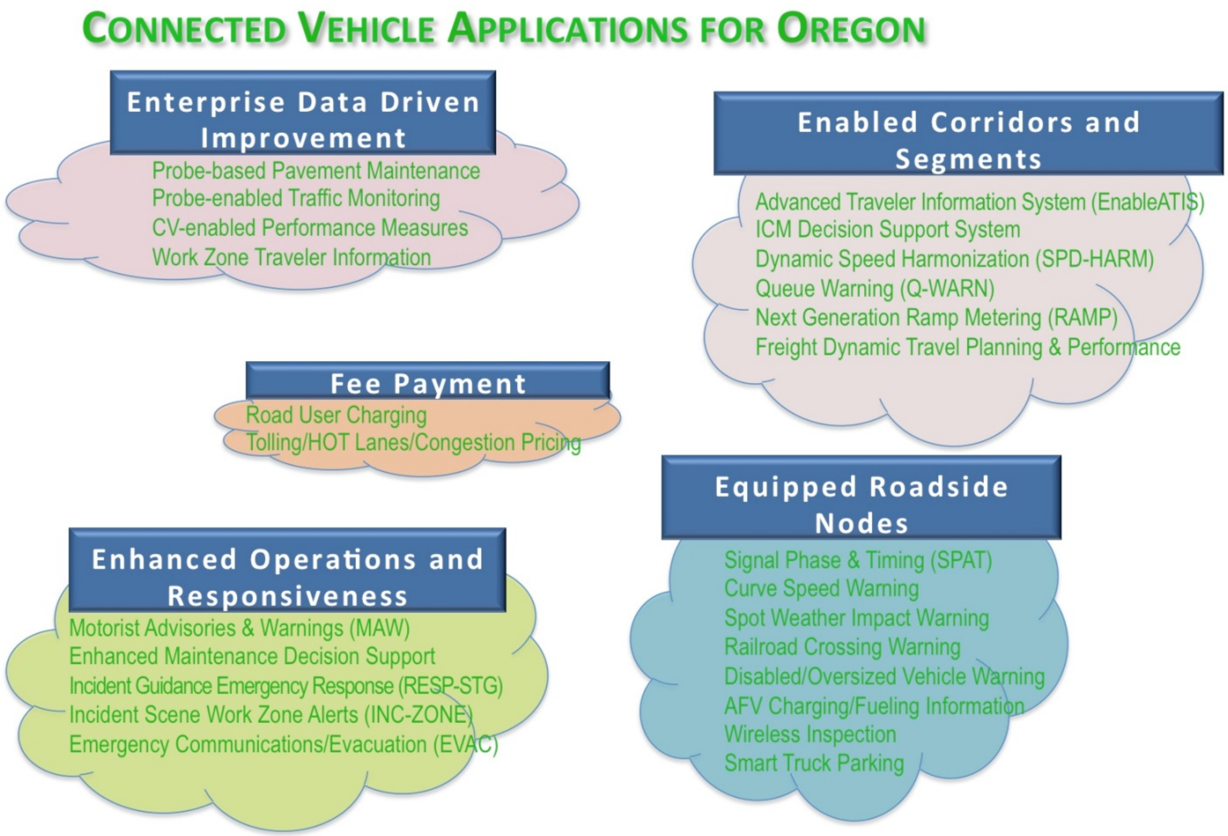


Figure 5.14: Identification and Re-Grouping of Priority 1 Applications

The application prioritization process with the TAC resulted in five groupings and 26 applications for Oregon that are open for further consideration, as depicted in Figure 5.14. There is of course any number of other ways to slice and dice this array of applications. But this arrangement made the most sense for Oregon as follows:

- **Enterprise Data Driven Improvement**: this category focuses on improving the overall transportation planning, design and maintenance enterprise for ODOT.
  - Probe-based Pavement Maintenance
  - Probe-based Traffic Monitoring
  - Connected Vehicle-enabled Performance Measures
  - Work Zone Traveler Information
- **Enabled Corridors and Segments**: this category emphasizes the capabilities that result when a transportation corridor or segment is enabled with connectivity. Benefits accrue to the agency and to users with the following six Priority 1 applications.
  - Advanced Traveler Information System (EnableATIS)
  - Integrated Corridor Management (ICM) Decision Support System

    - Dynamic Speed Harmonization (SPD-HARM)
    - Queue Warning (Q-WARN)
    - Next Generation Ramp Metering (RAMP)
    - Freight Dynamic Travel Planning & Performance
- **Fee Payment**: given Oregon's leading role in the development of new road usage charge systems, this category emerged with two or three specific applications.
    - Tolling
    - HOT Lanes
    - Congestion Pricing
- **Enhanced Operations and Responsiveness:** this category focuses on improving agency and system operations and proactive response times to emergencies.
    - Motorist Advisories & Warnings (MAW)
    - Enhanced Maintenance Decision Support
    - Incident Guidance Emergency Response (RESP-STG)
    - Incident Scene Work Zone Alerts (INC-ZONE)
    - Emergency Communications/Evacuation (EVAC)
- **Equipped Roadside Nodes**: many connected vehicle applications focus on specific points on the transportation network, including intersections and key geometric attributes such as curves, or other spots with weather-related concerns.
    - Signal Phase & Timing (SPAT)
    - Curve Speed Warning
    - Spot Weather Impact Warning
    - Railroad Crossing Warning
    - Disabled/Oversized Vehicle Warning
    - AFV Charging/Fueling Information
    - Wireless Inspection
    - Smart Truck Parking

6.0 BREAKOUT GROUPS AND IMPACT/EFFORT MAPPING

The workshop participants were divided into three groups, each with a facilitator as shown in Table 6.1. Each group was assigned a subset of the 26 Priority 1 applications as shown in Table 6.2.

