Implementing Oregon's Energy Plan: Opportunities for Intelligent Transportation Systems[1]

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1. Introduction

In the United States, transportation is the 2nd largest consumer of energy (28%). Only electric generation is a larger (41%); the other sectors are industrial (21%) and residential/commercial (10%)[4]. Economic and environmental imperatives drive interest in reducing energy consumption. Increased concern about climate change and global warming have brought focus to transportation strategies that reduce energy consumption and the associated emissions.

Many analyses adopt a four-fold framework of transportation options: vehicles, fuels, operations and behavior. Vehicle and fuel technologies offer very large long-term benefits but have limited potential for realizing immediate energy reductions. The Urban Land Institute's 2009 *Moving Cooler* report helped organize professional thinking about operations and behavior, both of which can achieve near-term reductions in energy consumption and greenhouse gas emissions.

As construction of the interstate highway system concluded in the late 1980's, interest grew in advanced technologies and their potential to enhance the performance and productivity of the nation's massive infrastructure investment. Promoters primarily emphasized the benefits of Intelligent Transportation Systems (ITS) in terms of reducing congestion and increasing safety.

In the last ten years, attention has shifted somewhat from the technologies themselves to the strategies they enable, generally referred to as Transportation System Management and Operations (TSMO). These strategies range from arterial management to incident response and are frequently multi-modal. By emphasizing the greenhouse gas reduction potential of operations, *Moving Cooler* helped establish ITS as an important strategy for energy and climate goals.

Very recently, the emergence of smartphones and "big data" has helped make ITS relevant to the fourth part of the framework: behavior. Increasingly, vehicles can communicate with the infrastructure and with each other. Hand-held and in-vehicle devices generate massive amounts of data. The web and mobile apps turn that data into information that travelers can use to manage their travel behavior, potentially with the result of reducing energy consumption and emissions.

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The purpose of this white paper is to support implementation of Oregon's 10-Year Energy Action Plan, which was adopted in December 2012. The plan identified ITS as a key strategy and this paper compiles evidence that is meant to help relevant stakeholders prioritize investments in the technologies with the greatest potential energy savings.

2. Supporting Legislation and Statewide Planning

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[1] This research was conducted with support from the Oregon Transportation Research and Education Consortium. The contents of this report reflect the views of the authors, who are solely responsible for the facts and the accuracy of the material and information presented herein.
[2] Oregon Transportation Research and Education Consortium
[3] Portland State University
[4] U.S. Energy Information Administration:
http://www.eia.gov/energy_in_brief/article/major_energy_sources_and_users.cfm

This action plan builds on previous statewide greenhouse gas (GHG) emissions reductions goals. In 2007, the Oregon state legislature established statewide goals for GHG emissions by passing House Bill 3543. The goals call for arresting increases in emissions by 2010, a ten percent reduction below 1990 emissions levels by 2020, and at least a 75 percent reduction below 1990 levels by 2050[5]. Recommendations set forth by the Governor's Advisory Group on Global Warming, a group established by Governor Kulongoski in 2004, established these GHG emissions targets.

In December 2012, Oregon Governor John Kitzhaber released a 10-Year Energy Action Plan to address the state's energy conservation and carbon reduction goals. The action plan focuses on three primary strategies: (1) maximize energy efficiency and conservation to meet 100 percent of new electricity load growth; (2) enhance clean energy infrastructure development by removing finance and regulatory barriers; and (3) accelerate the market transition to a more efficient, cleaner transportation system[6].

To reduce emissions to ten percent below 1990 levels, Oregon must reduce fossil fuel use by approximately 30 percent statewide. The transportation sector is the largest contributor of Oregon's carbon emissions, accounting for 37 percent of total statewide emissions[7]. Oregonians consume 1.5 billion gallons of gasoline and drive more than 33 billion miles annually[8]. According to *Moving Cooler*, the "transportation GHG emissions are the result of the interaction of four factors: (a) the number of miles that vehicles travel (activity level), (b) vehicle fuel efficiency, (c) the operational efficiency experienced during travel, and (d) the carbon content of the fuel burned".[9] As a rule of thumb, passenger vehicles produce one pound of C02 per mile.[10]

The Governor's action plan identifies technology and innovation as part of a critical path to achieving the statewide emissions goals by 2050. The Oregon Department of Transportation developed a Statewide Transportation Strategy that determined a combination of technology, transportation, and land use actions as required to reach Oregon's emissions targets. The Governor's 10-Year Energy Action Plan articulates four primary strategies:

- Continued investment in compact, multimodal, and mixed-use communities
- Accelerated fleet turnover (residential and commercial) to alternative fuels
- Implementation of intelligent transportation systems
- Innovation in financing of clean transportation systems

The next section of this white paper examines the capacity of intelligent transportation systems (ITS) to reduce fuel consumption and GHG emissions within the transportation sector.

3. Intelligent Transportation Systems: Applications and Benefits

ITS refers to the integrated application of advanced electronic communication technologies and management strategies to improve the safety and efficiency of the surface transportation system[11]. ITS technologies encompass a wide array of applications ranging from traffic signal systems to variable messaging signs that

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[5] Metro, 2011: Climate Smart Communities Strategy Toolbox for the Portland metropolitan region
[6] Office of Governor Kitzhaber, 2012: 10-Year Energy Action Plan.
[7] Oregon Department of Transportation, 2009: Potential Effects of Tolling and Pricing Strategies on Greenhouse Gas Emissions.
[8] Office of Governor Kitzhaber, 2012: 10-Year Energy Plan.
[9] Cambridge Systematics, 2009: Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.
[10] Assuming 19.75 pounds of carbon per gallon and a fleet average of 21.6 miles per gallon. Assumptions obtained from http://www.epa.gov/cleanenergy/energy-resources/refs.html
[11] U.S. Department of Transportation, 2006: Regional ITS Architecture Guidance Document.

alert drivers about delays. There are numerous ways to organize and represent the full range of advanced transportation technologies that are casually referred to as ITS.

