State of Knowledge and Practice: Opportunities for Intelligent Transportation Systems in the Energy Arena

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Abstract. This paper examines the capacity of Intelligent Transportation Systems (ITS) to reduce energy consumption within the transportation sector. Research includes a literature review focusing on the energy-saving capacity of ITS technologies and interviews with ITS stakeholders and transportation experts and practitioners. In addition, a case study of an ITS project in Portland, Oregon is included to demonstrate challenges and opportunities associated with implementing ITS technologies. The objective of this paper is to document the state of knowledge and practice and to create a resource for future action and implementation of ITS technologies with energy savings as a goal. Overall, there is a distinct lack of empirical evidence to substantiate the capacity of ITS to reduce energy in the transportation sector. However, research indicates that ITS implementations have contributed toward reductions in vehicular delay, but that further benefits may be limited. In contrast, ITS implementations do have the potential for reducing vehicle miles traveled (VMT) with significant benefits, but there is uncertainty about this. The shortage of empirical evidence of ITS benefits may be a function of the limited interest in the energy and environmental benefits of ITS relative to that of 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. Here, there is an opportunity to deploy ITS technologies with the explicit purpose of reducing energy consumption within the transportation sector, to document any gains, and address the lack of evidence supporting the energy-reducing capacity of ITS.

INTRODUCTION

In the U.S., transportation is the second largest consumer of energy (28%). Only electric generation is a larger contributor (41%); the other major sectors are industrial (21%) and residential/commercial (10%) (*1*). 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. Innovations in 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 (*2*).

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. 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 (*3*).

Over 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 (*2*).

More recently, the emergence of smartphones and "big data" has helped make ITS more 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 applications turn those data into information that travelers can use to manage their travel behavior, potentially with the result of reducing energy consumption and emissions.

INTELLIGENT TRANSPORTATION SYSTEMS: APLLICATIONS AND BENEFITS

ITS technologies encompass a wide array of applications ranging from traffic signal systems to variable message signs that alert drivers about delays. There are numerous ways to organize and represent the full range of advanced transportation technologies that are typically 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 (*4*).

- In 2009, the U.S. Department of Transportation’s ITS Joint Program Office (JPO) 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 (*5*).

- 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 (*6*).

Presently, the trajectory of ITS involves the possibility of communications among vehicles and between vehicles and infrastructure. The “Connected Vehicle Initiative,” administered by the U.S. Department of Transportation (DOT), envisions the deployment of dedicated-short range communications (DSRC) to enable wireless communication between vehicles and the transportation infrastructure. Safety is the number one goal of the connected vehicle program, with mobility and environmental applications and resulting benefits recognized as well (*7*). However, municipalities, vehicle manufacturers and travelers will need to comprehensively deploy DSRC-enabled tags and sensors in vehicles, highways, and roadside and intersection equipment to maximize safety, mobility and environmental benefits. By enabling communication among vehicles and between vehicles and infrastructure, the Connected Vehicle Initiative facilitates various ITS applications: crash warnings and avoidance, 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 (*8*).

Environmental benefits of ITS are typically documented through fuel savings, reduced emissions, and noise. The U.S. DOT’s ITS Joint Program Office has identified eight technologies with the greatest potential environmental benefits: advanced signal systems, dynamic message signs, service patrols, roadway surveillance, pre-trip information, speed control, congestion pricing, and electronic toll collection (*9*). These technologies are achievable through applications that include: Low Emission Zone, Eco-integrated Corridor Management, Eco-Signal Operations, Eco-Lanes, Support Alternative Fuel Vehicle Operations, and Eco-Traveler Information (*9*).

In 2010, JPO launched a research program called Applications for the Environment Real-Time Information Synthesis (AERIS). The program’s objective 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 (*9*)”. The program has a strong connection to USDOT’s Connected Vehicle initiative.

As part of its AERIS initiative, one JPO study offered seven categories of ITS applications with potential environmental benefits, which the report defined as reductions in greenhouse gas emissions, criteria air pollutants and fuel consumption (*10*):

- Demand and Access Management
- Eco-Driving
- Logistics and Fleet Management

- Traffic Management and Control
- Freight
- Transit
- Other

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* (*11*) and *Impact of Information and Communication Technologies on Energy Efficiency in Road Transport* (*12*).

