# Public Roads

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The Rise of Electric Cars
Mini-Roundabouts
Solar in the Right-of-Way

U.S. Department of Transportation
Federal Highway Administration

Public Roads

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—featuring developments in Federal highway policies, programs, and research and technology—

# Articles



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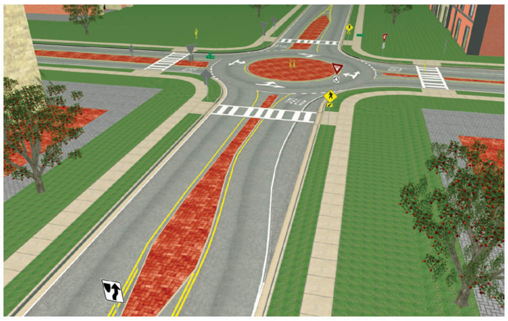

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# Departments




**Front cover**—To reduce the country's dependence on fossil fuels, electric vehicles are one option. With more of these automobiles on the road, California, Oregon, and Washington State are supporting the West Coast Electric Highway initiative, which aims to increase the availability of fast-charging infrastructure, such as the station this charger is connected to, along I–5 in Washington State. For more information, see "The Car of the Future, Today" on page 2 in this issue of PUBLIC ROADS. *Photo by Jessie Lin, Washington State Department of Transportation.*

**Back cover**—Oregon is leading the way in installing renewable energy along highways. This solar array is one of two projects recently completed along I–5 near Portland. The State has the potential to generate 68 million megawatt-hours of solar energy and, through even partial development of those resources, could produce its current annual energy use of 48 million megawatt-hours. For more information, see "Spotlight on Solar Arrays" on page 20 in this issue of PUBLIC ROADS. *Photo by Gary Weber, ODOT Photo/Video Services.*

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# Guest Editorial

## Living Laboratories: Taking Research to the Streets

For many, the terms "research" and "laboratory" conjure images of solitary scientists in white smocks hunched over their lab benches, engineers crunching numbers at their computers, and graduate students running experiments for their advisors. At the Federal Highway Administration's (FHWA) Turner-Fairbank Highway Research Center, there is a new initiative underway in the Office of Operations Research and Development (R&D) under the rubric of "living laboratories" that promises to create yet another picture of what transportation research might look like in the future.

To understand the concept of living laboratories, it helps to have some background on FHWA's Saxton Transportation Operations Laboratory and how the living laboratory idea evolved. The FHWA laboratory has a significant investment in traffic simulation, as demonstrated by past projects, internal expertise, and ongoing results that have become part of the lab's operations. To calibrate simulation tools and make them useful for testing new ideas, extensive observations are necessary to study the functioning of existing transportation systems. This observational research takes place on actual roadways—living laboratories—and helps researchers adjust and validate simulations.

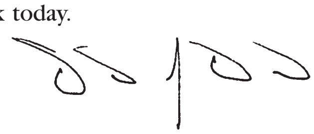
Once a simulation has demonstrated the viability and benefits of a design or innovation in the virtual world, living laboratories are critical to test and demonstrate the effectiveness of the idea in the real world. For example, FHWA researchers are working with colleagues from the Virginia Department of Transportation (VDOT) to enhance and extend simulations involving cooperative adaptive cruise control and speed harmonization to model a living laboratory on I–66 in northern Virginia.

The FHWA laboratory staff and VDOT researchers will conduct these experiments on a segment of highway that they collaboratively identified as a road experiencing traffic congestion that has a significant impact on surrounding communities. The researchers will instrument a limited number of vehicles with communications devices, sensors, and software featuring algorithms developed for these experiments through simulation models. The algorithms are first validated on a small scale at the Saxton Transportation Operations Laboratory and then taken to the highway for real-world testing.

The FHWA laboratory also plans to test technologies developed through the Connected Vehicle Program sponsored by the U.S. Department of Transportation's Intelligent Transportation Systems Joint Program Office. These tests will take place around the country in other cooperative living laboratories characterized by differing network geometries and local driving behaviors. The diversity of the U.S. population and terrain makes the concept of living laboratories especially important to testing and validating algorithms and concepts for acceptance and safe use nationwide.

Do you have a candidate living laboratory near you? The Saxton Transportation Operations Laboratory is seeking to accelerate the transfer of good ideas for better transportation operations from academia directly to testing on living laboratory roads and test tracks across the country. Staff members at the FHWA lab are developing a concept for identifying and cataloging researchers, living laboratory facilities, and programs nationwide. The end result will be a knowledge resource that can accelerate opportunities for collaboration and testing innovative ideas on the road. If you'd like to participate, please contact Ben McKeever at ben.mckeever@dot.gov.

The transportation laboratory of the future is here. And you just might have driven through it on your way to work today.



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# The Car of the Future, Today

by Diane Turchetta

***Plug-in electric vehicles have the potential to be a cleaner, more sustainable option for personal travel than conventional vehicles. But market penetration will take time.***


The traditional fossil fuels used to power the Nation's fleet of automobiles come with significant economic, national security, and environmental costs. For example, almost half of the total U.S. trade deficit in 2010—$265 billion of $646 billion—was oil related. In addition, as the world's largest oil importer, the United States is economically vulnerable to supply disruptions, resulting in the need for military operations to ensure that foreign oil fields and overseas shipping lanes remain open and secure. Further still, concerns persist about the impacts of the emissions from the burning of these fuels on air quality and climate change.

For these reasons and more, manufacturers and the traveling public are increasingly investing in plug-in electric vehicle (PEV) technologies. Electric vehicles include

**(Left) USDOT is funding research and development related to plug-in electric vehicles (PEVs), such as this one recharging at a station that is part of the ChargePoint network, a public-private partnership between DOE and Coulomb Technologies, Inc.** *Photo: Coulomb Technologies, Inc.*

pure battery electric vehicles, plug-in hybrid electric vehicles, hybrid electric vehicles, and extended-range electric vehicles. The increased adoption of this vehicle technology promises to yield multiple benefits, including reducing U.S. reliance on foreign sources of oil, lowering localized and regional onroad emissions, and potentially decreasing greenhouse gas emissions, depending on the source of fuel the electrical grid is using. Many States and localities in the United States are beginning to build the necessary infrastructure to support regular use of PEVs.

The Obama administration set a goal of getting 1 million advanced technology vehicles, such as PEVs, on the road by 2015. The administration also developed new initiatives to support advanced technology vehicles. For example, tax incentives have proven effective in providing the additional boost needed to encourage mainstream consumers to choose PEVs over conventional fuel vehicles. The American Recovery and Reinvestment Act of 2009 (Recovery Act) established tax credits for purchasing electric vehicles ($2,500–$7,500 per vehicle, depending on the battery capacity) and conversion kits to retrofit conventionally powered vehicles with electric vehicle capability ($4,000 per vehicle maximum). In addition, nearly all States and the District of Columbia have adopted other measures promoting electric-drive vehicle usage, including high-occupancy vehicle privileges and waived emissions inspections, as well as tax credits or rebates and preferred purchase programs.

Over the next few years, nearly all major automakers plan to put PEVs on the road. The U.S. Department of Energy (DOE) estimates PEV production levels to be more than 1.2 million total through 2015. However, actual production and market penetration depend on many variables, including improvements in PEV battery technology, vehicle cost, the price of conventional fuels, and consumer behavior. What follows is a closer look at these challenges and what is being done at the Federal and State levels to overcome them.

## Types of Electric Vehicles

- **Battery electric vehicles**, such as the Nissan LEAF®, are powered by an electric motor and run on batteries charged by electricity, similar to cell phones or digital cameras. Because battery electric vehicles run purely on electric charges, they emit no tailpipe emissions.
- **Plug-in hybrid electric vehicles** have both an electric battery and a gasoline or other hydrocarbon-fueled engine. These vehicles run on an electric charge but switch to other fuels when the battery runs down.
- **Hybrid electric vehicles** combine the engine of a gasoline or other hydrocarbon-fueled vehicle with the battery and electric motor of an electric vehicle. The combined engine allows hybrid electric vehicles to achieve better fuel economy than traditional vehicles. Hybrid electric vehicles do not need to be plugged in; the battery is charged by the internal combustion engine or other propulsion source and during regenerative braking.
- **Extended-range electric vehicles**, such as the Chevrolet Volt, have an electric motor. The owner can plug in while stationary to charge the battery; while traveling, an onboard generator, such as a gasoline-, diesel-, or ethanol-fueled engine, kicks in to further power the electric motor.

## Challenges to Mass Integration

A number of barriers stand in the way of broader consumer acceptance and more widespread deployment of electric vehicles. One major obstacle to the growth of the PEV market is the higher upfront vehicle cost compared to conventional automobiles. The high cost of the battery system for battery electric vehicles and the advanced drivetrain system for plug-in hybrid electric vehicles accounts for much of the additional cost. For example, the manufacturer's suggested retail price for the Chevrolet Volt is $39,145 and for the Nissan LEAF® is between $35,200 and $37,250, depending on the model. Even with Federal tax incentives, the cost of PEVs remains well above the cost of most comparably sized conventional automobiles, many of which retail in the range of $15,000 to $25,000.

For many consumers, the limited range of PEVs, especially battery electric vehicles, is also a barrier to purchasing. According to Nissan,


*AeroVironment, Inc.*

**Shown here is a residential charging station, the most common way today's PEV owners charge their vehicles.**

## Types of Charging

- **Level 1:** This level of service is provided by a typical household outlet and is most appropriate for PEVs with relatively small battery packs, low daily mileage, or limited access to Level 2 charging.
- **Level 2:** This level of service is appropriate to fully charge most PEVs overnight. Compared to Level 1 charging, it can cut the charge time in half. Level 2 charging may require homeowners to upgrade their electrical panel to provide a dedicated circuit for PEV charging. The same connector is used for Level 1 and 2 charging, and most new PEVs are compatible with both voltage levels.
- **DC Fast Charging:** DC charging is often referred to as "fast charging." This level of charging can accommodate high-traffic commercial locations, such as fleet installations, gas stations, and charging stations along major transportation corridors.
- **Battery Switching:** An automated process exchanges a depleted battery with a fully charged one.

the LEAF®'s expected all-electric range with a fully charged battery is more than 135 miles (217 kilometers) in ideal conditions, and the U.S. Environmental Protection Agency (EPA) lists the car's official range as 73 miles (117 kilometers) based on tests using varied driving conditions and climate controls. Consumers looking for a farther range may opt for plug-in hybrid electric vehicles, which switch to running fully on gasoline when the battery runs down.

Most of the PEVs currently on the market use lithium-ion batteries, widely known for their use in laptops and consumer electronics. However, work is currently underway to develop and test new battery chemistries. Under the Recovery Act, DOE is funding battery and electric drive component manufacturing, as well as research and development, so battery manufacturers can benefit from economies of scale to lower costs and develop new battery chemistries with higher energy densities. If successful, the new technologies could help reduce consumer concerns about driving range and vehicle price.

Another challenge to integrating PEVs into the mainstream is the availability of charging infrastructure. At least in the early stages of adoption, most PEV owners will charge their vehicles in their homes overnight. To do so, owners must have a Level 2 charger installed to fully charge a battery electric vehicle and at least a Level 1 charger for plug-in hybrid and extended-range electric vehicles. A Level 1 charger provides 2–5 miles of range per hour of charging, typically using a 120-volt outlet, and a Level 2 charger provides 10–20 miles of range per hour of charging using a 240-volt outlet.

Nonresidential charging infrastructure also is important for developing PEV markets. To maximize the full range of PEVs, consumers not only need a home charger but also will want to charge their cars while on the go. Charging stations could be installed on commercial properties such as places of employment, grocery stores, public parking lots, and airports; curbside at both commercial and residential locations such as apartment and condo buildings; and at stopping points along highways such as rest areas. In addition, each location would require an appropriate charging level to meet the needs of the various types of electric vehicles. Moving Ahead for Progress in the 21st Century (MAP-21), the most recent surface transportation bill passed in July 2012, permits transportation funding to be used to fund electric vehicle charging infrastructure at "fringe and corridor parking facilities."

Strategic placement is another issue related to nonresidential charging infrastructure. Placement may be influenced by land-use patterns, geography, and level of traffic congestion. Both the public and the private sectors have invested in charging infrastructure; however, public-private partnerships are the most popular method of deploying charging infrastructure to date. The two largest pilot projects are public-private partnerships between DOE and two private companies, ECOtality, Inc., and Coulomb Technologies, Inc. DOE also provided a nearly $1 million Electric Vehicle Readiness Grant to the New York State Energy Research & Development Authority on behalf of the Transportation and Climate Initiative. The grant supports the Northeast Electric Vehicle Network, a group of 11 Northeast States including the District of Columbia. Another example is the U.S. Department of Transportation's (USDOT) award of $3.34 million in TIGER (Transportation Investment Generating Economic Recovery) II grant funding to extend the initial network of direct current (DC) fast-charging stations in rural northwestern Oregon along key corridors such as routes to the coast and mountains, strategically linking travel destinations throughout the northwestern part of the State. The goals of these projects are to promote the deployment of infrastructure to support PEVs and to evaluate how that infrastructure is used.

An alternative to public fast-charging stations is battery switch

## Charging Options

| | Current Type | Amperage | Voltage | Kilowatts | Charging Time | Primary Use |
|---|---|---|---|---|---|---|
| Level 1 | Alternating current | 12–16 | 120 | 1.3–1.9 | 2–5 miles of range per hour of charging | Residential charging |
| Level 2 | Alternating current | Up to 80 | 240 | Up to 19.2 | 10–20 miles of range per hour of charging | Residential and public charging |
| DC Fast Charging | Direct current | Up to 200 | 208–600 | 50 to 150 | 60–80 miles of range in less than 30 minutes | Public charging |

*Source: DOE, Energy Efficiency and Renewable Energy, Vehicle Technologies Program, May 2011.*


*Coulomb Technologies, Inc.*

**(Above) Two PEVs are recharging at a ChargePoint station at the Oakland International Airport in Oakland, CA.**

stations, where a driver enters a lane and then a robotic system in the station takes over the process of switching out a depleted battery for a charged one. The car proceeds along a conveyor while the automated switch platform below the vehicle aligns under the battery, washes the underbody, initiates the battery release process, and lowers the drained battery from the vehicle. The depleted battery is then placed onto a storage rack for charging, monitoring, and preparation for use in another vehicle. A fully charged battery is lifted into the waiting car. The switch process takes less time than a stop at the gas station, and the driver and passengers may remain in the car throughout. The private sector is leading the charge to develop this battery-leasing business model and infrastructure, and introduce it to the United States in California.

Managing energy demand between PEV charging and the existing demand on the electrical grid is yet another challenge. The impacts of charging will vary by region, depending on PEV market penetration, the types of PEVs adopted, the method of electricity generation, and seasonal variations in electricity use. One potential solution is charging reduced electricity rates during offpeak hours, typically at night when most residential charging occurs. However, as PEV use increases and the need for charging during peak hours becomes a necessity, it could put stress on the grid and potentially cause disruptions in electric service.

Another potential solution is deployment of "smart grid" technology to ease the demand. Smart grid technology enables the grid to collect information about the electricity use patterns of suppliers and consumers to improve the efficiency and reliability of the grid, and provide more efficient transmission of electricity to the consumer, including quicker restoration of electricity after power disturbances.

Finally, perhaps the most crucial issue surrounding the success of PEV deployment is consumer acceptance. In order for manufacturers to meet PEV production goals by 2015, PEVs must generate a healthy demand among consumers. Demand could increase quickly if the price becomes more competitive with conventional automobiles, if vehicle tax incentives increase, or if gas prices rise significantly. Also, all levels of government, public utilities, automakers and dealers, and other private sector entities must address the need for public outreach and education on PEV issues, including PEV technology, driving ranges,

**(Below) This PEV owner plugs in his vehicle at a Blink charging station in Wilsonville, OR.**


*ECOtality, Inc.*

## Expected PEV Production Levels Through 2015*

| Make and Model | Type | 2011–2015 |
|---|---|---|
| Fisker Karma | Plug-in Hybrid Electric Vehicle | 36,000 |
| Fisker Nina | Plug-in Hybrid Electric Vehicle | 195,000 |
| Ford Focus | Battery Electric Vehicle | 70,000 |
| Ford Transit Connect | Battery Electric Vehicle | 4,200 |
| Chevrolet Volt | Plug-in Hybrid Electric Vehicle | 505,000 |
| Navistar eStar™ (truck) | Battery Electric Vehicle | 4,000 |
| Nissan LEAF® | Battery Electric Vehicle | 300,000 |
| Smith Electric Vehicles Newton™ (truck) | Battery Electric Vehicle | 5,000 |
| Tesla Motors Model S | Battery Electric Vehicle | 55,000 |
| Tesla Motors Roadster | Battery Electric Vehicle | 1,000 |
| THINK City | Battery Electric Vehicle | 57,000 |
| **Total** | | **1,232,200** |

**Note: This chart was developed before announcements that Chevrolet would idle production of the Volt in March and August 2012.*
*Source: DOE,* One Million Electric Vehicles by 2015: February 2011 Status Report*, 2011.*

charging infrastructure, and safety. In the end, the consumer will determine whether the adoption of PEVs accelerates or stalls.