Table 6.1: Group Members

Group 1	Group 2	Group 3
Kelly Bruce	*Erica McCartin*	*Jon Makler*
Pietz	O'Leary	Dunn
McGill	McCarroll	Larson
Crossler-Laird	Wang	Spencer
Price	Kimlinger	Knudson
Bertini	Griffin	Winterrowd
Fifer	Eyerly	Bryant

Each group discussed the range of applications and placed each one in a two-by-two grid with Effort on the x-axis (high effort on the left and low effort on the right) and Impact/Benefit on the y-axis. As shown in Figures 6.1-6.3 and Table 6.25 there were a total of seven applications that fell into the upper right hand corner of the grid, with high anticipated impact/benefit and low effort.

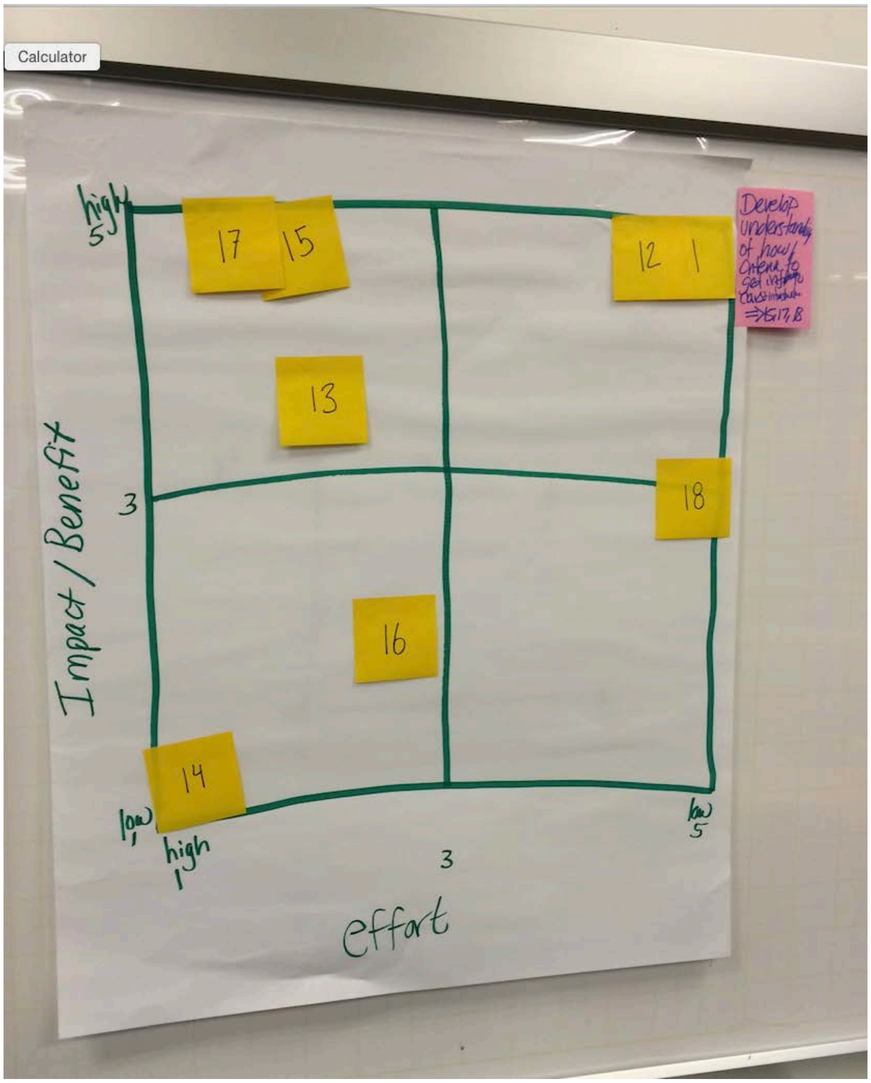


Figure 6.1: Workshop Results from Group 1

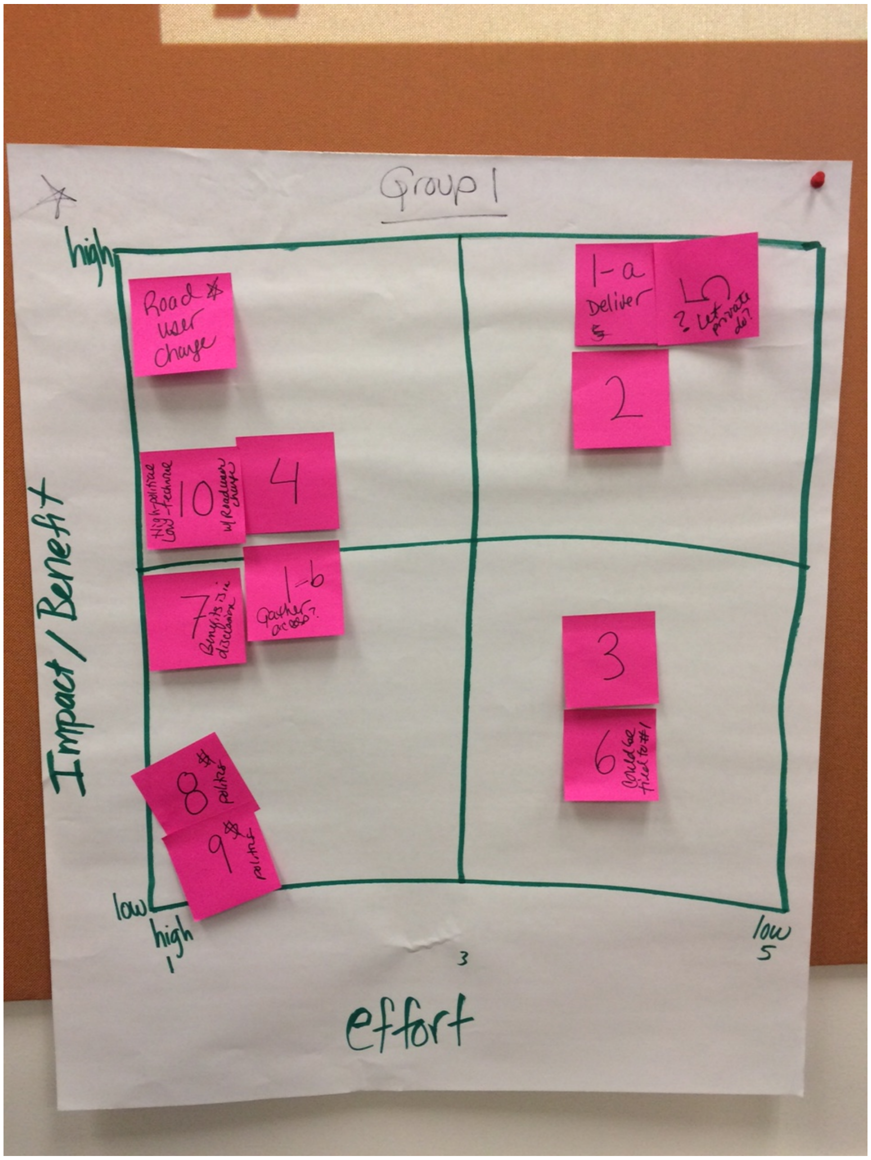


