SHRP2 SOLUTIONS

TOOLS FOR THE ROAD AHEAD

2016 IMPLEMENTATION HIGHLIGHTS

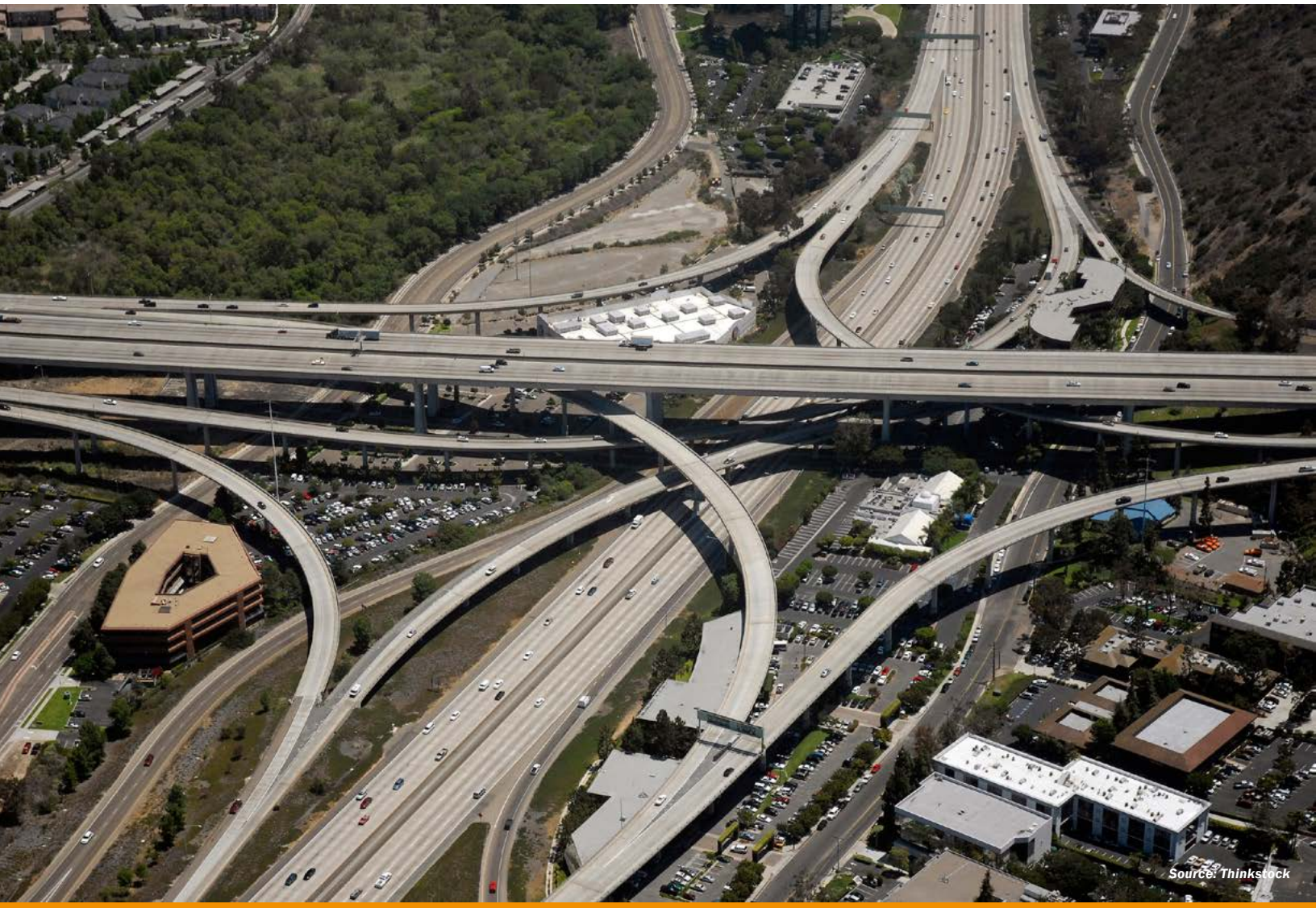
INNOVATE. IMPLEMENT. IMPROVE.

U.S. Department of Transportation
Federal Highway Administration

AASHTO

Working In Partnership

The second Strategic Highway Research Program (SHRP2) is a partnership of the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the Transportation Research Board (TRB). TRB completed the research, and now FHWA and AASHTO are jointly implementing the resulting SHRP2 Solutions that will help the transportation community increase safety, enhance productivity, boost efficiency, and improve the reliability of the nation's highway system.



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U.S. Department of Transportation
Federal Highway Administration

AASHTO

www.fhwa.dot.gov/GoSHRP2 · http://SHRP2.transportation.org

Turning Innovation into Action

The implementation of the second Strategic Highway Research Program (SHRP2) is a strong partnership between the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO). We are proud to share this report, which highlights some of the most significant 2016 accomplishments of our combined work implementing SHRP2 Solutions across the country.

The SHRP2 has yielded more than 60 transportation innovations to address state-specific and sometimes regional transportation challenges. With coordinated efforts from FHWA, AASHTO, and transportation agencies across the country, these solutions have moved rapidly out of research and into the real world. Nearly 90 unique transportation agencies are fueling the spread of innovation through training sessions and product demonstrations. State departments of transportation, metropolitan planning organizations, and other regional and local agencies are sharing valuable technical and project experience in field reports and case studies from the more than 430 SHRP2 projects underway in all 50 states, the District of Columbia, and Puerto Rico.

The majority of this product deployment was spurred by the Implementation Assistance Program (IAP), which is designed to systematically support the adoption of SHRP2 Solutions via direct funding and technical assistance. The IAP included seven rounds of assistance, each supporting a distinct set of SHRP2 Solutions. In this report you will find feature stories about projects launched in Rounds 4 through 6, from summer 2014 to December 2015. You also will read updates on projects initiated in earlier rounds.

The SHRP2's success is a testament to the strong partnership between FHWA and AASHTO. From implementation planning to the launch of the IAP in 2013 to having 430 SHRP2 projects in the field – we remain committed partners in innovation. We are gratified to see transportation agencies using new SHRP2 products and procedures in everyday practice and working together to pursue innovation. We are especially proud of the path SHRP2 is creating for future innovation programs.

But that is not the end of our story. We plan to follow the SHRP2 projects beyond completion to understand the impact of SHRP2 Solutions on the state of the practice and how we are changing the culture of the transportation industry. Look for these SHRP2 success stories in the next edition of the *SHRP2 Implementation Highlights* annual report.

David Bernhardt
President, AASHTO
Commissioner of Maine Department of Transportation

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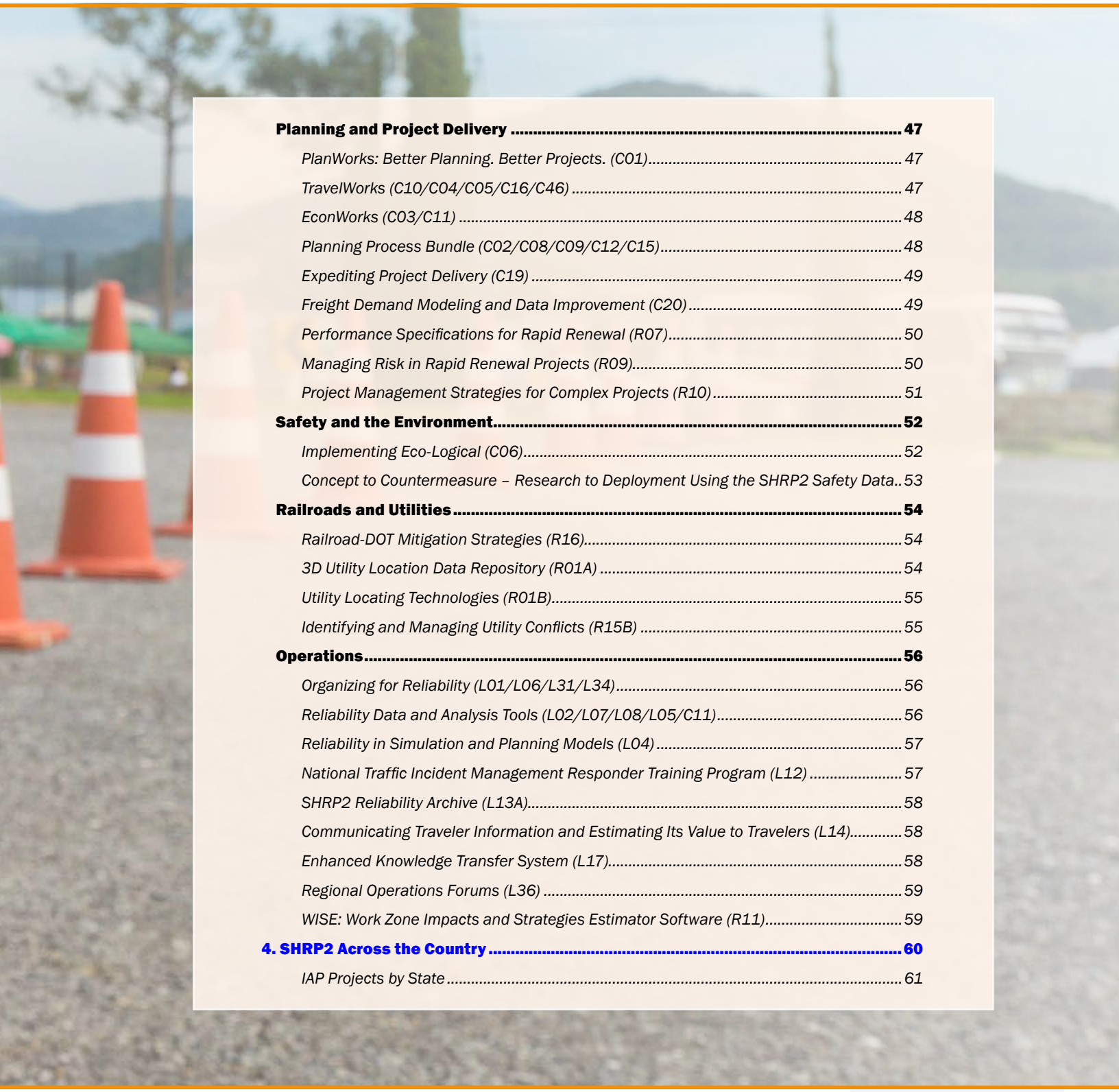


Save Lives **Save Money** **Save Time**

Innovations to help America improve safety; rebuild and repair aging roads and bridges; and reduce congestion.

1. SHRP2 Updates and Results

INNOVATE.

America's highway system provides vital links among all modes of transportation and supports everything we do. Like everyone else, transportation professionals and policymakers are keenly aware when the system is not working as well as it could. Crash fatalities and injuries, deteriorating bridges and pavements, relentless congestion, and insufficient capacity to sustain a growing population – these all affect the nation's economy and quality of life. Our customers demand longer-lasting facilities, less-costly and more expeditious projects, and reduced highway crashes and fatalities. These are the challenges SHRP2 was designed to meet.

Mandated by Congress in 2005, SHRP2 sought to address these pervasive highway transportation problems on a scale never before attempted. Building on the success of the first Strategic Highway Research Program, SHRP2 broadened its focus to address four strategic areas: Safety, Renewal, Reliability, and Capacity. The research, conducted by the Transportation Research Board (TRB), resulted in more than 60 real life solutions.

IMPLEMENT.

The Federal Highway Administration (FHWA) and the American Association of State Highway Transportation Officials (AASHTO) created a partnership dedicated to implementing those solutions. An authorized budget of just over $170 million supports SHRP2 implementation activities – with approximately $60 million of that contributed by the state departments of transportation from their research funds.

Since the 2015 report, ***SHRP2 Moving Us Forward***, the program has progressed along the implementation continuum. Many SHRP2 Solutions have been offered multiple times through the SHRP2 Implementation Assistance Program (IAP) – graduating from initial proof of concept pilots to lead adopter or user incentive offerings. In those cases, the products were fine-tuned by practitioners to better meet real world challenges.

SHRP2 implementation is now at its highest level of activity. All SHRP2 Solutions – more than 60 innovations – are in use on real-world applications. In June 2016, FHWA and AASHTO announced the recipients of the seventh and final round of the IAP, and those new projects are getting underway.

IMPROVE.

Implementation activities at agencies across the nation are at a peak, with more than **430 transportation projects** using the new SHRP2 products now underway to improve our nation's highway system. In the following pages, you will see highlights of some of the 2016 implementation successes, as well as updates on projects featured in the 2015 report. These stories show how SHRP2 continues to take on the nation's transportation challenges with new technologies; fresh insight; and marked improvements to organizations, systems, and training.

Future reports will focus on the products featured in the final round of the IAP and the ongoing success of all SHRP2 Solutions in addressing America's transportation challenges.

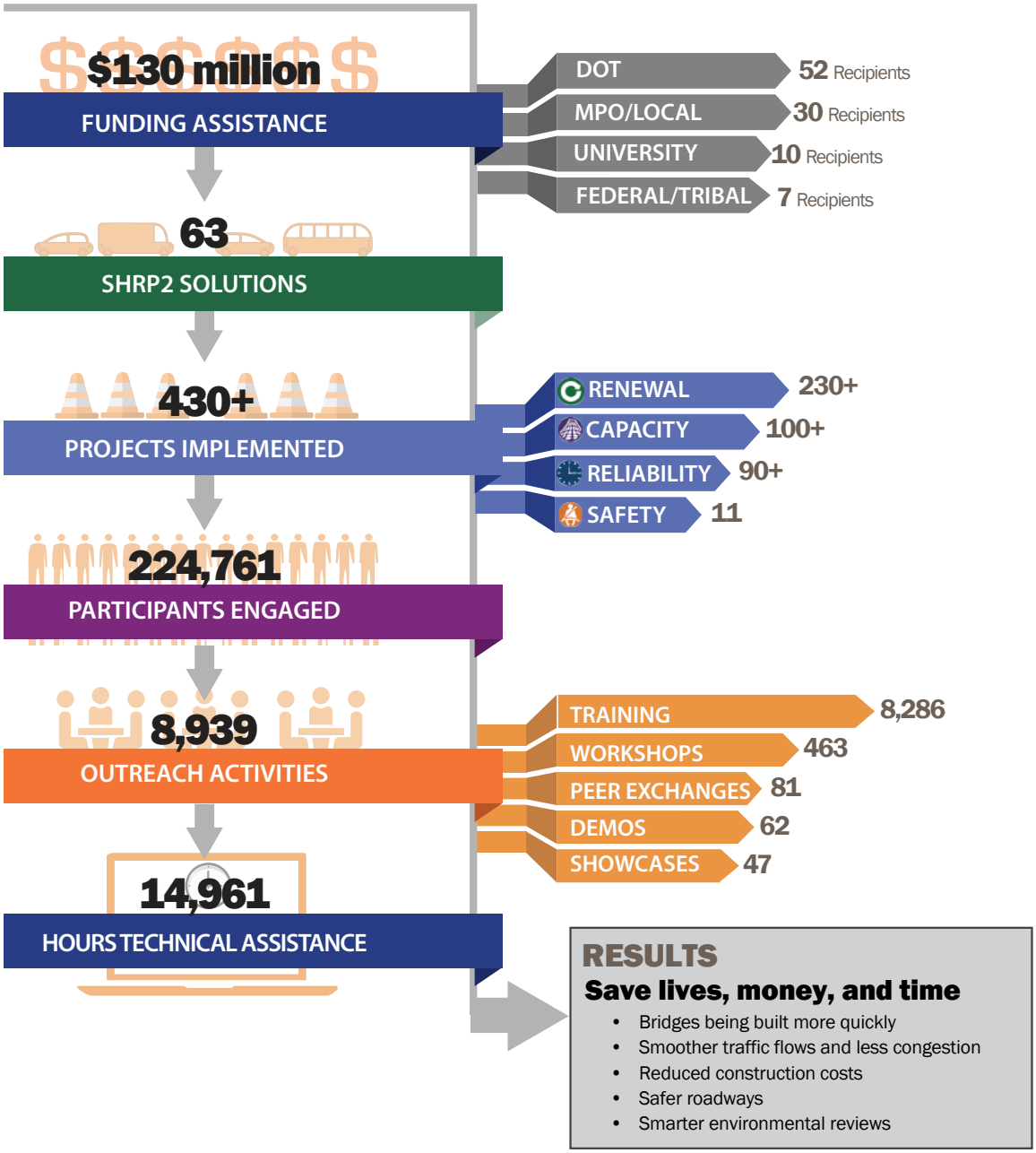
From Research into Practice: SHRP2's Implementation Progress

RENEWAL
Enabling faster, minimally disruptive, and longer-lasting infrastrcuture improvements.

CAPACITY
Working to build greater collaboration in transportation decision making.

RELIABILITY
Championing predictable travel times.

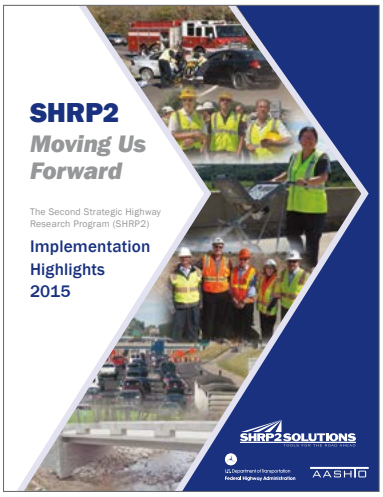
SAFETY
Seeking to identify the behaviors that cause and avert collisions.



The data shown here and throughout this report are as of November 1, 2016.

Keg Creek Bridge in Pottawattamie County, Iowa.

What's Happened Since 2015? Ongoing Progress and Success



Last year's report, *SHRP2 Moving Us Forward: Implementation Highlights 2015*, showcased the successful deployment projects of four SHRP2 Solutions in Rounds 1 through 3 of the Implementation Assistance Program (IAP). Over the past 12 months, this progress has continued, and the implementation focus has shifted to institutionalizing and expanding the reach of these SHRP2 Solutions. This update provides insight into these efforts and the inroads made during 2016 – along with a preview of a few 2017 activities.

The transportation community continues to embrace the new approaches offered through SHRP2 products, making it possible for these products to take root within institutions and become fundamental to successful day-to-day operations.