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 and reduced crashes. 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, as well as reductions in emissions. Similarly, if a crash is prevented, the associated delay, fuel/energy consumption and emissions are also avoided.

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.

LITERATURE REVIEW

We conducted a review of literature published within the last 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 capability 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 (*12*).

The majority of ITS research primarily relies on simulations and models to estimate emissions, driver behavior, and vehicle 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 ability of ITS applications to reduce fuel consumption and emissions as nominal. Implementation of ITS technologies could result in 0.3 to 0.6 percent cumulative reductions of greenhouse gases from a national baseline by 2050 (*2*). Although some studies document the environmental benefits of ITS technologies, more research on the relationship between ITS and energy savings is needed.

Reducing Delay

On arterials, many studies focus on the delay-reducing capacity of traffic signal timing and transit prioritization. A report by the Virginia Transportation Research Council identified the estimated benefits of coordinated actuated traffic signal systems from simulation studies (13) :

- 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. 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 (*14*).

A recent report by RITA further summarizes the capacity of other ITS technologies to reduce delay for travelers (*8*):

- 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. These systems also aim to dampen congestion and prevent crashes.
- Adaptive traffic signal control can reduce emissions by up to 50 percent for travelers moving in the peak direction. 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.
- In the freight sector, automated pre-clearance systems have also had significant delay-reduction benefits.

Reducing Vehicle Miles Traveled (VMT)

There are several strategies that reduce freeway delay and emissions through ITS applications, including incident management, ramp metering, and speed management, but many projects and studies utilized traffic signal controls for arterial traffic. 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 (*10*):

- 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, California, 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.

Other ITS-Enabled Strategies

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. In particular, the Connected Vehicle Initiative offers some energy saving potential simply by deploying certain technologies in an integrated rather than isolated manner.

- A report by RITA found that idle reduction technologies at truck stops have reduced emissions by up to 83% and platooning freight vehicles (vehicle-to-vehicle integration) can reduce fuel consumption by up to 20%. RITA cited an implementation of green delivery management system by UPS that reduced emissions by 32,000 MTCE (*10*).
- 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 (*15*).
- Similarly, Barth and Boriboonsomsin found that dynamic eco-driving can reduce fuel consumption and CO2 emissions between 10-20 percent (*16*).

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. Some 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 throughput on a transportation facility and reduces the emissions associated with idling and congestion.

In contrast, congestion pricing and mileage-based pricing schemes may increase the out-of-pocket costs of using a particular facility for road users during peak periods. 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 peak periods aims to smooth or reduce traffic flows (*17*). According to a report by The Information Technology and Innovation Foundation, Stockholm reduced congestion and carbon emissions by 15 percent through its congestion pricing system (*17*).

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 (*18*). 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 *Cruising for Parking*, Shoup found that even a small search time for a parking space can generate significant traffic (*19*).

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 (*10*). 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.

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 (*17*). However, driving assistance and eco-routing require a wide deployment of a consolidated vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) platform to maximize environmental benefits. Increasingly, cars in the U.S. are equipped with a global positioning system (GPS) or telematics systems that offer driving assistance services.

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, taxis or incident management vehicles (*17*).

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 signs and adaptive signal control rely on information obtained from sensors and roadside equipment, vehicle probes, cameras, and other devices that are all part of a V2V and V2I architecture that supports an integrated intelligent transportation system (*13*). 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 (*13*).”

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. Many traffic signals currently 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 (*13*).

Ramp metering is another transportation management system component that can provide environmental benefits (*17*). 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 freeway.

STATE OF DEPLOYMENT

The JPO’s triennial ITS Deployment Tracking project is the preeminent source of data on domestic implementation of ITS for the U.S. Many of the technologies identified in the previous section as having energy saving potential are specifically evaluated by the JPO data (*10*):

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

The 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 (*8*). In the freeway category, traveler information focuses on the location and duration of 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 (*8*).

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 (*8*).