### Other Issues

Additional issues from a transportation and highway perspective include: (1) concerns over life-cycle greenhouse gas emissions associated with the operation of PEVs, (2) impacts of reduced gas tax revenues on the Highway Trust Fund, and (3) the current prohibitions on commercialization of interstate rights-of-way as described in Title 23 of the U.S. Code of Federal Regulations.

Life-cycle greenhouse gas emissions account for emissions from an activity or source from "cradle to grave." This may include estimating emissions upstream of the traditional point of measurement—taking into account the raw materials used in making a product or the energy used to transport the product to a local market, for example—as well as estimating downstream emissions resulting from consumption and disposal. From an environmental perspective, it is important to ensure that PEV adoption does not result in the transfer of emissions from one sector (transportation) to another (electricity). PEVs produce no tailpipe emissions. However, from a life-cycle point of view, the electricity used to charge these vehicles could be associated with greenhouse gas emissions if generated by the burning of coal or other fossil fuels. Electricity generated from renewable energy sources, such as hydropower, solar, wind, biomass, or geothermal, results in significantly lower greenhouse gas emissions than that generated by coal-fired plants.

The impact of PEVs on transportation funding also remains to be addressed. Currently, Federal and State fuel taxes on gasoline and diesel provide a significant contribution to funding for maintaining roadways. Because electric vehicles do not use conventional fuel (that is, gasoline or diesel), they pay no fuel tax, which means they do not contribute to the Highway Trust Fund. While this is less a problem in the early stages of adoption, losses due to the use of electricity as a transportation fuel will comprise about 1 percent of projected revenue shortfalls through 2015. Some States, such as Washington, are currently considering legislation that will tax PEV owners based on the amount of electric miles driven. In March 2012, Washington State enacted legislation that imposes a $100 annual fee on electric vehicles, the proceeds of which must be used for highway maintenance and preservation. Separate legislation funded a feasibility study of a road user charge system, which may be tested first on electric vehicles to account for miles driven.

Another potential source of revenue for State departments of transportation (DOTs) from the installation of renewable energy technologies and alternative fuel facilities, including PEV charging, on the highway right-of-way is the sale of carbon offsets or renewable energy

This Blink charging station, part of a public-private partnership between DOE and ECOtality, Inc., is solar powered.

*ECOtality, Inc.*

WSDOT

In Skykomish, WA, several electric vehicles stop to charge up at this public charging station along Stevens Pass Greenway Scenic Byway.

credits. A carbon offset is a reduction in greenhouse gas emissions made in order to compensate for or offset emissions made elsewhere. A renewable energy credit represents the environmental attributes of the power produced when a renewable energy facility opens (one renewable energy credit is equivalent to 1 megawatt-hour of electricity generated). However, Section 111 of Title 23, United States Code, currently prohibits commercialization of interstate rights-of-way, including any activity that is fee based. Therefore, charging the public a fee for the electricity used to charge PEVs is prohibited. Removing this provision, or providing an exemption for charging infrastructure, could provide States with an opportunity to accelerate the transition to cleaner burning vehicles and potentially create a revenue source for highway construction and maintenance activities.

## FHWA Research And Initiatives

Recognizing the important role that PEVs likely will play in the future, and the potential impacts they will have on the Nation's transportation system, the Federal Highway Administration's (FHWA) Office of Planning, Environment, and Realty has initiated several projects to help accelerate the deployment of PEVs and charging infrastructure. The office is also analyzing how the penetration of PEVs into the current fleet may impact FHWA's mission.

"FHWA is committed to assisting State DOTs with determining what is necessary in establishing an infrastructure that supports and maximizes the benefits of electric vehicle deployment, including reducing energy consumption and improving the sustainability of the transportation system," says Gloria Shepherd, associate administrator of FHWA's Office of Planning, Environment, and Realty.

FHWA partnered with the American Association of State Highway and Transportation Officials (AASHTO), the Center for Climate and Energy Solutions, and numerous other stakeholders to develop *An Action Plan to Integrate Plug-In Electric Vehicles with the U.S. Electrical Grid*. The plan provides a comprehensive strategy for public and private actions to build infrastructure and

### I–5 by the Numbers

| | |
|---|---|
| 1,350 | Miles (2,173 kilometers) from Canada to Mexico |
| 550 | Miles (885 kilometers) pass through heavily congested urban areas |
| 71,000–300,000 | Number of vehicles on the corridor daily |
| 10,000–35,000 | Number of commercial trucks daily |
| 150,000 | Projected number of vehicles daily by 2035 without further improvement to the corridor |
| 95% | Portion of corridor projected to be heavily congested by 2035 without major intervention |

*Source: USDOT.*

educate consumers, with the goal of accelerating PEV adoption.

In January 2012, FHWA and RITA's John A. Volpe National Transportation Systems Center completed a report that investigates the implications of accommodating renewable energy technologies and alternative fuel facilities within highway right-of-way. The report, *Alternative Uses of Highway Right-of-Way*, offers a snapshot of issues in a rapidly evolving field and provides transportation agencies with information that could help them in pursuing future renewable energy projects.

FHWA has recently initiated a research project, titled Feasibility and Implications of Electric Vehicle Deployment and Infrastructure Development, which focuses on the prospects and expectations for short- and long-term deployment of electric vehicles. The study will analyze the potential impact of this deployment on FHWA's mission, the financial implications for available highway revenues, and potential infrastructure development needs. The results of the research will assist State and local transportation agencies in understanding whether and how transportation infrastructure might have to change to facilitate, support, and provide emergency response to electric vehicles.

**WSDOT Secretary of Transportation Paula Hammond speaks at a grand opening event for the West Coast Electric Highway in Bellingham, WA, on May 30, 2012.**


WSDOT

FHWA also is working to organize a summit to investigate the use of rights-of-way to grow biofuel feedstock crops. The goal would be to increase the production of biofuels without affecting food, fiber, feed, or flower production by using available lands along highway roadsides, at military bases, and at airports.

In addition, a new research project is underway, with support from FHWA's Exploratory Advanced Research Program, to study the use of inductive charging technologies for electric vehicles. Inductive charging uses an electromagnetic field from coils embedded in the ground to transfer electricity to the battery pack of a PEV without the need for a cord. This technology could be useful to curb consumer anxiety about charge range since charging can occur while a car is in motion.


WSDOT

**This WSDOT booth provided information about the West Coast Electric Highway to attendees at one of the grand opening events.**

## West Coast Electric Highway

The Washington State Department of Transportation (WSDOT) is among the States leading the charge to install PEV infrastructure. The department is supporting the West Coast Electric Highway, a network of electric vehicle fast-charging locations along I–5. The public charging stations enable


**The West Coast Green Highway initiative promotes the use of electric vehicles and cleaner fuels along I–5 from Canada to Mexico.** *Source: WSDOT.*

PEV drivers to travel the length of the State, 276 miles (444 kilometers) of I–5 between Washington's borders with Oregon and Canada. The $1.5 million project is funded by DOE with Recovery Act dollars administered by the Washington State Department of Commerce through the State Energy Program.

Through a competitive contract award process, AeroVironment, Inc., was selected to manufacture, supply, install, and operate the network of fast chargers. Stations are located every 20 to 35 miles (32 to 56 kilometers) along stretches of I–5 between the Canadian border and Everett and between Olympia and the Oregon border. Branching out from I–5 onto east-west corridors, charging stations are also in communities along U.S. 2 between Everett and Wenatchee and on I–90 between North Bend and Cle Elum.

The fast-charging stations can power an all-electric vehicle from zero to approximately 80 percent charged in 30 minutes. Each charging location also includes a Level 2 pedestal for other models of PEVs. The stations are conveniently placed at private retail locations such as shopping malls, fueling stations, and travel centers with easy access to the highway.

In addition to the private retail locations, Level 2 charging equipment is available at two of Washington's gateway safety rest areas along I–5 where a combined total of more than 1 million visitors stop each year. Nonprofit organizations Adopt a Charger and the Seattle Electric Vehicle Association cover the electricity costs for charging at these rest areas.

Similar projects managed by the Oregon Department of Transportation expand the charging network, giving Pacific Northwest drivers the ability to travel through Oregon to the California border. Both States' initiatives complement The EV Project, a $230 million public-private partnership project to deploy electric vehicle charging infrastructure in six States including California, Oregon, and Washington.

"A 21st century transportation system in Washington must provide options for drivers, especially as more people convert to electric vehicles," says WSDOT Secretary of Transportation Paula Hammond. "Creating a sustainable transportation system protects our air from harmful emissions and conserves our resources."

The EV Project was developed as part of the West Coast Green Highway initiative to promote the use of cleaner fuels along I–5 from British Columbia to Baja, CA. The initiative supports the development of a regional electric vehicle network spreading across the entire 1,350 miles (2,173 kilometers) of I–5 connecting three States and three countries. Officials expect that the corridor will serve up to 2 million electric vehicles on the west coast by 2020.

## The Future of Electric Vehicles

Electric vehicle development (both vehicle and battery technologies) and deployment are in their infancy, as is charging infrastructure. Nevertheless, the future may hold many innovative solutions to charging such as inductive, or wireless, charging or the use of solar energy.

The introduction of new technologies typically presents barriers and hurdles to be overcome. The deployment of PEVs and charging infrastructure is no different. If successful, the penetration of PEVs into the existing vehicle fleet will mean some significant changes for the transportation sector, from both the infrastructure and user perspectives.

"The use of PEVs and the continued research necessary to improve electric vehicle performance are essential to the development of a 21st-century transportation system," says Kevin Womack, associate administrator for the Office of Research, Development, and Technology at RITA. "The application of electric vehicles in any form is critical to the economic competitiveness and environmental well-being of the United States."

**Diane Turchetta** is a transportation specialist in FHWA's Office of Planning, Environment, and Realty. She works primarily on transportation and climate change issues. Turchetta received a B.S. in public administration from The Pennsylvania State University and a master's in public administration from Virginia Tech.

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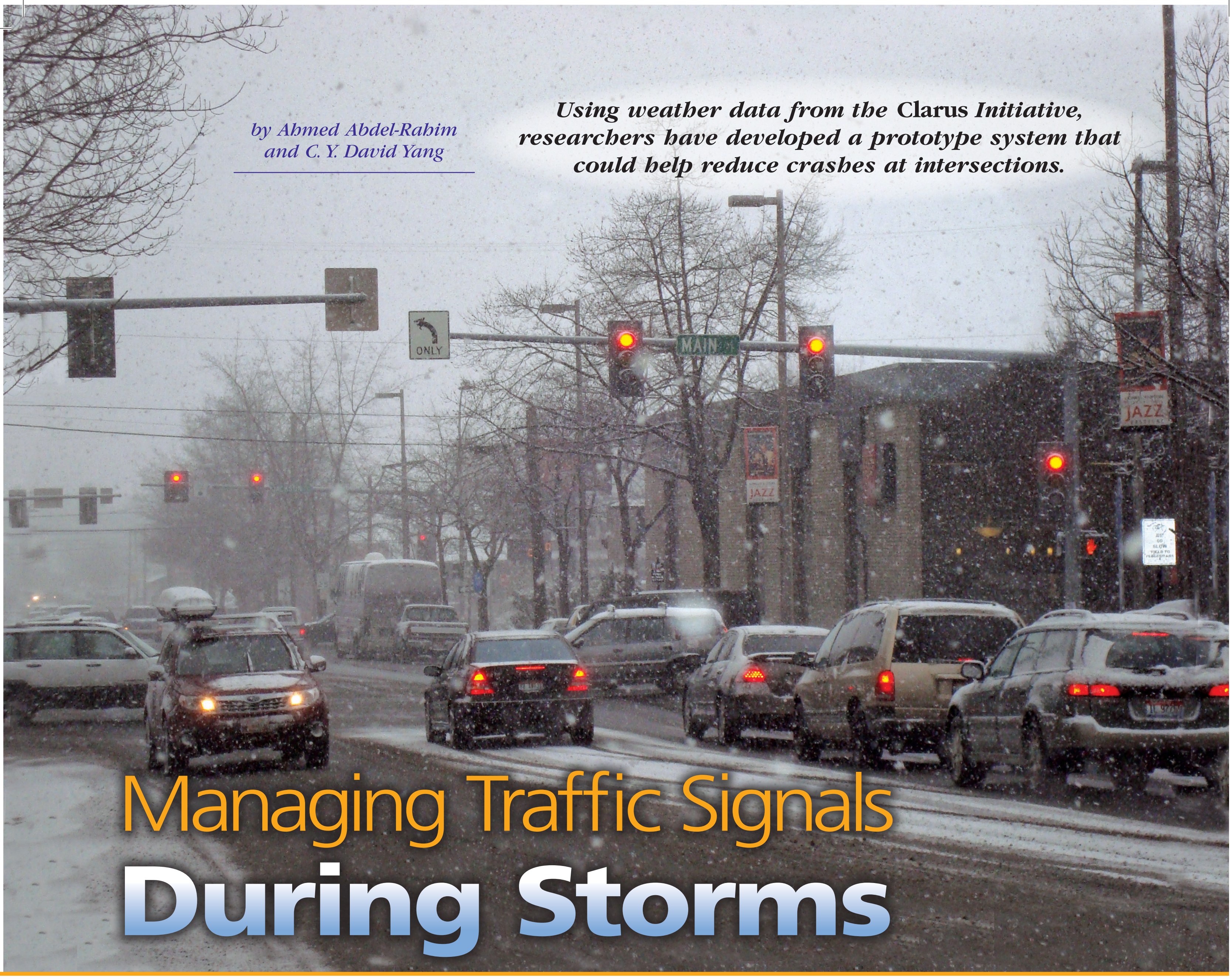



*by Ahmed Abdel-Rahim and C. Y. David Yang*

***Using weather data from the* Clarus *Initiative, researchers have developed a prototype system that could help reduce crashes at intersections.***

# Managing Traffic Signals During Storms

**(Above) *Clarus* Initiative researchers have developed a prototype application for a secure, dependable, real-time, and weather-responsive control system for traffic signals. Idaho researchers are field testing the prototype using weather and road surface data from this signalized intersection in Moscow, ID.** *Photo: University of Idaho.*

Adverse weather conditions such as rain, fog, and snow can reduce visibility and pavement friction, thereby impairing the ability of drivers to operate their vehicles safely. Lower visibility and reduced friction cause traffic to slow down, thereby limiting roadway capacity and significantly affecting both the safety and efficiency of arterial systems.

The effect of weather on traffic incidents and highway safety has been widely addressed in the literature. According to a study by the Western Transportation Institute, 17 percent of all traffic fatalities annually are attributed to weather-related factors. The same study also suggests that snow increases the risk of crashes that cause minimal injuries by approximately 120 percent, minor injuries by 80 percent, and major injuries and fatalities by 40 percent.

Other research examining the impact of weather on traffic signal operations along arterials shows that timing plans used under normal conditions become problematic in adverse weather. As reported by researchers at the University of Utah Traffic Lab in the paper "Modifying Signal Timing During Inclement Weather," presented at the Transportation Research Board's 2001 annual meeting, the reduction in average speeds and saturation flow rates, coupled with the increase in startup delays, make normal signal-timing parameters unsuitable during inclement weather.

Several studies have investigated the effect of inclement weather on signal timing. For example, a 2009 report by the Western Transportation Institute, *Evaluation of the Utah DOT* [Department of Transportation] *Weather Operations/RWIS* [Road Weather Information System] *Program on Traffic Operations*, shows that weather-responsive plans can improve both the safety and efficiency of traffic signal systems. Using microscopic simulation, the study revealed

reductions of 7–23 percent in average delays and 4–9 percent in vehicle stops, and an increase of 3–12 percent in average speeds.

In 2004, the U.S. Department of Transportation (USDOT) launched the *Clarus* Initiative, a research effort focused on developing a database system for storing and quality-checking observations from fixed and mobile road weather sensors. The initiative is a joint endeavor of the department's Intelligent Transportation Systems (ITS) Joint Program Office and the Federal Highway Administration's (FHWA) Road Weather Management Program, part of the Office of Operations. Under the initiative, researchers at the University of Idaho are using *Clarus* to receive and analyze road weather information from different weather stations and adapt signal timing in response to changes in road surface conditions and visibility levels.

## Weather Information in The *Clarus* Database

USDOT funded research to create *Clarus* (Latin for "clear"), which is a system for managing data on weather observations. The *Clarus* system's functions include assimilation, quality checking, and dissemination of weather data. The goal of the initiative is to establish a partnership to create a nationwide weather-observing and forecasting system for surface transportation. The *Clarus* system operates using near real-time atmospheric and pavement observations from participating States' environmental sensor stations (ESSs).

The States provide observations of various types to the *Clarus* database in order to report with the highest possible degree of reliability the weather conditions, visibility level, and roadway surface conditions at or near their ESS locations. For example, the States use a combination of observation types such as "essSurfaceStatus," which reports the status of the roadway surface (dry, wet, or snow and ice), and "essSurfaceTemperature," which reports the temperature of the roadway surface, to determine the road surface conditions at their ESS locations. Similarly, States use observation type "essVisibility" to provide an estimate of visibility levels (measured by distances that motorists are able to see). Observation type "PrecipType" and "essPrecipRate" provide data relevant to the precipitation type and rate, respectively, which are important in traffic signal operation. These observation types are sufficient to determine conditions that are relevant to the operation of traffic signal systems.