Innovative Bridge Designs for Rapid Renewal (R04)

The SHRP2 Solution, ***Innovative Bridge Designs for Rapid Renewal,*** uses a variety of accelerated techniques, including the use of precast bridge superstructures that are often constructed right next to the existing bridge, to speed construction and reduce road closure time. These techniques significantly reduce the inconvenience to motorists, compared to the much longer time bridges are closed when more traditional reconstruction methods are used. Following the highly successful completion of IAP-funded projects in eight states in 2015—Arizona, California, Kentucky, Maine, Michigan, Missouri, Rhode Island, and Wisconsin—the SHRP2 focus on Prefabricated Bridge Elements and Systems (PBES) implementation has shifted to engage state DOTs in the standard practice of using accelerated bridge construction (ABC) technology.

Implementation efforts now emphasize institutionalizing the design and construction options within the *Innovative Bridge Designs for Rapid Renewal: ABC Toolkit*. During 2016, the SHRP2 product team began updating the training material for a 1-day workshop to teach state DOTs how to implement PBES standards in routine bridge design work. Thus far, 22 states have

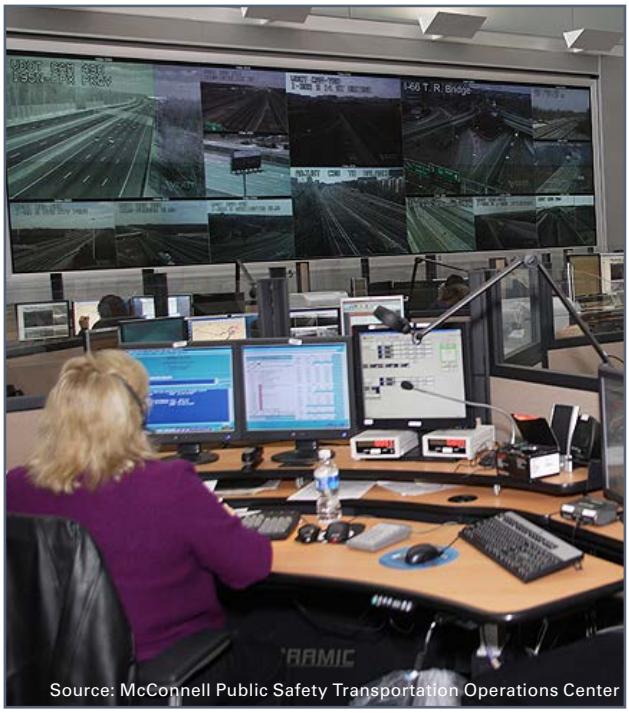
expressed interest in hosting the training workshop, and the team anticipates more states will sign up as workshop deployments progress through 2017. In addition, the team proposes supporting a demonstration project in 2017 that will develop standard bridge plans to be incorporated within the DOT's Bridge Design Manual. Webinars on PBES deployment and lessons learned from IAP projects will be developed as well.

Organizing for Reliability (L01/L06/L34/L31)

In the 2015 report, SHRP2's ***Organizing for Reliability*** projects in Tennessee, Ohio, and California were highlighted. During 2016, all three states began or completed transportation systems management and operations (TSMO) plans to help institutionalize TSMO programs in their agencies; and all three states are working to change the culture within their DOTs to embrace the TSMO philosophy. In addition, this year four more states completed TSMO program plans: Maryland, Iowa, Arizona, and South Dakota.

This SHRP2 Solution, *Organizing for Reliability*, fosters more reliable travel times by helping transportation agencies advance business processes and organizational capabilities for operations. Nearly 50 state and local agencies have now implemented the TSMO organizational capability assessment tool (L06). As part of the product implementation phase, the SHRP2 Reliability team developed and published a primer based on the product, *Guide to Integrating Business Processes to Improve Travel Time Reliability* (L01) entitled *Improving Business Processes for More Effective Transportation Systems Management and Operations*.

Additional work is ongoing to further support *Organizing for Reliability*. The team is creating a workshop to advance and promote L01. The workshop will guide agencies in using the web-based version of the guide, *E-Tool for Integrating Business Processes for Systems Operations* (L34), leading to customized recommendations based on user-provided input about its scenario.



Staff in the McConnell Public Safety Transportation Operations Center monitoring roadways in northern Virginia.

Drawing from the research conducted under SHRP2's *Business Process Capability Maturity Frameworks* (L34B), FHWA has developed a set of tools to help states and metropolitan agencies address process improvements that are critically needed to effectively deploy TSMO strategies.

These tools, collectively known as the "Business Process Frameworks," allow agencies to assess their capabilities in six program areas that are fundamental to effective TSMO: traffic management, planned special events, road weather management, traffic incident management, traffic signal system management, and work zone management.

These frameworks and the organizational assessment tool (L06) were developed based on a capability maturity model used prominently in the information technology sector. They include a set of assessment questions to guide an agency or region in determining its level of capability, and assist in identifying steps that can improve capabilities in each area.

Fifteen agencies were recipients of SHRP2 implementation assistance to become lead adopters and users of *Implementing Eco-Logical* in Round 1 of the SHRP2 Implementation Assistance Program.

Implementing Eco-Logical (C06)

During 2016, Maine and Michigan, two IAP states continued to apply ***Implementing Eco-Logical*** to improve the efficiency of their business processes and decrease the amount of time needed for environmental impact reviews. SHRP2's *Implementing Eco-Logical* brings together transportation agencies, resource agencies, and other key stakeholders to identify and map critical ecological areas. Through this collaborative process, environmental impacts can more quickly be addressed before, or during, the planning stage of transportation projects.

Under a SHRP2 implementation assistance award, Maine Department of Transportation (MaineDOT) continues its efforts to streamline project reviews that may affect distinct population segments of Atlantic salmon and critical habitat designated under the Endangered Species Act. Since 2015, when the U.S. Fish and Wildlife Service completed 10 consultations, MaineDOT has added an additional staff person with the goal of doubling the number of consultations. With the additional staff and other resources provided through SHRP2 implementation assistance, approximately 60 percent of MaineDOT's projects will be able to be processed within 30 days of submittal. As a result, costs associated with delays, redesigns, and redundant reviews will be largely eliminated.

Michigan also made important advances in 2016, during which time it finalized its Interstate 75 (I-75) conservation plan and prepared the plan for distribution via the Southeast Michigan Council of Governments website. This document will help transportation planners understand the ecological challenges of building transportation facilities in the Western Lake Erie Basin area. The report identifies priority conservation topics and actions to minimize some of the conservation threats in the area.

Michigan Department of Transportation moved forward with incorporating conservation priorities into the planning process for the next round of I-75 reconstruction projects by working with the project engineers to enlarge culverts in ecologically sensitive areas for improved wildlife passage. Wildlife fencing and a wildlife-friendly curb at priority crossing locations will help reduce wildlife mortality. The DOT is planning its largest threatened plant mitigation effort for the remaining construction projects, where 16,000 rare and state-listed threatened plant species will have seeds collected for replanting, plant relocation to other conservation lands, and possible storage of topsoil for re-application following construction. In addition, water quality improvements are anticipated from earthworks designed to accept storm water run-off from the road and trap sediment, preventing it from entering local waterways.

This Eco-Logical Starter Kit is a major resource for case studies, which illustrate how various state DOTS, MPOs, and other agencies have implemented specific steps of Eco-logical. In Virginia, the Charlottesville-Albemarle Metropolitan Planning Organization case study shows an example of *Implementing Eco-Logical* in steps 1-4, while a case study featuring the Colorado Department of Transportation's Interstate 70 Mountain Corridor demonstrates steps 7-9. A soon to be released case study highlights the North Carolina Department of Environmental Quality's In-lieu Fee Program and its implementation of steps 5-6.

Effective traffic incident clearance helps to improve safety and reduce congestion delays.

National Traffic Incident Management (TIM) Responder Training Program (L12, L32A/L32B/L32C)

The end goal for the ***National Traffic Incident Management (TIM) Responder Training Program*** is to train all 1 million emergency responders in the United States, and 2016 saw important advances toward that goal. TIM responder training helps to ensure a well-coordinated response to traffic incidents, achieving faster clearance and improved safety for both responders and motorists. By the end of 2016, this initiative had reached a total of more than 210,000 responders, including more than 12,000 responders who trained online. This is a notable increase from the total of 128,000 trained from August 2012 through 2015.

The SHRP2 TIM program leads are aggressively pushing forward with their quest to train responders for safer, faster, and more integrated incident response, and state and local agencies—as well as partner organizations—are eagerly taking up this challenge. For example, during 2016, the Oklahoma Traffic Incident Management Coalition Team launched a website, www.OkTIM.org, to promote effective TIM strategies. This site includes the Traffic Incident Management Basic Training and Traffic Incident Management Train-the-Trainer workshops. In addition, 2016 also saw the Towing and Recovery Association of America, Inc. (TRAA) announce an initiative to encourage all TRAA members, state towing associations, and their members to host the 4-hour version of the *National TIM Responder Training*.

In early Fiscal Year 2016, FHWA Office of Operations launched the third and final product under the SHRP2 L12/L32 suite of products, the *National TIM Responder Training Program Post-Course Assessment Tool* (L32C). The assessment tool provides federal, state, and local TIM operations agencies with the ability to assess student learning and evaluate the impacts that the training has had on operations, as well as assess the return on investment in TIM training. To date, there has been 640 registrations and responders have completed training surveys and tests at the 4 different training assessment levels.

Preliminary results have all been positive. The average post-test score for responder training classes is 76 percent, which is a 32 percent improvement over the average pre-test score of 43 percent. This indicates that students are learning and retaining the course information. Additionally, 75 percent of individuals felt an increase in their overall level of safety when working at traffic incident scenes after having received the training.

In August, the *National TIM Responder Training Program* reached a major milestone — **having trained 200,000 responders in all 50 states, the District of Columbia, and Puerto Rico.** Nearly 30 organizations and associations from the emergency responder community attended an event at the U.S. Department of Transportation on August 10, 2016 to commemorate this achievement.

SHRP2 Solutions have the potential to change how transportation agencies and other stakeholders plan for, design, build, and operate the nation's highway system.

2. Featured SHRP2 Solutions

Bridge removal project north of Ontario, Oregon on US 30.

> *"Our vision for this SHRP2 Solution was for agencies and railroads to identify and overcome points of conflict through better communication and coordination."*
>
> — Pam Hutton
> SHRP2 AASHTO Implementation Manager

Railroad-DOT Mitigation Strategies (R16)

Where Road Meets Rail

State Transportation Agencies, Railroads Work Together to Improve Efficiency, Reduce Project Risk

Railroads move more than 1.7 billion tons of freight and more than 30 million passengers across the United States each year, according to the Bureau of Transportation Statistics. Meanwhile, the nation's roadways support the movement of 12.4 billion tons of freight and more than 260 million vehicles. Railroads and roadways are critical to keeping people and goods moving, but these vital transportation systems can come to a halt when the rail and road meet during road improvement projects.

This scenario happens thousands of times each year as transportation agencies undertake projects to build roads that cross over, under, or run parallel to railroad rights of way. Each project requires coordination and agreements among the agencies and the railroad companies. Transportation agencies have varying requirements and business processes for their construction projects, often based on the source of the funding for each project, whether federal, state, or local. These requirements can vary from state to state. Combine these requirements with the railroads' own policies and guidelines – and the result can be lengthy delays in reaching agreements and approvals for road projects to proceed.

SHRP2's ***Railroad-DOT Mitigation Strategies*** (R16) encourages transportation departments and railroads to work together to identify issues and negotiate agreements to expedite development of highway projects. "Our vision for this SHRP2 Solution was for agencies and railroads to identify and overcome points of conflict through better communication and coordination. When agencies become collaborative partners with rail companies, that partnership will benefit agencies, railroads, and the public by saving time and money," said SHRP2 AASHTO Implementation Manager Pam Hutton.

The SHRP2 product was crafted to overcome communications hurdles that have long existed among railroads and transportation agencies. Ahmer Nizam, the technical services and business manager for Washington State Department of Transportation's (WSDOT) design office, has eight years of experience using the *Railroad-DOT Mitigation Strategies*. "WSDOT has been involved with R16 since the research phase in 2008," said Nizam. "Being part of the process – particularly having regular interaction with senior railroad managers and directors – was very valuable in addressing ongoing coordination challenges and refining our approach."

The model agreement library, tools, and training developed under the *Railroad-DOT Mitigation Strategies* enables agencies and railroads to identify sources of conflict and develop memorandums of understanding for projects and programs. With this series of model agreements, sample contracts, training materials, and standardized best practices, public agencies and railroads are able to apply a structured protocol that helps them identify and overcome conflicts. Model agreements are templates for different types of legal documents that reflect railroad and public agency perspectives, processes, budgets, funding, and good practices.


Source: AHTD

The Arkansas State Highway and Transportation Department is using tools from *Railroad-DOT Mitigation Strategies* to coordinate projects involving railroads.

For example, the template for a master project agreement includes a series of standard legal provisions common to nearly all projects and incorporates them into one overall agreement between the railroad and the agency. With a master agreement in place, the railroad can review individual project plans more quickly because it is assured that its basic concerns have already been addressed, so the railroad and highway agency only need to negotiate unique details. Other types of model agreements address resurfacing, overpasses, the use and positioning of warning devices,

laying pipes and wires, and other construction and engineering-related procedures and processes.

A Solution for Freight and Passenger Rail

In a case involving the Florida Department of Transportation (FDOT), CSX Transportation has a requirement to provide a flagger when the DOT performs any road work that comes into contact with the rails or the railroad's right of way. However, the CSX flaggers were not always available on the dates required, causing construction projects to encounter costly delays. FDOT resolved this challenge using facilitation services provided through SHRP2's Implementation Assistance Program and model agreements laid out under the *Railroad-DOT Mitigation Strategies.* FDOT met with the railroad and initiated a solutions-oriented conversation about the conflicting requirements.

The result was an innovative agreement with the railroad in which FDOT pays CSX for full-time, on-call flaggers to be present at rail locations where road work is underway. Since entering into this agreement, FDOT has saved nearly a quarter of a million dollars per year on projects involving railways – not including the savings from financial claims by contractors who had been subject to unexpected and costly delays when flaggers were not available. In addition, because FDOT provides a list of project priorities to CSX as part of the master agreement, the railroad is able to plan staffing more effectively. The agreement better serves the needs of the railroad and FDOT.

Although originally designed to help state agencies work with railroads that transport freight, the components of the *Railroad-DOT Mitigation Strategies* is also effective for working with passenger rail providers. The Pennsylvania Department of Transportation (PennDOT) applied those tactics to its work with Amtrak, the National Railroad Passenger Corporation.

PennDOT employed the SHRP2 *Railroad-DOT Mitigation Strategies* in a Pilot Partnering Initiative for Programmatic Solutions. This pilot brought together Amtrak, PennDOT, FHWA, and the Federal Railroad Administration to coordinate highway-passenger rail projects. "At our very first meeting with PennDOT and Amtrak, all parties laid out their respective processes, requirements, and concerns. In one case, there were four sets of requirements that needed to be followed depending on the source of funds, and this was causing a great deal of confusion," said Joseph Taylor, federal-aid programs engineer and FHWA's project manager for the SHRP2 *Railroad-DOT Mitigation Strategies*. "The more they talked, the more you could see communication happening – the DOT and Amtrak were actually coming up with their own solutions for concerns related to procedures, environmental issues, overhead bridge concerns, and other topics. They are

Community of Interest Brings Agencies Together to Meet Challenges

Initially established during the research phase of SHRP2, FHWA and AASHTO are working in partnership to revitalize a Community of Interest among state transportation agencies and railroads. A kick-off webinar was held on September 24, 2016, to support this national effort to improve coordination and communication. Two face-to-face meetings and five virtual meetings are planned over the next two years. The first face-to-face meeting will occur within the first quarter of 2017.

The Community of Interest serves as a collaborative forum to share successful practices, promote the dissemination of standard practices and better communications nationally to benefit other public transportation agencies and railroads facing similar challenges. Participation in the kick-off webinar included the Burlington Northern Santa Fe Railway, CSX Transportation, Genesee & Wyoming Inc., and the American Public Transportation Association, along with the departments of transportation from Arkansas, Colorado, Florida, Idaho, Iowa, North Carolina, Pennsylvania, and South Carolina.

now drafting a master agreement while they continue to collaborate and discuss solutions."

Reduced Project Delivery Time and Streamlined Business Processes

PennDOT is not alone in seeing significant time and cost benefits from using the various components of this SHRP2 Solution. The Connecticut Department of Transportation (ConnDOT) has a master agreement in place for all work performed by ConnDOT that involves Amtrak rights of way. As a result, ConnDOT has reduced project delivery time to less than one month, where previously it could take longer than a year.

Similarly, under a master agreement with Norfolk Southern and CSX, Tennessee DOT sends preliminary construction plans to affected railroads during the early design phase for review and approval. This allows for early identification of problems the railroad may have with the plans, thereby helping the agency reduce project time.

The Texas Department of Transportation (TxDOT) has used the products to forge agreements with several railroads that have streamlined business processes and provided significant time and cost savings. "TxDOT on average executes 180 to 200 construction and maintenance agreements annually. We are able to reduce the time to get projects approved from 12 or more months down to a few weeks for the simple projects, such as maintenance or pavement preservation," said Robert Travis, branch manager of rail highway safety at TxDOT. "For larger agreements we have seen a reduction in approval times from more than 8 months to 4 months or less."

"We have on the order of 35 states engaged in or expressing interest in using this SHRP2 product," said Pam Hutton, pointing to the reductions in cost, delay, and project risk that implementers have realized as proof of the value of the mitigation strategies. "We're talking about reductions of months of time for each and every construction project we've had – that's huge."

On the Fast Track to Mainstream Use

every day counts
An Innovation Partnership with States

Every Day Counts (EDC) is an initiative launch by the FHWA in cooperation with AASHTO to speed up the delivery of highway projects. The SHRP2 Solution, *Railroad-DOT Mitigation Strategies*, is also an EDC solution, launched in the third round of EDC (2015 – 2016). EDC-3 resulted in nine states having institutionalized *Railroad-DOT Mitigation Strategies*. The Every Day Counts website has additional information, including progress reports and a recording of the 2015 EDC Regional Summit.

Improving coordination where highways and railroads intersect.