- The National ITS Architecture includes eight "Service Packages": Archived Data Management, Public Transportation, Traveler Information, Traffic Management, Vehicle Safety, Commercial vehicle Operations, Emergency Management, and Maintenance and Construction Management.

- In 2009, the U.S. Department of Transportation's ITS Joint Program Office released a comprehensive, four-tier "ITS Taxonomy." Using 14 categories of "intelligent infrastructure" and three categories of "intelligent vehicles," the taxonomy organizes nearly 200 technologies into 80 subcategories. For example Adaptive Signal Control falls under Intelligent Infrastructure: Arterial Management: Traffic Control.

- For its triennial ITS Deployment Tracking Project the JPO employs a different set of seven categories: Freeway Management, Arterial Management, Transit Management, Transportation Management Center, Electronic Toll Collection, Public Safety – Law Enforcement, and Public Safety-Fire/Rescue.

- In Oregon, Metro developed a TSMO Action Plan organized by four functional areas: multimodal traffic management, traveler information, traffic incident management and transportation demand management.

Presently, the trajectory of ITS involves the possibility of communications among vehicles and between vehicles and infrastructure. USDOT's "Connected Vehicle Initiative" envisions the utilization of dedicated-short range communications (DSRC) to enable tags or sensors that allow communication between vehicles and the transportation infrastructure. However, municipalities must comprehensively deploy DSRC-enabled tags and sensors in vehicles, highways, and roadside and intersection equipment to maximize environmental benefits. By enabling communication among vehicles and between vehicles and infrastructure, the Connected Vehicle Initiative enables various ITS applications: adaptive signal timing, dynamic re-routing of traffic via variable message signs, lane departure warnings, curve speed warnings, and detection of roadway hazards, such as potholes, and weather-related conditions.[12]

Environmental benefits of ITS are typically documented through fuel savings and reduced emissions. The JPO identified eight technologies with the greatest potential environmental benefits: (1) advanced signal systems, (2) dynamic message signs, (3) service patrols, (4) roadway surveillance, (5) pre-trip information, (6) speed control, (7) congestion pricing, and (8) electronic toll collection[13].

In 2010, JPO launched a research program called AERIS: Applications for the Environment Real-Time Information Synthesis. The program's objective is to "generate and acquire environmentally-relevant real-time transportation, and use these data to create actionable information that support and facilitate 'green' transportation choices by transportation system users and operators.[14]" The program has a strong connection to USDOT's Connected Vehicle initiative.

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[12] The Information Technology and Innovation Foundation, 2011: Explaining International IT Application Leadership: Intelligent Transportation Systems.

[13] U.S. Department of Transportation Research and Innovative Technology Administration, 2011: Intelligent Transportation Systems Benefits, Costs, Deployment, and Lessons Learned Desk Reference: 2011 Update.

[14] http://www.its.dot.gov/aeris/index.htm

As part of its AERIS initiative, one JPO study[15] offered seven categories of ITS applications with potential environmental benefits[16], which the report defined as reductions in greenhouse gas emissions, criteria air pollutants and fuel consumption:

- Demand and Access Management
- Eco-Driving
- Logistics and Fleet Management
- Traffic Management and Control
- Freight
- Transit
- Other

Another way of looking at all of these technology taxonomies is the mechanism by which each strategy reduces energy consumption. As noted in the introduction, ITS has historically emphasized congestion mitigation and more recently focused on safety. Perhaps as a result, the energy-saving potential of most ITS deployments are through reduced delay. Traffic signals are a simple example because well-coordinated signals reduce delay and increase safety by enabling stable flow on arterials. In the energy arena, reduced stop-and-go traffic also means reduced fuel consumption.

In addition to reducing delay, another common mechanism for saving energy with ITS is reducing vehicle miles traveled (VMT). Low-tech carpooling was promoted during World War II and the energy crisis of the 1970's as a way to save energy by reducing VMT. Technology can improve the performance and appeal of alternatives to single-occupant cars, especially transit. Technology can create and disseminate data/information to enable users to make more informed choices. Technology can enable strategies that directly influence driving behavior, especially the pricing of roads and parking. Each of these examples illustrates the ways in which technologies can stimulate the reduction of VMT.

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The next section of this white paper reports on a review of literature published within the past five years that explicitly assesses the capacity of ITS technologies to reduce fuel consumption and emissions. Currently, there is a shortage of empirical evidence establishing the capacity of ITS technologies to reduce either fuel consumption or emissions. In 2009, the European Commission published a comprehensive *qualitative* analysis of the potential of ITS technologies for reducing greenhouse gas emissions related to road transport and found that more research on the energy-reducing capacity of ITS applications is needed[17].

The majority of ITS research primarily relies on simulations and models to estimate emissions, driver behavior, and vehicle speed trajectories. Several studies evaluated various ITS technologies, including: eco-routing or "green driving," signal timing, signal prioritization for public buses, ramp metering, variable speed limits (VMS), and ITS-enabled pricing schemes.