## Designing the *Clarus* Prototype

Researchers at the University of Idaho working on the *Clarus* project employed state-of-the art secure software and systems engineering to generate a "survivable" prototype of a weather-responsive control system for a signalized intersection. Survivability is defined as the capability of a system to fulfill its mission in a timely manner, despite component failures caused by malfunction, intrusions, attacks, sabotage, or natural disasters.

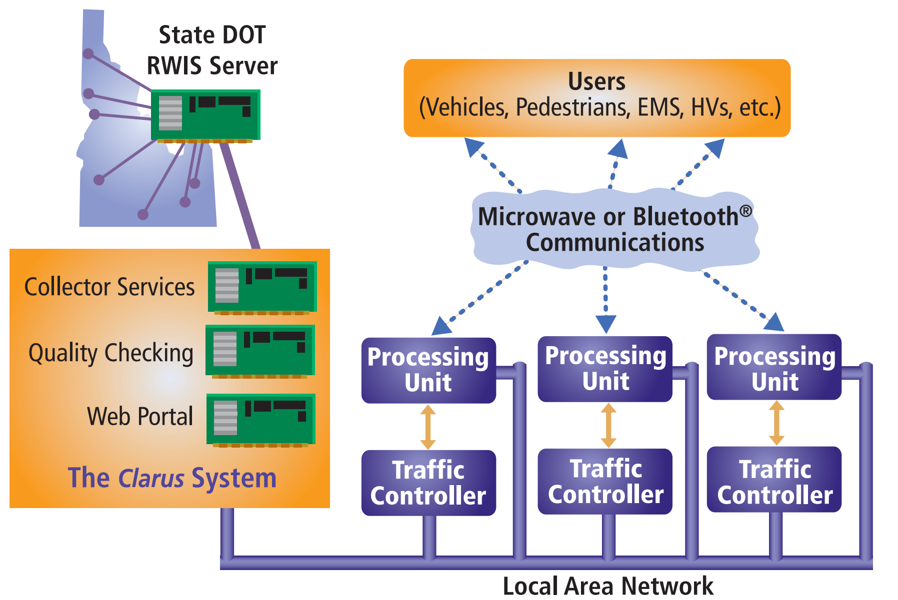
The *Clarus* software design ensures accurate execution of two tasks. In the first task, the software uses a network connection between the *Clarus* database and traffic controllers at signalized intersections to obtain near real-time data on atmospheric conditions, weather, visibility, and road surface conditions. In the second task, the software adapts signal timing at the intersections in response to inclement weather.

The system design requires minimal hardware for full implementation, as it operates using current traffic controllers at the ESS locations and existing cabinet standards

### Weather Condition Observation Types at Road Weather Information System Sites

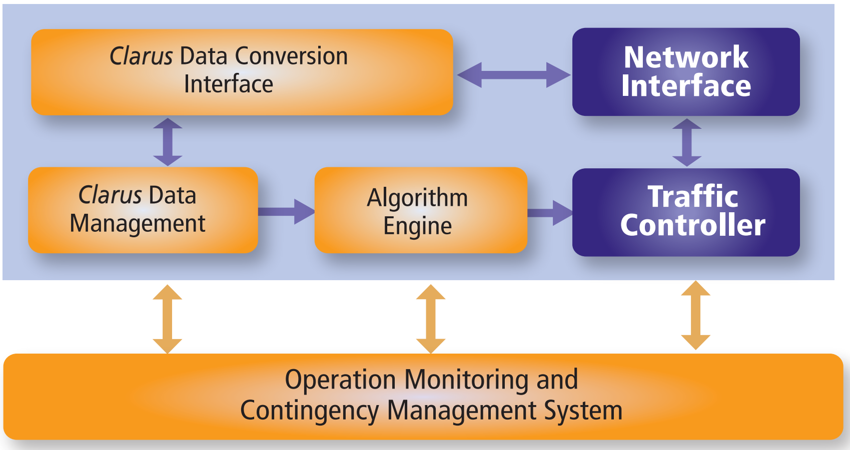
| Weather Element | Observation Type |
|---|---|
| Temperature | essAirTemperature<br>essSurfaceTemperature |
| Surface | essSurfaceStatus |
| Precipitation | essPrecipRate<br>PrecipType<br>essPrecipYesNo |
| Visibility | essVisibility |

### Communications Architecture




**Shown here is the information flow for integrating *Clarus* data into the operation of a traffic signal system. From collection sites in Idaho, data are transmitted to the State DOT's road weather information system (RWIS) server. From there, the data pass through the *Clarus* system, which includes collector services, quality checking, and a Web portal. Next, the data are funneled to a local area network consisting of individual traffic controllers and processing units. The processing units transmit information through microwave or Bluetooth® communications to and from road users, including vehicles, pedestrians, emergency medical services (EMS), and heavy vehicles (HVs).** *Source: University of Idaho.*

## *Clarus* Software Architecture




*Source: University of Idaho.*

**Shown here is an overview of the software architecture and its interface with *Clarus*. The dark blue blocks indicate the hardware interfaces.**

and technologies. "Incorporating the link to the *Clarus* system is a milestone in the development of traffic control systems, making them sensitive to current weather and road conditions," says Paul Pisano, team leader for the Road Weather and Work Zone Management program in FHWA's Office of Operations.

For the prototype, the *Clarus* researchers used microprocessor traffic controller communications based on the National Transportation Communications for ITS Protocol (NTCIP), verifying that the necessary read and write capabilities were available from the microprocessor to any NTCIP-compliant traffic controller. An off-the-shelf microprocessor and connecting cable were sufficient. The prototype functions for any field traffic control application where the overall process can be distilled to predictable tasks.

### Field Testing the *Clarus* Prototype

In May 2012, the Idaho Transportation Department (ITD) began field-testing a prototype of the weather-responsive traffic signal system developed as part of the *Clarus* project. The University of Idaho and ITD will continue testing the prototype through August 2013. The goal of the project is to develop and implement a real-time, weather-responsive traffic signal control system for the State of Idaho with the intent to improve the efficiency and safety of traffic signal operations during inclement weather. The ITD project is an example of how researchers can use *Clarus* data to inform traffic signal operation.

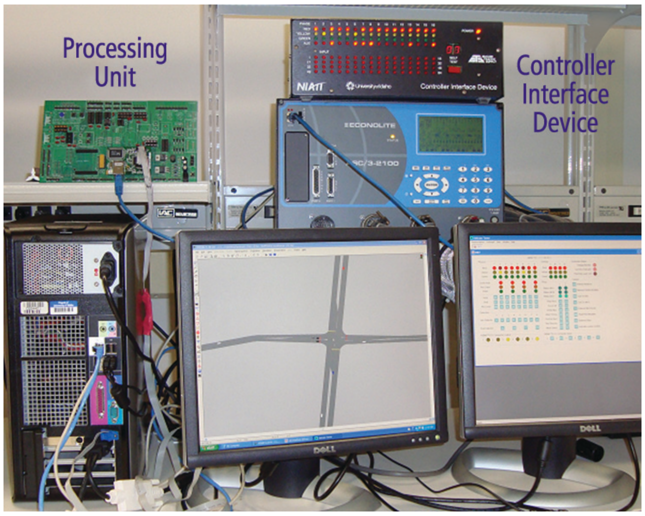
"Winter driving conditions decrease safety for the traveling public," says Brent Jennings, ITD's highway safety manager. "ITD continues to look for innovative ways to increase highway safety that align with our journey toward zero deaths on all roadways in Idaho. The department's Office of Highway Safety is excited about the recently implemented research project with the University of Idaho that integrates the *Clarus* weather data system into traffic signal operations. This project will assist in adapting automated signal timing during times of inclement weather, which has the potential to reduce deaths and serious injuries."

The system will receive and use weather information from *Clarus* and Idaho's road weather information stations to adapt signal timing in response to inclement weather. Researchers will install the weather-responsive system at one or more intersections during November 2012 and January 2013 and monitor the performance of the system and associated traffic controllers throughout the test period. Then they will use the data to evaluate the system's performance.

"Weather is a significant impediment to highway operations," says Mark Kehrli, director of the FHWA Office of Transportation Operations. "Rather than throwing up our hands and saying, 'You can't change the weather,' ITD is showing that there are real-world solutions to these types of impacts that can be implemented today."

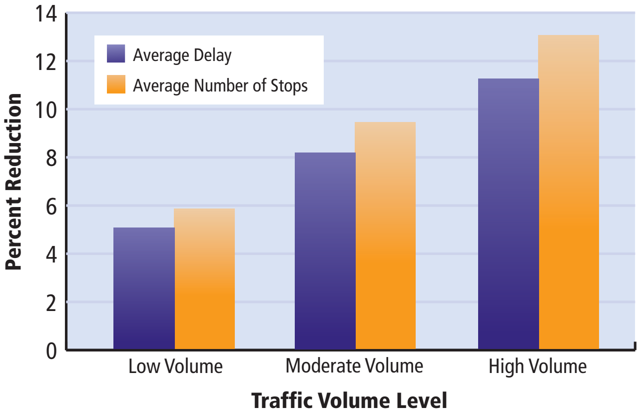
### Benefits of Weather-Responsive Systems

The University of Idaho researchers evaluated and tested the survivable weather-responsive traffic signal system developed for this project by conducting a benefits analysis. The researchers used a hardware-in-the-loop microscopic simulation model to assess the operational and safety benefits. The model includes a workstation running the VISSIM microscopic simulation model for the network, a traffic controller, and a controller interface device to facilitate the exchange of data between the simulation model and the traffic controller. An external processing



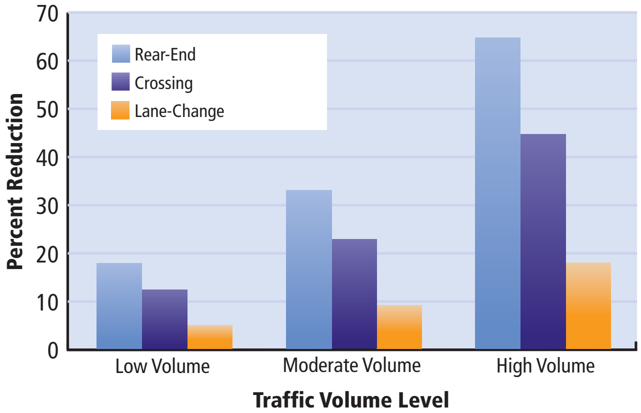

**The computer monitors, processing unit, and controller interface device shown here are some of the equipment set up at a University of Idaho laboratory to run a hardware-in-the-loop microscopic simulation model.** *Photo: University of Idaho.*

## Reductions in Delays and Stops During Snow and Ice Conditions




*Source: University of Idaho.*

## Reductions in Traffic Conflicts During Snow and Ice Conditions




*Source: University of Idaho.*

unit runs the software application and the weather-responsive control algorithm and is connected to both the *Clarus* system and the traffic controller. The researchers evaluated the traffic safety benefits through surrogate measures, such as the number and type of conflicts due to weather effects.

The results show that average intersection delays and average number of stops increased significantly during both snow and ice conditions. This pattern is consistent in the three levels of traffic volumes (low, moderate, and high) examined in the simulation study. The study revealed that, under snow and ice conditions, weather-responsive signals reduced intersection delays by an average of 8.2 percent and decreased the number of stops by an average of 9.5 percent. The reduction in delays and stops was higher for moderate and high traffic volumes.

The results of the simulation study reaffirm the potential safety benefits of weather-responsive traffic signal systems. In addition to fewer delays and stops, potential benefits include reductions in crash numbers, expressed as percent reductions in total, rear-end, and crossing conflicts. The potential benefits in crash reduction also were higher as traffic volumes increased. Rear-end crashes were the conflict type most eliminated by the system, with a potential average reduction of approximately 32 percent for moderate volume levels and 64 percent for high volume levels.

Although these results are based on microscopic simulation modeling and surrogate safety measures, they provide an indication of the crash reduction potential of weather-responsive traffic signal systems.

### Future Activities

Detecting a traffic control system's departure from normal behavior due to faults or malicious acts has challenged the security and survivability research community for years. Many researchers believe too little progress has been made to counter malicious acts, such as intrusions, attacks, or sabotage.

"The approach described here is a powerful step in the right direction toward increasing the reliability of the transportation system and the safety of the travelers," says FHWA's Pisano.

The focuses of future research include three areas. One is field-testing the system at signalized intersections under a variety of weather conditions. Another is expanding control modifications to include other traffic control parameters, such as vehicle passage time, minimum green, and offsets (one of the signal control parameters that defines the time lapse between the start of green in two intersections). The third area is increasing the power of the system to maintain reliable, secure, and survivable traffic signal service.

"State departments of transportation have invested millions of dollars in environmental sensor stations, primarily for winter maintenance purposes," Pisano says. "This project shows how these agencies can maximize the benefits of these investments, improving highway safety and mobility under a wide range of weather events."


**Ahmed Abdel-Rahim** is an associate professor in the Department of Civil Engineering at the University of Idaho. He is an affiliate faculty with the Center for Traffic Operations and Control at the university's National Institute for Advanced Transportation Technology. Abdel-Rahim's research interests include traffic operation and control technology, security and survivability of transportation networks, hardware-in-the-loop simulation modeling, and highway design and traffic safety. Abdel-Rahim received his B.Sc. and M.Sc. degrees in civil engineering from Assiut University, Egypt. He received his Ph.D. in civil engineering from Michigan State University.

**C. Y. David Yang** is currently the team leader for the Human Factors Team in FHWA's Office of Safety Research and Development (R&D) in McLean, VA. He joined FHWA in 2008, and work described in this article was carried out when Yang was with FHWA's Office of Operations R&D. He attended Purdue University, where he received his B.S., M.S., and Ph.D. degrees in civil engineering. His doctoral dissertation used principles of human information processing and human factors to develop design recommendations for advanced traveler information systems.

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An FHWA study offers recommendations for constructing mini-roundabouts to reduce congestion and improve safety at intersections throughout the United States.

# They're Small But Powerful

by Wei Zhang, Joe Bared, and Ramanujan Jagannathan

(Above) This mini-roundabout in Maryland contains a painted splitter island, a common feature of the mini-roundabouts constructed in this State. An FHWA study looked at the performance and safety features of mini-roundabouts like this one.

At many intersections in the United States, especially on roads that experience moderate congestion, traditional stop controls work well. This situation is changing, however, in many urban and suburban areas, where growing urbanization has resulted in traffic congestion and safety problems.

One potential solution might be the mini-roundabout. Other countries have been designing and constructing mini-roundabouts since the 1970s, but very few of these intersections are found in the United States. As used here, a mini-roundabout refers to a single lane with an inscribed circular diameter between 50 and 90 feet (15 and 27 meters). Its defining feature is traversable central and splitter islands to accommodate large vehicles.

"Traffic engineers and community planners are starting to recognize the mini-roundabout design as a

low-cost solution for improving intersection capacity and safety without the need for acquiring additional right-of-way," says Monique Evans, director of the Office of Safety Research and Development (R&D) at the Federal Highway Administration (FHWA).

To assess the viability of mini-roundabouts for use in the United States, in 2009 the FHWA Office of Safety R&D initiated a study—Field Testing, Marketing, and Crash Analyses of Mini-Roundabouts—to evaluate the operational and safety performance of these intersections. A review of design guides for mini-roundabouts from European countries, followed by visits to existing small roundabouts in the United States, provided insights into how the large roundabout's kid brother could relieve congestion and enhance safety on U.S. roads. Most of the mini-roundabouts in the United States lack a fully traversable feature, thereby limiting their capability to handle large vehicles longer than 25 feet (7.6 meters).

## Mini-Roundabout Design Considerations

The FHWA research team kicked off the study with a review of Germany's design guide for mini-roundabouts, which calls for the following geometric design criteria:

1. Inscribed diameter between 42.6 and 78.7 feet (13 and 24 meters)
2. Circular roadway width between 14.8 and 19.7 feet (4.5 and 6 meters)
3. Central island maximum height of 4.7 inches (12 centimeters)
4. Central island minimum curb height of 1.6 or 1.9 inches (4 or 5 centimeters)

The German highway code recommends mini-roundabouts for urban areas where the speed limit is 31 miles per hour, mi/h (50 kilometers per hour, km/h) or less. Evaluation revealed an average reduction of 30 percent in the crash rate—from 0.79 to 0.56 crashes per million vehicles—after conversions of intersections into mini-roundabouts.

Because of a lack of field evaluation results and formal guidelines in the United States, implementations of U.S. mini-roundabouts vary in design features. Some function as traffic-calming circles in residential areas, but many are not designed and constructed to handle heavy traffic demand.

Commonly asked questions about the suitability of a mini-roundabout include the following: How much traffic can a mini-roundabout handle? Will schoolbuses have difficulty navigating through mini-roundabouts? What are the impacts of onstreet parking curbside on approach roads? How should the safety of pedestrians and bicyclists be addressed?

The intent of the FHWA study is to address these and other relevant questions objectively, assess the pros and cons of existing designs, and develop a set of guidelines that will achieve design objectives effectively. Among the general design objectives is ensuring that vehicles up to the size of a single-unit truck can circulate around the central island while at the same time providing a way for larger vehicles to traverse the central and splitter islands. Other goals include reducing the number of intersection conflict points, increasing intersection capacity, and improving safety for all modes of traffic.