Using Emerging Technologies to Inspect Infrastructure

SHRP2 Renewal research was designed to develop the necessary tools to "get in, get out, and stay out" when renewing the existing highway infrastructure. The objective was to find technologies and processes that would minimize the impact of road reconstruction projects on highway users and result in better-constructed, longer-lasting facilities. Nondestructive testing (NDT) technologies encompass a wide group of analysis techniques for evaluating the properties of a material, component, or structure without causing damage. The technologies available today employ light (infrared and lasers), sound (vibration monitoring tools and radar), magnetism, and electricity to examine what really goes on inside roadway structures. As an added benefit, these rapid inspection techniques can be used to extend the lives of existing, older facilities and ensure that new construction is of the highest quality, requires minimal upkeep, and will last many years.

"We're seeing that these technologies may have multiple uses, and we're beginning to see different ways the same technology can be used to inspect different infrastructure types, whether bridges, tunnels, or asphalt, which makes investing in the technology more cost effective," said Pam Hutton, AASHTO's SHRP2 implementation manager.

SHRP2 research resulted in six products that help practitioners during specific phases of maintenance and reconstruction:

1. **Nondestructive Testing for Concrete Bridge Decks** (R06A) helps agencies quickly and safely test concrete bridge decks.
2. **Techniques to Fingerprint Construction Materials** (R06B) supports quality control for materials used during construction.
3. **Technologies to Enhance Quality Control on Asphalt Pavements** (R06C) allows contractor and agency inspectors to conduct uniformity measurements on new hot-mix asphalt layers during and shortly after placement.
4. **Advanced Methods to Identify Pavement Delamination** (R06D) explains how to use NDT technologies to detect debonding and stripping (i.e., types of separation) between layers of hot-mix asphalt.
5. **Tools to Improve PCC Pavement Smoothness during Construction** (R06E) detects surface irregularities during concrete paving operations, when they can be corrected before the concrete hardens.
6. **Nondestructive Testing for Tunnel Linings** (R06G) monitors the condition and deterioration of tunnel linings quickly and with minimal traffic disruption.

Three NDT Solutions are Benefiting Transportation Agencies Across the Country

Nondestructive Testing for Concrete Bridge Decks uses ground penetrating radar equipment mounted on mobile platforms to examine at highway speeds the level of rebar corrosion in bridge decking—eliminating the need for lane closures.

Technologies to Enhance Quality Control on Asphalt Pavements explains how infrared imaging is used successfully to detect pavement temperature irregularities during application, allowing contractors and agencies to identify problems and resolve them in real-time.

Tools to Improve PCC Pavement Smoothness during Construction details how infrared technology is being used to correct asphalt temperatures as it is applied, creating stronger, longer-lasting pavements.

While all of these benefits ultimately provide a more comfortable ride for drivers, they also offer more efficient construction processes that translate into fewer traffic delays, reduced labor hours (saving thousands of dollars in construction costs), and greater overall road safety due to fewer construction zones for motorists to navigate.

Classroom training for IAP recipients for *Nondestructive Testing for Concrete Bridge Decks*.

Nondestructive Testing for Concrete Bridge Decks (R06A)

New Applications for Existing Technologies Lead to Improved Bridge Deck Maintenance

One of the biggest problems affecting bridges in the United States is the number of concrete bridge decks in poor structural condition. According to the national inventory, the average age of bridges is more than 40 years. Traditional methods for identifying problems include coring, manually dragging chains across bridge decking, or striking the deck with hammers while listening for changes in the sound of the concrete. These techniques are either destructive to bridge decks and require more staff time and lane closures, or are subjective, as they depend heavily on the inspector's skills. These methods are unsafe for workers and time consuming for motorists and inspectors.

"The safety of both inspection crews and motorists is paramount. Finding methods to inspect bridges safely, accurately, and with minimal impact on mobility is an important element in the SHRP2 Nondestructive Testing (NDT) suite of products," said Hoda Azari, the program manager for nondestructive evaluations at FHWA. "Current methods can be disruptive to traffic flow and provide incomplete and subjective information about what's really going on beneath the surface."

The SHRP2 Solution, ***Nondestructive Testing for Concrete Bridge Decks*** (R06A), has identified and supported pilots for a series of advanced nondestructive technologies. Unlike traditional methods, these technologies can perform testing quickly, accurately, and in a manner that does not impact the integrity of a bridge's decking but does provide detailed information about defects. The SHRP2 research identified a set of eight advanced technologies for inclusion in the SHRP2 NDT products (see panel). These technologies are useful in examining bridges for specific, common issues that can lead to degradation and destruction of a bridge deck, namely, corrosion of the rebar rods used to strengthen concrete structures; delamination, or the separation of the two layers of concrete at the level of rebar; vertical cracking; and spalling, or the chipping or fragmenting of a bridge deck's surface when corrosion, cracking, or delamination are not timely detected and treated.

Although the uses for these technologies are new, the concepts behind them — ultrasonic sound waves, infrared (IR), and magnetic and electrical pulses — have long been proven effective as methods for detection in fields ranging from medicine to military defense.

As with most SHRP2 products, the IAP recipients are using the NDT solutions in different ways depending on their needs and requirements. For example, the Florida Department of Transportation (FDOT) first used IR technology to determine the location, depth, and extent of cracks, voids, and other internal decking defects

flagged by inspectors. The agency then followed up with ground-penetrating radar and impact echo technologies to confirm the findings of the IR inspection. While FDOT was using these new technologies, the agency discovered something unexpected, according to Ross Hammock, FDOT District 2 engineering section manager.

"While we were using the IR cameras in the field, we decided to take a look at the underside of the deck and noticed that we were able to see some delaminations and incipient spalls," Hammock explained. "It makes sense, because in Florida the chlorides are absorbed from the underside due to the salt water environment, whereas in the northern states, they have the de-icing salts that are absorbed from the top." This led the agency to conclude that, in Florida, the IR technology may have a role in examining the health of substructure components of FDOT's bridges, since these components are subjected to chlorides in the salt water.

The Indiana Department of Transportation (INDOT) recently completed its efforts to apply an air-coupled, ground-penetrating radar (GPR) array and IR technologies to inspect 46 bridge decks across the state. The GPR system was mounted on a vehicle, enabling the data collection to proceed at highways speeds and limiting the need for lane closures. "We wanted high-speed data collection for network-level assessments," said Jeremy Hunter, bridge design manager for INDOT. "After the SHRP2 demonstration, we determined that GPR and IR would be the most likely to provide the necessary data at highway speeds." As a result, INDOT performed IR scanning at low speed and applied GPR at highway speed.

"We had great results with the GPR data collection," Hunter said, noting that the data was collected quickly and efficiently. In addition, with no need to close lanes, both safety and full mobility were maintained during the inspection process. A final report on the IR data collection and results at low speed is will become available in 2017.

The findings from the GPR implementation were very positive. INDOT estimated that the traditional sounding method costs just over $1,000 per bridge. With the GPR scanner costing about $46,000, the equipment would pay for itself after inspecting 46 locations. An additional benefit is significant time savings. The agency estimated it would take about 23 nights to

NDT Technologies

IR Camera.

Impact Echo (IE) – a seismic or stress-wave-based method used to detect defects in concrete, primarily delamination, due to variations in the vibrations reflected from subsurface materials.

Ultrasonic Surface Waves – uses sound waves to assess concrete degradation and estimate the depth of vertical cracks within bridge decks and concrete structures.

Impulse Response – uses a low-strain impact to send vibrations through concrete. These vibrations are used to locate delaminated concrete, vertical cracking, and regions containing voids that can lead to spalling.

Ground-Penetrating Radar (GPR) – transmits high-frequency electro-magnetic waves into the structure and detects the reflected signals, which can be used to identify and map areas with a high likelihood of corrosion-based deterioration such as corroded rebar, vertical cracking, delamination, and spalling. Notably, GPR can be ground-coupled (i.e., cart-mounted) or air-coupled (i.e., vehicle-mounted), meaning data can collection be conducted at walking speed or at highway speeds, respectively.

Infrared (IR) Thermography Analysis – uses infrared imaging to detect temperature variations on the surface resulting from differences in the temperature of sub-surface materials when delamination and cracking are present.

Electrical Resistivity – used to evaluate the existence of water, chlorides, salts, and other corrosives that degrade concrete. This technology can be used in tandem with other corrosion assessment techniques such as half-cell potential to provide a more comprehensive assessment of the level of corrosion present.

Galvanostatic Pulse – uses electrical pulses to assess the presence and level of corrosion in steel-reinforced concrete structures.

Half-Cell Potential – uses electrical currents to identify the presence of corroded rebar in reinforced concrete structures.

conduct sounding on 46 decks. By comparison, GPR scanning only took one to two nights to complete 46 decks, because it is performed at highway speed and does not disrupt traffic.

"The time savings, safety, and better overall condition assessment are the benefits of doing high-speed GPR versus sounding. We sounded several bridges on Interstates 70 and 65 between the north and south splits last summer, and it was very difficult to hear delaminations with traffic running in the adjacent lanes; therefore, we believe that GPR provides a higher quality deck survey in high-traffic areas," Hunter said.

Michael Todsen of the Iowa Department of Transportation's Office of Bridges and Structures agrees: "The time to collect data using impact echo technology appears comparable to hand sounding, but with less effort and better record keeping. As far as the operation and data collection are concerned, our field staff is enthused about using the equipment. We think the products will be very useful." But Todsen added one caution, "One of the key factors is clearly determining what information you want to collect and what technologies can best provide it."

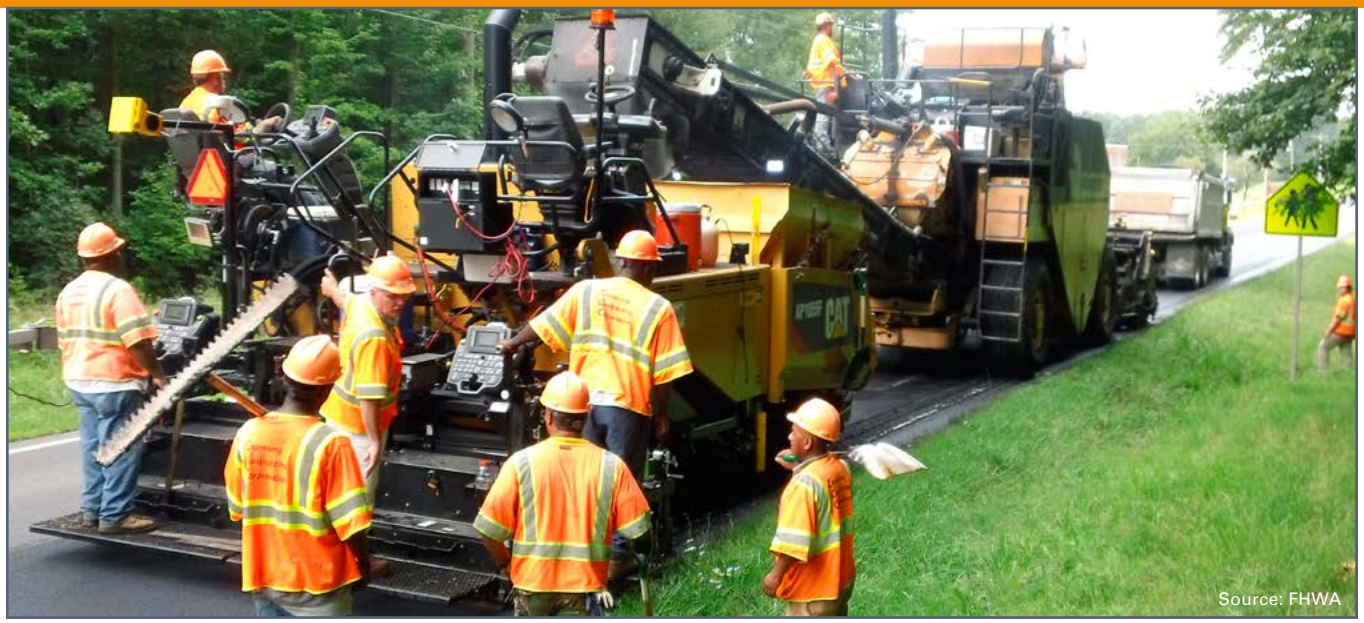
Like Florida, Iowa also began using an impact echo system during 2016. The Iowa DOT wanted to identify deterioration in bridge decks beneath a dense concrete overlay. According to Todson, the agency plans to perform the data collection with bridge maintenance field staff and perform the analysis with central office engineering staff. The field staff will be trained by the central office staff. In the end the agency will have a core group of people who understand both the technology and the implementation process, and will be able to share their knowledge and lessons with other staff.

Those wishing to join Florida, Indiana, and Iowa in exploring the possibility of using any or all of the NDT products are invited to begin with the Nondestructive Evaluation (NDE) Web Manual. The interactive web-based manual allows users to search for technologies relevant to specific materials, types of deterioration, or infrastructure elements. The manual provides concise descriptions of each technology, including the physical principle behind the technology, performance attributes and limitations, best practices for test procedures and protocols, and sample applications and results. The manual is available at https://fhwaapps.fhwa.dot.gov/ndep/.

"We look at this implementation as an opportunity to update and improve current practices and to deliver more detailed results," Todsen said, highlighting the improved accuracy and efficiency of the inspection process using the SHRP2 products.

In addition to Florida, Indiana, and Iowa, the other five lead adopter states for the SHRP2 *Nondestructive Testing for Concrete Bridge Decks* products include Louisiana, Missouri, Oregon, Pennsylvania, and Virginia – all of which are at various stages of implementing the technologies most useful for their needs.

***Nondestructive Testing for Concrete Bridge Decks* in the field.**



Using NDT infrared technology on asphalt pavements in Virginia.

Technologies to Enhance Quality Control on Asphalt Pavements (R06C)

Real-Time Monitoring Tools Help States Create Longer-Lasting Roads

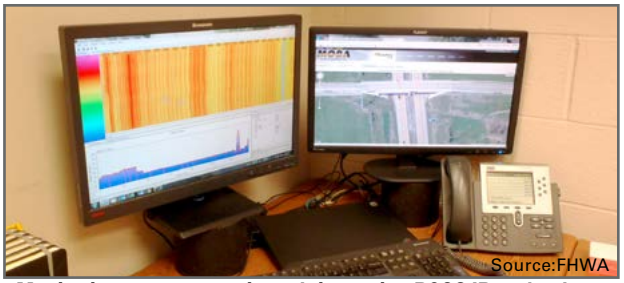
When state transportation agencies know they are getting a better asphalt roadway right from the very beginning, everyone wins – the contractors who can confidently deliver a high-quality project, the state agencies that can save on future maintenance costs, and the drivers who end up with better roads that last longer. With new nondestructive testing (NDT) tools available through ***Technologies to Enhance Quality Control on Asphalt Pavements*** (R06C), state agencies and contractors can monitor the pavement area as the materials are being applied so they can detect and fix problems right away, saving transportation dollars in the long run.

This SHRP2 Solution offers two products designed to provide real-time monitoring of the pavement area: (1) an infrared (IR) scanner system that measures temperature differential; and (2) a ground-penetrating radar (GPR) system that estimates asphalt density. The tools not only tackle these measurements for road builders, they can potentially monitor 100 percent of the pavement area, a much larger range than existing methods for hot- or warm-mix asphalt construction. *(Editor's Note: The GPR system is currently in the testing and development phase, so this article will focus mostly on the IR scanner system.)*

"We know that if we can keep the asphalt materials consistent in temperature and density, we can create more durable, longer-lasting pavements," explained Steve Cooper, SHRP2 renewal pavement engineer in the Federal Highway Administration's Office of Technical Services. "R06C allows us, for the first time, to deploy IR technology that covers the full width of the pavement area, enabling contractors to see any temperature variations as the area is being paved so they can make the necessary changes and correct the problem in real time."

Segregation of hot-mix asphalt (HMA) as it is being applied to the roadway leads to weak spots, causing faster surface deterioration, pavement delamination, and eventually potholes. Although segregation can first occur during production, it can also happen when the material is loaded into the transport trucks and when it is being placed by the paver.

"With the IR scanner, segregation appears as a temperature difference," explained Harold Von Quintus, the subject-matter expert for the R06C solution. "You're able to get a good visual image of changes in temperature, allowing for quick adjustments by the paving crew and minimizing segregation problems that can occur when the temperature is too low. This takes



Monitoring temperature in real time using R06C IR technology.

the guesswork out of knowing whether you have an issue with the mat temperature or not."

The Alaska Department of Transportation and Public Facilities (ADOT&PF) saw the impact of these SHRP2 technologies first hand and now requires the IR scanner on many of the state's four-lane repaving projects. Alaska is one of 10 states receiving funding and training to use the IR tools through the SHRP2 Implementation Assistance Program (IAP). The agency conducted its first demonstration project of the IR technology in June 2015 at the Ted Stevens Anchorage International Airport, where the team, during a recent runway paving project, monitored the placement of the base asphalt layer using the IR scanner system.

Prior to using the IR technology, ADOT&PF used random testing to ensure the pavement materials were a consistent temperature. Random testing, however, did not provide the full picture.

"I've never had much confidence in random testing because all it does is find the average value of your paving operation and doesn't pick up the way-below-average areas or cold spots. That's what leads to problems on our roads," said Richard Giessel, ADOT&PF's state quality assurance engineer.

With the IR and GPR technologies, transportation agencies can locate problems and make adjustments to the equipment or another part of the construction operation "on the fly," Giessel added. "As an agency, we are always striving to use the best tools, to write the best possible specifications, and to have the best mix design, but if the material is not being placed in the field correctly our pavements aren't going to last."

Pam Hutton, AASHTO's SHRP2 implementation manager, says this SHRP2 Solution is a success both for departments of transportation (DOT) and for contractors. "Typically you don't know during construction if all the materials are being applied correctly and at the proper temperature. If the DOT learns through random testing after the initial construction that the quality of materials or workmanship isn't satisfactory, the contractor is often subject to disincentives, which cost them money. This technology allows contractors to make adjustments in real time, avoiding penalties the DOT might assess."

This means DOTs "can be sure they are getting a better roadway product right from the very beginning," Hutton said.

R06C IR technology in Virginia.

While it is still too early to know just how much money these SHRP2 tools will save states and contractors in the long run, it is clear from the IR demonstration projects that the technologies are a major asset, according to Von Quintus.

"On three or four of the IR demonstration projects, just by making small changes during their operation, they were able to cut average temperature differentials in half – bringing them down from 30 degrees to 15 degrees Fahrenheit," Von Quintus said. "By using the IR and making these small changes to keep them within acceptable differences, contractors have reduced their penalties."