Figure 6.2: Workshop Results from Group 2

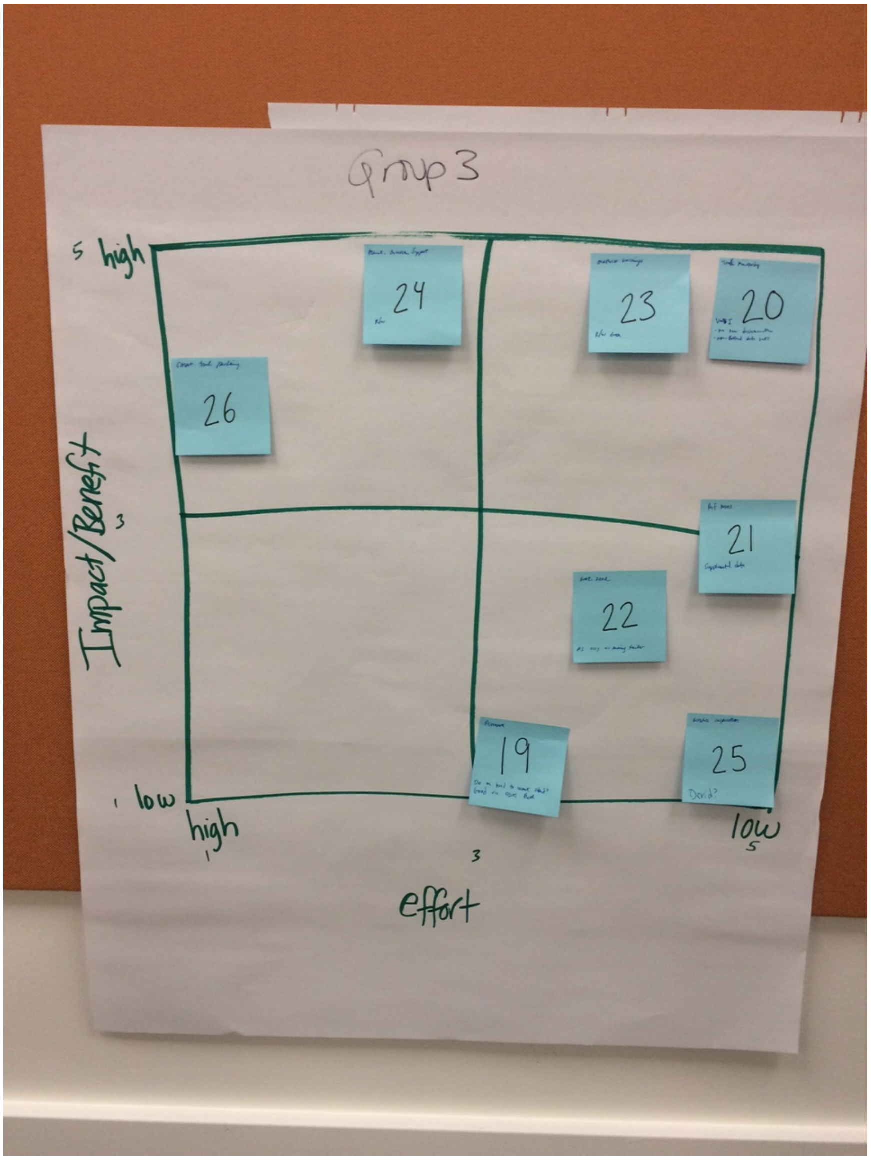


Figure 6.3: Workshop Results from Group 3

Table 6.2: Group Prioritization Results

No.	Application	Group	Impact/Benefit	Effort	
1	Advanced Traveler Information System	1	H	L	★
2	Dynamic Speed Harmonization	1	H	L	★
3	Queue Warning	1	L	L	
4	Next Gen. Ramp Metering	1	H	H	
5	Freight Dynamic Travel Planning & Performance	1	H	L	★
6	AFV Charging/Fueling Information	1	L	L	
7	Eco-ICM Decision Support System	1	L	H	
8	Tolling	1	L	H	
9	HOT Lanes	1	L	H	
10	Congestion Pricing	1	H	H	
11	Signal Phase and Timing	2	H	L	★
12	Curve Speed Warning	2	H	L	★
13	Spot Weather Impact Warning	2	H	H	
14	Railroad Crossing Warning	2	L	H	
15	Disabled/Oversized Vehicle Warning	2	H	H	
16	Incident Guidance Emergency Response	2	L	H	