The fundamental difference between mini-roundabouts and all other types of modern roundabouts is reflected in the design concept. For mini-roundabouts, the roundabout elements such as approach lane, entrance, central island, circulating lane, splitter islands, and guidance signs are designed and placed in such a way to enable 97 percent of vehicles such as cars, vans, SUVs, and small trucks to pass through by staying in the circulatory roadway. The traversable central island and splitter islands are left for very large vehicles, such as full-size schoolbuses, to drive through. In implementation, this difference in design concept can result in a significant difference in cost.

## Survey of Current U.S. Implementation

The FHWA research team visited six small roundabouts in five States. Five locations are in Delaware, Maryland, Texas, and Washington State. The sixth mini-roundabout studied by the team is not described because it is on a college campus and serves mainly bicycle traffic. The researchers also studied photos of mini-roundabouts from other cities.

This survey showed that mini-roundabouts in the United States are constructed at junctions where the peak-hour traffic demand is less than 500 vehicles per hour. Costs of

### Measurements and Peak-Hour Traffic Demands at Five U.S. Mini-Roundabouts

| | Central Island | | Splitter Island | | |
|---|---|---|---|---|---|
| Location | Diameter (ft) | Height (in) | Length (ft) | Height (in) | Peak-Hour All-Entering Volume (VPH) |
| Location 1 | 24 | 6 | 205 | 6 | 241 |
| Location 2 | 27 | 6 | 205 | 6 | 243 |
| Location 3 | 14 | 0/6* | 70 | 4 | 467 |
| Location 4 | 36 | 0 | 64/152** | 0 | N/A |
| Location 5 | 17 | 0 | 26 | 6 | N/A |

*Note: Intersection locations were intentionally made anonymous.*
**Vertical height above adjacent ground of the central island's edge and crown at this location.*
***This location has two splitter islands with two different lengths.*
*Source: FHWA.*

The researchers believed this splitter island at the mini-roundabout at location 2 in Texas might be difficult to traverse because of the high curbs. Unless splitter islands are traversable, mini-roundabouts can become traps for large vehicles.

the mini-roundabouts ranged from approximately $20,000 to $250,000 per intersection. The objectives for constructing mini-roundabouts varied considerably for these installations but included the following:

- Improve access for pedestrians and bicyclists.
- Encourage more school-aged children to walk to school.
- Reduce the occurrence of speeding and running STOP signs.
- Reduce the noise caused by vehicles braking hard and accelerating at intersections.
- Preserve the values of the neighboring properties.
- Increase intersection capacity.
- Improve intersection safety.

At the mini-roundabout in location 2 in Texas, the researchers observed that a splitter island curb looks difficult to traverse due to the height of the curb, as does the central island. At some locations, such as location 5, the mini-roundabout has KEEP RIGHT signs mounted at the edge of the central island, preventing large trucks from traversing it. At other locations, mini-roundabouts have tall trees planted at the center of the central islands. These practices can make the central and splitter islands difficult to traverse and might create traps for large vehicles. A photograph taken by one of the FHWA researchers shows a long truck making a right turn at a mini-roundabout in location 4 in Maryland and illustrates the need for traversable splitter and central islands.

Painted flush splitter islands are common in some regions of the United States. Flush splitter islands are fully traversable, but less effective in enforcing the design intent. For example, at some mini-roundabout locations, the researchers observed several drivers of passenger cars illegally crossing the flush splitter island to make left turns, rather than circulating through the mini-roundabout to make the turn. At the mini-roundabout in location 4 in Maryland, when it was first completed, vehicles were seen cutting through the flush central island and creating unsafe traffic conditions. The State's department of transportation (DOT) mitigated the problem by installing flexible posts (a quick and low-cost solution) on the central island.

Some mini-roundabouts were built as low-cost streetscape projects. As a result, these mini-roundabouts included the following design elements that resulted in undesirable field performance:

- Stop bars corresponding to the former STOP signs remained in place after construction, along with the yield signs at the entrances to the mini-roundabouts. The FHWA team observed some drivers treating the intersection as stop controlled rather than yield controlled.
- Intersection markings for pedestrian crossings were not removed and relocated at least 20 feet (6 meters) before the yield lines, creating conditions conducive to vehicle-pedestrian conflicts inside the intersection. According to the National Cooperative Highway Research Program's (NCHRP) Report 672, *Roundabouts: An Informational Guide*, pedestrian crossings should be placed inside the approach lane instead of at the intersection to reduce potential vehicle-pedestrian conflicts.
- Central islands were too small and the circulating lane too wide, coupled with flush-painted splitter islands, making it too easy for drivers to make a left turn by crossing the splitter island rather than circulating the central island.
- Curbside, onstreet parking allowed all the way to the intersection was coupled with flush-painted splitter islands, tempting drivers to make a U-turn before the intersection when spotting an empty parking space, rather than circulating around the central island to make the U-turn.

The above observations showed that central and splitter islands need to be traversable to accommodate large vehicles, but they should be raised, or delineated by flexible posts, rather than being flush only. The islands need to create physical channelization and discourage small vehicles from mounting them.

## Intersection Traffic-Handling Capacity

The research team recorded field videos of traffic passing through the mini-roundabout at location 4 in Maryland during the afternoon peak-traffic period on a typical weekday. The researchers also manually logged 5-minute traffic counts at that location. The peak-hour traffic demand was 924 vehicles per hour (VPH).

**This mini-roundabout in location 5 contains traffic signs in the central island, making it difficult for large vehicles to traverse the island. Trucks with more than two axles are prohibited on this roadway.**

The corresponding traffic videos showed no signs of a queue forming.

The researchers derived two potential maximum peak-hour traffic capacities in the following manner. First, they multiplied the peak 5-minute traffic counts from 4:15 p.m. to 4:20 p.m. by 12, giving a potential capacity of 1,140 VPH. From the traffic scenes in the videos, the level of service corresponding to this level of traffic demand would be an "A," meaning the intersection delay is 15 seconds or less. Next, the researchers multiplied the 5-minute peak counts on all of the individual approaches by 12, giving a potential capacity of 1,368 VPH.

The researchers derived the capacity under the first scenario by assuming that the traffic pattern from 4:15 p.m. to 4:20 p.m. would repeat itself for the entire hour. The traffic scenes corresponding to the first scenario are visible in the videos, which showed no queuing.

For the second scenario, the team derived the capacity by assuming the 5-minute peak traffic from each approach would happen simultaneously, and that period would repeat itself for the entire hour. The traffic conditions of the second scenario can be created by adding 0, 12, and 7 more vehicles to leg 1, leg 2, and leg 3, respectively, to the traffic demand of the first scenario, which is the equivalent of adding 0, 2.4, and 1.4 more vehicles per minute to leg 1, leg 2, and leg 3. Judging from the available gaps observed in the videos, this mini-roundabout would have no problem handling these additional traffic demands.

At some evaluation sites where the researchers collected data before construction, stop-controlled intersections experienced recurring congestion when the traffic entering from all directions exceeded 900 VPH.

From the videos of the mini-roundabouts, the FHWA team estimated the parameters of driver behavior, such as gap and followup headway (the spacing in seconds between the leading vehicle's rear bumper and the following vehicle's front bumper) that most motorists would accept when entering the mini-roundabout. The team then conducted numerous simulation analyses by saturating one entrance with simulated vehicles and gradually increasing the circulating traffic flow to assess the capacity. These simulation studies indicated that a mini-roundabout can carry up to 1,000 VPH (circulating traffic plus entering traffic) per approach. In June 2012, at the Transportation Research Board's Urban Street Symposium, T. Lochrane presented these results in a separate paper, "Traffic Capacity Models for Mini-Roundabouts in the United States: Calibration of Driver Performance in Simulation," coauthored by N. Kronprasert, J. Bared, D. Dailey, and W. Zhang.

The research team conducted capacity analyses of several potential sites using the critical lane-volume and simulation methods and concluded that mini-roundabouts can conservatively handle 1,600 VPH (the sum of entering traffic demand for all approaches), while providing an adequate level of service.

## Recommended Design Elements

The review of German design guides and the results of the U.S. field survey suggest that mini-roundabouts are a viable design option for high-traffic intersections of collector roads when four conditions are met. The proposed mini-roundabout is an intersection of two- or three-lane collector roads, the posted speed limit is 35 mi/h (56 km/h) or less, the traffic demand from the major and minor approaches is comparable, and the roads have a

**A member of the FHWA research team took this photograph of a long truck trying to make a right turn at the mini-roundabout at location 4.**

## Traffic Counts at Location 4 Mini-Roundabout

| 5-Minute Volumes | | | | |
|---|---|---|---|---|
| P.M. | Leg 1 | Leg 2 | Leg 3 | Total |
| 3:45 | 0 | 0 | 1 | 1 |
| 3:50 | 15 | 13 | 16 | 44 |
| 3:55 | 9 | 29 | 19 | 57 |
| 4:00 | 29 | 38 | 14 | 81 |
| 4:05 | 24 | 41 | 30 | 95 |
| 4:10 | 19 | 29 | 15 | 63 |
| 4:15 | 39 | 29 | 27 | 95 |
| 4:20 | 26 | 28 | 34 | 88 |
| 4:25 | 18 | 27 | 15 | 60 |
| 4:30 | 35 | 25 | 17 | 77 |
| 4:35 | 25 | 29 | 12 | 66 |
| 4:40 | 27 | 27 | 24 | 78 |
| 4:45 | 23 | 27 | 22 | 72 |
| 4:50 | 24 | 25 | 25 | 74 |
| 4:55 | 21 | 25 | 14 | 60 |
| 5:00 | 28 | 33 | 29 | 90 |
| 5:05 | 34 | 27 | 24 | 85 |
| 5:10 | 29 | 25 | 25 | 79 |
| 5:15 | 14 | 20 | 34 | 68 |
| 5:20 | 12 | 23 | 23 | 58 |
| 5:25 | 18 | 18 | 26 | 62 |
| 5:30 | 22 | 26 | 18 | 66 |
| 5:35 | 30 | 16 | 13 | 59 |

| Actual Hourly Volumes | | | | |
|---|---|---|---|---|
| P.M. | Leg 1 | Leg 2 | Leg 3 | Total |
| 3:45 to 4:45 | 266 | 315 | 224 | 805 |
| 3:50 to 4:50 | 289 | 342 | 245 | 876 |
| 3:55 to 4:55 | 298 | 354 | 254 | 906 |
| 4:00 to 5:00 | 310 | 350 | 249 | 909 |
| 4:05 to 5:05 | 309 | 345 | 264 | 918 |
| 4:10 to 5:10 | 319 | 331 | 258 | 908 |
| 4:15 to 5:15 | 329 | 327 | 268 | 924 |
| 4:20 to 5:20 | 304 | 318 | 275 | 897 |
| 4:25 to 5:25 | 290 | 313 | 264 | 867 |
| 4:30 to 5:30 | 290 | 304 | 275 | 869 |
| 4:35 to 5:35 | 277 | 305 | 276 | 858 |
| | | | | |
| Potential Maximum Volume_1: | | | | |
| | 468 | 348 | 324 | 1,140 |
| | | | | |
| Potential Maximum Volume_2: | | | | |
| | 468 | 492 | 408 | 1,368 |

**This table shows the 5-minute and peak-hour traffic counts, plus two forms of potential peak-hour traffic counts.**
*Source: FHWA.*

low percentage of single-unit trucks or larger vehicles (5 percent or less).

Although the FHWA simulation analysis of mini-roundabouts indicates a potential capacity of up to 1,000 VPH per entrance, actual field capacity also depends on the presence of other modes of traffic, such as pedestrians and bicyclists.

The design of the central and splitter islands should fulfill the following requirements:

- Be fully traversable by large vehicles.
- Discourage drivers of small vehicles from trying to traverse the central island.
- Design the curb height to avoid causing difficulties for snowplowing operations (in States where it snows).
- Prohibit curbside, onstreet parking 100 feet (30 meters) from the intersection or from the starting point of the splitter island, whichever is greater.

Properly raised central and splitter islands are preferred to help ensure driver compliance with the design intent. The central island could be painted yellow to make it more conspicuous. Flush central islands are acceptable but might have to be combined with retroreflective flexible posts to realize the design intent.

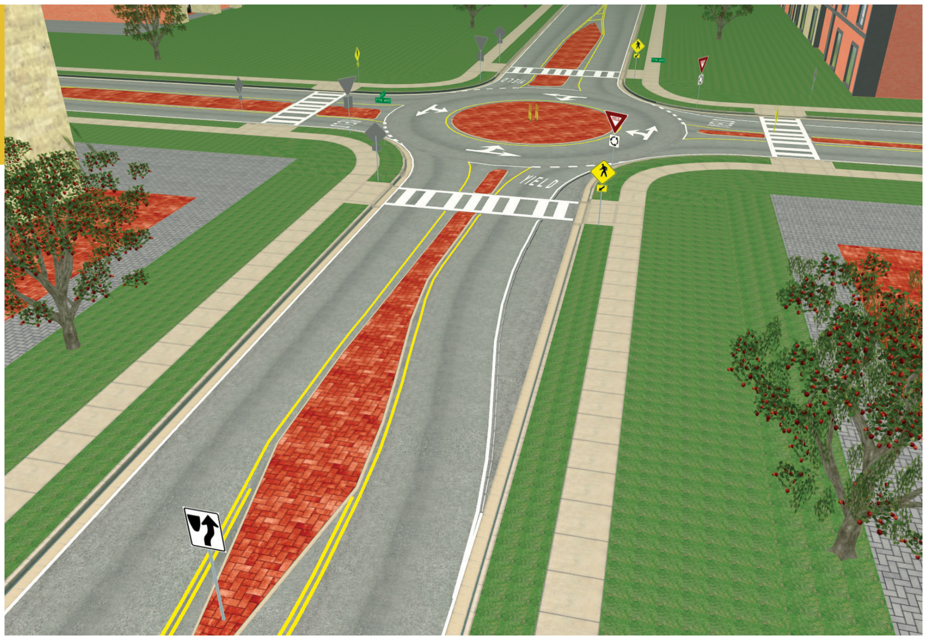
The FHWA research team developed three mini-roundabout design templates using a WD-50 truck (50-foot, five-axle tractor cab and trailer) as the design vehicle and assuming a typical two-lane urban street in the United States. These streets normally have approach widths of 24 feet (7 meters). The approach widths of three-lane streets are 36 feet (11 meters) with corner radii of 30 feet (9 meters). The inscribed circular diameters of all three mini-roundabout templates would fit entirely within existing intersection boundaries.

The team used the following control parameters in producing the design templates:

- Circulating drive lane width—between 14 and 16 feet (4 and 5 meters) wide
- Mini-roundabout entrance lane—10 to 11 feet (3 to 3.4 meters) wide
- Pedestrian crossing—10 feet (3 meters) wide and placement at least 20 feet (6 meters) before the yield line
- Splitter island—4 feet (1.2 meters) minimum width

For the design of a mini-roundabout, the research team suggests making the central island as large as

**This rendering shows a fully conforming mini-roundabout for a 24- by 36-foot (7.3- by 11-meter) intersection.**



possible after achieving the desired width for the circulating lane. Also, the central island should be raised to a maximum height of 5 inches (13 centimeters) with a slope of 1:15 (vertical: horizontal) to allow water to drain away from the central island.

## Observations

The field evaluations conducted to date yielded several observations. First, the objectives for implementing mini-roundabouts vary greatly, depending on a project's location and traffic, safety, or other issues of concern. Second, the cost of mini-roundabout design and construction also varies greatly, depending on the condition of the existing pavement and the need for relocating or repairing subsurface facilities such as utility lines and drainage systems. Third, raised central and splitter islands function better for channelizing traffic and ensuring driver compliance with the intent of the mini-roundabout design.

In sum, mini-roundabouts can be a preferred design option on two-lane and three-lane road junctions currently controlled by STOP signs (or traffic signals) that are experiencing recurring congestion. This conclusion is especially applicable to junctions with existing traffic demands in excess of 900 VPH from all directions and projected traffic demands up to 1,600 VPH.

Observation suggests that mini-roundabouts also can improve traffic flow at intersections with lower traffic demands. Regarding a mini-roundabout at Stevensville, MD, Eduardo Arispe, operations research analyst with FHWA, says, "The traditional STOP sign [control] on Thompson Creek Road was easy to understand but [tended to] cause an unnecessary queue of vehicles at a place with very low traffic volume. Although it took [drivers] some time to adjust to the new mini-roundabout design, the traffic flow is much smoother as a result."

Anecdotal testimony also suggests that a mini-roundabout in Lake Stevens, WA, has been greeted with enthusiastic approval. Brooke Severns with the Seattle real estate division of Safeway, Inc., says that a manager of the grocery store near the roundabout reports, "There have been absolutely no complaints from our customers, just the opposite; everyone finds the traffic to be moving much smoother in and out of our store parking lot and the surrounding roads." In recent months, Severns adds, sales at this location have increased. "I wouldn't hesitate to say that [the roundabout] contributed to a portion of that increase," she says. "I think we would certainly do this in another location after our experience here."

Still, not all is roses. Mick Monken, director of public works with the Lake Stevens city government, reports, "I have received a unique complaint from four citizens following the opening of the mini-roundabout accessing the shopping center. That is, since the city completed these roundabouts, finding a parking space has become difficult as more people are now using these stores."

In this particular case, the full parking lot indicates a successful outcome since one objective of the project was to retain businesses and attract new ones.