States participating in the IAP see another benefit from using the IR technology, notably increased communication among paving crews, their supervisors, and transportation agency personnel. This proved especially true for the Missouri Department of Transportation (MoDOT), which conducted a demonstration project along I-29 in St. Joseph, located about 60 miles north of Kansas City. Bill Stone, a research administrator for MoDOT's Construction and Materials Division, said that during a recent night paving project, plant operators 10 miles from the work site could watch remotely as the pavement was being delivered and monitor the temperature.

"[Plant operators] were communicating with personnel in other parts of their operation based on information they were obtaining from the tool," Stone said.

Next season, MoDOT plans to incorporate the IR technology, coupled with intelligent compaction, on 10 of its projects. "It's just a really good quality control tool. If we can reduce temperature segregation and achieve proper compaction, I think we will end up with a much better quality pavement," Stone noted.

The *Technologies to Enhance Quality Control on Asphalt Pavements* IR scanning tool is being used in several other states across the country through the IAP, including Alabama, Illinois, Maine, New Jersey, North Carolina, Virginia, and West Virginia.

Tools to Improve PCC Pavement Smoothness during Construction (R06E)

A Winning Combination: DOTs Get Longer Pavement Life, the Public Enjoys a Smooth Ride, and Contractors Earn Incentives

Transportation professionals know that a smooth ride leads to a more comfortable driving experience, which makes for happier drivers and passengers. Traditionally, newly constructed or resurfaced concrete roads undergo extensive retreatment after initial installation to ensure smoothness and "rideability." Often this happens after the concrete has hardened and strengthened – in many cases, days or weeks after construction. With concrete in this semi-final state, retreatment means extra road or lane closure time to address the defects. This, in turn, equates to additional funds spent on equipment and labor, and further delays. When this happens, the public often asks, "Why didn't they pave it right the first time?"

This problem was the impetus behind the SHRP2 research into methods to improve process control and allow for on-the-fly adjustments to correct surface irregularities on concrete pavements while still in a semi-plastic state. The result was ***Tools to Improve PCC Pavement Smoothness during Construction*** (R06E), a set of real-time smoothness (RTS) detection technologies that equipment manufacturers are now incorporating to control road smoothness during, not after, the concrete pouring process. The smoothness factor is determined by an international measuring standard called the International Roughness Index (IRI).

Jon Ogden, Region 2 field engineer with the Utah Department of Transportation (UDOT), observed, "IRI is a combination of concrete mixture factors, paving factors, and human factors. Some combination of these three things is required to achieve the IRI 'sweet spot,' which can be different for every project or location. These technologies enable contractors and transportation agencies to detect surface smoothness and make adjustments to equipment settings, paving

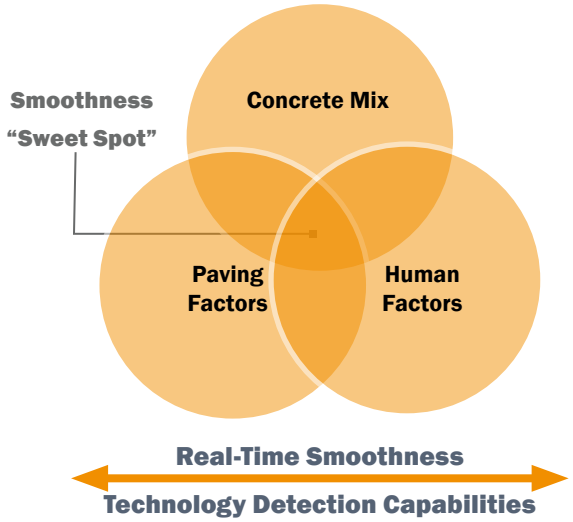


Figure 1.

speed, the composition of the concrete mix, and other factors, cutting out the costly and inefficient final step of post-installation smoothing activities."

A pavement's smoothness contributes directly to pavement quality, durability, driving experience, and even carbon dioxide emissions. A smooth, well-laid pavement is one that will last longer, reducing the cost of maintenance over the life of the roadway.

Road smoothness measured by IRI also serves as a quality specification or performance measure common among designers, builders, and those who maintain pavement surfaces. For example the UDOT uses an IRI performance specification that contractors must meet or exceed before the DOT will accept a new concrete surface. This makes installing smooth roads the first time very important to construction contractors.

Steve Cooper, FHWA's SHRP2 program manager for pavements points out, "Contractors don't want smoothness values tomorrow; they need to know now to keep on budget." The construction contractor for

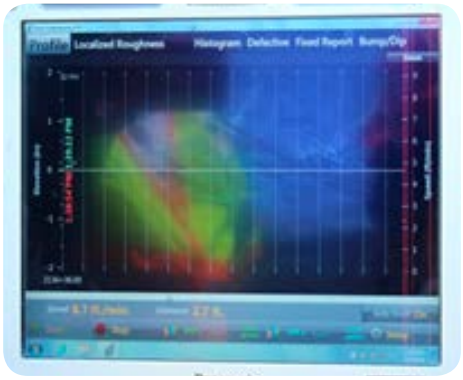


Figure 2. Pavement profile sensor. RTS output screen during pavement operations.

UDOT's Interstate 15 corridor paving project – spanning North Farr to Brigham City – is on track to reap full incentives related to pavement smoothness and early completion due in part to this SHRP2 Solution.

Several contractors nationwide use the SHRP2 tools to identify surface bumps, dips, and smoothness issues on the equipment screen, shown in Figure 2, and document possible contributing circumstances as these occur. The RTS devices use software that can log roadway factors that negatively affect IRI readings. This allows equipment operators and crews to analyze the road and environmental characteristics that contribute to IRI changes.

Detection, however, is only half of the story. Once detected, the issue still has to be corrected. That is where the value comes in for the DOT and the contractor: the technology affords operators the ability to "tune the paver" in real-time.

The real-time smoothness technologies consist of several pavement profile sensors equipped with a laser that helps develop a pavement profile (Figure 3). The sensors are sensitive enough to detect smoothness changes at 0.002 inches. Jason Simmons, a Region 2 pavement engineer with UDOT, embraces the outcomes that RTS technologies afford. "IRI relates directly to pavement life. If IRIs for new pavements are not optimized, the DOT and public won't get the full extent of pavement life that could have been captured," Simmons said.

Considering that average concrete paving jobs cost from $1.1 to $2 million per lane mile, the technology typically pays for itself after the first job. RTS is available through several manufacturers, and equipment and software costs are about $50,000. In the case of large concrete contracts, pavement smoothness incentives can be in the six-to-seven figure range.

On large jobs, the RTS benefit-cost ratio could be huge. The technology gives back on most paving jobs. "RTS allows inspectors and contractors to make immediate changes during paving, ensuring pavement smoothness meets performance specifications before results are literally set in stone," said Simmons.

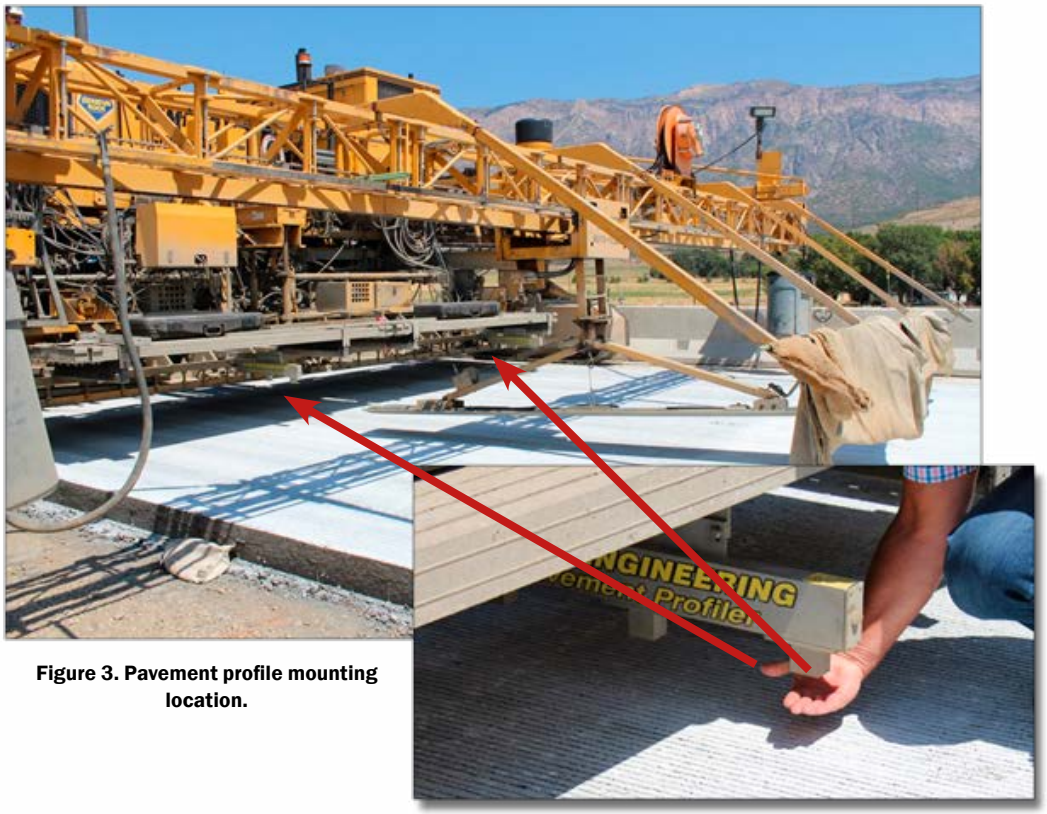


Figure 3. Pavement profile mounting location.

Reliability: A New Way to Look at Travel Performance

You are on your way home from work when, suddenly, traffic comes to a complete stop. You turn on the radio and learn that an unanticipated incident ahead could keep you in gridlock for an hour or more. This delay is not just a matter of losing an hour of your time, it is the unexpected cost of having to pay the babysitter for an extra hour and having to ask your spouse to leave work early – possibly losing an hour of pay – to pick up your older child from soccer practice on the other side of town. It is also the unexpected cost of fuel wasted while waiting in traffic, and of having to stop and pick up a carry-out dinner because you will not have time to prepare a meal for your family as you had planned. Sound familiar?

Congestion on America's roadways disrupts daily personal schedules, business travel, and freight deliveries. Much of the congestion is due to unexpected or nonrecurring delays caused by crashes, work zone construction, special events, or other factors. Inconsistent travel conditions are frustrating, cost travelers time and money, and put motorists and traffic incident responders at risk.

But what if there was something—a method, a system, an innovation—that could improve travel-time reliability so that driving was made a little easier and more predictable? There is just such an innovation. It is the SHRP2 Solution called ***Reliability Data and Analysis Tools*** (L02/L05/L07/L08/C11).

Travel-time reliability is a measure of the consistency or predictability of getting from one place to another. Improving travel-time reliability is about managing traffic and incidents. This is accomplished by clearing crashes more quickly, effectively planning for road work and special events, addressing bottlenecks and other operational conditions that lead to congestion, and providing timely and accurate information to travelers and shippers. The SHRP2 Solution, *Reliability Data and Analysis Tools*, provides transportation agencies with key innovations to improve travel-time reliability. Agencies require data monitoring, analysis, and planning tools to understand fluctuations in traffic and to identify effective strategies to reduce the variable and uncertain travel times caused by nonrecurring congestion.

Traditional analysis tools have focused on average conditions, not on the range of travel times that vary over time in response to traffic, roadway, and weather conditions. Transportation agencies have increasingly begun to acknowledge the reality that many drivers know to be true: "There are not many typical days," said Jim Henrickson, Metro District traffic forecaster at the Minnesota Department of Transportation (MnDOT). "A typical day is the exception, not the rule in metropolitan areas."

"This was the genesis of the SHRP2 Reliability program," said Doug Laird, FHWA transportation specialist and program manager for *Reliability Data and Analysis Tools*. "The idea is to get away from the 'average day' as being descriptive, because it isn't," he said. "A more complete and nuanced approach has been taken in developing the *Reliability Data and Analysis Tools*. This represents a real departure from the way we've looked at performance in the past."

The diverse set of products comprising this SHRP2 Solution are designed to help agencies gather travel-time data and estimate the economic and travel-time benefits expected from adopting a reliability focus. Agencies then can integrate reliability considerations into the processes they use to select transportation projects. These SHRP2 products give agencies a better picture of the far-reaching, real-world impacts of delays, which in turn helps them hone in on solutions that will maximize benefits to travelers. The SHRP2 Solution, *Reliability Data and Analysis Tools*, helps agencies in three areas:

Data Collection

Guide to Establish Monitoring Programs for Travel-Time Reliability (L02) — helps agencies design programs to monitor travel-time reliability by creating a baseline that establishes current performance and identifies areas for improvement.

Analysis

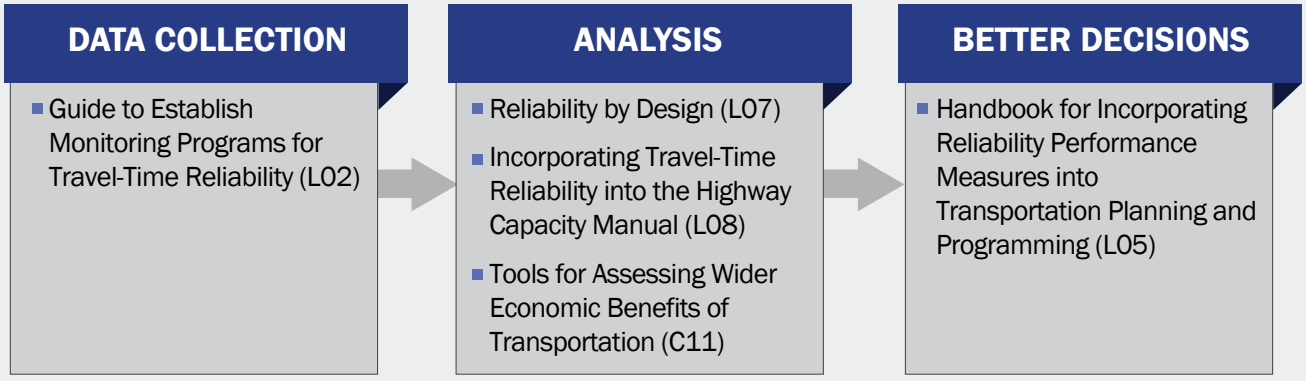
Reliability by Design (L07) — helps agencies estimate the effectiveness of design treatments for improving travel-time reliability and compare the economic benefits of applying different design options at specific locations.

Incorporating Travel-Time Reliability into the Highway Capacity Manual (L08) — helps planners and engineers estimate travel-time reliability on major freeways and urban arterials in a corridor.

Tools for Assessing Wider Economic Benefits of Transportation (C11) — helps agencies determine reasonable expectations of the economic impacts (including from improved travel time reliability) of a proposed highway project.

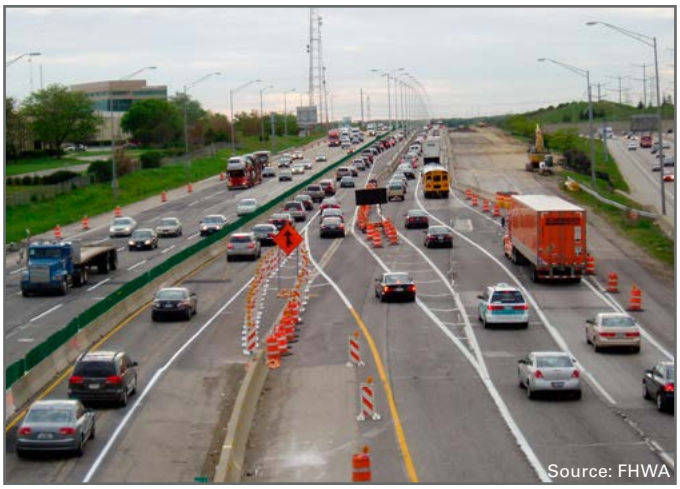
Better Decisions

Handbook for Incorporating Reliability Performance Measures into Transportation Planning and Programming (L05) – provides an overview of different approaches agencies can use to incorporate reliability considerations when selecting from among different transportation investments.



Minnesota DOT: Using All Five Products from Data Collections to Better Decisions

By the end of 2016, 18 states had deployed *Reliability Data and Analysis Tools* on 21 unique projects. One of these states, Minnesota, has used this suite of products on several projects in the Twin Cities region with notable results in reducing congestion and improving travel-time reliability.



SHRP2's *Reliability Data and Analysis Tools* help to address congestion – especially nonrecurring causes of congestion, such as crashes, work zones, poor weather conditions, and special events.

Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)

The Minnesota Experience: Turning Data Into Knowledge

The idea of the "average day," defined by generally predictable congestion during a morning and afternoon rush hour, is becoming obsolete in the modern world of transportation analysis and planning. A simple average fails to capture and account for the unpredictable delays travelers encounter from crashes, inclement weather, work zones, fluctuations in demand, and even location-specific factors, such as the sun causing glare on a high-volume roadway at a certain time of day.

The SHRP2 Solution, ***Reliability Data and Analysis Tools*** (L02/L05/L07/L08/C11), is designed to help transportation agencies reduce the impacts of unanticipated delays on travelers and to provide motorists with more consistent trip times. "What that means is, if a person's trip from home to work takes about a half hour every day, it's consistent, but if it takes 20 minutes one day, an hour the next day, and 40 minutes the day after, it isn't," said Patricia Bush, AASHTO program manager for bridges and highway design. Consistency of travel times is important not only to the public, but also to businesses that rely on "just-in-time" freight arrival in order to run efficiently. Without the prompt delivery of goods, businesses can suffer and stagnate, negatively affecting jobs and regional economies.

This SHRP2 Solution also helps agencies identify cost-effective strategies for combating specific traffic challenges that contribute to unexpected delay and make travel unreliable. Many areas of the country have unique combinations of factors that can lead to unexpected delay on the transportation system. "For example, in Minnesota's Twin Cities, delay could be caused by folks headed out to the countryside to enjoy a crisp fall weekend, while at the same time there is a college football game and hunting season is starting," said Doug Laird from FHWA. "Unless highway conditions are carefully monitored, even a minor accident could lead to widespread delays."