Moving Cooler identified the capacity of ITS to reduce fuel consumption and emissions as nominal.[6] Implementation of ITS technologies could result in 0.3 to 0.6 percent cumulative reductions of greenhouse

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[15] Joint Program Office, 2011: AERIS Applications State of the Practice Assessment Report

[16] The AERIS report credits two international studies as the primary basis for these categories: Methodologies for Assessing the Impact of ITS Applications on CO2 Emissions (European Commission-Japan Ministry of Trade and Industry Task Force, March 2009; Impact of Information and Communication Technologies on Energy Efficiency in Road Transport, European Commission, September 2009)

[17] European Commission, 2009: The Potential of Intelligent Transport Systems for reducing road transport related greenhouse gas emissions.

gases from a national baseline by 2050. Although some studies document the environmental benefits of ITS technologies, more research on the relationship between ITS and energy savings is needed.

3.1 Reducing Delay

Most studies focus on the delay-reducing capacity of signal timing and prioritization. A report by the Virginia Transportation Research Council identified the estimated benefits of coordinated actuated traffic signal systems from simulation studies[18]:

- The City of Syracuse, New York implemented a traffic signal project to improve air quality in 1993 and used Synchro, a software package, to model the performance of the system before and after the project. Results indicate a 14 to 19 percent reduction in vehicle delay.
- Denver, implemented a regional traffic signal improvement program that reduced delay by 36,000 vehicle hours per day and saved 15,000 gallons of fuel.
- The Colorado Springs Traffic Engineering Division conducted a signal coordination study in 2005 and reported a 10 to 30 percent improvement in travel time.

The JPO's benefits database summarized the benefits of a traffic signal timing project in Oakland County, Michigan in 2004[19]. They found that the retiming of 640 traffic signals during a two-phase project reduced travel time by 16.7 percent and delay by 18.8 percent. Additionally, fuel consumption decreased by 13.8 percent and lowered vehicle emissions by 13 percent.

A recent report by RITA further summarizes the capacity of other ITS technologies to reduce delay for travelers[20]:

- Incident management systems from across the United States have documented fuel savings of up to 6.83 million gallons of fuel annually. Additionally, combining incident management systems with traveler information systems can reduce emissions by another 3 percent.
- Studies of ramp metering projects in Minnesota demonstrate reduced emissions from three to eight percent and without ramp metering, emissions increase by 1,160 tons annually. Ramp metering can however, have negative impacts on delay for high demand periods.
- In Europe, speed management systems have reduced NO_x emissions by up to 25 percent.
- Adaptive signal controls can reduce emissions by up to 50 percent for travelers moving in the direction of adaptive signal controls. Those travelers not favored by the signal can experience up to a nine percent increase in emissions.
- Transit signal priority projects in Europe indicate emissions reductions of up to 30 percent for buses, but increased emissions for non-transit vehicles by 11 percent.

There are several strategies that reduce delay and emissions through ITS applications, including incident management, ramp metering, and speed management, but many projects and studies utilized traffic signal controls.

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[18] Park, B. and Chen, Y., 2010. Quantifying the Benefits of Coordinated Actuated Traffic Signal Systems: A Case Study. Virginia Transportation Research Council.
[19] U.S. Department of Transportation Research and Innovative Technology Administration, 2004: ITS Benefits Database.
[20] Joint Program Office, 2011: AERIS Applications State of the Practice Assessment Report

3.2 Reducing Vehicle Miles Traveled (VMT)

Other ITS applications can reduce road users' VMT through several strategies: pricing schemes including parking, fleet management, and transit operations. The AERIS State of the Practice Assessment Report identified the following benefits:

- In the U.S., electronic toll collection (ETC) can reduce annual emissions by up to 265,000 metric ton carbon equivalent (MTCE)).
- Internationally, congestion pricing has demonstrated CO_2 reductions by up to 14 percent, NO_x reductions by up to 15 percent, and particulate matter reductions by up to 20 percent.
- Studies of mileage-based fee pilot projects have shown reductions in VMT by up to 13 percent.
- Automatic vehicle location systems optimize routes for fleet, including freight, which can also reduce VMT. The City of Napa used automatic vehicle location systems and on-board diagnostics technology in the city's fleet to reduce annual GHG emissions by 44,000 pounds.
- Parking information systems that inform drivers of available parking spaces can reduce the time that drivers spend searching for a space. Many researchers connect the reduced time spent searching for a parking space to reductions of emissions.
- Bus Rapid Transit can reduce travel time by up to 25 percent in the United States and potentially, increasing ridership and decreasing VMT.

3.3 Connected Vehicle and Other ITS-Enabled Strategies

Some ITS applications offer the ability to reduce energy consumption without reducing delay or VMT. In particular, the Connected Vehicle Initiative offers some energy saving potential simply by deploying certain technologies in an integrated rather than isolated manner.

Demand and Access Management

There are three ITS-enabled strategies that address demand and access management: electronic toll collection, congestion pricing, and mileage-based pricing. Many electronic toll collection systems utilize DSRC-enabled tags and sensors to enable road users to automatically pay tolls while they drive. This increases both road users' convenience and through put on a transportation facility and reduces the emissions associated from idling and congestion. Members of TransPort identified tolling as one their top ten ITS strategies to deliver environmental benefits and improve the operating and system efficiency of Oregon's transportation systems.

In contrast, congestion pricing and mileage-based pricing schemes increase the cost of using a particular facility for road users. Several international cities have implemented congestion pricing, including Singapore, Stockholm, London, Oslo, and Jakarta. Congestion pricing not only reduces congestion, but also reduces annual VMT for cities. Charging road users more during congested periods can smooth or reduce traffic flows.[21] According to a report by The Information Technology and Innovation Foundation, Stockholm reduced congestion and carbon emissions by 15 percent through a congestion pricing system.[16]

Eco-Driving

Driving assistance and eco-routing are widely-recognized ITS applications that provide drivers with real-time travel and traffic information, navigation, information about delays from congestion or accidents, weather conditions, and road work.[16] Vehicles equipped with driving assistance features provide feedback to the driver on how to operate the vehicle at the most fuel-efficient speeds in various driving conditions. Eco-routing applications designed specifically for freight vehicles include information on available parking spaces during periods of rest, information about delays and weather conditions.