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**Joe Bared** is the concepts and analysis team leader in the FHWA Office of Operations R&D. He has worked for FHWA for more than 22 years. In his current position, he manages research related to modeling and simulation of intelligent transportation systems technologies. Previously, he managed the development of the first roundabout guide in the United States and the new FHWA publication, *Alternative Intersections/Interchanges: Informational Report* (FHWA-HRT-09-060). He holds a Ph.D. from the University of Maryland.

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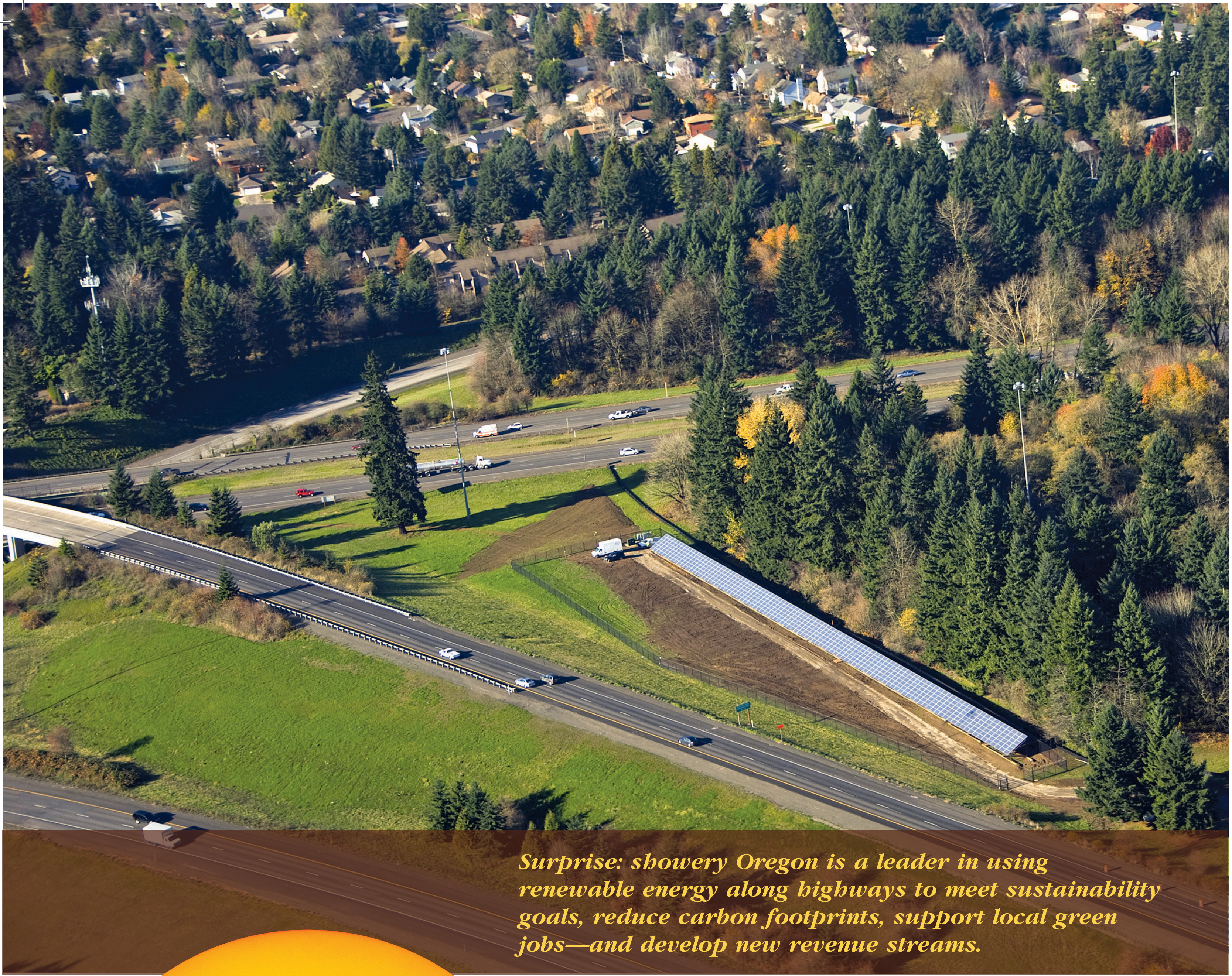


*Surprise: showery Oregon is a leader in using renewable energy along highways to meet sustainability goals, reduce carbon footprints, support local green jobs—and develop new revenue streams.*

# Spotlight on Solar Arrays

*by Allison Hamilton*

*All photos by Gary Weber, ODOT Photo/Video Services.*

Today, transportation agencies face challenges unheard of 100, or even 50, years ago. In addition to keeping vehicles moving safely and efficiently, agencies must meet environmental regulations, social justice targets, goals for economic development and job creation, and, more recently, sustainability objectives and targets for reducing greenhouse gas emissions. All of these requirements are occurring at the same time that agencies are facing declining tax revenues as gas prices rise, inflation reduces the buying power of those revenues, and motorists conserve fuel and purchase more efficient vehicles. How a State department of transportation responds to these challenges can determine how smoothly it will transition into the future.

The Oregon Department of Transportation's (ODOT) Innovative Partnerships Program is tackling these issues head-on. Not only is ODOT's partnership program a national leader in exploring road usage fees—"pay by the mile"—as a way of funding the transportation system of the future, but also it is a leader in the installation of charging stations for electric vehicles.

What's more, it is the Nation's first transportation agency to host privately owned solar arrays on operating rights-of-way: a 104-kilowatt array at the intersection of two major freeways and a 1.75-megawatt array at a safety rest area.

"The Oregon Solar Highway Program showcases what can be accomplished when multiple values align," says Matt Garrett, director of ODOT. Garrett is referring to State and national policies supporting development of renewable energy and green energy jobs, trades, and manufacturing; legislation encouraging private sector investment in public assets; reduced use of fossil fuels; and the desire for a clean, sustainable, and secure energy future.

**(Above left) The Oregon Department of Transportation (ODOT) located its first demonstration of a solar highway, seen here in this aerial photo, at the intersection of interstates 5 and 205 just south of Portland.**

## Oregon's Innovative Partnerships Program

Like most States, Oregon traditionally has relied on taxes, fees, and Federal grants to fund transportation projects. Over the years, it became clear that these sources soon would no longer meet the needs of an aging infrastructure. In 2003, the Oregon Legislative Assembly, looking to provide a foundation for exploring other funding opportunities, passed Senate Bill 772 establishing the Oregon Innovative Partnerships Program within ODOT. This legislation gives ODOT broad authority to enter into long-term contractual agreements with private sector firms and units of government. In effect, the law removes barriers to formation of potentially successful public-private partnerships, with each party sharing in the possible risks and rewards in accordance with legal structures developed specifically for each project.

In reviewing partnership opportunities, the Oregon Department of Justice determined that, because electricity is needed to operate and maintain the State highway system, public-private partnerships for the delivery of electricity are a legal use of the State Highway Fund. In some cases, Federal grants can augment these partnerships, as is the case with ODOT's initiative to deploy charging infrastructure for electric vehicles.

Typically a negotiated agreement will specify the responsibilities and risks for the project's delivery and operation that each party will assume against predetermined standards of performance established by government. The agreement also will specify the relative financial and other contributions each party will bring to the partnership.

For Oregon's Solar Highway Program, the benefits or revenues come from the monetization of State and Federal tax credits, accelerated depreciation, and the sale of the electricity to utility customers. The government is compensated in return for the use of the land. In the solar program, the compensation takes the form of a share of the renewable energy certificates generated by the solar array and/or an annual site license fee. Other ancillary public benefits include supporting local green energy jobs, trades, and manufacturing; adding renewable energy to the grid and thereby offsetting fossil fuels; and making progress toward a clean, sustainable, and independent energy future.

### Guaranteeing the Work

In a public-private partnership, the government keeps control over the quality of public infrastructure in a number of ways:

- The government typically owns the base asset (in this case, the land) while the private sector partner has a lease or a right to use it, which expires at the end of the contract period. For the Solar Highway Program, this is the solar site license agreement.
- The government and private partner agree on performance standards that are spelled out in the legal agreement. There are repercussions to the private sector partner in the event that standards are not met.
- The government establishes user charges and terms on which the private partner can use the public asset.

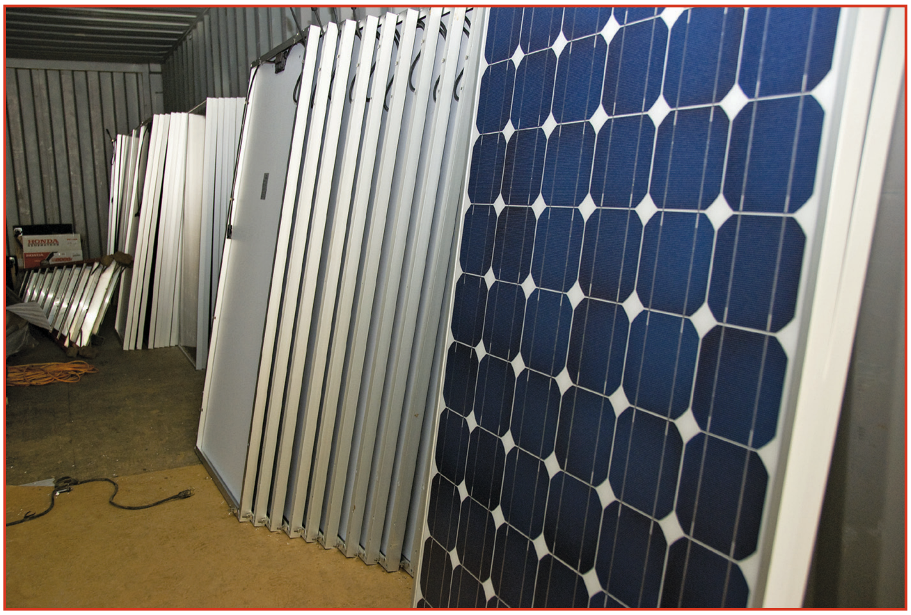
### Advantages of Public-Private Partnerships

When ODOT delivers new highway projects *without* using a public-private partnership, typically it will do the following:

- Employ private sector consultants who design and engineer all or part of the project and then bid construction to a private sector company. Taxpayers bear the full cost of the project and the responsibility for any budget overruns or delays.
- Issue a bond to private sector investors to finance construction. Taxpayers are responsible for repayment of the interest and principal.
- Take responsibility for operating and maintaining the facility, elements of which might be contracted out to a private company. Again, taxpayers bear responsibility for any quality defects or unexpected problems.

By entering into a public-private partnership, all of these activities are integrated into one long-term contract with a private sector partner. For solar highway projects, utility ratepayers receive advantages from the State and Federal tax credits. Accelerated depreciation and utility incentives enable these renewable energy projects to be delivered at reduced cost to the ratepayers, including ODOT. In addition, ODOT retains the underlying land asset and has the ability to recall that asset any time that it is needed for a transportation use.

With a partnership and funding in place to purchase these solar panels, ODOT was set to start the next steps in making its solar highway a reality.



## In the Beginning

In 2007, after watching a public broadcasting special showing solar arrays operating along the autobahn in Germany, an ODOT project director wondered, “If they can do it there, why can’t we do it here?” That question opened the door to the future.

Although many people might not think of Oregon as a sun-drenched place, solar is the State’s most abundant renewable energy resource. According to the *Renewable Energy Atlas of the West*, Oregon has the potential to generate 68 million megawatt-hours of solar energy and, through even partial development of those resources, could produce its current annual energy use of 48 million megawatt-hours.

The nonprofit Solar Oregon reported, “Germany is installing more new solar energy systems per capita than any other country, yet its capital, Berlin, receives less sun than the cloudiest location in Oregon, near Astoria.”

ODOT’s executive management agreed with the concept of highway solar arrays and supported the idea of developing a demonstration project. The following year, in 2008, the Nation’s first solar highway project—a solar array on publicly owned and operated right-of-way—got underway. The initial project connected to the grid in December 2008, with the second, larger project following in January 2012.

Efforts underway today include exploring a statewide inventory of potential sites, developing a solar array option on an upcoming major project for transportation modernization (a new access-controlled four-lane facility), and assisting other States and countries in setting up their own solar highway programs.

## Partnerships Were Vital

Despite management support, funds were not available for the department to simply select a portion of ODOT-owned right-of-way and erect a solar array. Private sector participation was needed, both for the infusion of funding and for expertise. ODOT engineers know the business of transporting people and goods, but not electrons.

ODOT turned to the State’s largest utility, Portland General Electric, for assistance. The utility supplies electricity to Oregon’s biggest population centers and other buyers, including 17 million kilowatt-hours annually to ODOT alone. This energy is used for buildings, street lighting and illumination, ODOT’s intelligent transportation systems, and more.


For its solar demonstration project, shown here, ODOT partnered with Portland General Electric, which supplies the transportation agency with 17 million kilowatt-hours of electricity annually. Now some of that power is produced by alternative energy.

During the early stages of construction of the demonstration project, these workers were pouring concrete for the solar array's foundation.

The utility expressed interest for several reasons. First, the State's renewable portfolio standard, mandated by the Oregon legislature, requires the utility to acquire 25 percent of its new electrical generation from renewable energy resources by 2025. Second, the utility's customers want and support renewable energy; more than 10 percent of its residential and small nonresidential customers are enrolled in the utility's Clean Wind program, voluntarily paying a premium to receive green energy. A solar array alongside a highway in Portland General Electric's territory would provide a highly visible statement of the utility's commitment to a clean energy future.

"When ODOT approached us with its idea for a solar highway project, we decided to do what we

The demonstration project's completed foundation. Next step, erecting the solar array.

## Solar Arrays in Other States

Renewable energy technologies promote energy security by helping diversify the means of energy generation and delivery, and by reducing reliance on imported fossil fuels. These technologies contribute to lowering emissions of greenhouse gases and other pollutants, and they create jobs.

Renewable energy has been used in roadway applications for at least 60 years. *Generating* renewable energy within highway rights-of-way, on the other hand, is an emerging concept in the United States. Many of the properties that departments of transportation (DOTs) manage have the potential to generate significant amounts of renewable energy.

To date, Europe has been a leader in implementing solar applications alongside travel lanes (versus in roads themselves). Several States, however, are beginning to pursue similar projects. In addition to ODOT's efforts, the DOTs in California, Massachusetts, and Ohio each have highway right-of-way solar projects at various stages of development.

Much like ODOT, these transportation agencies plan to use their initial experiences to evaluate equipment for future solar installations within rights-of-way. Whether under a DOT's approved utility accommodation plan or through a lease, agencies that are considering solar or other renewable energy projects need to ensure that they have the capacity, policies, and procedures in place to verify that the desired operation is progressing as planned and not adversely affecting highway safety and traffic flow.

*—by Virginia Tsu, Assistant Division Administrator, Federal Highway Administration (FHWA) South Dakota Division*

could to make it work," says Mark Osborn, a manager at Portland General Electric. "It makes sense for us. Our customers embrace renewable power, and solar power is a growing part of our renewable power mix. Oregon also is becoming a hub for production of solar panels and other equipment."

Osborn adds, "By partnering with local banks, we were able to create successful financing and ownership models. ODOT's leadership and determination were key to our success. This public-private partnership has resulted in two projects that have helped put Oregon on the solar highway map."

With the resolve between both parties firmly in place to develop a project, meetings between ODOT and the utility then focused on two parameters: where to put the array and how to finance it.

### Location, Location, Location

The primary purpose of a transportation system is to move people and products safely. Thus, the State's site options first had to pass the safety filter, meaning that potential locations had to be outside the safety zone and situated in a manner that would avoid producing glare from oncoming headlights.

Further considerations included identifying a parcel of land that the department would not need for at least 20 years—the typical transportation planning horizon and the typical length of a solar power purchase agreement. The parcel also would need access to the utility grid; freedom from environmental constraints, such as being located outside any areas with threatened or endangered species; good solar access (no shading); and high visibility to showcase the project to the public.

The department located an ideal site meeting those requirements at the intersection of interstates 5 and 205, just south of Portland. A 3-acre (1.2-hectare) parcel had been graded during construction of the freeways, and interconnection to the utility grid existed a short distance away on the west side of southbound I–5. In 2011, more than 130,000 vehicles passed by the site daily. In selecting this site, ODOT launched its first solar highway as a demonstration project.

A second, larger project is located at the northbound I–5 Baldock Safety Rest Area in unincorporated Clackamas County, about 7 miles (11 kilometers) south of the first project. The rest area project also meets all of the requirements, safety and otherwise.

### Financing a Solar Highway

Although the economic climate then—and now—was far from robust, ODOT found that financing mechanisms are available. The State provided a 50-percent tax credit for renewable energy projects (the program sunsets in 2012). Further support came from a 30-percent Federal tax credit for solar investments and accelerated depreciation. Energy

Workers place a solar panel.

**A worker directs placement of a solar panel.**

respectively, with options during that time to renew in 5-year increments. At the end, Portland General Electric will deconstruct each project and return the land to preproject conditions, or ODOT may choose to purchase the projects at very low cost. At any time, if the land is needed for an official purpose, ODOT may exercise its option to have the project removed. The cost for doing so decreases over time based on fair market value, which includes the remaining project value and the lost future energy sales.

## The Public Cost and Benefit

The State transportation agency has no ownership invested in either

Trust of Oregon supplied grant funding, with Portland General Electric's Clean Wind program making up the gap. The total cost of the demonstration project was $1.28 million.