The Minnesota Department of Transportation (MnDOT) has been involved with SHRP2's *Reliability Data and Analysis Tools* since the product development phase. "One reason we were excited about it is we saw there was real value in terms of performance measurements and evaluations – these tools would enable us to paint a more complete picture at a system-wide level," said Michael Sobolewski, a transportation planner in MnDOT's Metropolitan District, Office of Planning, Program Management and Transit. MnDOT is using all five of the products that comprise *Reliability Data and Analysis Tools*, and is planning to use the tools to support the development of a congestion management safety plan.

Improving Public Engagement While Enhancing System Efficiency

While the tools are successfully supporting agency efforts to combat congestion, the true winner is the public. The SHRP2 product helps MnDOT condense complex technical content into readily understood information. The MnDOT team began to experiment with ways to illustrate reliability and explain the data to stakeholders using visual tools such as pie charts and heat maps. "A key benefit for us has been turning data into information and communicating it to create knowledge," said Jim Henrickson, Metro District traffic forecaster at MnDOT. The ability to convey this knowledge effectively also makes it easier for the public to be engaged in the project planning process and leads to better informed decision making by elected officials and agency management.

For example, MnDOT staff used the *Guide to Establish Monitoring Programs for Travel-Time Reliability* (L02) to illustrate the benefits of the I-35W North MnPASS managed lane project. The agency applied the *Reliability by Design* (L07) product to compare different design options and determine which would be most effective in reducing both congestion and travel-time variability. For this project, the public raised questions as to whether adding a high-occupancy toll (HOT) lane rather than simply adding another general purpose lane was the best approach.

The *Guide to Establish Monitoring Programs for Travel-Time Reliability* gave the project team the skills and vocabulary they needed to clearly explain the results of the reliability evaluation. The Reliability by Design analysis predicted that the number of peak period users who would experience a free-flow trip as a result of the tolled lanes would increase by 75 percent compared to the scenario in which a general purpose lane was added.

Maintaining free-flow conditions on managed lanes is particularly important, Sobolewski said. "Free flow conditions are why people pay to use the lanes," he pointed out. Further, the freeway overall would be capable of serving an additional 4,000 people (not vehicles) during peak periods by encouraging carpooling and transit use, thereby accommodating more travelers while reducing congestion.

MnDOT used Reliability Data and Analysis Tools to address congestion and travel-time reliability.

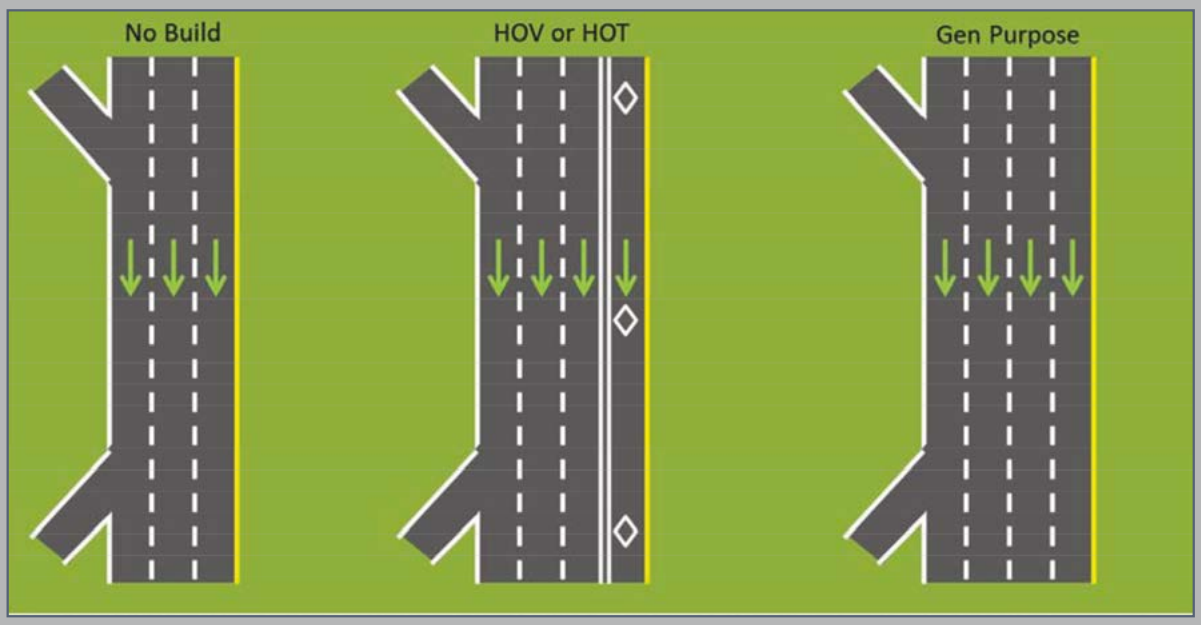
In addition to improving public understanding of the tradeoffs, being able to communicate the evaluation results also helped the agency build credibility within the community. For example, the agency used the *Reliability Data and Analysis Tools* to conduct a before-and-after comparison of congestion at a two-lane exit ramp and flyover that had been built a few years earlier. The assessment proved that the new design reduced delay by several hours during the afternoon rush hour and validated the benefits of the project to the public.

Better Informed Decisions

MnDOT is leveraging the information in the *Handbook for Incorporating Reliability Performance Measures into Transportation Planning and Programming* (L05) to incorporate reliability considerations when selecting from among different transportation investments. The agency is integrating reliability measures throughout the state, focusing on projects that can benefit from reliability analysis as part of the decision-making process. This is introducing various practitioners and decision makers (e.g., state DOTs, county officials, state officials, MPOs) to the reliability concepts and tools rapidly, and has been a fundamental means of institutionalizing reliability considerations throughout the agency and within the planning process.

For example, the agency is using the handbook in developing the Twin Cities Metro District's *Congestion Management Safety Plan* (CMSP). This multi-year plan identifies areas with the most critical congestion and safety concerns on the regional highway system

I-35 W North Managed Lanes



Source: SRF Consulting

Reliability Data and Analysis Tools **evaluate adding an HOV/HOT/managed lane versus a general purpose lane of capacity.**

and determines the solutions that offer the highest return on investment. Because this process involves selecting specific projects where limited funds can be spent, it is important to explain to the public and decision makers why one project should be selected to be completed before another.

"Local stakeholders and the public tend to look at corridors in isolation; they don't always see the big picture," Henrickson explained. "The SHRP2 products help us communicate with them so that when we show them their problems on a regional map, they can also see where there are other problem areas that we need to address." This lets the public and decision makers see that, while the area they think is of greatest concern will need to be addressed, other areas may need much more immediate attention from a safety and reliability perspective. With the help of the SHRP2 products, the public not only better understands where the worst congestion and safety problems are, it also benefits from having those project sites selected first to receive improvements.

The Reliability Tools also helped MnDOT determine how to use speed data acquired from a third party vendor to supplement the data it collects to evaluate congestion and reliability on the Twin Cities' roadways. After combining all the data, the agency had a more complete picture of mobility performance across the entire system that supports final project selection and programming in the CMSP.

A More Reliable Transportation System

MnDOT and FHWA foresee working together to promote the *Reliability Data and Analysis Tools* to other states by sharing examples and details of the successes Minnesota has experienced, perhaps through webinars, workshops, or peer exchanges.

In addition to Minnesota, several other states also are engaged as Implementation Assistance Program recipients. For example, the Florida Department of Transportation (FDOT) is using the entire suite of tools to update its internal analytical tools and project evaluation procedures. During its implementation, the state will apply reliability performance estimates to support agency decisions about project funding and prioritization.

> *"These tools provide a whole new capability to consider reliability in the analysis of transportation improvements. Now agencies can account for a more complete set of benefits and make more informed decisions. It's not surprising that there has been a lot of interest in using these tools."*
>
> — Tracy Scriba
> SHRP2 Reliability Program Manager

The Maryland State Highway Administration is using the complete suite of *Reliability Data and Analysis Tools* to accelerate implementation of its reliability roadmap. The pilot testing will both provide a better understanding of congestion and its sources, as well as incorporate mainstream reliability considerations into the agency's work processes.

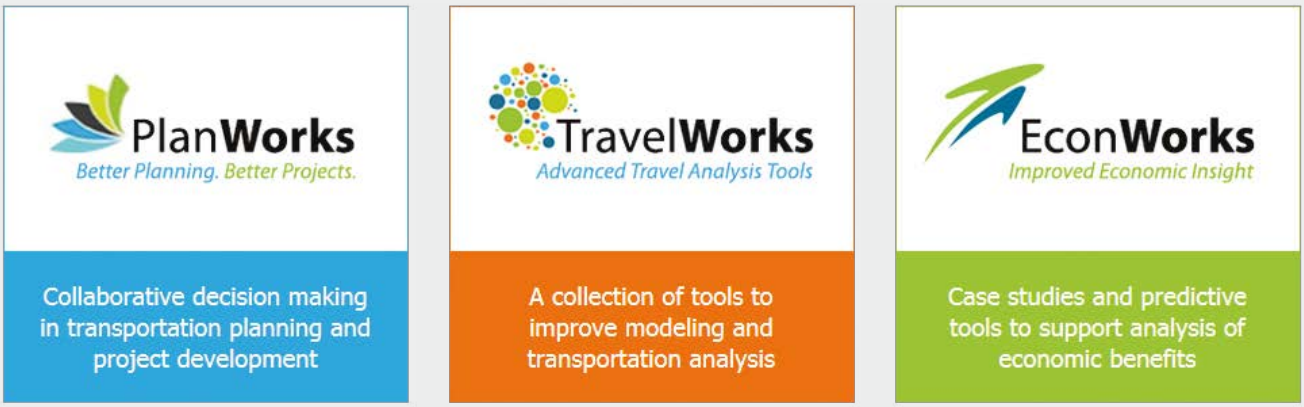
The Washington State Department of Transportation is testing three products (L02, L05, and L07). The agency is using the products to enhance the development of its "DriveNet" data collection system, which supports the testing of highway improvement options and heightens the consideration of operations in project identification, selection, and prioritization. Notably, statewide truck travel is a component of the testing.

"States like Minnesota are ready to go out and help us support these tools and share their experiences with others," Laird said. As part of its implementation effort, MnDOT is planning to hold a peer exchange workshop in early 2017 to introduce reliability concepts and products to surrounding state DOTs and to share its findings and previous experiences. This aligns well with FHWA plans for a similar peer exchange with the sites currently receiving implementation assistance and other interested parties.

"These tools provide a whole new capability to consider reliability in the analysis of transportation improvements," said Tracy Scriba, FHWA's SHRP2 Reliability program manager. "Now agencies can account for a more complete set of benefits and make more informed decisions. It's not surprising that there has been a lot of interest in using these tools."

Going Mainstream

Findings from one of the products within the bundle—*Incorporating Travel Time Reliability into the Highway Capacity Manual* (L08)—are resulting in new content for the *Highway Capacity Manual*. Transportation planners and design engineers use the *Highway Capacity Manual* as the standard reference book and software for calculating the capacity and quality of service for various roadway types, as well as facilities for transit, bicycles, and pedestrians.



THE "WORKS": PlanWorks, TravelWorks, and EconWorks

How will the national, regional, or even local transportation system perform 30 years into the future? What policies or investments could influence system performance? How will economic, demographic, or land-use changes affect congestion? Will a new transit investment attract riders?

The products developed through the three SHRP2 Solutions, *PlanWorks, TravelWorks, and EconWorks,* are specifically designed to support executive decision making on questions like these that have direct, daily impact on the public. When deciding on projects that will define the future of the transportation system, decision makers must often juggle many competing interests and priorities, everything from congestion to environmental stewardship to economic growth.

- ***PlanWorks*** is a web resource that supports collaborative decision making in transportation planning and project development. *PlanWorks* is built around key decision points in long-range planning, programming, corridor planning, and environmental review.
- ***TravelWorks*** is a suite of five SHRP2 products that includes a set of powerful travel models to help planners forecast what a region will look like well into the future. These models support decision making by providing clear-cut information about the impacts that alternative transportation investments and policies can have based on different scenarios, including demographic shifts and economic trends.
- ***EconWorks*** is a collection of web-based tools designed for transportation planners, helping them incorporate economic analysis into early project decision making and to select the projects that give the most value for the dollar.

Learning more about TravelWorks: Implementation in North Carolina and Oregon

The SHRP2 *TravelWorks* solution lends transparency to the decision-making process by providing specific, quantitative information about travel demand and transportation system performance that everybody can understand. This information can be the basis for better informed decisions about how agencies can achieve both operational goals (i.e., installing HOV lanes to reduce the number of cars on the road during rush hour and improve traffic flow) and policy goals (i.e., reducing emissions) that benefit the entire region.

Several transportation agencies are implementing and testing elements of *TravelWorks*. This feature highlights the successful implementation of TravelWorks in North Carolina and Oregon. One particular example is the Rapid Policy Assessment Tool—RPAT, developed through the SHRP2 product, *The Effect of Smart Growth Policies on Travel Demand* (C16). RPAT is producing valuable results and information, helping agencies make informed decisions.

TravelWorks (C10/C04/C05/C16/C46)

Helping Agencies Make Informed Planning Choices for the Future

With limited funding and unknown future conditions, selecting the right investment and policy solutions to address transportation and land use issues is increasingly difficult for planners – and more important than ever. Traditional travel demand forecasting models do not consider emerging operations strategies such as variable road pricing (e.g., tolls), ramp metering, reversible lanes, variable speed limits, and other dynamic transportation management strategies. Nor are these tools able to incorporate potential policy changes such as the implementation of flexible work schedules, or the construction of HOV lanes, which can have important impacts on travel scheduling.

For "smart growth" to be a component of regional planning and decision making, local practitioners need tools that help them engage in strategic scenario planning and make informed decisions about how alternative policies and dynamic growth scenarios affect travel patterns. The *TravelWorks* product suite contains several advanced analysis tools to help planners and decision makers comprehend travel demand in a way that integrates people's activities, travel networks, and the environment. Travel demand modeling systems can now reflect how travelers respond to congestion, travel-time reliability, and pricing, so decisions about operational improvements can be based on more reliable models.

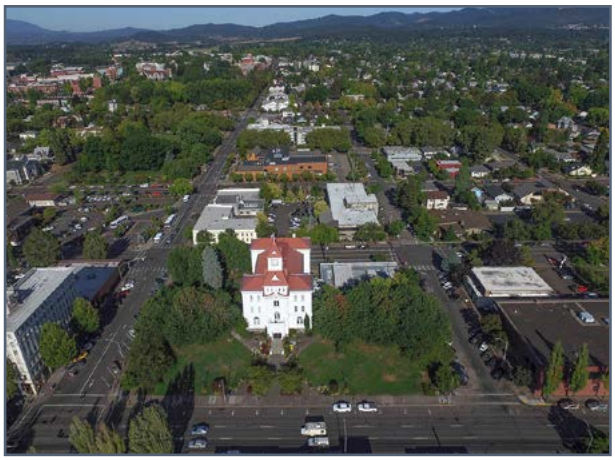
One of the *TravelWorks* solutions currently being used by agencies is *The Effect of Smart Growth Policies on Travel Demand* (C16), which includes the Rapid Policy Assessment Tool (RPAT). RPAT is a software application that helps transportation agencies engage in strategic scenario planning and make informed decisions. RPAT allows planners to input a range of factors to help them build individual scenarios and measure them against each other to determine the best fit for their region's unique needs. Using this tool, planners and modelers can quickly compare the broad transportation impacts of various land use, investment, and policy scenarios.

"The approach the product development team took with RPAT was to allow users to look at a host of policy options in one model," said Brian Gardner, the FHWA program manager for *TravelWorks*. The goal was to build a flexible, powerful model that would incorporate factors such as where people work, where they live, and

TravelWorks
Advanced Travel Analysis Tools

- **Partnership to Develop an Integrated, Advanced Travel Demand Model and a Fine-Grained, Time-Sensitive Network (C10)**
- **Improving our Understanding of How Highway Congestion and Price Affect Travel Demand (C04)**
- **Understanding the Contribution of Operations, Technology, and Design to Meeting Highway Capacity Needs (C05)**
- **The Effect of Smart Growth Policies on Travel Demand (C16)**
- **Resources for Using State-of-the-Art Travel Demand Models (C46)**

Raleigh, North Carolina.



Corvallis, Oregon.

where they choose to locate their businesses, and then look at how those factors influence travel trends.

"For example, what if you made transit more important or less important and then looked at the implications in a development context within a region?" Gardner asked. "You can explore hundreds of different combinations—what investment and policy options move you away from your objectives, and what options bring you closer. That's the outcome we're looking for: We want to help decision makers address a broad set of issues."

Through the SHRP2 Implementation Assistance Program, several transportation agencies received user incentives to implement and test RPAT. Two of the recipients were the Durham-Chapel Hill-Carrboro Metropolitan Planning Organization (DCHC MPO) in North Carolina and the Oregon Department of Transportation (ODOT).

North Carolina RPAT Implementation

Developing a metropolitan transportation plan – which is a long-range planning document that identifies transportation deficiencies, opportunities, policies, strategies, and projects over 20 years – is an important function of metropolitan planning organizations such as the DCHC MPO. In partnership with other regional stakeholders, DCHC MPO began to evaluate RPAT for its ability to support collaborative, long-range planning activities. Using the tool, the MPO has been able to analyze different transportation and land use scenarios and successfully develop performance measures related to greenhouse gas emissions, economic efficiency, and safety.

RPAT also allows the DCHC MPO to answer policy questions from decision makers on topics such as fuel price impacts, demand management strategies, and the benefits of using intelligent transportation systems — topics that could not be addressed by the traditional model, which the planners previously used. Being able to clearly and quantitatively identify long-range impacts from many different scenarios has made it possible for the MPO to clearly determine which projects and policies will best support the community's long-term vision for transportation efficiency, economic vitality, and environmental conservation.

"The project was valuable for the sheer number of scenarios that we could run, which we cannot measure with a traditional travel demand model—particularly to assess greenhouse gas emissions and cost impact," said Yanping Zhang, technical/modeling team leader for the DCHC MPO. The information provided by the RPAT tool made it easier for decision makers to pinpoint the projects, strategies, and policies most helpful in reaching the region's environmental goals based on smart growth solutions, which will reduce emissions and contribute to healthier lives — while proactively ensuring that only the most cost-effective projects are funded.

In addition to the metropolitan transportation plan, the DCHC MPO is also using RPAT to assess policies and projects for other planning needs, such as project ranking and prioritization for the Transportation Improvement Program, regional transportation project assessments, and comprehensive transportation plan studies.