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[21] The Information Technology and Innovation Foundation, 2011: Explaining International IT Application Leadership: Intelligent Transportation Systems.

Driving assistance and eco-routing systems can empower drivers with information about optimal route selection, navigation, and operational conditions. This allows drivers to operate a vehicle so that it achieves greater fuel efficiency or to choose a route that is most fuel efficient. However, driving assistance and eco-routing require a wide deployment of a consolidated V2V and VII platform to maximize environmental benefits. Increasingly, cars in the United States are equipped with GPS or telematics systems that offer driving assistance services. Currently, Oregon does not have an eco-routing assistance program for freight or an integrated and comprehensive communication platform. However, Oregon has an extensively deployed pre-trip and en-route traveler information system.

Logistics and Fleet Management
Automatic vehicle location (AVL) enables vehicles to report their current location and operations managers to construct real-time information about vehicles of a particular fleet. AVL-enabled dispatch is often used in public transportation systems, but can be used for other fleets, such as freight or incident management vehicles.

Parking management systems can make parking easier by providing drivers information about available parking spaces. For example, San Francisco has deployed a system, SFpark, that indicates to drivers where available parking spaces are located via a website or iPhone app, a 511 system, and electronic signs[22]. Parking management systems can reduce congestion in areas by making it easier and more convenient for drivers to park. It reduces VMT by reducing the amount of time drivers must spend searching for a parking spot. In Portland, electronic message signs are utilized to inform drivers of available parking spaces at the airport and at a various parking garages. Expanding parking information and management presents an opportunity for Oregon and TransPort identified it as one of ten promising strategies with potential environmental benefits.

Traffic Management and Control
Transportation management systems include ITS applications that focus on traffic control devices, such as traffic signals, ramp metering, and dynamic or variable message signs. As mentioned above, variable message sings and adaptive signal controls rely on information obtained from sensors and roadside equipment, vehicle probes, cameras, and other devices that are all part of a V2V and VII architecture that supports an integrated intelligent transportation system.[18] Transportation management centers coordinate and manage the various transportation management system components. "Centralized traffic management centers run by cities and states worldwide, rely on information technologies to connect sensors and roadside equipment, vehicle probes, cameras, message signs, and other devices together to create an integrated view of traffic flow and to detect accidents, dangerous weather events, or other roadway hazards".[18] There are only four transportation management centers across Oregon. While this presents an opportunity to expand deployment of ITS application across the state, it requires a significant investment in resources and staff time to realize maximum benefits.

However, many transportation management components can provide environmental benefits distinct from a transportation management center. Adaptive signal controls and ramp metering have demonstrated their capacity to reduce delay. Adaptive traffic signals refers to dynamic signals designed to detect the presence of waiting vehicles, which can improve the timing of signals, enhance traffic flow, and reduce congestion and delay.[18] Many signals utilize outdated or static signal timing systems in the U.S.; poor signal timing accounts for approximately five to 10 percent of congestion on major roadways. [18] According to TransPort, both transit signal priority and truck signal priority potentially have environmental benefits.

Ramp metering is another transportation management system component that can provide environmental benefits. Ramp meters are signals on freeway ramps that control the flow of vehicles entering the freeway. They can improve traffic flows on freeways and reduce clusters of vehicles attempting to merge onto the

[22] Simons, D., (2012). SFpark: San Francisco Knows How to Park It. *Sustainable Transport*, 33.

freeway. Portland has a very high deployment of ramp metering in the metro area, but there are opportunities for expansion across the state. TransPort identified ramp metering as a promising ITS application.

Some ITS strategies do not fit neatly into either a reduced delay or reduced VMT category, but instead increase the operating efficiency of vehicles and the transport system.

- A report by RITA found that idle reduction technologies at truck stops have reduce emissions by up to 83% and platooning freight vehicles (vehicle-vehicle integration) can reduce fuel consumption by up to 20%. RITA cited an implementation of green delivery management system by UPS that reduce emissions by 32,000 metric tons of carbon equivalent (MTCE).
- According to a 2012 study, time sensitive "green routing" in the Buffalo-Niagara region can reduce carbon dioxide (CO2) emissions by just over 12 percent[23].
- Similarly, Barth and Boriboonsomsin found that dynamic eco-driving can reduce fuel consumption and CO2 emissions between 10-20 percent[24].

4. State of Deployment

As previously mentioned, the JPO's triennial ITS Deployment Tracking project is the preeminent source of data on domestic implementation of ITS. Many of the technologies identified in the previous section as having energy saving potential are specifically evaluated by the JPO data:

A. Incident Management: JPO's report emphasizes growth in the coverage of CCTV cameras nationwide, from 15% of centerline miles in 2000 to nearly 50% in 2010. Deployment of inductive loops and other detection technologies has also increased, though not as much; the percentage of freeways under incident detection algorithms, which rely on detection data, is much lower and the trend much flatter.
B. Ramp Metering: Only 29 agencies (of 125 completed surveys) report ramp metering capability and most (27) perform metering based on time of day rather than real-time conditions.
C. Active Traffic Management: Variable Speed Limit, the most basic strategy associated with ATM, has been deployed by merely 9 agencies covering a total of 277 centerline miles.
D. Adaptive Signal Control: Of 290 responding agencies, 61 have 9179 intersections with a traffic responsive signal timing plan (out of 42,587) and 26 have deployed adaptive signal systems covering a total of 1271 intersections.
E. Traffic Signal Coordination: 290 agencies (of 356 surveyed) responded to this item, with 231 operating a total of 75,141 intersections with coordinated traffic signals.
F. Electronic Toll Collection: 64 agencies operate 845 plazas and 4669 lanes of electronic toll collection.
G. Congestion Pricing: Only six agencies (including 3 different divisions of the New Jersey Turnpike Authority) report deploying congestion pricing although 13 expressed the intention/expectation of deployment "in the next few years."
H. Transit Signal Priority: 36 agencies with fixed route buses and 11 agencies with light rail vehicles have (or will imminently have, as of 2010) transit signal priority.