17	Incident Scene Work Zone Alerts	2	H	H	
18	Emergency Communications/Evacuation	2	L	L	
19	Probe-based pavement maintenance	3	L	L	
20	Probe-enabled traffic monitoring	3	H	L	★
21	CV-enabled performance measures	3	L	L	
22	Work zone traveler information	3	L	L	★
23	Motorist advisories and warnings	3	H	L	
24	Enhanced maintenance decision support	3	H	H	
25	Wireless Inspection	3	L	L	
26	Smart Truck Parking	3	H	H	

6.1 WORKSHOP RESULTS

As shown in Figure 6.4, the break out sessions and discussions led to seven applications emerging as being meaningful and manageable for ODOT.

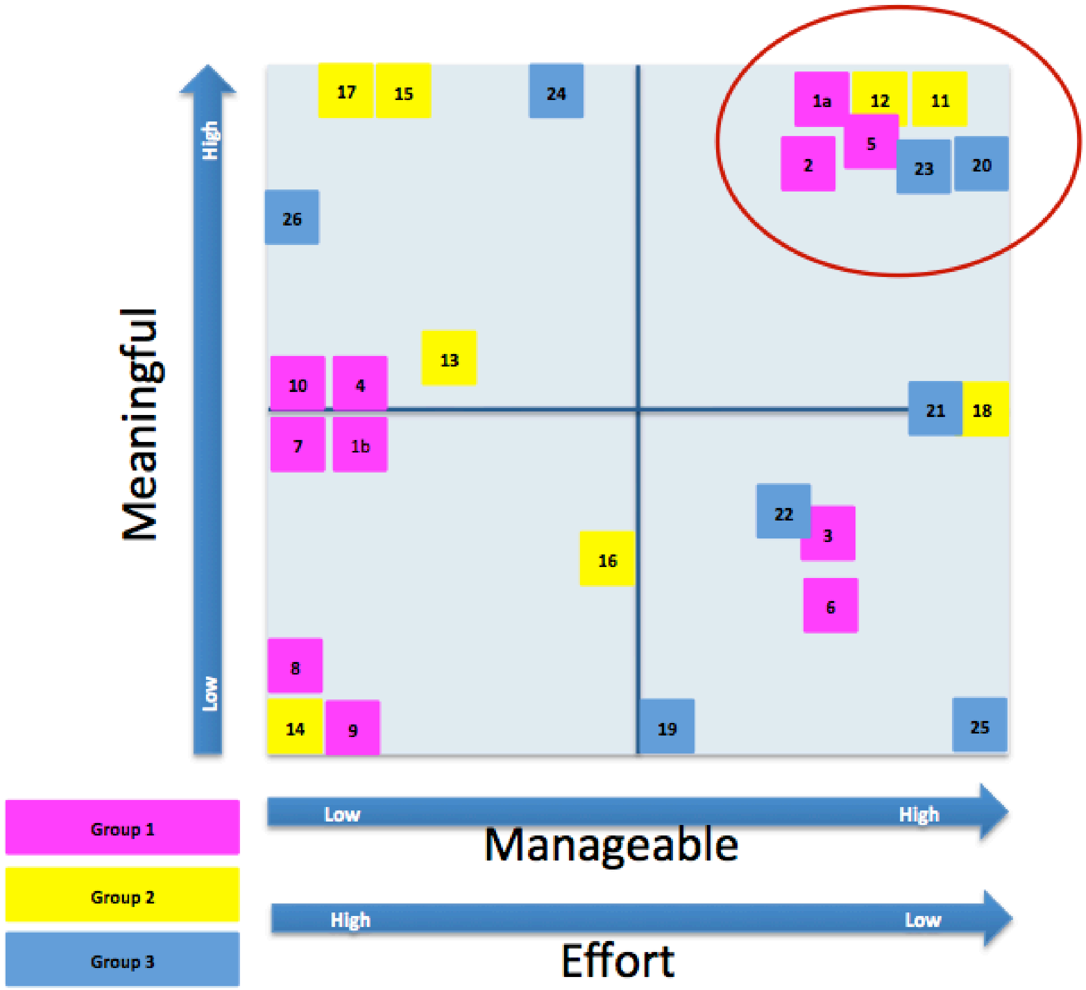


Figure 6.4: Workshop Results

The seven identified applications were as shown in Table 6.3. The following CV applications were selected as highest priority.