Oregon DOT RPAT Implementation

ODOT used the RPAT tool to analyze how alternative land-use policies could affect vehicle travel, non-motorized travel, and greenhouse gas emissions. ODOT implemented RPAT alongside its own Regional Strategic Planning Model (RSPM), and compared the two models. For this project, ODOT worked in partnership with the Corvallis Area Metropolitan Planning Organization (CAMPO). The ultimate goal of the implementation was to enhance capabilities for integrating transportation and land use analysis into planning processes.

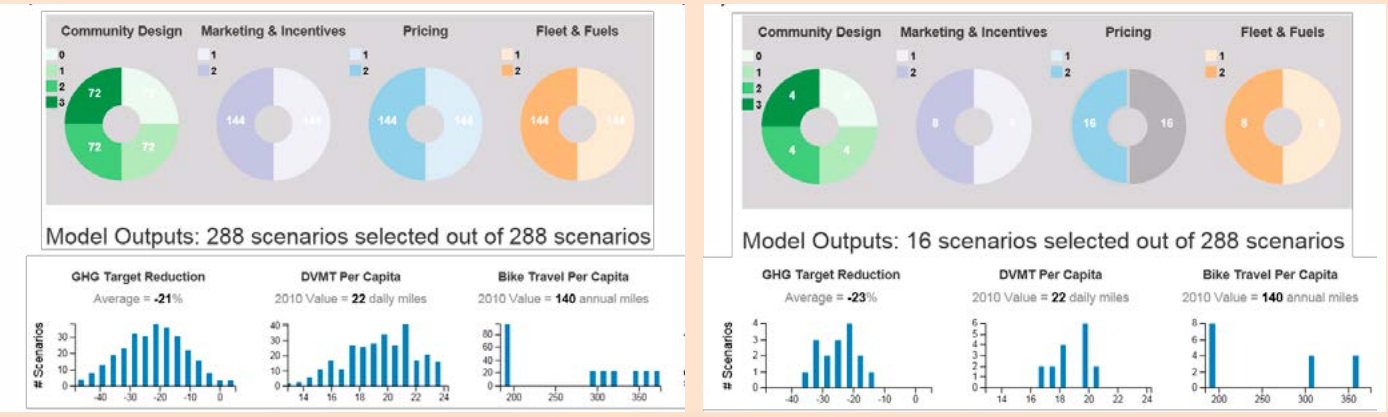
Transparency is an important element in decision making by regional planning bodies. Using both RSPM and RPAT enabled ODOT to support communities like CAMPO in quickly assessing changes to long-term Regional Transportation Plans – and helped inform local planning advisory committees about the impacts of alternative policies, policy shifts, and transportation development projects. CAMPO's use of RSPM and RPAT allowed planners to proactively engage the public and stakeholders in the development and implementation of its regional transportation plans.

ODOT also used RPAT as the base to develop a Scenario Viewer. The Scenario Viewer was used as a public engagement tool to enable stakeholders to explore hundreds of alternative futures and to better understand the complex tradeoffs involved with different policy choices. Using RPAT and the Scenario Viewer, CAMPO was able to illustrate options that permit the planning community to remain true to the regional vision for safety, accessibility, and environmental stewardship. The tools made it possible for CAMPO to facilitate a dialogue with the public and enabled non-transportation stakeholders to buy into plans for projects that balanced environmental impacts with cost-effectiveness.

As RPAT evolves, agencies will be able to use the Scenario Viewer to work more closely with the public and non-transportation stakeholders to evaluate and screen future scenarios before undertaking more time- and resource-intensive transportation demand models.

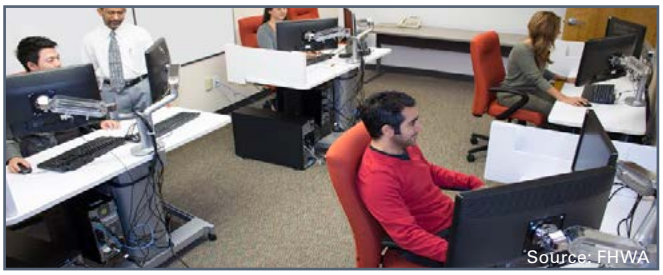
Future Directions

During 2017, the *TravelWorks* product team will solicit and incorporate feedback from the states currently implementing this tool, and perform updates to RPAT. The tool will also be expanded to an open-source platform so that the software can continue to adapt to user needs, as those needs evolve.



Source: Oregon Department of Transportation

This Scenario Viewer enables stakeholders to explore alternative futures and to better understand the complex tradeoffs involved with different policy choices.



The Safety Training and Analysis Center (STAC).

Driver behavior is cited as the primary factor in more than 90% of crashes.

Concept to Countermeasure - Research to Deployment Using the SHRP2 Safety Data

Safety by the Numbers – Innovative Approaches to Analyzing Driver Behavior and Roadway Data

Analyzing driver behavior to understand the factors contributing to highway crashes.

Most drivers in any community know the particular locations that are difficult to drive: the sharp curves that need to be taken extra slowly, the congested intersections where left turns are difficult to make safely, or the tricky freeway interchange. While it's true that roadway features can be dangerous and contribute to crashes, research has shown that driver behavior is cited as the primary factor in more than 90 percent of crashes.

"From the engineering side, we can always go back and reconstruct the accident to determine the physical attributes of the crash, but the driver behavior aspect is something that has been missing for a long time," noted SHRP2 Safety Implementation Program Coordinator Aladdin Barkawi, "What is the driver doing in those 15 to 20 seconds prior to the crash?"

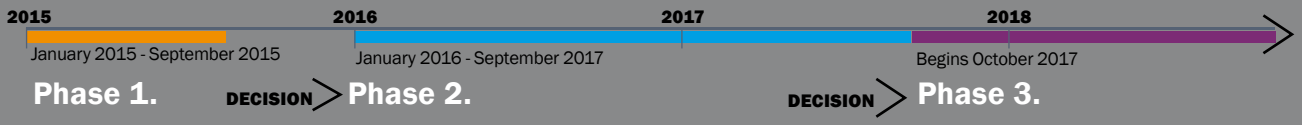
The purpose of the SHRP2 Safety research is to close that gap and offer answers about the human behaviors that result in crashes. This research will lead to new real-world devices, policies, standards, and even roadway designs that will result in fewer crashes and fewer lives lost. To find out exactly what behaviors are causing crashes, SHRP2 sponsored the Naturalistic Driving Study (NDS).

The following phase studies from the Phase 1 of the Implementation Assistance Program were selected to receive additional funding to continue into Phase 2, using a larger set of data from the NDS and RID.

State	Topic	Research Title
Florida	Pedestrian	Understanding Interactions between Drivers and Pedestrian Features at Signalized Intersections
Iowa	Road Departure	Use of SHRP2 NDS Data to Evaluate Roadway Departure Characteristics
Michigan	Speeding and Speed-Related	The Interrelationships between Speed Limits, Geometry, and Driver Behavior
Minnesota	Work Zones	Evaluation of Work Zone Safety Using the SHRP2 NDS Data
North Carolina	Horizontal/ Vertical Curves	Evaluation of the Interaction between Horizontal and Vertical Alignment on Rural Two-Lane Roads: An Investigation Using the SHRP2 NDS
Utah	Interchanges	Driver Behavior and Performance in the Vicinity of Closely Spaced Interchange Ramps on Urban Freeways
Washington	Speeding and Speed-Related	Influence of Roadway Design Features on Episodic Speeding in Washington State
Washington	Lighting	Impact of Roadway Lighting on Nighttime Crash Performance and Driver Behavior – Final Summary Report
Wyoming	Adverse Weather	Driver Performance and Behavior in Adverse Weather Conditions: An Investigation using the SHRP2 NDS Data

The NDS was the largest coordinated safety data gathering program ever undertaken in the United States. The study used forward and rear-facing in-vehicle cameras to capture videos, and Global Positioning System (GPS) tracking, and other recording devices to collect data. Driving behaviors were observed during 5 million trips by more than 3,400 drivers. However, just studying the driver and vehicle is not enough; knowing what the roadway looks like is also necessary to understand how and why crashes happen. The Roadway Information Database (RID) provides that information. SHRP2 researchers constructed the RID by driving an instrumented van on routes traveled by NDS participants and recording all aspects of the physical roadway – everything from pavement markings to curves to intersections. The RID also includes factors that are not permanent, such as work zones and weather.

THE SAFETY IMPLEMENTATION ACTIVITES INCLUDE RESEARCH CONDUCTED IN THREE PHASES.



Phase 1.

Conducted "Proof of Concept" pilots. 10 state DOTs worked on 11 research topics.

DECISION

Phase 2.

Conducting 9 in-depth research and analysis studies with countermeasure identification using full data set.

DECISION

Phase 3.

Adopt, champion, and implement countermeasures nationally. Typical activities may include integrating findings into manuals, guidelines, or policies. Develop countermeasures and conduct pilot testing.

The magnitude of information available in these two databases is incredibly powerful, according to Barkawi. "This data is one of a kind. I don't think anyone has anything like it anywhere in the world," he added. Together, the databases contain more than two petabytes — or more than two million gigabytes — of data. This wealth of human and roadway data will have a broad, wide-ranging impact on our understanding of how specific roadway elements interact with human behaviors to increase the risk of crashes. This understanding is a first step in identifying new ways to prevent crashes and save lives. The research currently underway with this data will lead to changing policies, programs, and standards to address the following needs:

- Roadway designs, advance warnings, and roadway surfaces that will reduce roadway departures, especially on curves.
- Countermeasures, policies, and programs that will reduce speed-related traffic crashes and injuries on high-speed roads, in work zones, and in other areas where periodic speeding results in a high crash rate.
- Countermeasures to improve safety at closely spaced interchange ramps based on a better understanding of drivers' lane changing behaviors.
- An understanding of how lighting affects behavior among drivers of different ages on complex roadway segments, resulting in more effective state and national lighting design guidelines.

Safety Focus – From Concept to Countermeasures

The Florida Department of Transportation (FDOT) is using the implementation assistance funding to examine the interactions between drivers and pedestrian features (pedestrian related signage, signals, and pavement markings) at signalized intersections. "Our ultimate goal is to develop effective engineering, education and enforcement countermeasures to make signalized intersections safer for pedestrians and bicyclists in Florida," said Dr. Pei-Sung Lin, the program director for intelligent transportation systems, traffic operations, and safety at the University of South Florida's Center for Urban Transportation Research.

"The NDS datasets provided the needed information for our researchers to investigate and analyze the interactions between drivers and each pedestrian feature to fully understand human factors, the drivers' behavior, and the drivers' demographics behind these interactions. From our research project, we concluded that without the video data, sensor data, and detailed participant information obtained from the NDS and RID, most of our research objectives and goals could not be fully achieved," Lin said.

"Safety is a top priority at FDOT, and the NDS and RID are making it possible to do research that would not likely be possible otherwise," said Darryll Dockstader, manager of FDOT's Research Center. "FDOT is actively leveraging these resources to develop safety solutions that will reduce crashes and save lives."

Source: Transportation Research Board

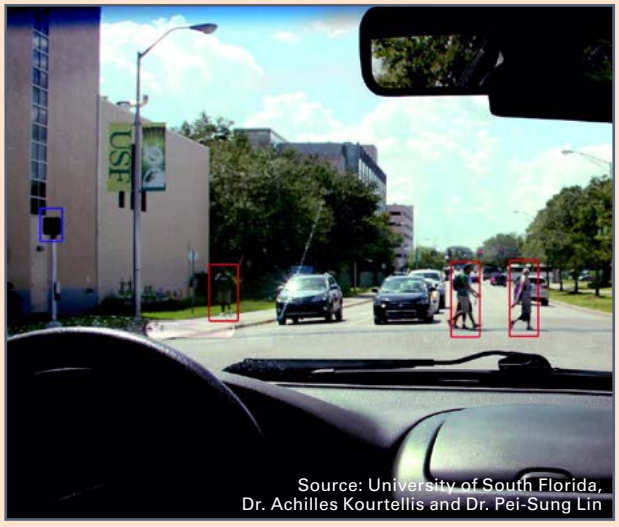
Head camera unit used to collect data for the Naturalistic Driving Study.

More than 3,100 volunteer drivers in six locations had their cars outfitted with miniature cameras, radar, and other sensors to capture data as they went about their usual driving tasks.

Pam Hutton, the SHRP2 implementation manager for AASHTO, noted that when the Safety research initiative was launched, the initial response was tremendous. "We had an overwhelming number of applications—more than 30—the second highest number in all of the SHRP2 Implementation Assistance Program offerings," she said. "This indicates how important the safety aspect of the SHRP2 program is, and that there is a built up demand for ways to increase our understanding of the role driver behavior plays in crashes."

"Speeding is commonly observed on virtually all roads, but efforts to control speeding behavior have been stymied by a lack of understanding of exactly how often speeding occurs, who speeds and under what circumstances," said Paul Jovanis, a SHRP2 subject matter expert and emeritus professor from Pennsylvania State University. "SHRP2 data offer the potential to study driver behavior and relate it to road infrastructure elements through the RID. This is a unique research opportunity."

Concurrently with Phase 2, FHWA has established the Safety Training and Analysis Center (STAC), a secure location outside of Washington, D.C. designed to expand FHWA's services to state DOTs by providing technical assistance and training opportunities. The vision for the STAC is that it will increase researchers' understanding of the data and their potential to address a variety of transportation problems, especially those related to driver behavior. The STAC will host graduate and postdoctoral students, fellows, and other researchers sponsored by state DOTs to conduct research using the NDS and RID data. In addition, visiting researchers will be trained how to use the data and will have the opportunity to use the data analysis tools developed in Phase 1 to further new research.



Understanding the interactions between pedestrians and drivers at signalized intersections.

The SHRP2 Naturalistic Driving Study Pooled Fund: Advancing Implementable Solutions

In 2016, SHRP2's Safety focus area sponsored a series of webinars concerning the SHRP2 Naturalistic Driving Study Pooled Fund. This pooled fund will conduct groundbreaking research in Highway Safety, Operations, and Planning. The STAC is seeking state commitments to the pooled fund until March 17, 2017.

The in-vehicle data acquisition system unit gathers and stores data from forward radar, four video cameras, accelerometers, vehicle network information, a Geographic Positioning System, and onboard computer vision algorithms.

What is a Pooled Fund?

When significant or widespread interest is shown in solving transportation-related problems a pooled fund study may be initiated. Just as it sounds, a pooled fund study pools the funding of transportation agencies, academic institutions, foundations, or private firms to research an issue of common interest. The STAC has announced a pooled fund to conduct research into driver behavior using the SHRP2 data from the NDS and RID.

Implementing the results and findings of research that will be conducted using the SHRP2 NDS data and RID will result in a more efficient, reliable and inherently safer experience for road users. The pooled fund will:

- Advance the development of implementable solutions that address issues of high-priority to state and local transportation agencies in the broad areas of highway safety, operations, and planning.
- Create a venue for highway practitioners to share information and collaborate on research that advances their individual disciplines and addresses cross-cutting areas, including but not limited to, the advancement of a connected-automated highway system.
- Allow researchers to communicate with each other and leverage research results as they work toward the common goal of a safer and more reliable experience for the road user.

Pooled Fund Webinars

States interested in participating in the pooled fund should make their commitment before the solicitation closes. To learn more about the pooled fund opportunity, recordings of the informational webinar series are available on the STAC website (https://www.fhwa.dot.gov/research/resources/stac/).

- **Webinar 1: Overview of NDS and RID Data and Pooled Fund**
- **Webinar 2: Examples of How These Data are Being Used for Highway Safety**
- **Webinar 3: SHRP2 Implementation Assistance Projects**
- **Webinar 4: Advancing Implementable Solutions**

View the solicitation at http://pooledfund.org/Details/Solicitation/1427.

Offset left-turn lanes are the subject of a study utilizing NDS and roadway data.

SHRP2 Education Connection

Bringing SHRP2 Solutions into the Classroom

"Students will learn better if they understand why it matters." This comment by Dr. Kevin Chang of the University of Idaho expressed his enthusiasm for the SHRP2 Education Connection initiative. After receiving an Education Connection award, Chang embedded a SHRP2 Solution into his existing coursework on public transportation and transportation engineering.

In 2015 the Federal Highway Administration (FHWA) created the SHRP2 Education Connection to connect SHRP2 with the academic community. The goal was to expose the next generation of transportation professionals to SHRP2 Solutions so they could apply them in the real world—and, ideally, embed these solutions into transportation culture.

The FHWA awarded 10 universities with $10,000 cooperative agreements to integrate their choice of one or more SHRP2 Solutions from the **Renewal, Reliability,** and **Capacity** focus areas into their existing curriculum. "The universities' enthusiasm for this initiative proved what we hoped to be true – that the SHRP2 Education Connection was a viable link to academia," said Amy Lucero, chief technical services officer for FHWA. The products these universities chose fit into not only traditional transportation programs like engineering and transportation planning, but also disciplines such as urban planning, economics, government, and even human resources. The selected universities proposed different teaching approaches, ranging from one-day workshops to site visits to integrating newly developed material into existing course curricula.

RENEWAL

The University of Missouri chose to develop a graduate-level course based on the SHRP2 *NDToolbox* (R06). The toolbox is now available online as the ***Nondestructive Evaluation (NDE) Web Manual***. Course material focused on use and limitations of NDE technologies through a combination of lectures, case studies, and experimentation. The problem-based course explored the role of NDE technologies in maintaining the structural integrity of engineered structures, particularly pavements and bridges. The curriculum incorporated case studies to illustrate current successful practices, the underlying physics of NDE, and how NDE integrates with engineering judgment, management of facilities, and safety.

Using the *Encouraging Innovation in Locating Utilities* (R01) products, the University of Nebraska helped its students understand real-world construction issues, as well as the construction methods and equipment used to locate underground utilities. Subsurface exploration of existing assets or utility relocation is a vital element in designing and constructing civil engineering projects, so this is an important educational topic for future engineers. The new curriculum used SHRP2 research findings to instruct students on subsurface utility engineering, identifying challenges and utility issues in transportation projects, geophysical methods and their characteristics, excavation methods for locating utilities, and nondestructive inspection tools.

"The introduction of SHRP2 materials highly benefited our students in terms of equipping them with [an understanding of] actual construction issues, better understanding of construction methods and equipment in locating underground utilities, earth-moving operation, and overall horizontal construction, which helps them become better decision makers," said Dr. Asregedew Woldesenbet, who noted that the materials were well-received by the students, whose feedback included comments such as "cool and neat technologies," "a fun topic to learn," and "very practical – applies to my work."