Traveler Information

JPO's 2011 report summarizing the 2010 deployment statistics emphasizes major changes in traveler information, mainly driven by the evolution of mobile internet. Although websites, dynamic message signs, 511 and highway advisory radio have the highest levels of deployment, the trend favors emails, mobile alerts and social media. In the freeway category, traveler information focuses on the location and duration of

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[23] Guo, L., Huang, S., and Sadek, A.W., (2012). An evaluation of environmental benefits of time-dependent green routing in the greater Buffalo-Niagara region. Journal of Intelligent Transport Systems.

[24] Barth, A. and Boriboonsomsin, K., (2009). Energy and emissions impacts of a freeway-based dynamic eco-driving system. *Transportation Research Part D*, 14, 400-410.

incidents and construction. Deployment levels are much lower among arterial systems and the emphasis in that setting is more on construction management. A very high percentage (85%) of transit agencies rely on webpages to disseminate real time information.

Notably, most of the report's summary observations are related to the dramatic changes in traveler information. The ubiquity of real-time data has enabled transportation managers to be more pro-active. It has also enabled transit and other agencies to provide a much higher level of customer service to system users. Communication advances have also enabled much better interagency communication and integration.

Deployment in Oregon

The Oregon Department of Transportation organizes many of its operations activities according to five highway districts. The Department's ITS Unit used the JPO's taxonomy of ITS to assess the level of deployment across the five districts. Data from this assessment are included in an appendix; some highlights are summarized below.

- Arterial Management: Throughout the state, there is extensive traffic control on arterials that the state owns and operates. In other areas (surveillance, information dissemination), the activity is limited to the Portland region.
- Freeway Management: Surveillance and information dissemination are thoroughly deployed all across the state while ramp control is limited to the Portland region. Other strategies, including lane management, are extremely limited or nonexistent.
- Road Weather Management: Throughout the state, ODOT has a high level of deployment for surveillance, monitoring and prediction as well as information dissemination advisory strategies.
- Traffic Management Center: Four operations centers cover the entire state.
- Traffic Incident Management: In addition to extensive deployment of surveillance and detection hardware, the state is strong in the area of information dissemination across the board as well as mobilization and response in certain regions.
- Electronic Payment and Pricing: The state collects no tolls, transit fares or parking fees but is currently carrying out experiments related to mileage-based fees.
- Traveler Information: Oregon has extensive deployment of pre-trip and en-route information and moderate implementation of tourism and event information.
- Commercial Vehicle Operations: In conjunction with its weight-mile tax, the state has a comprehensive deployment of electronic screening technology for trucks.

In February 2013, members of TransPort, which is the Portland region's ITS coordinating committee, responded to a survey about technologies that have potential energy benefits as well as a low level of existing deployment. The survey used JPO's ITS Taxonomy as a reference. The group produced the following recommendations:

- Transit Signal Priority
- Enhanced Transit Service
- Tolling
- Information Dissemination
- Parking (information, pricing)
- Special Event (management, information)
- Expansion of Arterial Management & Traffic Control
- Interagency Coordination
- Truck Signal Priority
- Ramp Control (statewide)

The following table offers a comparison of Portland to Seattle (neighbor), Sacramento, CA and Rochester, NY (peer regions) as well as national averages using the data reported to JPO in the 2010 survey.

Table 1.0: Comparison of ITS Deployment between Portland, other U.S. Cities, and the Nation as a Whole

Category	Strategy/Technology	Port.	Seat.	Sacr.	Roch.	U.S.
Freeway Management	Miles under electronic surveillance	64%	53%	41%	14%	54%
	Ramps controlled by ramp meter	100%	48%	N/A	N/A	9%
	Miles under lane control	3%	43%	5%	0%	9%
	Number of Dynamic Message Signs (DMS)	21	93	50	18	4038
	Miles covered by Highway Advisory Radio (HAR)	0%	36%	100%	28%	21%
Freeway Incident Management	Freeway miles under incident detection algorithms	64%	0%	0%	0%	11%
	Freeway miles covered by surveillance cameras (CCTV)	73%	48%	41%	32%	40%
	Freeway miles covered by service patrols	73%	56%	69%	32%	41%
Arterial Management	Signalized intersections covered by electronic surveillance	52%	63%	58%	36%	50%
	Signalized intersections under closed loop with field masters only	1%	22%	3%	7%	7%
	Signalized intersections under closed loop with field masters and central management system	21%	5%	1%	0%	13%
	Number of Dynamic Message Signs (DMS)	34	23	54	0	886
	Arterial miles covered by Highway Advisory Radio (HAR)	0%	0%	40%	0%	4%
Arterial Incident Management	Arterial miles under incident detection algorithms	0%	0%	0%	49%	2%
	Arterial miles covered by surveillance cameras (CCTV)	4%	79%	5%	13%	10%
	Arterial miles covered by service patrols	86%	0%	27%	0%	17%
Transit Management	Fixed route buses equipped with Automatic Vehicle Location (AVL)	100%	79%	N/A	N/A	66%
	Fixed route buses with electronic real-time monitoring of system components	0%	79%	N/A	N/A	36%
	Demand responsive vehicles that operate under Computer Aided Dispatch (CAD)	99%	100%	N/A	N/A	87%
	Bus stops with electronic display of dynamic traveler information to the public	1%	0%	N/A	N/A	3%
Electronic Fare Payment	Fixed route buses equipped with Magnetic Stripe Readers	0%	0%	N/A	N/A	61%
	Fixed route buses equipped with Smart Card Readers	0%	95%	N/A	N/A	40%
Emergency Management	Vehicles under Computer Aided Dispatch (CAD)	80%	99%	83%	56%	80%
	Vehicles equipped with on-board navigation capabilities	36%	66%	83%	17%	44%