As a public agency, ODOT has no tax liability and therefore could not take advantage of State and Federal tax incentives or accelerated depreciation. To address this issue, Portland General Electric, along with a tax equity partner, formed a limited liability company that could use the tax credits and other incentives.

As with the demonstration, the second project included a tax equity partner but used a "sale, lease-back" contract. That is, the utility financed and constructed the project and sold it upon completion to a tax equity partner, which then leased it back to the utility to operate and maintain. The total cost of the second project was $10 million.

For both projects, at the end of the tax recapture period (60 to 72 months), Portland General Electric will have the option to purchase the array from the tax equity partner at fair market value. That value is based on the present-day value of the sale of electricity generated for the remaining life of the project. Upon purchase, the utility will add the projects to its electrical generation rate base.

The two projects' legal agreements run for 20 and 25 years,

## FHWA Research on Solar Applications

As the U.S. highway network becomes more adaptable, the use of sensors to assess variables such as rainfall and truck weights is increasing. Research is leading to new materials that can adapt and respond in ways that can lead to significant improvements in safety, efficiency, and life-cycle costs. Sensors and actuators, however, require power—sometimes in places where electricity is not readily available or at times when the supply is temporarily unavailable, such as after a hurricane or other extreme events. Accordingly, FHWA is helping to advance research that will meet emerging and critical needs for future highway structures and pavements.

One example is a project led by the University of Nebraska–Lincoln and funded by FHWA's Exploratory Advanced Research Program titled A Roadway Wind/Solar Hybrid Power Generation and Distribution System: Towards Energy-Plus Roadways. The aim of this project, which includes support from the city of Lincoln, NE, is to develop a roadside hybrid power generation and distribution system that is intended to produce more energy than demanded by the infrastructure it supports. The system would constitute a low-footprint, intelligent, and multilayer power system designed for integration into urban and suburban areas, thereby reducing the need for new distribution networks. The hybrid system represents a dramatic change in the role of the public right-of-way from an energy consumer to an energy producer and therefore could aid in reducing the operating costs of transportation systems.

FHWA is also leading a Small Business Innovative Research project called Solar Roadways. The intent is to demonstrate the potential for developing structural pavement panels that can convert solar radiation to electricity and disseminate the power to meet local electricity demands. Each panel would be controlled by an integrated circuit and wired with LED lighting for programmable demarcation or messaging illuminated from below rather than painted on the surface. Some of the energy collected also might be applied to prevent snow and ice buildup in northern climates via resistance heating similar to a car's rear window defogger. The panels would be mounted on existing roadway surfaces and composed of materials that maximize use of recyclables. Initial evaluation and demonstration will be conducted on a parking lot at the Solar Roadways facility in Sagle, ID.

*—by David Kuehn, Program Manager, Exploratory Advanced Research Program, FHWA, and Eric J. Weaver, Research Civil Engineer (Highway), FHWA*

**A worker in a protective mask is using a blowtorch to weld frames for the array.**

project; its contribution is the land. Early on, ODOT defined its role as offering land it determined to be in a shovel-ready condition and available for a period of 20-plus years. Being shovel-ready meant the environmental assessments were done, and permitting needs were identified.

The rationale behind this contribution is the cost of risk. If a parcel has unknown qualities, subsurface or otherwise, a solar developer will include the cost of those risks when estimating the project. The more unknowns, the higher the cost of the project. An overarching goal for the development of renewable energy today is to lower the cost per installed watt. ODOT's assessment work in providing a property ready to roll made a difference in that risk estimation.

On ODOT's side of the equation, two tangible benefits are realized from the I–5 and I–205 intersection and the Baldock rest area projects: a revenue stream in the form of an annual license payment for use of the Baldock land (the site license fee for the demonstration project was waived in recognition of its prototypical cost) and a dedicated percentage of the renewable energy certificates generated by the projects. The certificates count against ODOT's carbon footprint, offsetting its nonrenewable-energy electrical usage. One certificate equals 1 megawatt-hour or 1,000 kilowatt-hours of renewable energy. Voluntary markets exist worldwide for buying and selling these certificates, but at this point, ODOT has decided to retain ownership of the renewable energy certificates and count them directly against the department's nonrenewable-energy electricity use.

"[ODOT's] focus on the renewable energy certificates—rather than on the energy produced by the Baldock solar highway project—was inspired," says Lynn Frank, president of Five Stars International, a consultant to ODOT. "By receiving a share of the renewable energy certificates, the transportation system can claim a share of the solar power produced. [ODOT] understood that it will continue to receive the electricity it needs from the utility, but now it could brand some of that electricity as renewable—wherever that electricity is used."

Frank adds, "This means that solar highway projects can be located on transportation system sites with the most promising solar resource opportunity, and the benefits can be assigned to where the electricity is used. This simple concept extends the opportunity to consider solar highway projects on all 19,000 lane miles [30,578 kilometers] in Oregon and all 8 million lane miles [13 million kilometers] across the Nation."

## The Demonstration Project

On December 19, 2008, ODOT placed the Nation's first solar highway project in service—the I–5 and I–205 intersection project—and it has been operating seamlessly ever since. The 104-kilowatt, direct-current, ground-mounted solar array is made up of 594 solar panels stretching about two football fields in length and about one-third of the parcel, which allows for further expansion.

Net metering indicates that the array produces approximately 120,000 kilowatt-hours of renewable energy annually, offsetting about one-third of the energy needed for freeway illumination at the site. ODOT purchases the power generated through a solar power purchase agreement, but for this initial project, all of the renewable energy certificates generated go to the Energy Trust of Oregon in exchange for grant funding that helped bring the cost of the energy down to market rates.

The site has restricted access for maintenance personnel off an I–205 ramp to I–5 and is surrounded by an 8-foot (2.4-meter)-tall security fence. In accordance with the project's solar site license agreement, Portland General Electric has full responsibility for everything inside the fence, including the array, transformer, inverters to transform the direct current into alternating current, and even lawn mowing, which has been the only maintenance required so far. Oregon's abundant rainfall has managed to keep the panels clean.

Further, the site has several security cameras monitored by the utility, and the fence is equipped with a motion detection system. To date, Portland General Electric has seen no evidence of tampering. In addition to the fence, the steady flow of traffic passing by on three sides is likely a strong deterrent.

## The Baldock Project

Following the success of the demonstration array, ODOT partnered with Portland General Electric on a second solar project, which borders farm fields on two sides and a safety rest area on the remaining sides. The 1.75-megawatt project with 6,994 solar panels sits on just under 7 acres (2.8 hectares) of ODOT property on the east side of the rest area. This project is the largest single ground-mounted solar array in Oregon. The array will produce an estimated 1.97 million kilowatt-hours of renewable energy annually.

Construction began in early August 2011, and the project was placed into service on January 17, 2012. In addition to the panels, the Baldock project includes a public interpretive display on solar energy installed on land bordering the solar array and funded as a Federal Highway Administration (FHWA) Transportation Enhancement project. The array is further bordered by an ornamental community garden featuring a low-maintenance and waterwise design to reflect the sustainable nature of the array.

For the Baldock project, ODOT used a legal structure that differs slightly from the one used for the demonstration project. Although the energy produced by the Baldock panels feeds directly into the electricity grid, it is not net metered, unlike the demonstration project. ODOT does not directly purchase the energy generated, so there is no power purchase agreement.

In return for use of the land, ODOT receives a small annual site license fee and a percentage of the renewable energy certificates generated over the life of the project. ODOT's percentage is equal to its share of the above-market costs to the department—site assessments, staff time, consultant fees, and the costs of public involvement. As a result, 23 percent of the renewable energy certificates generated by the project over the life of the contract period (25 years initially, with two additional 5-year options to renew) goes to ODOT, and the department will apply those certificates toward ODOT's electricity use.

Because ODOT holds a share of the renewable energy certificates, the department can legally say that the rest areas at Baldock, both northbound and southbound, are powered by the renewable energy produced by the solar array. The certificates essentially "color" all of the electricity used at the rest areas as green.

The site usage fee, while small, was important in creating the legal framework for future projects. As solar costs continue to decline, it is expected that the department will be able to command higher fees over time, making solar highways a real revenue generator for the transportation system of the future.

**These volunteers are planting between two fences (the "friendly" short fence on the left and the "we mean it" unfriendly tall fence) at ODOT's second solar project, located at the Baldock rest area 7 miles (11 kilometers) south of the first solar project.**

**This volunteer is helping plant a waterwise, low-maintenance garden at the Baldock rest area, which includes an interpretive display on solar energy.**

Someday, perhaps, solar arrays like these could provide power for electric cars in Oregon!

## Adding Value To the Equation

Because Oregon's solar highway projects were dependent on State and Federal tax credits and grants, the project team asked itself the question, "What public values are being secured or advanced by the investment of these public resources?" The team made a conscious decision to seek more than the lowest common denominator of cost. Given the investment of public resources, the team sought a broader return on the investment that would express the additional public values of supporting new sustainable businesses, creating jobs, producing renewable energy, using innovative green technology, and taking national leadership in sustainable development.

Because of the innovative public-private partnership in place with Portland General Electric and in consideration of the use of State tax credits, the procurement developed by ODOT and used by the utility resulted in the selection of solar panel and inverter manufacturers that reflect the State's public policy objectives. The procurement required the winning companies to accomplish the following:

- Meet strict environmental compliance regulations and commit to end-of-useful-life recycling (product life-cycle stewardship).
- Meet or exceed current, world-leading performance and industry-leading guarantees.
- Have in place or implement a corporate sustainability policy.
- Describe the relevance of a triple bottom line (people, planet, and profit) in company practices.
- Support or be engaged in training programs for disadvantaged-, women-, and minority-owned businesses.
- Exhibit a local presence in order to respond quickly to project needs.
- Demonstrate a proven manufacturing history and the financial backing to support all product claims and warranties.
- Support or be engaged in the local community.

The procurements resulted in the selection of two Oregon-based firms: SolarWorld, a German-owned company with U.S. headquarters in Hillsboro, OR, for the panels and Advanced Energy in Bend, OR, for the inverters. Altogether, Oregon companies designed, built, operate, and maintain the projects.

## What's Next

With the success of the first project and concurrently with Baldock's development, ODOT contracted for a geographic information system (GIS)-based study of all ODOT-owned land in the State to identify other potential sites for future solar projects. In addition to the siting criteria mentioned previously, other screens included size—minimum of 5 acres (2 hectares) for an estimated 1-megawatt array—and year-round access, appropriate slope and orientation, absence of scenic or cultural resources or wetlands, and more.

To date, the study has identified approximately 200 potential sites.

## Relevant Reports

FHWA and the U.S. Department of Transportation's (USDOT) John A. Volpe National Transportation Systems Center's report *Alternative Uses of Highway Right-of-Way* (January 2012) investigates the implications of accommodating renewable energy technologies and alternative fuel facilities within highway rights-of-way. The report, which offers a snapshot of issues in a rapidly evolving field and provides transportation agencies with information that is expected to help in pursuing future projects, is available at www.fhwa.dot.gov/real_estate/publications/alternative_uses_of_highway_right-of-way.

Similarly, the National Cooperative Highway Research Program's 25-25/Task 64: *Feasibility Study of Using Solar or Wind Power for Transportation Infrastructure* (March 2011) provides an overview of current and emerging technologies used in wind and solar applications. The report presents a general design approach for installations near roadway rights-of-way and includes a tool for performing a life-cycle cost analysis to determine the feasibility of potential transportation-related renewable energy installations. The document is available at http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP25-25(64)_FinalHandbook.pdf.

In-office verification—reviewing the GIS data online as opposed to actual site visits—is underway and is expected to result in a prioritized list of sites. Those sites then will undergo more rigorous environmental review, with the goal of future permitting and financing.

Lynn Averbeck, senior project executive with ODOT in charge of the GIS study, environmental clearances, and permitting, notes, "While each site will be different and will have its own challenges, by using due diligence when searching for potential sites, we have found that solar highway projects can be selectively placed where they do not have significant environmental impacts and can fit nicely into either the urban built environment or undeveloped rural areas."

Averbeck continues: "With early and genuine outreach to adjacent communities and other local stakeholders, the permitting processes can be fairly straightforward and uncontroversial. The biggest cause for confusion is how the projects fit into existing local codes, which were not written with this type of project in mind."

With the exceptional access offered to the public at the Baldock project, local solar highway supporters hope that public fears can be dispelled by getting up close and personal with a solar array.

More information on the projects and program, including photos, video, and links to real-time solar energy generation at each site, is available at www.oregonsolarhighway.com. Also available on the site is a manual titled *Solar Highway Program: From Concept to Reality*, designed to help other public and private organizations develop their own solar highway programs and projects.

## The Future Is Bright!

The Oregon Solar Highway Program seeks to increase understanding of solar's role in greening the Nation's electricity grid, add value to the existing public right-of-way asset, and supply clean, renewable, homegrown energy to Oregonians—and thus support the drive to energy independence.

Oregon's solar highway future holds the promise of miles of solar highway installations, collecting fuel from the sun for the transportation system of the future. That future is underway today.

As Federal Highway Administrator Victor Mendez noted at the groundbreaking for Baldock on August 23, 2011, "Between this project—the largest of its kind in the Nation—and the solar interchange a few miles north of here, it's clear the road to the future starts here in Oregon. Well done, Oregon, for leading the way in building the solar highway."

**Allison Hamilton** manages the Oregon Solar Highway Program in ODOT's Office of Innovative Partnerships and Alternative Funding. She has a B.S. in civil engineering and an A.S. in structural engineering from the Oregon Institute of Technology.

*For more information, contact Allison Hamilton at 503-551-9471 or allison.m.hamilton@odot.state.or.us.*

These workers are installing a power vault for the solar array.

# Along the Road

*Along the Road is the place to look for information about current and upcoming activities, developments, trends, and items of general interest to the highway community. This information comes from U.S. Department of Transportation (USDOT) sources unless otherwise indicated. Your suggestions and input are welcome. Let's meet along the road.*

## Management and Administration

### Administrator Mendez Joins Washington Governor at Tunnel Groundbreaking

Federal Highway Administrator Victor Mendez recently joined Washington State Governor Chris Gregoire to kick off construction of the S.R. 99 tunnel in downtown Seattle. The tunnel will improve safety for hundreds of thousands of Seattle area drivers. It will be the world's largest tunnel, with a diameter of 57.5 feet (17.5 meters).


**Federal Highway Administrator Victor Mendez (far left) joins Washington State Governor Chris Gregoire (center, in brown and tan) and nine others, including Washington State Secretary of Transportation Paula Hammond (in green, fifth from left), to ceremonially break ground for the S.R. 99 tunnel in downtown Seattle.**

The 1.7-mile (2.7-kilometer) S.R. 99 tunnel will replace the Alaskan Way Viaduct, a double-decker bridge that handles more than 100,000 vehicles a day as a main north-south route through Seattle. Moving S.R. 99 traffic underground will improve safety in the corridor because the tunnel was designed to withstand a major earthquake. The change will avoid major disruption of traffic patterns due to loss of capacity on S.R. 99 in the case of viaduct damage or failure.

The viaduct that the tunnel replaces was built in 1953 and was severely damaged during the Nisqually earthquake in 2001. Engineers designed the four-lane underground tunnel as one of the safest places to be during a quake. A state-of-the-art control center will be installed to facilitate responding to emergencies, and the tunnel will be equipped with lighting, ventilation, and fire suppression systems. Wider lanes will ensure enough space for all vehicles, and long, gentle curves will provide safe sight distances for drivers in the tunnel.

In addition, by moving the highway below ground, the city will be able to open more space above ground for promenades and parks, so communities can reconnect with the waterfront.

*For more information, visit www.wsdot.wa.gov/Projects/Viaduct.*

### FHWA Signs Partnering Agreement with APWA

The Federal Highway Administration (FHWA) recently signed a partnering agreement with the American Public Works Association (APWA) to promote continued collaboration between the two organizations to provide high-quality, cost-effective, and safe transportation systems.

FHWA and APWA have maintained ongoing partnership agreements since 1997. Under the current agreement, activities will embrace innovation and new technologies and will center on continued education, outreach, information exchange, and proactive leadership. The partnership also will assist public works professionals in promoting safety, enhancing mobility, advancing communities' economic growth and development, and protecting the environment.

The agreement enables FHWA and APWA to capitalize on opportunities to improve service at the Federal, State, and local levels of government. To meet the partnership's goals, the two organizations will work cooperatively to understand the needs of public works officials and how they can best prepare for the future, educate the traveling public on the significance of infrastructure investment, and streamline the delivery of transportation projects. Further, the organizations will provide mutual assistance in educating and training transportation personnel to increase the effective use of technologies available to meet present and future transportation needs.

The two organizations also agree to collaborate on committees, in meetings and conferences, in research and training opportunities, and in other joint activities.

*APWA*

## Technical News

### Handheld Device Collects Data on Wildlife-Vehicle Collisions

Researchers at the Western Transportation Institute at Montana State University have created the Roadkill Observation Collection System (ROCS), a tool that enables road crews to collect accurate information about wildlife-vehicle collisions. ROCS integrates a handheld computer or PDA with GPS supported by customized software. Field personnel use the tool to document information such as the collision location and the species of wildlife.