RELIABILITY

Dr. Kevin Chang of the University of Idaho developed course content based on SHRP2's ***National Traffic Incident Management (TIM) Responder Training*** (L12). The students felt the course materials helped them better understand the complexity of incident response activities—and how a coordinated team approach improves communication among all responders on the scene. Students also offered feedback for improving course content, such as adding notable practices for reducing secondary crashes. According to Chang, "The opportunity to share real-world applications with students helps to reinforce learning and explain how transportation engineers operate in day-to-day activities. The SHRP2 TIM materials offered one such opportunity, as students were provided with a window into the many roles and responsibilities of the different responders."

North Dakota State University modified three graduate-level classes to include materials from four Reliability products. The lectures focused on travel-time reliability theories and principles supplemented by lab-based modeling assignments, product tutorials, and case studies. "The SHRP2 Education Connection products provided instructors with tools that bridged theory and practice," said Dr. Diomo Motuba. "For example, students [learned] that for an identical transportation problem, two geographic areas could have different solutions that were optimal to them based on the experiences, transportation goals, and expectations of the geographic area. That was an invaluable experience for the students," he added. Dr. Motuba believes that the "SHRP2 products improved the teaching experience by providing the instructor with tools to illustrate how the theories in class are actually applied in practice. It also greatly enhanced the learning experience of the students by providing them with tools to apply theories and prepare them better for the industry." The SHRP2 products used were:

- ***Reliability in Simulation and Planning Models*** (L04)
- ***Reliability Data Archive*** (L13A)
- ***Organizing for Reliability*** (L01/L06)
- ***Framework for Improving Travel-Time Reliability*** (L17)

CAPACITY

Methodist University in North Carolina incorporated *Implementing Eco-Logical* (C06) – a landscape-scale approach to transportation infrastructure development and ecosystem conservation – into a senior-level undergraduate course on important environmental review processes found in the National Environmental Policy Act.

Students learned about the hierarchy of mitigation (avoidance, minimization, and compensation) and how it can improve decision making and speed project completion. The course featured a combination of case studies and project site visits to illustrate how the Eco-Logical methodology streamlined the environmental process. The curriculum will be used to develop a one-day certificate workshop targeting both students and transportation professionals. That's only the beginning according to Dr. Deb Branson. "I see the next step as partnering with others (universities) to build on and sustain these products in the university curriculum," she said.

The University of North Carolina at Charlotte selected three solutions in the SHRP2 ***TravelWorks*** (C04/C05/C16) product bundle as the basis for a special topics course. The project team developed 15 lectures based on the material and visual aids within the products. The lectures included student exercises and offered the opportunity for discussion and interactive exchanges with instructors. The lectures also included three quizzes, one on each product area, to assess student learning in that area.

"The universities' enthusiasm for this initiative proved [...] that the SHRP2 Education Connection was a viable link to academia."

—Amy Lucero
Chief Technical Services Officer, FHWA

A Blended Approach

Rowan University, located in New Jersey, took an ambitious approach involving 16 SHRP2 products from three focus areas. The professors integrated the products vertically, meaning they inserted SHRP2 lectures into seven courses that covered the full 4 years of Rowan's civil engineering curriculum. Professors designed instructional materials including quizzes, exams, and homework assignments. "We [Rowan] plan to continue the lectures on the SHRP2 products as we have a system in place to fully integrate the product into our full curriculum," said Professor Yusuf Mehta. Professors videotaped lectures for future use and hope to incorporate additional SHRP2 products down the road. A course evaluation revealed that students were most interested in two products: ***Innovative Bridge Designs for Rapid Renewal*** (R04) and the ***EconWorks*** (C03/C11) website.

Building On Success

"The first round of SHRP2 Education Connection was extremely successful in that it brought 22 SHRP2 products or product bundles into classrooms across the country," said Lucero. "Based on this strong response from the academic community, we hope to offer a second round of the initiative and are now exploring the possibility of expanding the model to other technology deployment efforts. There's tremendous value in helping our future workforce apply these innovative solutions."

SHRP2 Education Connection Recipients

In 2015, the FHWA awarded 10 universities with cooperative agreements to integrate their choice of one or more SHRP2 Solutions into their existing curriculum. To learn more about the SHRP2 Education Connection course materials, please contact the individual university instructors. Contact information is available on the GoSHRP2 Education Connection site.

- Bradley University (Illinois)
- Colorado State University
- Methodist University (North Carolina)
- North Dakota State University– Upper Great Plains Transportation Institute
- Rowan University (New Jersey)
- University of Missouri
- University of Idaho
- University of Nebraska–Lincoln
- University of North Carolina–Charlotte
- University of Wisconsin

Rowan University Presents SHRP2 Curriculum at American Society of Engineering Education Conference

At the June 2016 Annual Conference & Exposition for the American Society of Engineering Education, the three instructors from Rowan University presented at the Use of Technology in Civil Engineering Courses session. Their paper, entitled *Integration of Strategic Highway Research Program 2 Products within the Entire Civil Engineering Curriculum*, describes how the instructors methodically integrated 16 SHRP2 Solutions from the Renewal, Capacity, and Reliability focus areas from the freshman year through its senior and graduate courses.

3. SHRP2 Product Highlights

STRUCTURES

Lynn Camp Bridge project in Kentucky.

Innovative Bridge Designs for Rapid Renewal (R04)

Building Bridges Faster Saves Money While Reducing Risk and Delay

SHRP2's ***Innovative Bridge Designs for Rapid Renewal*** is a toolkit offering standard plans and techniques that can be adapted to rebuild most small- to medium-sized bridges. Standardized approaches streamline the activities required to get bridge replacement systems installed more quickly and less expensively. One project, the Sacaton Road Bridge in Arizona's Gila River Indian Community, used a bridge slide technique to reduce traffic disruption time by 22 weeks. The project subsequently received the Award of Merit: Highway/Bridge from ENR Southwest.

PROGRESS TO DATE

in use in **8** states
3 peer exchanges
220 peer exchange participants
280 hours technical assistance

Nondestructive Testing for Concrete Bridge Decks (R06A)

Applying Advanced Technologies to Rapidly, Safely Inspect Aging Bridges

The SHRP2 Solution, ***Nondestructive Testing for Concrete Bridge Decks***, introduces advanced technologies that rapidly and safely allow agencies to examine and locate primary deficiencies in aging concrete bridge decks. Nondestructive testing (NDT) technologies have the potential to quickly and reliably provide information about the true condition of the bridge deck structure. Accurate assessments reduce the need for frequent follow-up inspections, leading to fewer traffic interruptions from lane closures during testing operations. Agencies implementing NDT technologies are lowering costs, shaving days off inspections, and improving roadway safety. (To learn more, read about this SHRP2 Solution on page 15.)

PROGRESS TO DATE

in use in **8** states
8 field demonstrations
150 training participants

Colorado DOT staff using R06G tunnel inspection equipment.

Nondestructive Testing for Tunnel Linings (R06G)

Using Advanced Technologies to Inspect Tunnel Linings

Tunnel owners routinely need to test the integrity of the concrete lining of their tunnels to maintain and repair their assets. The SHRP2 Solution, ***Nondestructive Testing for Tunnel Linings***, has developed a user's manual for selecting NDT technologies for tunnels. The manual includes more in-depth information on equipment, test procedures, inspector's training requirements, data management procedures, data analysis procedures, limitations, and interpretation guidelines. These NDT technologies offer multiple benefits: They can minimize tunnel shutdowns, resulting in fewer detours; improve safety during the testing process; and capture 100-percent coverage of the tunnel walls.

PROGRESS TO DATE

in use in **2** states
2 training sessions
50 training participants

Service Life Design for Bridges (R19A)

Helping Engineers Design for Extended Bridge Service Life

SHRP2's ***Service Life Design Guide for Bridges*** is a comprehensive reference document that equips bridge engineers with tools to develop solutions for given conditions (including environmental considerations) and constraints. The guide shows engineers how to extend service life by using durable, state-of-the-art materials; new construction techniques; and emerging technologies that are ideally suited for specific bridge components. A report, *Durability Assessment of a Bridge Substructure*, is available, along with a graphical solution and full probabilistic tools to aid agencies undertaking the challenge of service life design.

PROGRESS TO DATE

in use in **5** states & FHWA Central Lands
1 training session
7 training session participants
1,440 hours technical assistance

Service Limit State Design for Bridges (R19B)

Planning for Strength and Durability to Extend Bridge Life

Bridges are designed to support bumper-to-bumper traffic on all lanes – and to even go beyond that for additional safety. This is known as "ultimate limit state performance" and refers to maximum load limits. The SHRP2 Solution, ***Service Limit State Design for Bridges***, is a toolkit that provides a quantitative framework to help transportation agencies more accurately predict bridge deterioration leading to cracks, corrosion and deformation, also known as the "service limit state." The toolkit provides actual performance data, component-based distress models, and specific guidance for selecting more durable common bridge elements. These tools can help increase the service life of bridge components and allows designers to select components based on expected maintenance time, difficulty of replacement, and load-limit requirements.

PROGRESS TO DATE

2 proof of concept awards in round 7 of the IAP

CONSTRUCTION & PAVEMENTS

GeoTechTools (R02)

Using the Right Technology Solution to Build Roads More Efficiently

Knowing the type of soil underneath a road or bridge is critical to ensuring safe and cost-effective construction projects. SHRP2's ***GeoTechTools*** is a web-based technology catalog with detailed information on more than 50 geoconstruction and ground modification techniques. The web-based system also contains a Technology Selection System to help users identify potential solutions to project delivery issues, factoring constraints and addressing risk. GeoTechTools can be effectively used for communication during project planning and scoping, solution identification during preliminary engineering, and better informed solution selection during final design and quality assurance. Learn more at www.GeoTechTools.org.

PROGRESS TO DATE

in use in **15** states
6,000+ registered website users

Worker Fatigue Risk Management (R03)

Increasing Awareness to Reduce Risk

Performing maintenance, rehabilitation, and reconstruction requires time consuming, complex work where the ability to close highways for repairs or reconstruction is limited. Transportation agencies' normal practice now includes extended hours of operation; longer work shifts; and night, evening, and weekend shifts. These conditions can cause worker fatigue, stress, and distraction that increase the risk of construction site injury or death. SHRP2's ***Worker Fatigue Risk Management*** developed a toolbox that offers strategies for managing workforce fatigue, stress, and distraction on rapid renewal projects. This product was not rolled out in rounds 1 – 7 of the Implementation Assistance Program, but work is underway to heighten awareness in the transportation industry, and to inform construction management and workers of the increasing dangers and hazards. The Texas DOT, with technical support from the Texas A&M Transportation Institute, is developing various safety awareness information and training materials for distracted and fatigued workers in construction work zones.

PROGRESS TO DATE

Safety awareness campaign

PCP installation at an intersection along Rockaway Boulevard in New York.

Precast Concrete Pavement (R05)

Sharing Knowledge about New Technologies to Promote More Efficient Projects, Longer Lived Roads

The SHRP2 Solution, ***Precast Concrete Pavement (PCP)***, offers a series of guidelines and model specifications to help agencies effectively select projects for PCP, and to design, fabricate, and install long-life jointed and prestressed PCP systems. The FHWA is delivering webinars and workshops for state DOTs and other agencies, and is providing assistance in the development of plans and specifications for PCP projects. States are initiating more projects as agencies learn the benefits of PCP – the majority of which involve concrete panel replacement, especially at busy intersections. Twelve states have received implementation assistance through SHRP2. Beyond SHRP2, an additional 20 transportation agencies have initiated projects. *Precast Concrete Pavement* has moved into routine use in four states.

PROGRESS TO DATE

in use in **32** states
18 training sessions
45 peer exchange participants

Technologies to Fingerprint Construction Materials (R06B)

Verifying Construction Materials without the Wait

Quality assurance operations during construction are important to ensure all contract requirements are met and projects are built to last. SHRP2 research evaluated several technologies to assist inspectors in conducting onsite analysis of commonly used construction materials. Two that show promise are the hand-held X-ray florescence (XRF) instrument and the compact Fourier transform infrared spectroscopy (FTIR) unit – both included in the SHRP2 Solution, ***Technologies to Fingerprint Construction Materials***. Using these tools, inspectors are able to quickly verify some materials in the field, thereby reducing the use of unacceptable materials, and expediting the overall construction process. This is a benefit to all involved: state and local transportation departments, contractors, materials suppliers, and the public.

PROGRESS TO DATE

in use in **3** states
30 training & showcase participants
80+ hours technical assistance

Technologies to Enhance Quality Control on Asphalt Pavements (R06C)

Controlling for Quality during Construction Promotes Longer Pavement Life

The uniform blending of hot-mix asphalt is critical to the durability and long-term performance of an asphalt roadway. The SHRP2 Solution, ***Technologies to Enhance Quality Control on Asphalt Pavements***, uses infrared radar (IR) and ground-penetrating radar (GPR) to measure temperature and density uniformity during construction. These technologies deliver real-time testing of potentially 100 percent of the pavement area during construction, providing much greater inspection coverage than existing quality control methods. The IR technologies also improve process control, providing immediate information to contractors on equipment operations. Contractors can complete projects faster, saving time and money, while delivering a high-quality product. Read more about this SHRP2 Solution on page 18.

PROGRESS TO DATE

in use in **9** states & Federal Lands
13 field demonstrations
400+ hours of technical assistance
150+ field demonstration participants

Advanced Methods to Identify Pavement Delamination (R06D)

Faster Technologies for Evaluating Asphalt Pavement

The SHRP2 Solution, ***Advanced Methods to Identify Pavement Delamination***, offers nondestructive testing technologies that can detect delamination in hot-mix asphalt faster and without damage to the pavement. The first technology identified is 3D ground-penetrating radar, which can operate at up to 40 miles per hour while covering the full width of a lane. The second technology is impact echo (IE) combined with seismic analysis of surface waves (SASW). IE and SASW – when used together – complete data collection in less than 1 percent of the time required by manual testing.

PROGRESS TO DATE

in use in **5** states
35 training & showcase participants
80+ hours technical assistance

GPR can help detect delamination in hot-mix asphalt.

Real-time smoothness measurements (self-propelled work bridge).

Tools to Improve PCC Pavement Smoothness during Construction (R06E)

Promoting Advanced Technologies that Speed Project Delivery

Most states have smoothness requirements for concrete pavements, but often contractors cannot determine smoothness before the concrete hardens. Correcting surface irregularities after hardening can lead to increased costs and project delays. The SHRP2 Solution, ***Tools to Improve PCC Pavement Smoothness During Construction***, evaluated and tested several innovative technologies to improve process control and allow on-the-fly equipment and operations adjustments. During construction, while the concrete is still in a semi-plastic state, contractors can identify and reduce surface irregularities on concrete pavements—meeting quality requirements in real time and completing projects on schedule. Agencies and contractors can avoid the costs and delays associated with performing additional work to correct problems after the concrete hardens. Read more about this SHRP2 Solution on page 20.

PROGRESS TO DATE

in use in **9** states
10 field demonstrations
400+ training session participants
450+ hours of technical assistance

Composite Pavement Systems (R21)

Designing and Constructing Durable Concrete Projects at Potentially Lower Costs

Many agencies today are faced with the challenge of designing and constructing sustainable (using recycled materials) and economical projects in rehabilitating pavements, all while providing for a long service life. Pavements that combine new asphalt over concrete or new 2-lift concrete generally have a long service life with excellent smoothness, structural capacity, and the ability to be renewed rapidly. SHRP2's ***Composite Pavement Systems*** provides transportation agencies with guidance, specifications, objective and reliable performance data, and life-cycle cost analyses to support use of these pavement systems. A field report from the Tennessee Department of Transportation outlines how the agency integrated the construction of two-lift concrete composite pavement into an existing full-depth concrete replacement project on Interstate 65 just north of downtown Nashville, TN. The report is available on the GoSHRP2 website.

PROGRESS TO DATE

in use in **4** states
10 training sessions
900+ training session particpants

Building long life pavements using existing pavements in place.

Iowa microsurfacing project.

Pavement Renewal Solutions (R23)

Reusing Existing Pavements to Save Resources, Increase Pavement Longevity

Transportation agencies get environmental and economic benefits by recycling existing pavement materials when rehabilitating roadways. The technique reduces costs, accelerates project completion, and saves valuable resources while building pavements that can last 30 to 50 years. While reusing pavements is not always possible, SHRP2's ***Pavement Renewal Solutions*** product and the rePave tool help agencies identify projects where reuse can be successful. rePave is an interactive web-based pavement design scoping tool (http://www.pavementrenewal.org) that helps users examine advantages and disadvantages, timing, and methods for integrating recycled materials with adjacent road structures. When the Washington Department of Transportation used these tools on a project to rehabilitate Interstate 5, the agency saw a 20 percent savings in construction costs and reduced construction-related lane closures by 43 percent.

PROGRESS TO DATE

in use in **9** states
9 field demonstrations
100+ field demonstration participants
540+ hours technical assistance

Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)

Identifying Optimal Times for Pavement Treatments to Minimize Delay, Extend Pavement Life

Extending the life of high-traffic roadways without major reconstruction and traffic disruption saves time and money. SHRP2's ***Guidelines for the Preservation of High-Traffic-Volume Roadways*** gives transportation agencies decision-making tools to identify the right pavement preservation technique for their unique situation. This product suggests a systematic approach that addresses different road conditions and preferred timing of treatments to reduce traffic impacts. Product resources available include an introductory webinar, a presentation on implementation strategies, and a product annual report.

PROGRESS TO DATE

in use in **16** states & the District of Columbia
2 peer exchanges
6 workshops
400+ participants

PLANNING & PROJECT DELIVERY

PlanWorks: Better Planning. Better Projects. (C01)

Improving Transportation Collaboration

PlanWorks gives transportation agencies a web-based resource to improve decision making throughout their transportation planning and project development processes. It helps agencies find better ways to improve planning business processes, including collaboration and coordination with stakeholders and partners. *PlanWorks* is built around four components: Decision Guide, Assessments, Applications, and the Library. Several SHRP2 products in planning and project delivery are integrated within the *PlanWorks* website and its four components. In 2017, *PlanWorks* will be updated with new case studies, examples of successful collaboration, content updates, online training, and other features.