Another valuable comparison is between Portland and its smaller neighbor to the south, Eugene, also based on JPO's 2010 data:

Table 1.1: Comparison of ITS Deployment in Oregon

Deployment	Eugene	Portland
Centerline Miles (CLM)	60	82
CLM with real-time data collection	0	72
Detector Stations	0	150
Miles covered by Highway Advisory Radio	60	0
Dynamic Message Signs	4	21
Entrance Ramps	53	150
Ramps with metering	0	140
CLM with managed lanes	0	3
Closed Circuit TV (CCTV) cameras	5	150
% CLM with CCTV Cameras	10%	100%

5. Findings

The importance of reducing energy consumption and greenhouse gas emissions in the near term has brought attention to system and demand management strategies as complements to longer-term changes in vehicle and fuel technology. This research has summarized an inventory of intelligent transportation systems, noting the emerging focus on integrating technologies through the Connected Vehicle Initiative. This paper has reported on the very limited literature that addresses the energy-saving potential of ITS.

Finding #1: Reducing delay with ITS is reliable but the benefits may be small

Because ITS has been deployed mainly to decrease congestion and increase safety, there is abundant documentation of the ability of technologies (and the strategies they enable) to reduce delay. However, very little of that documentation connects reductions in delay with environmental benefits, such as energy savings. One can be confident that investments in certain technologies/strategies will reduce delay but the scale is uncertain, especially in terms of the energy benefits.

Finding #2: Reducing VMT with ITS could have major benefits but there is great uncertainty

In contrast, the energy benefits of reducing VMT are large and certain. Furthermore, focusing on VMT is very consistent with the long-term focus of Oregon's transportation policies. However, the ability of ITS to reduce VMT is very uncertain.

Finding #3: Oregon's existing deployment of ITS is an advantage

In the past 25 years, some states have been the beneficiary of USDOT's large ITS demonstration grants (the term "model deployment" was common in the 1990's) but Oregon is not one of them. However, the state has made consistent investments in ITS and has a very good technology infrastructure on which it can build new initiatives. For example, a comprehensive fiber optic cable network in the Portland metropolitan region reduces the cost of adding new field devices. Major transportation operators, including the Oregon DOT and TriMet, have invested aggressively in traveler information systems.

Finding #4: If road pricing is essential, Oregon has a head start

Pricing roads and/or parking is a strategy with significant potential to reduce VMT but it has been dismissed historically because of political and technical barriers. Recently, these barriers have begun to seem less insurmountable. While fiscal imperatives have raised the appeal of a mileage-based fee, technological advances have reduced the administrative cost as well as the logistical problems associated with implementing road pricing. Meanwhile, Oregon has been a national leader in exploring mileage-fee options, implementing a first pilot program in Portland in 2006 and a second statewide in 2012.

Finding #5: The energy benefits from ITS may depend on investments in staffing/operations rather than capital
A common challenge for calculating the benefits of investments in ITS is that many technologies and strategies depend on the human beings operating them. Even the most advanced traffic signals, for example, require ongoing maintenance and management. Some strategies, such as incident management, are especially staffing intensive. The opportunities to achieve energy savings from ITS may include leveraging devices already deployed around Oregon with more staff, more training of existing staff and more coordination among existing teams or departments.

6. Conclusion

Although *Moving Cooler* and other analyses make a compelling case for operational and behavioral strategies that can be implemented in the near term (mainly because of relatively low capital costs), there is a very limited literature to substantiate the opportunities. Technologies that reduce delay seem to have the greatest potential. Technologies that target behavior (VMT) have greater uncertainty. However, the shortage of empirical evidence may be a function of the limited interest in the energy and environmental benefits of ITS relative to congestion and safety.

In the ITS industry, the present focus is on the Connected Vehicle initiative and, more broadly, the many opportunities to integrate and leverage multiple ITS applications. In this regard, Oregon's existing ITS infrastructure makes it prepared to transition from isolated to connected operations and such a paradigm shift could both enable and directly deliver energy savings.

For reducing delay, the greatest potential for Oregon seems to be related to technologies that can be deployed with or enhanced by active management. Variable speeds on freeways, incident management and other strategies require staffing and interagency coordination. In other words, reducing delay might depend more on agency commitment to collaboration and the cost of labor than on the ubiquity of devices in the field.

For reducing VMT, the potential for enabling road or parking pricing with technology is matched by political resistance. Prospects seem better, then, for building on some early successes with traveler information. As an early adopter of open source development, TriMet helped set the standards for data in the transit industry. It seems that if transportation agencies continue to offer condition data in an open and standardized way it would maximize the possibility of third party applications. In turn, apps and other tools can drive a reduction in VMT.

* * *

Appendices

- Taxonomy of Intelligent Transportation Systems
- Assessment of ITS Deployment in Oregon: Survey Results

In each of ODOT's five highway regions, this table ranks the scale of deployment for each ITS subcategory based on survey responses. The categories (rows) are derived from the JPO "ITS Taxonomy" . "0" is used to represent no deployment and "N/A" indicates uncertainty. Otherwise, the scale is from 1 (limited deployment) to 5 (comprehensive deployment).