For transportation agencies, the immediate benefits of using ROCS include identification of high-risk road segments, access to information that supports mitigation efforts, and the availability of paperless reporting options. If widely deployed, the device has the potential to increase the collection and cross-jurisdictional sharing of standardized, accurate collision data throughout the United States. Additional broad benefits could include enhanced safety


Western Transportation Institute

A researcher demonstrates the handheld data collector developed for the Roadkill Observation Collection System project.

for travelers, preservation of wildlife and habitats, and targeted initiatives to protect endangered species.

In the initial project phase, researchers created and field-tested a successful proof-of-concept system, including an easy-to-use interface that facilitated rapid data entry. In the second phase, they developed practical modifications and customization of the software and hardware. The institute recently completed a third phase, which achieved goals related to managing, sharing, visualizing, and analyzing the data. New components include an Internet-based means of storing and retrieving data, and software to place the information on maps or to download it for analysis.

Up next, the researchers are pursuing efforts to facilitate broader deployment, including development of a smartphone application. For field crews with smartphones, a ROCS application would reduce the necessity and costs of obtaining additional PDA-GPS units.

*For more information, visit http://utc.dot.gov/publications/spotlight/2012_03/html/spotlight_1203.html.*

### USDOT Research Shows Drivers Support Connected Vehicle Technology

An overwhelming majority of drivers who are given the opportunity to experience technology that enables vehicles to communicate with each other have a highly favorable opinion of its safety benefits, according to data released by USDOT. The National Highway Traffic Safety Administration (NHTSA) and the Research and Innovative Technology Administration (RITA) have been working with the auto industry, as well as State and Federal partners, to research the effectiveness and feasibility of connected vehicle technology that enables cars and trucks to "talk" to one another wirelessly. This technology could help prevent crashes and save lives.

USDOT held six driver acceptance clinics across the country between August 2011 and January 2012 to gather feedback from 688 drivers who participated in tests of vehicle-to-vehicle communications. The driver clinics, the first phase of USDOT's Connected Vehicle Safety Pilot Program, gathered information on how drivers interact with the technology. Four out of five participants, or 82 percent, strongly agreed that they would like to have vehicle-to-vehicle safety features in their personal vehicles. In addition, more than 90 percent of the participants believed that a number of specific features of the connected vehicle technology would improve driving in the real world, including features alerting drivers about cars approaching an intersection, warning of possible forward collisions, and notifying drivers of cars changing lanes or moving into the driver's blind spot.

In August 2012, USDOT launched the year-long second phase of the pilot program, which will test the performance of approximately 3,000 vehicles equipped with crash-avoidance technologies that include in-vehicle forward-collision warnings, "do not pass" alerts, and warnings that a vehicle ahead has stopped suddenly. The program will take place on roads in Ann Arbor, MI, and will also involve testing of technologies enabling vehicles to communicate with devices installed along the roadway.

Eight major automotive manufacturers are working with USDOT on this research through partnering agreements. NHTSA will use the information collected from the pilot program to determine whether to proceed with additional vehicle-to-vehicle communication activities, including possible future rulemakings, by 2013.

*For more information on the Connected Vehicle Safety Pilot Program, visit www.its.dot.gov/safety_pilot/index.htm.*

### FHWA Geotechnical Expo Goes Virtual

In early 2012, FHWA held its first-ever virtual conference, offering free online attendance to approximately 150 participants from 22 State departments of transportation (DOTs). Attendees of the Virtual Foundation Expo could view and listen to presentations on drilled deep foundation technology, talk to presenters, and interact with other participants, all without leaving their offices.


During FHWA's Virtual Foundation Expo, presenters and attendees were represented by avatars as they participated in live presentations and panel discussions, as shown here.

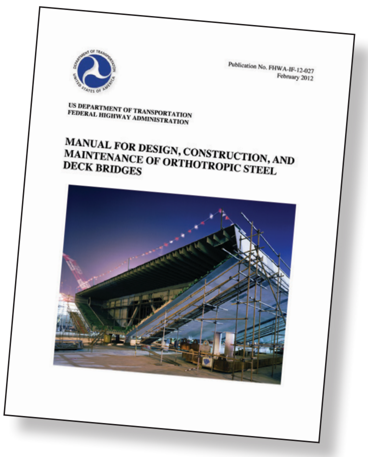
Held in conjunction with the 2012 International Association of Foundation Drilling conference in San Antonio, TX, and organized by the FHWA Office of Bridge Technology and National Highway Institute (NHI), the 2-day expo featured panel discussions on topics including quality in deep foundations, use of slurry in drilled foundations, and techniques for large-diameter and small-diameter hole excavation.

The second day of the expo featured live presentations streamed from the conference. Topics included load and resistance factor design (LRFD), anchored earth retention systems, and micropile systems. Videos showed demonstrations of geotechnical equipment, as well as interviews with equipment vendors.

For many agencies, several staff members were able to participate, increasing the value and knowledge gained. Based on the enthusiastic response from participants, NHI is exploring additional uses for the virtual technology.

*For more information and to view videos and recordings from the expo, visit http://vimeopro.com/adsc/virtualfoundationexpo.*

### Manual on Orthotropic Steel Deck Bridges Released




FHWA's recently released *Manual for Design, Construction, and Maintenance of Orthotropic Steel Deck Bridges* (FHWA-IF-12-027) presents a comprehensive guide to this technology for bridge design. First developed in Germany in the 1930s, the orthotropic steel deck system continues to offer tremendous potential for building efficient and cost-effective modern structures with extended service lives.

The defining characteristic of the orthotropic steel deck bridge is that its nearly all-steel superstructure has the potential to provide extended service life, standardized modular design, and rapid assembly compared to more conventional bridge construction. These bridges can have lower life-cycle costs because they include watertight, continuous riding surfaces with minimal joints, preventing leakage and protecting other structure components. Since most components are prefabricated, free of cast-in-place concrete, and lightweight, an orthotropic steel deck bridge can be built quickly.

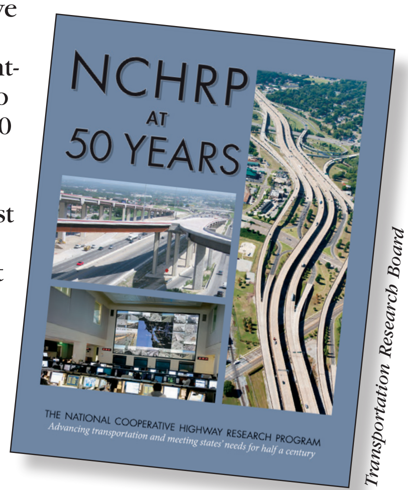
Based on worldwide practice and modern analytical techniques, the manual describes many aspects of orthotropic bridge engineering, including analysis, design, fabrication, testing, inspection, and repair. This publication supplements and expands the 1963 *Design Manual for Orthotropic Steel Plate Deck Bridges* published by the American Institute of Steel Construction and is based on the *AASHTO* [American Association of State Highway and Transportation Officials] *LRFD Bridge Design Specifications, Sixth Edition*.

The manual examines orthotropic steel deck applications, as well as structural behavior and analysis. Sections of the manual cover design and construction, as well as techniques for inspection, evaluation, repair, and testing.

*For more information and to download the manual, visit www.fhwa.dot.gov/bridge/pubs/if12027/if12027.pdf.*

## Public Information and Information Exchange

### NCHRP Celebrates 50 Years




*Transportation Research Board*

The National Cooperative Highway Research Program (NCHRP) recently released a brochure to commemorate its first 50 years and to highlight some of the program's milestones. Over the past 5 decades, the program has produced significant research that has had a lasting impact on how State highway agencies build, manage, and maintain the Nation's highway system.

At the time of NCHRP's founding in 1962, construction of the interstate highway system was already underway, and traditional highway problems were becoming much more complex. Responsibility for U.S. highways was still highly decentralized, and there was no vehicle through which State highway departments could pool resources to address common research problems.

Born of discussions between the predecessor of AASHTO and the Bureau of Public Roads (now FHWA), NCHRP was envisioned as a research body to advance the state of highway technology for all States and provide technical guidance across the highway transportation sector.

During its first year, the program initiated 34 projects valued at $3.5 million. Over the 50 years that followed, NCHRP has worked to help USDOT solve critical problems, deliver transportation research over a wide range of issues, and establish standards for how the Nation's highways are designed, built, operated, and maintained.

NCHRP has produced numerous publications, guidelines, and synthesis reports on topics of interest to the transportation community, including safety, highway capacity and design, asset management, security planning, and materials and construction.

*To access the 50th anniversary brochure, visit http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP_50thAnniversary.pdf.*

*Transportation Research Board*

National Center for Safe Routes to School

**These children from Mesilla Elementary School in Mesilla, NM, were among thousands who participated nationwide in the first National Bike to School Day.**

### First National Bike to School Day Spurs Nearly 1,000 Events

On May 9, 2012, communities across the country celebrated the inaugural National Bike to School Day. Schools, cities, bicycle groups, public health organizations, and parents organized bike rides and pelotons to highlight the benefits of choosing foot-powered transportation to school. Almost 1,000 Bike to School Day events in 49 States and the District of Columbia registered through the official event Web site at www.walkbiketo school.org.

"We knew there was support for a spring Bike to School Day, as many local bike-focused events have been held in the past," says Lauren Marchetti, director of the National Center for Safe Routes to School, which coordinates National Bike to School Day. "But the turnout for this first-time event was spectacular! We couldn't be more pleased with how many communities and families came together to promote biking to school on this 1 day."

Bike to School Day encourages a bike-focused celebration and builds on the popularity and success of International Walk to School Day, also coordinated by the National Center for Safe Routes to School and celebrated around the world each October. Both events encourage more physical activity for children and adults, and help to reduce vehicle emissions.

At an event in Washington, DC's Lincoln Park, NHTSA Administrator David Strickland joined students from several area schools to officially launch National Bike to School Day. The event was organized by the District Department of Transportation and the Capitol Hill Public Schools Parent Organization.

In total, more than 900 Bike to School events have been held nationwide in 2012, most of which occurred in May to support National Bike Month. The next National Bike to School Day will be held May 8, 2013.

*For more information, visit www.walkbiketoschool.org.*

*National Center for Safe Routes to School*

### ODOT Works to Establish Public-Private Partnerships

The Ohio Department of Transportation (ODOT) recently followed the example of many other States entering into public-private partnerships for delivery of public projects and services. These partnerships can provide numerous benefits in the finance, design, construction, and operation of transportation facilities.

To develop and implement its partnerships-related policies and programs, ODOT launched the Division of Innovative Delivery. The division's mission is to identify innovative and alternative funding sources and advance ODOT's goal of developing long-term, sustainable solutions to fund future transportation construction projects. By reducing agency costs, commercializing noninterstate rest areas, and seeking sponsorship and naming rights for certain infrastructure projects, ODOT could save nearly $200 million annually.

The Division of Innovative Delivery is researching and developing alternative funding solutions for financing the construction of several transportation projects in Ohio, including a bridge spanning the Ohio River, a bypass, and an intermodal connector. The division also will seek to identify and generate potential alternative funding sources from State assets, such as the Ohio Turnpike; in addition, it is considering a sponsorship program for rest areas, bridges, interchanges, and sections of highways.

Currently, ODOT is reviewing all transportation projects in the State to identify those that could be potential candidates for public-private partnerships, as well as additional sources of revenue to aid in the funding of major transportation projects across Ohio.

*For more information, contact Steve Faulkner at 614–644–7101 or steve.faulkner@dot.state.oh.us. See also the Web site for FHWA's Office of Innovative Program Delivery at www.fhwa.dot.gov/ipd.*

*ODOT*

### Scan Team Investigates Innovations For Roadway Tunnels

A domestic scan team sponsored by FHWA, NCHRP, and AASHTO recently traveled the country investigating innovations and best practices for roadway tunnel design, construction, maintenance, inspection, and operations. The project focused on the need for national standards and an inventory of all tunnels in the United States.

Team members included representatives from FHWA, State DOTs, and academia. The team visited California, Colorado, Maryland, Massachusetts, New Jersey, New York, Virginia, and Washington State and conducted Web conferences with representatives from other DOTs. Tunnels visited during the tour include the Central Artery/Tunnel in Massachusetts, the Eisenhower/Johnson Memorial Tunnel and the Hanging Lake Tunnel in Colorado, as well as the Chesapeake Bay Bridge–Tunnel and Hampton Roads Bridge–Tunnel in Virginia.

The scan team considered the issues of fire suppression, traffic management, incident detection and

Washington State Department of Transportation

**A domestic scan team visited tunnels in several States, including the twin-bore Mount Baker Ridge Tunnel, shown here in the background, in Seattle, WA.**

management, and repairs of existing tunnels, and reviewed innovations in construction and operations. Team members also looked at use of prefabricated elements like submersed tubes, ceiling panels, and concrete floors to accelerate tunnel construction.

"We had the opportunity to learn about best practices and innovations that States are using, so that these can be shared with other States," says scan cochair Jesús Rohena of FHWA. "We also observed the challenges that tunnel owners are facing throughout the country as tunnels get older. The scan proved to be an effective way to learn about the existing condition of the U.S. tunnels. We will use the information collected to provide input into future FHWA guidelines, policies, and regulations to make U.S. tunnels safer and more secure."

Based on the information gathered during the tour, the team made a number of recommendations, which include developing an emergency response plan specific to each facility, considering inspection and maintenance operations during the design stage, and developing site-specific plans for safe and efficient operation of tunnels.

*For more information and to download the report,* Best Practices for Roadway Tunnel Design, Construction, Maintenance, Inspection, and Operations*, visit http://bridges.transportation.org/Documents/NCHRP20-68A_09-05%20(1).pdf.*

# Reporting Changes of Address

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Paula Magoulas, Editor-in-Chief
October 9, 2012

# Internet Watch

*by Kate Sullivan*

## Updated LTPP Products Online

Why do some pavements perform better than others? To find out, the Federal Highway Administration (FHWA) launched the Long-Term Pavement Performance (LTPP) program, building on research started in the 1980s. More than 25 years later, the program continues to investigate various designs, pavement structures, materials, environments, and maintenance practices—with the objective of increasing pavement life. FHWA researchers created an information management system to house the collected data, and today this relational database contains more than 600 tables.

Accessing these data, research findings, and related products just got easier. FHWA recently unveiled the improved "LTPP Products Online," with a fully updated version of LTPP DataPave Online. The Web site enables users to view and extract data in a faster, easier-to-navigate environment.

"LTPP Products Online 2.0 with DataPave Online is a huge improvement over the original version," says Antonio Nieves Torres, a concrete pavement engineer with FHWA's Office of Infrastructure. "It is much more user friendly. More data are displayed, and the selection process for downloading data is much more comprehensive than before."

### Expanded Data, Enhanced Navigation

DataPave Online, the original site's flagship and the primary means of accessing raw data, is completely updated and features an intuitive user interface for simpler navigation and easy extraction of data. One new feature is the integration of images of pavement distress from LTPP test sites, previously available only by special request. The LTPP program also updated the navigation map on the Web site using the latest Google™ mapping capabilities including aerial and zoom views to make it easier for users to find and examine test sites.

The data summary sheet was expanded to provide a more detailed and useful overview of the LTPP test sites selected by the user. The site integrates the Distress Viewer and Analyzer application—originally a stand-alone application that displayed images, videos, and other data from pavement distress surveys of LTPP test sites.

A new function of DataPave Online is "Export by Topic," which enables users to explore the LTPP data by topic, selecting multiple data elements and viewing the number of available records before downloading. Researchers can refine an export selection, such as traffic data, by filtering by increasingly specific subtopics like traffic counts, then heavy trucks per day.

The updated LTPP Reference Library is now completely searchable using keywords. The system upgrade also integrates the LTPP data directly with the library. When a user selects data elements to export, the site generates a list of related materials from the library, such as books, articles, and product briefs.

The site also boasts improved performance with bandwidth doubled from 3 to 6 megabits per second, providing faster access times for videos, images, and maps.

"These Web site enhancements are especially valuable to the research community," says Shelley Stoffels, associate professor of civil engineering and director of the Larson Institute Transportation Infrastructure Program at Penn State University. "The improvements in search, retrieval, and display all facilitate the research process and provide users with a much improved tool. They also serve to make the data much more accessible to students at all levels, helping to educate a future generation of highway engineers."


### InfoPave: The Next-Generation LTPP Interface

To further improve the user experience and ease of access to LTPP data, and to stay at the forefront of technology advancements, the LTPP team recently awarded a contract to develop the next-generation Web interface: LTPP InfoPave. This program will expand and replace LTPP Products Online. When launched, InfoPave will be the focal point of the LTPP program, providing user-friendly Web access to the LTPP data on demand, with tools to maximize utilization and user understanding. FHWA expects to release InfoPave to the public in January 2014 at the Transportation Research Board's annual meeting.

*For more information, visit www.ltpp-products.com or contact Antonio Nieves Torres at 202-366-4597 or antonio.nieves@dot.gov.*

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**Kate Sullivan** is a contributing editor for PUBLIC ROADS.

# Training Update

*by Candice Jackson*

## Balancing Preservation and Transportation Needs

The relationship between the Nation's transportation infrastructure and places of historical, cultural, and environmental importance is complex. In order to build and improve the transportation system while maintaining the integrity of historic places and environmental resources, the Federal Government has enacted several regulations to guide transportation planning and project development. These regulations include Section 106 of the National Historic Preservation Act, the National Environmental Policy Act, and Section 4(f) of the Department of Transportation Act.