6.1.1 Advanced Traveler Information Systems

6.1.1.1 Definition

Advanced Traveler Information Systems applications collect, aggregate, and disseminate a wide range of transportation information. Information collection includes traffic, transit, road weather, work zone, and connected vehicle related data. All data sources are aggregated into environments that can be used to drive data portals. This allows dissemination of the entire spectrum of transportation information to travelers via mobile devices, in-vehicle displays, web portals, 511 systems, and roadside signage. (http://www.iteris.com/cvria/html/applications/app4.html)

6.1.1.2 Workshop Finding

- ODOT priorities: Traveler information is well established as a core management strategy for ODOT and this application leverages previous investments.

- Benefit (5): Traveler information helps with several important agency goal areas, primarily mobility but also secondary benefits for safety and sustainability.

- Effort (5): Implementing this application is mostly based on receiving data from connected vehicles, although additional value could be gained if it is possible to disseminate traveler information from our infrastructure to equipped vehicles on our facilities.

6.1.2 Dynamic Speed Harmonization

6.1.2.1 Definition

This application determines speed recommendations based on traffic conditions and weather information. The speed recommendations can be regulatory (e.g. variable speed limits) or advisory. The purpose is to change traffic speed on links that approach areas of traffic congestion, bottlenecks, incidents, special events, and other conditions that affect flow. Speed harmonization helps maintain flow, reduce unnecessary stops and starts, and maintain consistent speeds. The application utilizes V2I communication to detect the precipitating roadway or congestion conditions that might necessitate speed harmonization, generating the appropriate response plans and speed recommendation strategies for upstream traffic, and to broadcast recommendations to affected vehicles. The speed recommendations can be provided in-vehicle for connected vehicles, or through roadside signage for non-connected vehicles. (http://www.iteris.com/cvria/html/applications/app68.html)

6.1.2.2 Workshop Finding

- ODOT priorities: Utilizing existing infrastructure in a more efficient manner. Extension of ATM efforts already underway that rely on advisory variable speed limit signs above or beside the roadway.

- Benefit (4): reflects the value of stabilizing traffic flow, which improves reliability and safety.

- Effort (4): the application can run based on information flow from vehicles to infrastructure, even if it is not possible to push the advisory speed information back to the vehicles.

6.1.3 Freight-Specific Dynamic Travel Planning

6.1.3.1 Definition

The Freight-Specific Dynamic Travel Planning application provides both pre-trip and en route travel planning, routing, and commercial vehicle related traveler information, which includes information such as truck parking locations and current status. The information will be based on data collected from the commercial fleet and general traffic data collection capabilities. The information, both real time and static can be provided directly to fleet managers, to mobile devices used by commercial vehicle operators, or directly to in-vehicle systems as commercial vehicles approach roadway exits with key facilities such as parking. (http://www.iteris.com/cvria/html/applications/app32.html)

6.1.3.2 Workshop Finding

- ODOT Priorities: Reducing freight congestion and delays, which result in high economic costs

- Benefit (5): high value in an application that focuses on helping goods movement avoid congestion. This has benefits for economic competitiveness as well as general mobility; sustainability is a side benefit.

- Implementability (5): if the dissemination of information is based on a limited audience of "professional" dispatch operators and third party information providers.

6.1.4 Signal Phase and Timing

6.1.4.1 Definition

Signal Phase and Timing Application is a support application that provides the current intersection signal light phases. The current state of all lanes at a single intersection are provided as well as any preemption or priority then follows in a structure for the whole intersection. This application is used to support a variety of V2I applications. (http://www.iteris.com/cvria/html/applications/app67.html)

6.1.4.2 Workshop Finding

- ODOT priorities: Mobility and safety at the intersection level is one of the major motivations behind connected vehicles. The auto manufacturers are highly motivated to collaborate with transportation agencies on this issue.

- Benefits (5): mobility and safety are both very high.

- Effort (5): intersections are an optimal site for DSRC deployment (pre-existing power and communications).

6.1.5 Curve Speed Warning

6.1.5.1 Definition

The curve speed warning application allows a connected vehicle to receive information that it is approaching a curve along with the recommended speed for the curve. This capability allows the vehicle to provide a warning to the driver regarding the curve and its recommended speed. Additionally, the vehicle can perform further warning actions if the actual speed through the curve exceeds the recommended speed. (http://www.iteris.com/cvria/html/applications/app13.html)

6.1.5.2 Workshop Finding

- ODOT Priorities: Safety. The outcome of this application is a longstanding objective of our agency and we have employed many different tactics in the past.

- Benefits (5): Increased safety.

- Effort (5): The application is very site specific, which is suitable for DSRC, and the universe of possible deployments is both finite and well known/ understood.

6.1.6 Probe-Enabled Performance Monitoring and Planning

6.1.6.1 Definition

The Performance Monitoring and Planning application uses information collected from connected vehicles to support performance monitoring and other uses of historical data including transportation planning, condition monitoring, safety analyses, and research. The information may be probe data information obtained from vehicles in the network to determine network performance measures such as speed and travel times, or it may be information collected from the vehicles and processed by the infrastructure, e.g. environmental data and infrastructure conditions monitoring data. This application supports archiving of all types of data either directly from the connected vehicles or processed by the infrastructure. (http://www.iteris.com/cvria/html/applications/app88.html)

6.1.6.2 Workshop Finding

- ODOT Priorities: Central to the business case of connected vehicles for a state DOT. The opportunity to collect highly detailed information from the traveling fleet can inform our analytical and planning processes.