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 achievable, but the benefits may be small.
Because ITS has been deployed mainly to decrease congestion and improve safety, there is abundant documentation of the ability of technologies (and the strategies they enable) to reduce delay. However, very little of that documentation specifically connects the 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. Modeling and evaluation tools are lacking in this area.

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. However, the ability of ITS to reduce VMT is quite uncertain.

Finding #3: 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 with more staff, more training of existing staff and more coordination among existing agencies, teams or departments.

CASE STUDY: IMPLEMENTING OREGON'S 10-YEAR ENERGY ACTION PLAN

Oregon leads in its pursuit of clean energy policies and programs to reduce energy and promote renewable energy. However, Oregon continues to balance the development of an energy strategy that achieves the state's energy conservation and emissions reduction goals while providing reliable and affordable energy (*20*). Oregon's 10-Year Energy Action Plan addresses these challenges by proposing specific initiatives that can be implemented in the near-term. The action plan identifies accelerated deployment of ITS technologies as an important near-term strategy to attain its energy conservation and emissions goals (*20*).

Two factors position Oregon to gain environmental benefits from existing and future deployments of ITS technologies: strong political support and consistent deployment of ITS. Governor Kitzhaber created a statewide mandate to deploy ITS technologies that reduce energy consumption through the 10-Year Energy Action Plan (*20*). Although Oregon has not deployed ITS technologies to the extent of other states, such as New York and Minnesota, it has consistently deployed ITS technologies and infrastructure throughout the past 25 years.

Oregon is one of few states attempting to leverage the capacity of ITS technologies to not only improve the safety, mobility, and sustainability of its surface transportation system, but to also reduce the associated energy consumption and emissions. A review of Oregon's efforts to implement the 10-Year Energy Action Plan, and the associated challenges and opportunities, can provide a valuable resource to other states as they work to implement ITS technologies and reach energy conservation and emissions objectives.

Oregon's 10-Year Energy Action Plan

Similar to national trends, Oregon's transportation sector consumes vast amounts of energy and produces a significant portion of emission statewide. Annually, Oregonians consume 1.5 billion gallons of gasoline and drive more than 33 billion miles (*20*). The transportation sector is the largest contributor to Oregon's carbon emissions, accounting for 37 percent of total emissions statewide (*4*).

However, Oregon has achieved gains where other states have not. Over the past four decades, Oregon has developed a more efficient transportation sector characterized by reduced fuel consumption and emissions (*20)*. According to an Oregon Department of Transportation report (*21*), per capita vehicle miles traveled (VMT) have been in decline since 2000.

In addition, Oregon developed ambitious air quality and emissions goals. In 2007, the Oregon state legislature passed House Bill 3543, which established statewide goals for greenhouse gas (GHG) emissions. The goals call for a ten percent reduction below 1990 emissions levels by 2020, and at least a 75 percent reduction below 1990 levels by 2050 (*20*). To reduce emissions to ten percent below 1990 levels, Oregon must reduce fossil fuel use by approximately 30 percent statewide (*21*).

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 objective of this plan is to implement strategies that will help Oregon attain goals to reduce statewide greenhouse gas (GHG) emissions and promote energy conservation. The Governor's action plan outlines three state energy goals: (1) maximize energy efficiency and conservation to meet 100 percent of new electric 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. As part of the third state energy goal, the action plan identifies four primary actions, one of which is the implementation of ITS (*20*).

Oregon's 10-Year Energy Action Plan focuses on both near-term and long-term strategies to achieve reductions in energy consumption and emissions associated with the transportation sector. The action plan proposes the accelerated deployment of intelligent transportation systems and electric vehicles to achieve a market transition to a more efficient, cleaner transportation system. Although both strategies are important components of the action plan, the deployment of ITS can be implemented in the near-term while the deployment of electric vehicles is a long-term strategy. It will take much longer for electric vehicles to be deployed on a scale that will effectively reduce energy consumption and emissions.