To assist those who carry out or are affected by transportation projects, the National Highway Institute (NHI) offers a 3-day course that introduces the basics of historic preservation law and compliance. Course 142049 Beyond Compliance: Historic Preservation in Transportation Project Development presents the fundamentals of Section 106, which requires Federal agencies to take into account the effects of their projects on properties listed in or eligible for the National Register of Historic Places, and places them in context with other environmental requirements. The course also examines effective practices that integrate the Section 106 process with the requirements of the National Environmental Policy Act and Section 4(f). Hosting agencies can tailor the course to meet their individual needs and those of their participants.

### Streamlined Review Process

Course 142049 presents a number of innovative approaches to Section 106 compliance that result in streamlined and enhanced environmental reviews and project delivery. A critical component of compliance involves balancing historic preservation concerns with the needs of Federal undertakings through consultation with resource agencies, stakeholders, and the public, and considering historic preservation factors during transportation planning and early project development.

The course also provides information about consulting with federally recognized Native American tribes in the context of the Section 106 process. Participants are provided with guidance on how to consult effectively with tribes, taking into account their varied religious and cultural values.

### Customized Training Content

Prior to each session, NHI instructors work with the staff of the hosting State department of transportation to address local historic preservation and project delivery issues and concerns. For example, before presenting multiple sessions of course 142049 in Hawaii, NHI customized the training to reflect the State's existing transportation programs and procedures for meeting local historic preservation goals, including working with Native Hawaiian organizations. The National Historic Preservation Act defines Native Hawaiian organizations as "any organization [that] serves and represents the interests of Native Hawaiians; has as a primary and stated purpose the provision of services to Native Hawaiians; and has demonstrated expertise in aspects of historic preservation that are significant to Native Hawaiians." These organizations play a major role in transportation planning in the State. NHI worked closely with the Hawaii Department of Transportation and the Federal Highway Administration's (FHWA) Hawaii Division to incorporate into the course curriculum materials and information specific to consulting with these organizations.

*Lynne Sebastian, SRI Foundation*

**The Hana Highway, a popular road for tourists, includes a series of historic one-lane bridges such as the one shown here. The road's historic and environmental features exemplify the types of complex issues that prompted the Hawaii Department of Transportation to request customized sessions of course 142049.**

"Native Hawaiian organizations are different from tribes because they are not structured governments that qualify as nations recognized by the Federal government, so we customized the course to address their specific role in the process," says MaryAnn Naber, Federal preservation officer with FHWA. "We wanted to make it relevant to those in Hawaii so we changed case studies, images, and one whole unit to apply to Native Hawaiian organizations."

Pat Phung, lead civil engineer with the FHWA Hawaii Division, has participated in the course more than once and found the customization extremely helpful in making it applicable to Hawaiian transportation projects. "The course brings higher awareness to the challenges and opportunities of working with Native Hawaiian organizations," says Phung. "It addresses significant places of worship, historic sites, and geographic features that we try to avoid or where we at least minimize our footprint. The course even included Hawaiian words and local issues that really made it real for participants."

*For course details and to schedule a session, visit NHI's Web site at www.nhi.fhwa.dot.gov.*

**Candice Jackson** is a contractor for NHI.

# Communication Product Updates

*Compiled by Michael Thoryn of FHWA's Office of Corporate Research, Technology, and Innovation Management*

*Below are brief descriptions of communications products recently developed by the Federal Highway Administration's (FHWA) Office of Research, Development, and Technology. All of the reports are or will soon be available from the National Technical Information Service (NTIS). In some cases, limited copies of the communications products are available from FHWA's Research and Technology (R&T) Product Distribution Center (PDC).*

*When ordering from NTIS, include the NTIS publication number and title. You also may visit the NTIS Web site at www.ntis.gov to order publications online. Call NTIS for current prices. For customers outside the United States, Canada, and Mexico, the cost is usually double the listed price. Address requests to:*

**National Technical Information Service**
**5301 Shawnee Road**
**Alexandria, VA 22312**
**Telephone: 703–605–6000**
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**Web site: www.ntis.gov**
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*Requests for items available from the R&T Product Distribution Center should be addressed to:*

**R&T Product Distribution Center**
**Szanca Solutions/FHWA PDC**
**13710 Dunnings Highway**
**Claysburg, PA 16625**
**Telephone: 814–239–1160**
**Fax: 814–239–2156**
**Email: report.center@dot.gov**

*For more information on R&T communications products available from FHWA, visit FHWA's Web site at www.fhwa.dot.gov, the FHWA Research Library at www.fhwa.dot.gov/research/library (or email fhwalibrary@dot.gov), or the National Transportation Library at ntl.bts.gov (or email library@dot.gov).*

### Jointed Full-Depth Repair of Continuously Reinforced Concrete Pavements (TechBrief) Publication No. FHWA-HIF-12-007

This TechBrief describes an alternative method for making full-depth repairs in continuously reinforced concrete (CRC) pavements—those with continuous longitudinal steel reinforcement and no regularly spaced contraction or expansion joints. The alternative method does not use continuous longitudinal reinforcement in the repair area. This method is suitable for repairing a single lane (or two of three adjacent lanes), and results in repairs that have continued to perform well after several years.

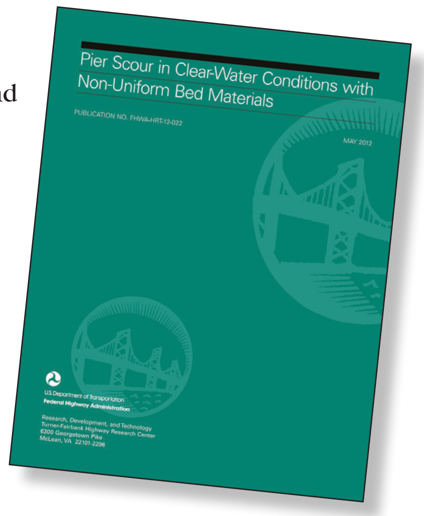
The continuous joint-free length of CRC pavement can extend to several miles, with breaks provided only at structures. These pavements can develop a transverse cracking pattern with cracks generally spaced at about 2 to 6 feet (0.6 to 1.8 meters). The cracking pattern is affected by the ambient weather condition at the time of construction, the amount of steel reinforcement, and concrete strength.


The South Carolina Department of Transportation developed a simple and innovative method for restoring CRC pavements using a jointed full-depth repair technique. For repairs in the outside lane of a two-lane roadway or in two adjacent lanes of a three-lane roadway, this technique has resulted in more than 10 years of good performance. It has not been applied to the repair of all lanes of a CRC pavement at a given location, which would leave the CRC pavement unrestrained at the transverse faces of the full-depth repair and subject to damage from daily and seasonal movements caused by fluctuations in ambient temperature.

This report presents some fundamental information about CRC pavement design, describes the methods that typically have been used for repair of CRC pavements, and discusses South Carolina's experience using a jointed full-depth repair technique.

The document is available to download at www.fhwa.dot.gov/pavement/pub_details.cfm?id=736. Printed copies are available from the PDC.

### Pier Scour in Clear-Water Conditions with Non-Uniform Bed Materials (Report) Publication No. FHWA-HRT-12-022




Scour hazards—the water-induced erosion of the soil surrounding bridge foundations—and flooding are the most common causes of bridge failures in the United States. State bridge authorities have identified flooding and scour among the top issues in bridge design and maintenance. A recent evaluation of research on bridge scour indicated a need to change the current design method because substantial advances have been made in understanding pier scour processes. The evaluation compared several design methods and determined which effectively included the variables now believed to determine pier scour characteristics.

This report describes a new method for estimating pier scour based on the latest knowledge regarding flow, structure, and sediment interactions and to address weaknesses in earlier methods. The research focuses on clear-water scour at singular piers in noncohesive sediment mixtures. Researchers undertook a critical review of selected studies and proposed a simplified scour mechanism in terms of a pressure gradient resulting from the flow-structure, flow-sediment, and sediment-structure interactions. Based on this simplified mechanism, researchers then proposed an equilibrium scour depth equation, and then validated and refined the equation using a combination of laboratory and field data. The proposed equation is primarily applicable to clear-water scour conditions with non-uniform coarse bed materials.

This report is intended for hydraulic and bridge engineers involved in bridge foundation design. The document is available to download at www.fhwa.dot.gov/publications/research/infrastructure/structures/12022. Printed copies are available from the PDC.

### Evaluation of State Quality Assurance Program Effectiveness (Report) Publication No. FHWA-HRT-12-027


Transportation agencies' construction quality assurance programs help ensure low-cost, high-quality construction, but how should these programs be evaluated? This report documents a study to develop, apply, and make recommendations for a procedure that can quantify and improve the effectiveness of existing quality assurance programs by analyzing the statistical risk inherent in complying with construction specifications.

Three State highway agencies provided quality assurance data from their construction projects for analysis. FHWA researchers selected four construction specifications for analysis from the three State highway agencies, two for asphalt pavements and two for portland cement concrete pavements. This report includes analysis of the specifications, particularly the risks involved, and recommendations for improving areas that are considered unclear or statistically invalid.

The study shows that software programs like SpecRisk or computer simulations can be used to analyze the statistical risks of most, if not all, specifications. The researchers found that both asphalt specifications and one of the portland cement specifications could be analyzed using SpecRisk because they are based on the statistical quality measure of percent within limits. This measure uses the sample mean and sample standard deviation to estimate percentage of a population that is within a specified range. The remaining portland cement pavement specification was based on averages of the quality characteristics and had to be analyzed by computer simulation.

The document is available to download at www.fhwa.dot.gov/publications/research/infrastructure/12027. Printed copies are available from the PDC.

### Ultra-High Performance Concrete Composite Connections for Precast Concrete Bridge Decks (TechBrief) Publication No. FHWA-HRT-12-042


Ultra-high performance concrete (UHPC), a durable and resilient construction material, can help highway agencies complete bridge construction and reconstruction projects rapidly onsite. FHWA researchers recently used UHPC to develop a novel composite connection detail for joining precast concrete bridge decks to supporting superstructure elements. This TechBrief discusses a research project to redesign a composite connection offering the following benefits: simple details, an absence of interference or field setup issues, increased long-term durability, and reduced concerns about aesthetics and rideability.

Researchers demonstrated that the field-cast UHPC composite connections are capable of meeting critical design, construction, and response requirements. The connections withstood loads greater than those required by the American Association of State Highway and Transportation Officials' bridge design specifications and exhibited performance surpassing that of a conventional test specimen. Based on the findings of the study, the report provides conceptual guidance to practitioners and researchers interested in using the UHPC composite connection detail. The TechBrief includes information on field-cast UHPC connections, mechanical and durability properties, composite connection details, and the physical testing program.

The document is available to download at www.fhwa.dot.gov/publications/research/infrastructure/structures/hpc/12042. Printed copies are available from the PDC.

# Conferences/Special Events Calendar

| Date | Conference | Sponsors | Location | Contact |
|---|---|---|---|---|
| February 7–9, 2013 | 12th Annual New Partners for Smart Growth Conference | Hosted by Local Government Commission | Kansas City, MO | Melissa Shelley<br>916-448-1198 ext. 327<br>mshelley@lgc.org<br>www.newpartners.org |
| February 22–26, 2013 | ATSSA 43rd Annual Convention and Traffic Expo | American Traffic Safety Services Association (ATSSA) | San Diego, CA | Melanie McKee<br>540-368-1701<br>melanie.mckee@atssa.com<br>www.atssa.com/2013Convention.aspx |
| March 3–6, 2013 | ITE Technical Conference and Exhibit | Institute of Transportation Engineers (ITE) | San Diego, CA | Sallie Dollins<br>202-785-0060 ext. 149<br>sdollins@ite.org<br>www.ite.org |
| March 10–14, 2013 | 8th International Conference on Fracture Mechanics of Concrete and Concrete Structures (FraMCoS-8) | International Association of Fracture Mechanics for Concrete and Concrete Structures | Toledo, Spain | Begoña Pérez Moraga<br>34 926 295 300 ext. 6372<br>congress.framcos8@uclm.es<br>www.framcos8.org |
| March 19–21, 2013 | World of Asphalt 2013 | See conference Web site for a list of sponsors. | San Antonio, TX | World of Asphalt Show Management<br>414-298-4138<br>info@worldofasphalt.com<br>www.worldofasphalt.com |
| March 20–22, 2013 | ICRI 2013 Spring Convention | International Concrete Repair Institute | St. Pete Beach, FL | Naomi White<br>248-848-3809<br>naomi.white@icri.org<br>www.icri.org/events/upcomingevents.asp |
| April 14–18, 2013 | ACI Spring 2013 Convention | American Concrete Institute (ACI) | Minneapolis, MN | Renee Lewis<br>248-848-3794<br>renee.lewis@concrete.org<br>www.aciconvention.org |
| April 16–18, 2013 | International Highway Transportation Summit: Innovative Approaches and Best Practices | Transportation Research Board and China Highway Transportation Society | Beijing, China | Betty Guo<br>86-10-64813501<br>Betty05122@163.com<br><br>Nina Guan<br>86-10-64813501<br>Ninee818@hotmail.com<br>www.trb.org/Calendar/Blurbs/166851.aspx<br>http://gclt.chinahighway.com |
| April 21–25, 2013 | NACE Annual Conference | National Association of County Engineers (NACE) | Des Moines, IA | Constantine Radoulovitch<br>202-393-5041<br>nace@naco.org<br>www.countyengineers.org |

# U.S. Department of Transportation
# National Engineers Program

## ENGINEERS DAY® 2013

## March 7

## Catholic University of America
### Pryzbyla Center
## Washington, DC

Contact Stephanie Carter at stephanie.carter@dot.gov or Clark Martin at clark.martin@dot.gov for more information.

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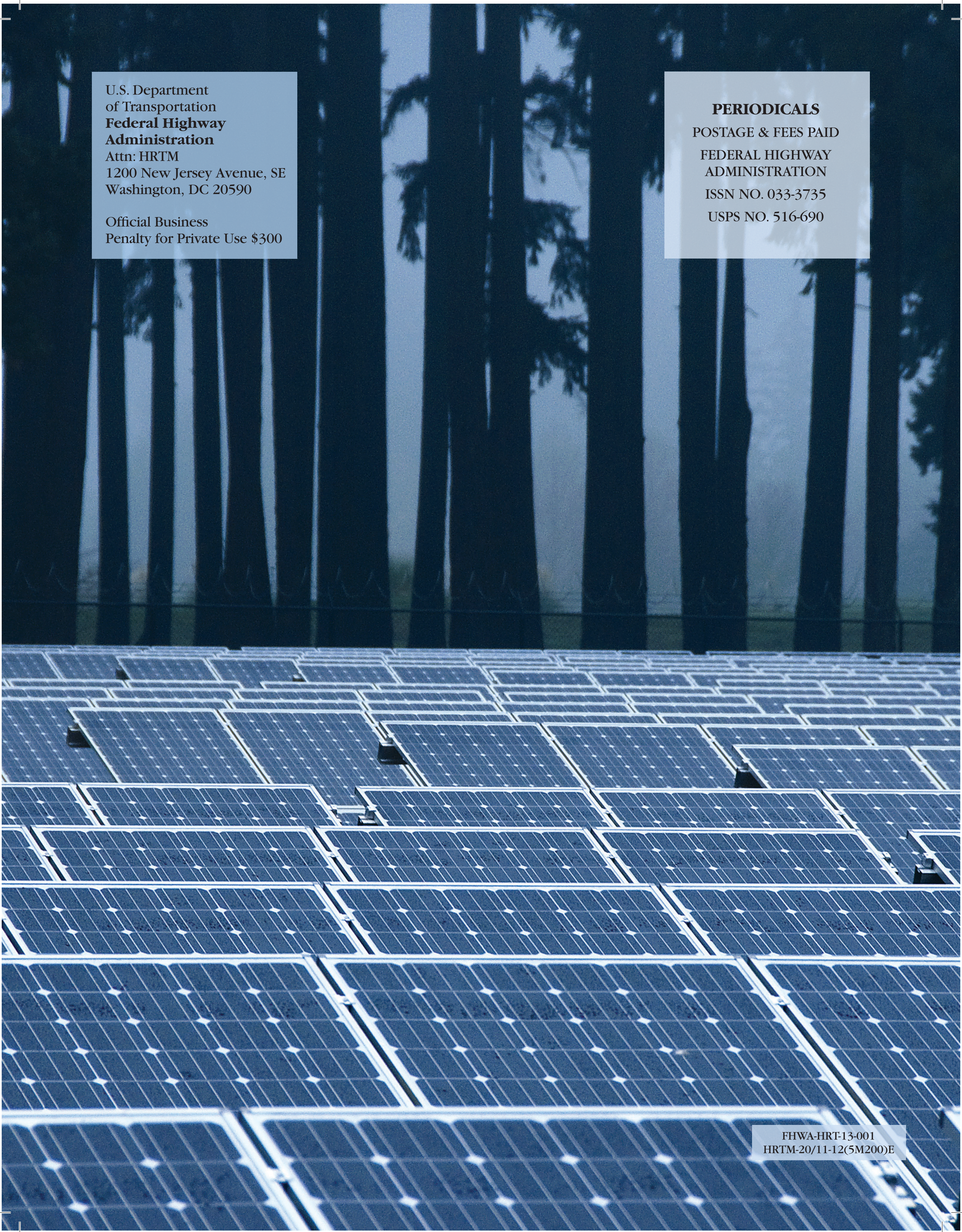


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