- Benefit (5): Data to inform and enhance other processes.

- Ease (5): Assuming collecting this data is simply a matter of “listening” to connected vehicles

6.1.7 Road Weather Advisories and Warnings for Motorists

6.1.7.1 Definition

The Road Weather Advisories and Warnings for Motorists application collects road weather data from connected vehicles and uses that data to develop short term warnings or advisories that can be provided to individual motorists. The information may come from either vehicles operated by the general public and commercial entities (including passenger cars and trucks) or specialty vehicles and public fleet vehicles (such as snowplows, maintenance trucks, and other agency pool vehicles). Raw data will be processed in a controlling center to generate road segment-based data outputs. The processing will also include a road weather motorist alerts algorithm to generate short time horizon alerts that will be pushed to user systems and available to commercial service providers. The information collected can also be combined with observations and forecasts from other sources to provide medium (next 2-12 hours) or long term (more than 12 hours) advisories through a variety of interfaces including web-based and connected vehicle based interfaces.
(http://www.iteris.com/cvria/html/applications/app46.html)

6.1.7.2 Workshop Finding

- ODOT Priorities: Safety, leverage existing investments in traveler information channels to disseminate advisories and warnings

- Benefit (5): Opportunity to help drivers avoid unsafe (or otherwise undesirable) conditions.

- Effort (4): There is some uncertainty about exactly how to collect the data from connected vehicles in the field (unlike signals, the relevant circumstances here are dispersed and only partially known).

Table 6.3: Summary of Selected Priorities

	Connected Vehicle Application	Connection to Goal/ Benefit to ODOT	Issues/Challenges/Concern Areas
1a	Advanced Traveler Information System (Enable/ATIS) Deliver		
2	Dynamic Speed Harmonization (SPO-HARM)		
5	Freight Dynamic Travel Planning & Response		
11	Signal Phase and Timing (SPAT)		
12	Curve Speed Warning	Safety: We already have electrical infrastructure at our most major curves. This could be a good place to test it out (we already display speed info on VMS etc. in these areas). If successful, could redeploy to other curve areas at lower cost?	How to send information to the vehicle? Will car manufacturers allow it? Will it be a third party?
20	Probe-enabled Traffic Monitoring		
23	Motorist Advisories & Warnings (MAW)		

Some discussion items to note:

- Many applications can be grouped together.
- Applications 15 and 17 (Disabled/Oversized Vehicle Warning and Incident Scene Work Zone Alerts) seemed to go together for a similar deployment
- When thinking about work zones, don't simply think about construction work zones, but continue including incident work zones in evaluating opportunities
- Pedestrian safety – look for opportunities to include pedestrian safety in our focus areas
- Application 22 (Work Zone Traveler Information), evaluate current ranking of this item

- Application 14 (Railroad Crossing Warnings) – reevaluate ranking of this one. Note that there are 1,889 public at-grade crossings and approximately 2,200 private at-grade crossings in Oregon.

There are some additional general theme areas where additional opportunities may exist. For example:

- Reduction in "vulnerable" conflicts (pedestrians/bicycles/motorcycles/people with disabilities)

  - Applications that assist in Oregon's reduction in pedestrian fatalities even if it isn't our traditional role (e.g., pedestrians would carry a smart phone, nothing for us traditionally to do but perhaps a marketing or leadership role)

- Work Zone Safety: key focus area for us in other areas of the Agency. Applications that continue our focus in this area

- Road Usage Charge: Applications that support our leadership in this areas

- Opportunities to learn more about how to receive information from vehicles

- Opportunities to learn more about how to send information to vehicles (example: curve warning signs)

6.2 NEXT STEPS

- Put all 26 into 3 categories

  - Near Term Focus for ODOT (Table 6.4)

  - ODOT Should Monitor, Possibly Collaborate, Leadership by Others (Table 6.5)

  - Leadership by Others, ODOT Monitor (Table 6.6)

- Vet/socialize selections with ILT and other focus groups/stakeholders/leadership teams

- Review and modify selections

- Develop initial list of risks and steps to move forward on these priorities

Table 6.4: 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 6.5: 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 6.6: 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

7.0 CONNECTED AND AUTOMATED VEHICLES STRATEGIC FRAMEWORK WORKSHOP PHOTOS


Workshop group facilitated by Jon Makler.