ITS can achieve environmental benefits in the near-term. Near-term strategies are an important component of any comprehensive effort to reduce energy consumption and emissions because they reduce the total amount emissions that must be addressed in the future. According to *Moving Cooler*, "near-term strategies such as lower speed limits, congestion pricing, eco-driving, operational improvements, and improved transit level of service, [when] implemented, are among strategies that would achieve GHG reductions relatively quickly. Achieving early results would reduce the cumulative GHG reduction challenge in later decades (*2*)". Additionally, the implementation of near-term strategies can accelerate innovations in vehicle and fuel technology.

Existing ITS Deployment in Oregon

Over the past 25 years, Oregon has consistently invested in and deployed ITS technologies. The existing ITS infrastructure provides an established framework upon which a more integrated system can be built. 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. The research team assessed the existing ITS deployment in *Survey of ITS Deployments in Oregon* (Makler, J., unpublished data). 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.

Implementing the 10-Year Energy Action Plan

The Oregon Transportation Research and Education Consortium (OTREC) partnered with Oregon Solutions to accelerate ITS projects to support the implementation of Oregon's 10-Year Energy Action

Plan. The purpose of the project was to identify and launch two to four initiatives with the capacity to accelerate implementation of energy-conserving ITS strategies across the state in the near-term.

OTREC and Oregon Solutions brought diverse and complimentary expertise and experience to the project. OTREC is a partnership between Portland State University, the University of Oregon, Oregon State University, and the Oregon Institute of Technology. The university transportation center strives to conduct research on surface transportation, educate current and future transportation leaders, and encourage real-world use of research results (*22*). OTREC contributed technical expertise and research on transportation and ITS technologies. Oregon Solutions convenes stakeholders across various jurisdictions, sectors, and issues and facilitates collaborative agreements between them to solve complex problems (*23*). Oregon Solutions provided staff with facilitation and consensus-building skills.

The partner organizations convened a steering committee to assist with the assessment and project designation phases. With the assistance of the steering committee, Oregon Solutions and OTREC, identified key participants and stakeholders to interview. The interviews focused on evaluating the capacity of specific ITS technologies to reduce energy consumption. Oregon Solutions conducted 22 interviews with local and national transportation practitioners and experts during January and February of 2013. Participants were selected based on their knowledge of and experience with various ITS technologies and strategies. The interviews were summarized in *Intelligent Transportation Systems Pilot Project: Project Assessment Interview Summary*. Several themes emerged from the assessment interviews (Hampton, T. and Conover, J., unpublished data):

- Effectively reducing emissions and energy consumption associated with the transportation sector will require a diverse set of strategies, one of which is the implementation of ITS technologies.
- Pricing is a strategy that could effectively induce behavior change, although a pricing project did not emerge as a result of the assessment process.
- There is consistent interest in the continued development of an open information environment to provide more complete, dynamic information so that users can make informed decisions and maximize the transportation system.
- Although many MPOs acknowledge the importance of ITS, existing deployments could be better integrated or effectively managed.

Simultaneously, OTREC's team conducted research to assess the capacity of ITS technologies to reduce energy consumption and GHGs. This research, combined with information from the assessment interviews, resulted in a report that included recommendations to support decision makers as they implement the action plan. In addition to assessment interviews, the research team conducted independent interviews with local transportation and ITS practitioners to assess the potential environmental benefits associated with the deployment of ITS technologies.

In February, the team surveyed the members of TransPort about technologies that have potential energy benefits as well as a low level of existing deployment. TransPort is the Portland region's ITS coordinating committee and includes representatives from FHWA, ODOT, counties, cities, Metro, universities and the private sector. The survey used JPO's ITS Taxonomy as a reference.

The group identified ten strategies with potential environmental benefits: (1) transit signal priority, (2) enhanced transit service, (3) tolling, (4) information dissemination, (5) parking information and pricing, (6) special event management and information, (7) expansion of arterial management and traffic control, (8) interagency coordination, (9) truck signal priority, and (10) ramp control. Members of Transport identified tolling and expansion of parking information and management as leading strategies to deliver environmental benefits (Makler, J., unpublished data).

Based on research and assessment interviews, Oregon Solutions and OTREC developed eight potential ITS projects, which are summarized below (Hampton, T., and Conover, J., unpublished data).