Category	Subcategory	ODOT Region				
		1	2	3	4	5
Arterial Management	Surveillance	3	3	1	1	1
	Traffic Control	5	5	5	5	5
	Lane Management	0	0	0	0	0
	Parking Management	1	0	0	0	0
	Information Dissemination	2	0	0	0	0
	Enforcement					
Freeway Management	Surveillance	5	4	4	4	4
	Ramp Control	5	1	0	0	0
	Lane Management	0	0	0	0	0
	Special Event Trans. Mgmt.	N/A	N/A	N/A	N/A	N/A
	Information Dissemination	5	4	4	4	4
	Enforcement	0	0	0	0	0
Crash Prevention & Safety	Road Geometry Warning	1	1	1	1	1
	Highway-Rail Crossing Warning Systems					
	Intersection Collision Warning	0	0	0	0	0
	Pedestrian Safety	N/A	N/A	N/A	N/A	N/A
	Bicycle Warning	N/A	N/A	N/A	N/A	N/A
	Animal Warning	0	0	0	0	0
Road Weather Management	Surveillance, Monitoring & Prediction	4	3	3	4	4
	Information Dissemination Advisory Strategies	4	4	4	4	4
	Traffic Control Strategies	1	0	0	0	0
	Response & Treatment Strategies	1	1	0	0	1
Roadway Operations & Maintenance	Information Dissemination	4	4	4	4	4
	Asset Management					
	Work Zone Management	1	1	1	1	1

Transit Management	Operations & Fleet Management	0	0	0	0	0
	Information Dissemination	2	2	2	2	2
	Transportation Demand Management	5	4	3	2	1
	Safety & Security	0	0	0	0	0
Traffic Management Center	Temporary TMC	0	0	0	0	0
	Permanent TMC	5	5	5	5	1
Traffic Incident Management	Surveillance & Detection					
	Mobilization & Response	4	4	0	2	0
	Information Dissemination	5	5	5	5	5
	Clearance & Recovery	3	0	1	0	0
Emergency Management	Hazardous Materials Management					
	Emergency Medical Services					
	Response & Recovery	5	5	5	5	5
Electronic Payment & Pricing	Toll Collection	0	0	0	0	0
	Transit Fare Payment	0	0	0	0	0
	Parking Fee Payment	0	0	0	0	0
	Multi-Use Payment	0	0	0	0	0
	Pricing	0	0	0	0	0
Traveler Information	Pre-Trip Information	5	5	5	5	5
	En-Route Information	4	4	4	4	4
	Tourism & Events	3	3	3	3	3
Information Management	Data Archiving	5	3	3	3	3
Commercial Vehicle Operations	Credentials Administration	N/A	N/A	N/A	N/A	N/A
	Safety Assurance	N/A	N/A	N/A	N/A	N/A
	Electronic Screening	5	5	5	5	5
	Carrier Operations & Fleet Mgmt.	3	3	3	3	3
	Security Operations	N/A	N/A	N/A	N/A	N/A
Intermodal Freight	Freight Tracking					
	Asset Tracking					
	Freight Terminal Processes					
	Drayage Operations					
	Freight-Highway Connector System					
	International Border Crossing Process					

Taxonomy of Intelligent Transportation Systems Applications

Arterial Management
- Surveillance
  - Traffic
  - Infrastructure
- Traffic Control
  - Adaptive Signal Control
  - Advanced Signal Systems
  - Variable Speed Limits
  - Bicycle & Pedestrian
  - Special Events
  - Eco-Signal Priority
  - Eco-Traffic Signal Timing
- Lane Management
  - HOV Facilities
  - Reversible Flow Lanes
  - Pricing
  - Lane Control
  - Variable Speed Limits
  - Emergency Evacuation
  - Eco-Lanes Management
  - Queue Warning
- Parking Management
  - Data Collection
  - Information Dissemination
  - Eco-Smart Parking
- Information Dissemination
  - Dynamic Message Signs
  - In-Vehicle Systems
  - Highway Advisory Radio
- Enforcement
  - Speed Enforcement
  - Traffic Signal Enforcement

Freeway Management
- Surveillance
  - Traffic
  - Infrastructure
- Ramp Control
  - Ramp Metering
  - Ramp Closures
  - Priority Access
- Lane Management
  - HOV Facilities
  - Reversible Flow Lanes
  - Pricing
  - Lane Control
  - Variable Speed Limits
  - Emergency Evacuation
  - Eco-Lanes Management
  - Queue Warning
  - Speed Harmonization
- Special Event Trans. Mgmt.
  - Occasional Events
  - Frequent Events
  - Other Events
  - Temporary Traffic Management Center
- Information Dissemination
  - Dynamic Message Signs
  - In-Vehicle Systems
  - Highway Advisory Radio
- Enforcement
  - Speed Enforcement
  - HOV Facilities
  - Ramp Meter Enforcement

Roadway Operations & Maintenance
- Information Dissemination
  - Dynamic Message Signs
  - Highway Advisory Radio
  - Internet / Wireless / Phone
  - In-Vehicle Systems
  - 511
- Asset Management
  - Fleet Management
  - Infrastructure Management
- Work Zone Management
  - Temporary Traffic Management
  - Temporary Incident Management
  - Lane Control
  - Variable Speed Limits
  - Speed Enforcement
  - Intrusion Detection
  - Road Closure Management