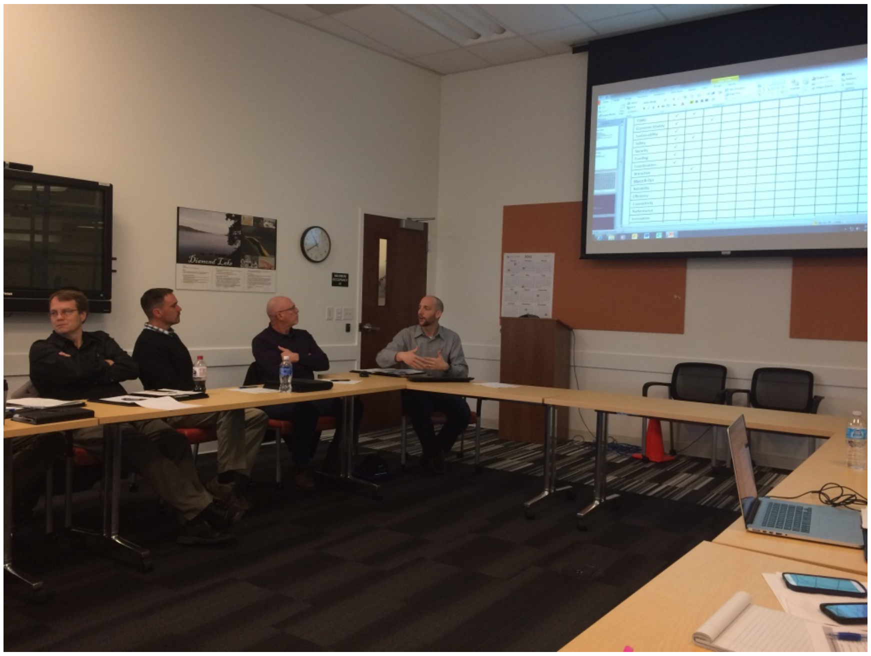
Jon Makler briefs the workshop participants.

Workshop participants.

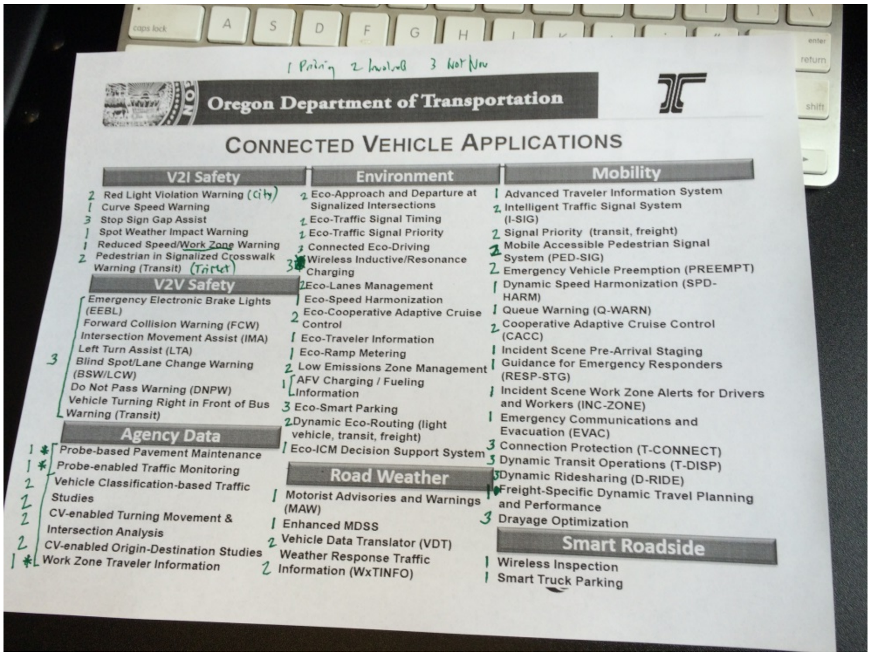
Workshop participants.

Workshop participants.

Workshop participants.



Workshop participants.



1 Priority 2 Involved 3 Not Now

Oregon Department of Transportation

CONNECTED VEHICLE APPLICATIONS

V2I Safety
- 2 Red Light Violation Warning (City)
- 1 Curve Speed Warning
- 3 Stop Sign Gap Assist
- 1 Spot Weather Impact Warning
- 1 Reduced Speed/Work Zone Warning
- 2 Pedestrian in Signalized Crosswalk Warning (Transit) (TriMet)

V2V Safety (3)
- Emergency Electronic Brake Lights (EEBL)
- Forward Collision Warning (FCW)
- Intersection Movement Assist (IMA)
- Left Turn Assist (LTA)
- Blind Spot/Lane Change Warning (BSW/LCW)
- Do Not Pass Warning (DNPW)
- Vehicle Turning Right in Front of Bus Warning (Transit)

Agency Data
- 1 * Probe-based Pavement Maintenance
- 1 * Probe-enabled Traffic Monitoring
- 2 Vehicle Classification-based Traffic Studies
- 2 CV-enabled Turning Movement & Intersection Analysis
- 2 CV-enabled Origin-Destination Studies
- 1 * Work Zone Traveler Information

Environment
- 2 Eco-Approach and Departure at Signalized Intersections
- 1 Eco-Traffic Signal Timing
- 1 Eco-Traffic Signal Priority
- 3 Connected Eco-Driving
- 3 Wireless Inductive/Resonance Charging
- 2 Eco-Lanes Management
- 1 Eco-Speed Harmonization
- 2 Eco-Cooperative Adaptive Cruise Control
- 1 Eco-Traveler Information
- 1 Eco-Ramp Metering
- 2 Low Emissions Zone Management
- 1 AFV Charging / Fueling Information
- 3 Eco-Smart Parking
- 2 Dynamic Eco-Routing (light vehicle, transit, freight)
- 1 Eco-ICM Decision Support System

Road Weather
- 1 Motorist Advisories and Warnings (MAW)
- 1 Enhanced MDSS
- 2 Vehicle Data Translator (VDT)
- 2 Weather Response Traffic Information (WxTINFO)