- Open Source Platform and Open Data: Expand an open source platform and open data sources in Oregon to support the development of key user information designed to affect and influence behavior change.
- Coordinated Incident Management: Engage with emergency response professionals to identify their interests and create incentives to improve incident clearance time.
- Freight Signal Priority Pilot: Select key freight corridors and establish signal priority for freight vehicles.
- Truck Parking Availability: Provide highway signs and mobile device applications that indicate availability of parking for drivers during required breaks.
- Adaptive Signal Control Test Bed: Provide the opportunity to test various signal control technologies and determine which technology works best under various conditions.
- Hillsboro Go-Point: Support or expand the implementation of the City of Hillsboro's mobility hub concept.
- Connected Vehicle Pilot: Adapt an existing fleet or several fleets with current vehicle communications technology to test signal priority or other key aspects of the technology.
- Variable Speed Limit Pilot: Develop variable speed limit test programs to evaluate impacts on safety and congestion.

After the assessment phase, OTREC and Oregon Solutions selected two projects to develop: a Traffic Incident Management (TIM) training project and a Connected Vehicle (CV) test bed project. The TIM project will develop a training program to more effectively coordinate emergency response professionals to traffic incidents and reduce clearance time. The National Traffic Incident Management Coalition estimates that during peak travel periods, every minute a freeway lane blocked results in four minutes of delay after the incident is cleared (*24*). This project could achieve environmental benefits by reducing delay associated with traffic incidents.

The CV project will develop a test bed to demonstrate potential environmental benefits achieved through vehicle-to-vehicle and vehicle-to-infrastructure technology. Although the environmental benefits associated with CVs are somewhat uncertain, there is an opportunity to leverage this emerging technology to improve air quality and reduce energy consumption. Presently, the U.S. DOT is conducting research to determine the benefits associated with V2V and VII applications. The primary objective of this research is to determine the safety benefits associated with this technology (*7*). Although environmental objectives are often included in CV pilot projects and research, it is not often the sole objective. There is an opportunity for Oregon to leverage its existing ITS infrastructure and create an innovative CV test bed that demonstrates the potential for this technology to achieve environmental benefits.

Findings

Oregon's initiative to implement the 10-Year Energy Action Plan illustrates the potential challenges and opportunities associated with deploying ITS technologies. This can serve as a resource to other states as they work to deploy ITS technologies and achieve environmental benefits in the near-term.

Finding #1: Oregon's political support for ITS is an advantage.
The 10-Year Energy Action Plan identifies the accelerated deployment of ITS as an important strategy for achieving Oregon's energy conservation and emissions reduction goals. This top-down mandate from Governor Kitzhaber provides tremendous support for the deployment of ITS technologies capacities across the state.

Finding #2: 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, 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 (the transit provider for the Portland metropolitan region), have invested aggressively in traveler information systems.

Finding #3: 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 #4: A constrained fiscal environment will continue to be a significant barrier to implementation.
As OTREC and Oregon Solutions worked to develop a Connected Vehicle project a primary concern was to identify and secure funding for a future project. Although there were no funding opportunities available, the team determined that the creation of a CV test bed may position the state to take advantage of future funding opportunities.

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.

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.

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. Other states can take advantage of this trend and position themselves to be competitive applicants for future federal funding opportunities through the establishment of a CV test bed or pilot program.

For example, the U.S. DOT's Safety Pilot Model Deployment currently underway in Ann Arbor, Michigan is examining the safety benefits of CV technologies (*25*). This pilot was funded through a U.S. DOT grant. In addition, the establishment of an advisory committee that assumes responsibility for the advancement of ITS technologies can contribute to the successful deployment of technologies aimed at achieving environmental benefits.

Although the ITS industry has focused on safety, mobility, and efficiency in the past, there are indications that this trend is shifting to include environmental benefits. Research programs such as AERIS have the potential to present empirical evidence that more definitively demonstrates the energy-conserving capacity of ITS technologies. States can establish pilot programs or test beds to take advantage of federal trends toward CVs and position themselves as competitive applicants for future funding opportunities.

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