Crash Prevention & Safety
- Road Geometry Warning
  - Rollover Warning
  - Curve Speed Warning
  - Downhill Speed Warning
  - Overheight / Overwidth Warning
- Highway – Rail Crossing Warning
- Intersection Collision Warning
  - Left Turn Assist
  - Traffic Control Violation Warning
  - Stop Sign Assist
- Pedestrian Safety
- Bicycle Warning
- Animal Warning
- Collision Avoidance
  - Obstacle Detection
  - Lane Change Assist
  - Lane Departure Warning
  - Road Departure Warning
  - Forward Collision Warning
  - Rear Impact Warning
  - Do Not Pass Warning
- Collision Notification
  - Mayday / ACN
  - Advanced ACN
- Weather Warning
- Work Zone Warning

Road Weather Management
- Surveillance, Monitoring, & Prediction
  - Pavement Conditions
  - Atmospheric Conditions
  - Water Level
- Information Dissemination
  - Dynamic Message Signs
  - Internet / Wireless / Phone
  - Highway Advisory Radio
  - In-Vehicle Systems
  - 511
- Traffic Control
  - Variable Speed Limits
  - Traffic Signal Control
  - Lane Use / Road Closures
  - Vehicle Restrictions
- Response & Treatment
  - Fixed Winter Maintenance
  - Mobile Winter Maintenance

Transit Management
- Operations & Fleet Management
  - AVL / CAD
  - Transit Signal Priority
  - Maintenance
  - Planning
  - Service Coordination
- Information Dissemination
  - In-Vehicle Systems
  - In-Terminal / Wayside
  - Internet / Wireless / Phone
- Transportation Demand Management
  - Ride Sharing / Matching
  - Dynamic Routing / Scheduling
- Safety & Security
  - In-Vehicle Surveillance
  - Facility Surveillance
  - Employee Credentialing
  - Remote Disabling Systems

Transportation Management Center
- Temporary TMC
  - Seasonal
  - Special Events
  - Work Zones
- Permanent TMC
  - Freeway
  - Arterial
  - Transit
  - Rural
  - Multi-Agency / Co-located

Alternative Fuels
- Charging / Fueling Information
- Charging / Fueling Payment
- Inductive Charging

Traffic Incident Management
- Surveillance & Detection
  - Detectors
  - Imaging / Video
  - Wireless Enhanced 9-1-1
  - Mayday / ACN
  - Call Boxes
  - Traveler Reported
- Mobilization & Response
  - AVL / CAD
  - Response Routing
  - Service Patrols
- Information Dissemination
  - Dynamic Message Signs
  - Highway Advisory Radio
  - In-Vehicle Systems
  - Internet / Wireless / Phone
- Clearance & Recovery
  - Investigation
  - Imaging / Video
  - Temporary Traffic Control

Emergency Management
- Hazardous Material Management
  - Tracking
  - Detection
  - Driver Authentication
  - Route Planning
- Emergency Medical Services
  - Advanced ACN
  - Telemedicine
- Response and Recovery
  - Early Warning System
  - Response Management
  - Emergency Vehicle Signal Preemption
  - Evacuation & Re-Entry Management
  - Emergency Traveler Information

Traveler Information
- Pre – Trip Information
  - Internet / Wireless
  - 511
  - Other Telephone
  - TV / Radio
  - Kiosks
- En Route Information
  - Wireless
  - 511
  - Other Telephone
  - Radio
  - In-Vehicle Systems
  - Dynamic Message Signs
  - Highway Advisory Radio
- Tourism & Events
  - Travel Services
  - Advanced Parking
- Multimodal Traveler Information
  - Eco-Traveler Information

Driver Assistance
- Navigation / Route Guidance
  - Eco-Routing
- Driver Communication
  - With Other Drivers
  - With Carrier / Dispatch
- Vision Enhancement
- Object Detection
- Adaptive Cruise Control
- Connected Eco-Driving
- Intelligent Speed Control
- Lane Keeping Assistance
- Roll Stability Control
- Drowsy Driver Warning Systems
- Precision Docking
- Platooning
- In-Vehicle Monitoring
  - Cargo Condition
  - Safety & Security
  - Vehicle Diagnostics
  - Event Data Recorders

Information Management
- Data Archive
- Multimodal Traveler Information Management
- Performance Measurement

Commercial Vehicle Operations
- Credentials Administration
  - Electronic Funds
  - Electronic Registration / Permitting
- Safety Assurance
  - Safety Information Exchange
  - Automated Inspection
- Electronic Screening
  - Safety Screening
  - Border Clearance
  - Weight Screening
  - Credential Checking
- Carrier Operations & Fleet Mgmt.
  - AVL / CAD
  - In-Vehicle Monitoring
  - Traveler Information
  - Freight Signal Priority
- Security Operations
  - Asset Tracking
  - Remote Disabling Systems

Intermodal Freight
- Freight Tracking
- Asset Tracking
- Freight Terminal Processes
- Drayage Operations
- Freight – Highway Connector System
- International Border Crossing Process
- Freight Travel Planning

Electronic Payment & Pricing
- Toll Collection
- Transit Fare Payment
- Parking Fee Payment
- Multi – use Payment
- Pricing
  - Congestion
  - Cordon
  - Distance / Mileage
  - Emissions
  - Variable Lane

Acronyms:
ACN: Advanced Collision Notification
AVL: Automatic Vehicle Location
CAD: Computer Aided Dispatch
DMS: Dynamic Message Sign
HOV: High Occupancy Vehicles
TMC: Transportation Management Center

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Visit the ITS Knowledge Resources Online

Applications Overview
http://www.itsoverview.its.dot.gov/

Benefits Database
http://www.itsbenefits.its.dot.gov/

Costs Database
http://www.itscosts.its.dot.gov/

Lessons Learned
http://www.itslessons.its.dot.gov/