Mobility
- 1 Advanced Traveler Information System
- 2 Intelligent Traffic Signal System (I-SIG)
- 2 Signal Priority (transit, freight)
- 1 Mobile Accessible Pedestrian Signal System (PED-SIG)
- 2 Emergency Vehicle Preemption (PREEMPT)
- 1 Dynamic Speed Harmonization (SPD-HARM)
- 1 Queue Warning (Q-WARN)
- 2 Cooperative Adaptive Cruise Control (CACC)
- 1 Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)
- 1 Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)
- 1 Emergency Communications and Evacuation (EVAC)
- 3 Connection Protection (T-CONNECT)
- 3 Dynamic Transit Operations (T-DISP)
- 3 Dynamic Ridesharing (D-RIDE)
- 1 Freight-Specific Dynamic Travel Planning and Performance
- 3 Drayage Optimization

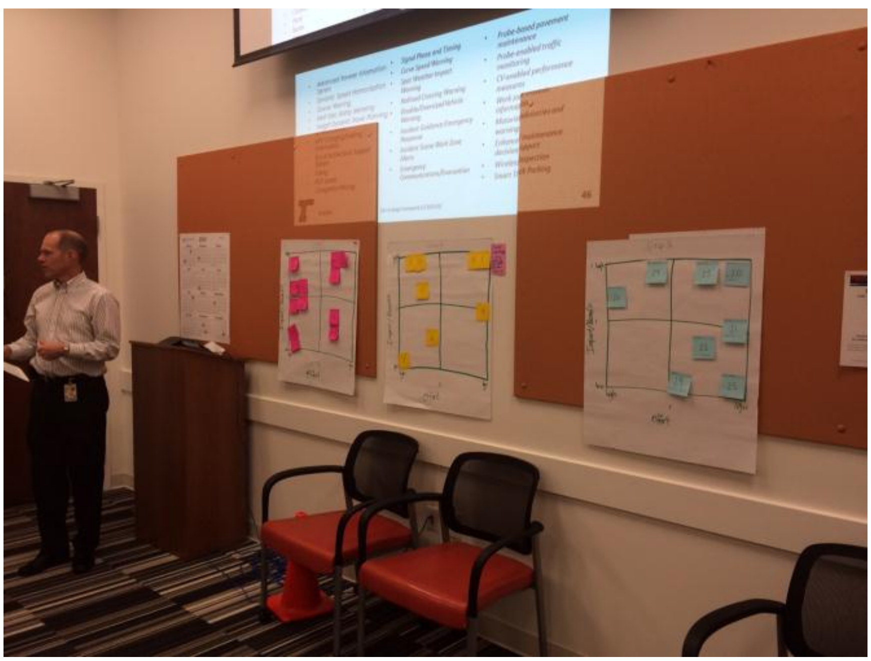
Smart Roadside
- 1 Wireless Inspection
- 1 Smart Truck Parking

Connected vehicle application grouping exercise.

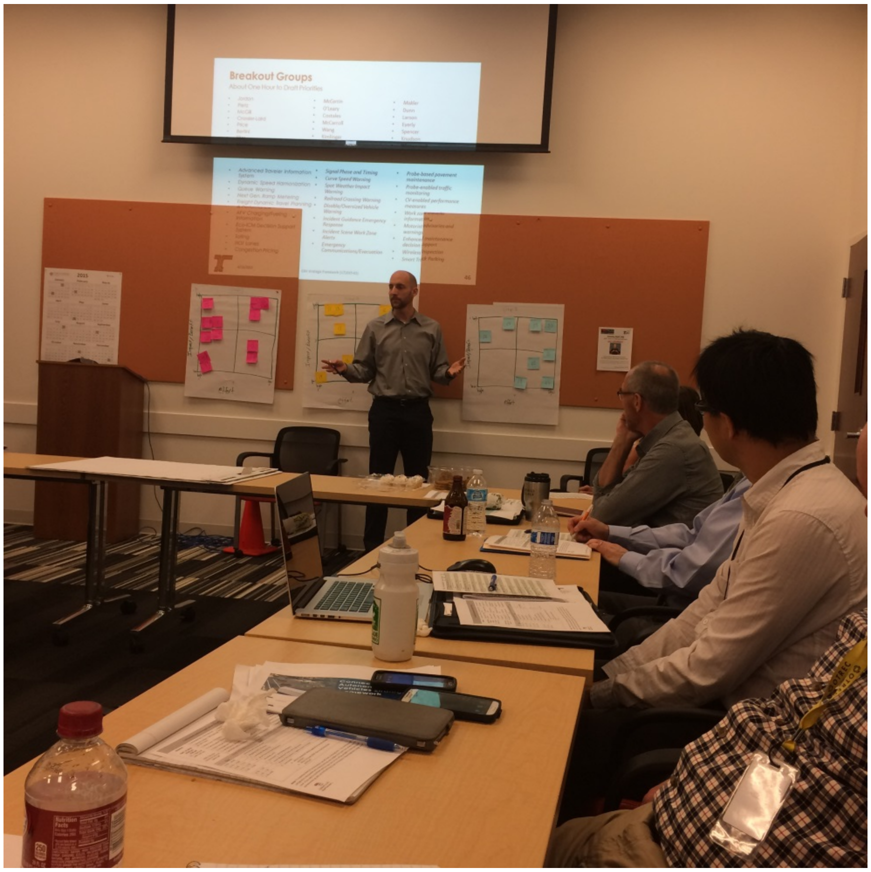
Breakout group confers.

Breakout group confers.

Breakout group confers.



Final discussion of breakout group results.



Final discussion of breakout group results.