PROGRESS TO DATE

in use in **12** states
229 participants trained
250 hours technical assistance or support provided

TravelWorks (C10/C04/C05/C16/C46)

- **Partnership to Develop an Integrated, Advanced Travel Demand Model and a Fine-Grained, Time-Sensitive Network (C10)**
- **Improving our Understanding of How Highway Congestion and Price Affect Travel Demand (C04)**
- **Understanding the Contribution of Operations, Technology, and Design to Meeting Highway Capacity Needs (C05)**
- **The Effect of Smart Growth Policies on Travel Demand (C16)**
- **Resources for Using State-of-the-Art Travel Demand Models (C46)**

Integrating Complex Factors into Travel Demand Models for More Accurate Planning Decisions

Planners often have difficulty forecasting how highway congestion, congestion pricing, and smart growth policies will affect travel demand. ***TravelWorks*** is a set of advanced travel analysis tools that address today's transportation planning and modeling challenges. This SHRP2 suite of five products helps planners estimate travel demand in a way that integrates activities, networks, and the environment. Travel demand modeling systems can now reflect how travelers respond to congestion, travel-time reliability, and pricing, so decisions about operational improvements can be based on more reliable models. With better models, agencies can

understand how operations can improve the function of their highway networks. Read more about *TravelWorks* on page 28.

PROGRESS TO DATE

in use in **8** states
3 workshops
5 peer exchanges
200 workshop participants

EconWorks (C03/C11)

- **EconWorks Case Studies (C03)**
- **EconWorks Wider Economic Benefits (W.E.B.) Tools (C11)**

Communicating Economic Analysis Outcomes to the Public and Decision Makers

Investing in highway capacity supports the economic vitality of a region by making it attractive for new businesses and jobs. Transportation planners must select projects that will provide the greatest benefit for the least cost. This is a complex process, and explaining to officials and the public why one project is a better investment than another can be challenging. The SHRP2 Solution, ***EconWorks***, is a collection of tools designed to help planners assess and logically explain these details to decision makers and the public. These tools are designed to help planners incorporate economic analysis into early transportation project decisions. The *EconWorks* site includes a 75-minute training course on economic analysis in transportation planning, in addition to an "Assess My Project" feature. In 2016, transit projects were added to the *EconWorks* Case Studies so practitioners can determine their potential economic outputs.

PROGRESS TO DATE

in use in **9** states
111 case studies available
170 participants trained

Planning Process Bundle (C02/C08/C09/C12/C15)

- **Performance Measures for Highway Capacity Decision Making (C02)**
- **Transportation Visioning for Communities (C08)**
- **Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Framework (C09)**
- **Guide to Public-Private Partnerships and Non-Standard Procurements (C12)**
- **Integrating Freight Considerations into the Highway Capacity Planning Process (C15)**

Incorporating Diverse Stakeholder Groups to Improve Planning and Decision Making

Transportation planning is a complicated business, and decision makers require reliable and accurate information to achieve successful outcomes. This means collaborating with other agencies, organizations and local communities to obtain data, collect feedback, and coordinate projects that meet the needs of all transportation stakeholders. The ***Planning Process Bundle*** is a complementary group of SHRP2 products that helps agencies collaborate to consider performance measures; visioning; greenhouse gas emissions; public-private partnerships; and freight during the transportation planning, programming, and project development processes. For example, the Kentucky, Ohio, West Virginia Interstate Planning Commission – known as KYOVA – is using this SHRP2 product to improve the project prioritization process for the metropolitan area's transportation planning efforts.

Products in the *Planning Process Bundle* have been integrated throughout *PlanWorks* to improve collaboration with stakeholders.

PROGRESS TO DATE

in use in **12** states
2 workshops
250 hours of technical assistance

Expediting Project Delivery (C19)

Accelerating Project Execution and Delivery to Reduce Project Costs

Speeding up the delivery of transportation projects is high on everyone's agenda — from the traveling public to the communities and businesses that rely on timely delivery of goods and services. SHRP2's ***Expediting Project Delivery*** offers two dozen strategies, new approaches, and recommendations for early coordination among agencies, stakeholders, and the public. These strategies address 16 common constraints and provide innovative approaches to transportation decision making that result in better projects and environmental outcomes. *Expediting Project Delivery* has been integrated into the *PlanWorks* Assessments component. At a peer exchange in July 2016, representatives from state transportation agencies in Arizona, Massachusetts, Florida, and Vermont joined with the Maricopa Association of Governments to present the benefits, challenges, and lessons learned implementing *Expediting Project Delivery* strategies within their organizations.

PROGRESS TO DATE

in use in **10** states by **20** state DOTs & **2** MPOs
8 workshops
225 workshop participants
1 peer exchange with **6** IAP recipient presentations
60 peer exchange attendees

Freight Demand Modeling and Data Improvement (C20)

Predicting Freight Trends to Improve Project Investment Decisions

Moving freight efficiently is important to everyone – from shippers and motorists who share the roadways to the businesses and consumers who need the goods and services carried by millions of trucks each day. Increased freight traffic will affect everything from roadway safety and congestion to the condition of the transportation infrastructure. SHRP2's ***Freight Demand Modeling and Data Improvement*** offers guidance that will lead to improved freight data sets and freight modeling practices. This SHRP2 Solution provides a strategic plan to guide and help state, regional, and local planners better predict trends in freight movement and make more informed project investment decisions. The strategic plan and the Winston-Salem Metropolitan Planning Organization's case study report are both available on the GoSHRP2 website.

PROGRESS TO DATE

in use in **11** states
2 workshops
47 workshop participants
2 peer exchanges

Performance Specifications for Rapid Renewal (R07)

Fostering Innovation that Leads to Faster Project Delivery and Safer, More Durable Solutions

In response to the widening gap between investment needs and available resources, transportation agencies have begun to explore ways to shift more responsibility for product performance to contractors. The traditional way of building highway projects – using minimum requirements that tell the contractor how to perform the work – does not provide an incentive to do more than meet those minimum requirements. SHRP2's ***Performance Specifications for Rapid Renewal*** includes model performance specifications for various project types and project delivery methods. These specifications allow the highway construction industry to offer creative solutions in transportation projects, which can result in faster project delivery, minimal disruption, and greater durability. In November 2015, five state departments of transportation and one tollway authority shared their experiences with *Performance Specifications for Rapid Renewal* during a peer workshop. A follow-up peer exchange in September 2016 shared information among 12 state DOTs, one toll authority, Federal Lands, and academia. Those presentations are available on the GoSHRP2 website, and a final peer exchange is planned for March 2017.

PROGRESS TO DATE

in use in **5** states & Federal Lands
75 workshop & peer exchange participants

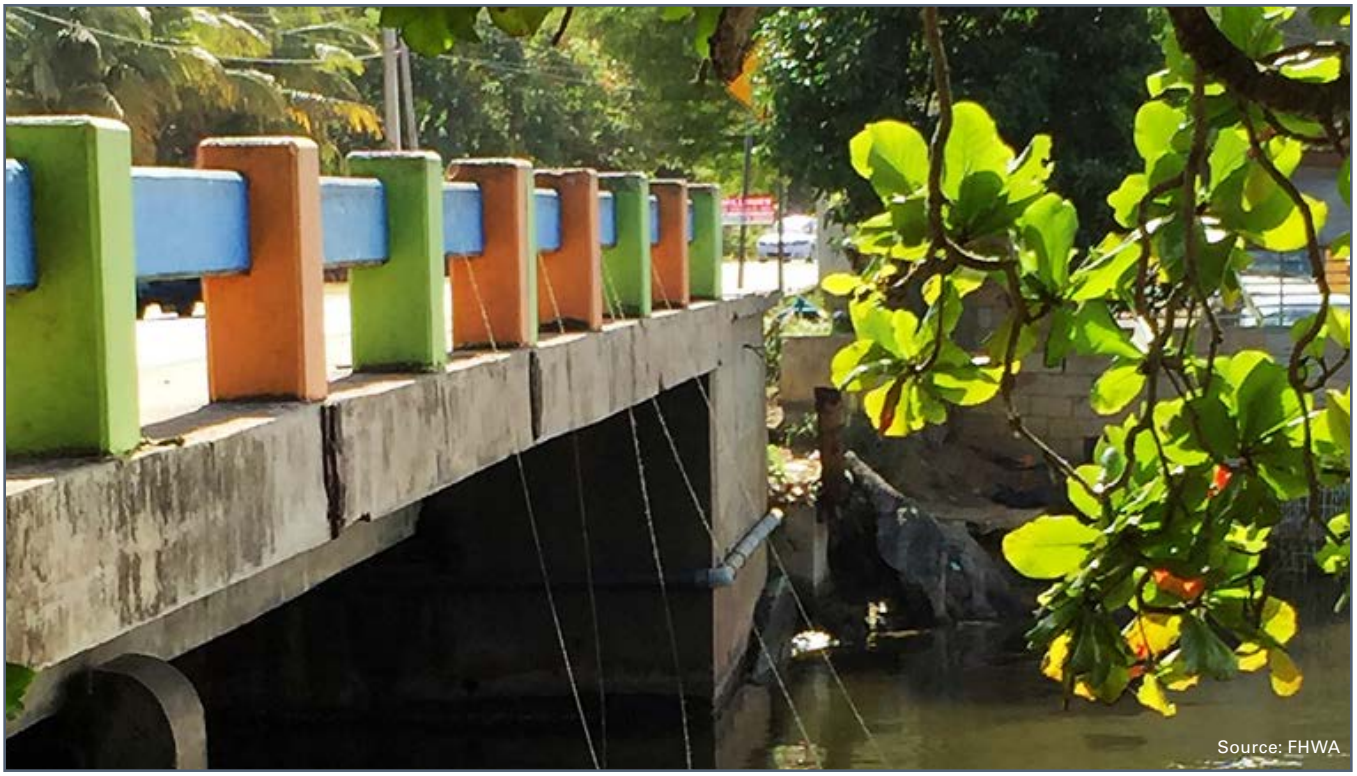
Managing Risk in Rapid Renewal Projects (R09)

Proactively Identifying and Mitigating Risks Before They Become Costly

Highway projects vary in sizes and complexity and use a variety of financing mechanisms and delivery methods. Every construction project involves the potential for schedule delays, budget overruns, and other unexpected problems or risks that affect project performance. These risks not only incur delays, unforeseen changes, and extra expenses, but they also undermine public confidence. SHRP2's ***Managing Risk in Rapid Renewal Projects*** shows managers and project teams how to quantify risks and offers practical methods to identify, assess, mitigate, allocate, and monitor risk throughout a project. Understanding risk leads to better financial management and fewer construction changes, saving both project time and money. Case studies from Puerto Rico and Oregon are available on the GoSHRP2 website, in addition to a risk management template and user's manual.

PROGRESS TO DATE

in use in **8** states
5 workshops
7 facilitator training sessions
284 training & workshop participants



Bridge 702 on Puerto Rico Route 681 before Arecibo, Puerto Rico.

Project Management Strategies for Complex Projects (R10)

Spurring Innovative Solutions While Anticipating Project Complexities

Project management has long focused on three elements — cost, schedule, and technical requirements. While these are essential, complex projects, particularly those in the rapid renewal area, require better strategic planning and execution from conception through construction. SHRP2's ***Project Management Strategies for Complex Projects*** expands the traditional three-dimensional analysis of cost, schedule, and technical requirements, and creates a model that supports project management needs in five areas by adding financing and context considerations. *Project Management Strategies for Complex Projects* supports a systematic management approach that speeds decision making, addresses complex issues, and accelerates government approvals for rapid renewal projects. A peer exchange report and video, and cases studies from Rhode Island, Washington, and Wisconsin are available on the GoSHRP2 website.

PROGRESS TO DATE

in use in **12** states
7 training sessions
121 training session and peer exchange participants
101 hours technical assistance

SAFETY & THE ENVIRONMENT

Implementing Eco-Logical (C06)

Identifying and Planning for Eco-Logical Priorities

Transportation agencies must always consider environmental concerns when building transportation projects. By using the tools offered in ***Implementing Eco-Logical***, agencies can improve environmental outcomes, stay on schedule, and strengthen relationships with federal, state, and local regulatory agencies. The Eco-Logical approach organizes current methods for addressing natural resource identification, avoidance, minimization and compensatory mitigation into a systematic process that takes projects from start to finish. Users can select which steps of the approach best meet their program needs.

The Eco-Logical Starter Kit provides a framework for implementing the Eco-Logical approach and establishing a Regional Ecosystem Framework. In addition, the Starter Kit is a major source for case studies that illustrate how various state DOTs, MPOs, and other agencies have implemented specific steps of Eco-logical. The Charlottesville-Albemarle MPO case study shows an example of steps 1-4, while a case study featuring the Colorado DOT's Interstate 70 Mountain Corridor demonstrates steps 7-9. A soon-to-be released case study highlights the North Carolina Department of Environmental Quality's In-lieu Fee Program and its implementation of steps 5-6.

Implementing Eco-Logical has been integrated into the PlanWorks' Applications component and offers strategies to improve collaboration with environmental stakeholders and accelerate project delivery. More about this SHRP2 Solution can be found on page 8, in an update on the progress of the Eco-Logical Approach currently used in Maine and Michigan.

PROGRESS TO DATE

in use in **11** states
15 training sessions
9 peer exchanges
917 participants

The Safety Training and Analysis Center is located at the Turner-Fairbank Highway Reseach Center.

Concept to Countermeasure – Research to Deployment Using the SHRP2 Safety Data

Driver-Roadway Interactions to Develop Effective Countermeasures

Driver behavior is cited as the primary factor in more than 90 percent of crashes, but little is known about what role this behavior plays in causing or preventing these crashes. Under the SHRP2 Safety focus area, two comprehensive databases were produced to provide researchers an in-depth understanding of how drivers interact with their vehicles and the roadway. The Naturalistic Driving Study (NDS) database and the Roadway Information Database (RID) offer more than two petabytes of driver behavior data to researchers and their DOT counterparts.

To continue this research beyond SHRP2, FHWA has established the Safety Training and Analysis Center (STAC) to help the research community and state departments of transportation use data from the NDS and RID. The STAC provided technical support to the New England Transportation Consortium (a research cooperative between the Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont DOTs) on a recent solicitation to use the NDS to examine safety concerns for older drivers. Read more about this SHRP2 Solution on page 32.

PROGRESS TO DATE

Phase 1 concluded **2015**
9 of 11 Phase 1 studies advanced to **Phase 2**
Phase 2 initiated in 2016

RAILROADS & UTILITIES

Railroad-DOT Mitigation Strategies (R16)

Bringing Agencies and Railroads Together to Coordinate Solutions

The tactics included in SHRP2's ***Railroad-DOT Mitigation Strategies*** streamline and improve project coordination between public highway departments and railroads, saving time and money for both entities. Through a collection of model agreements, sample contracts, training materials, and standardized best practices, public agencies and railroads can identify and work through or avoid sources of conflict to advance projects more quickly, reducing construction costs resulting from lengthy project delays. This SHRP2 Solution is also an Every Day Counts (EDC) innovation. In addition to SHRP2 implementation, through EDC-3, nine states have put this innovation into regular practice. To learn more, read about this SHRP2 Solution on page 10.

PROGRESS TO DATE

in use in **28** states
4 training sessions
72 workshop participants

SHRP2 Utility Solutions

When it comes to designing and implementing transportation projects, utility conflicts identified at the end of the design period or during construction can extend construction time, pose safety concerns, and increase costs. The SHRP2 Utility Solutions comprise a related group of SHRP2 products that address elements of utility locating techniques and technologies, and the storage and retrieval of this critical data.

3D Utility Location Data Repository (R01A)

Locating Utility Lines before Construction to Reduce Costly Delays

Thousands of hours of delay and potentially millions of dollars in costs can accrue annually from construction activities that inadvertently cut or damage underground utility lines. The SHRP2 Solution, ***3D Utility Location Data Repository***, is a 3D storage and retrieval data model that allows designers to identify locations where utility lines must be moved or protected. The model can suggest optimal solutions since it can accommodate large volumes of utility data, interface with existing design software, and provide a method for organizing the data. Knowing the location and depth of utilities enables designers to change designs to avoid costly utility relocation and delays in project delivery. During construction, contractors can pull up mapping systems that

accurately display the location and depth of the utilities, so the utilities can be avoided and delays prevented. The ability to store data in a single platform also can minimize the cost of data collection on future projects.

PROGRESS TO DATE

in use in **5** states
5 IAP training sessions
150 hours technical assistance

Utility Locating Technologies (R01B)

Using Advanced Technology to Locate Utility Lines, Saving Time and Money

Underground utilities are made from many different types of materials and can be located at random depths in soil conditions ranging from silty clay to sandy loam. Knowing the location, depth, and other important attributes of utilities enables more efficient and productive coordination with utility owners during the design process of a roadway project. Having this vital information helps minimize utility conflicts, and can save lives, money, and time. The SHRP2 Solution, ***Utility Locating Technologies***, identifies two advanced utility locating technologies that help agencies detect subsurface utilities. The first is multi-channel ground-penetrating radar (MCGPR), which is only suitable in some geographical areas of the United States due to attenuation of MCGPR signals in clay or other conductive soils. The second utility technology is Time Domain Electromagnetic Induction (TDEMI), which can work in highly conductive soils and identify metal utilities or those installed with a metal tracer wire. Fewer unexpected delays or complications are encountered when these subsurface utility engineering technologies are used.

PROGRESS TO DATE

in use in **5** states
5 training sessions
530 hours technical assistance

Identifying and Managing Utility Conflicts (R15B)

Improving Cooperation among Highway Agencies and Utilities for Faster Project Delivery

By using the tools developed through the SHRP2 Solution, ***Identifying and Managing Utility Conflicts***, highway agencies can identify and resolve conflicts regarding utilities and roadways early in a project, avoiding costly delays and saving thousands of dollars. This solution includes a training course, a companion report, and the Utility Conflict Matrix (UCM). The UCM and its companion report *Identification of Utility Conflicts and Solutions* provide concepts and procedures to identify and resolve utility conflicts that public agencies and utilities can use to help improve the highway project development process. Additionally, a one-day training course has been developed to help agencies incorporate the UCM in existing business practices so that utility conflicts are identified throughout the design process. The Kentucky Transportation Cabinet integrated the UCM into its internal utility application and has conducted statewide training and field deployment. The case study is available on the GoSHRP2 website.

PROGRESS TO DATE

in use in **13** states
11 training sessions
220 hours technical assistance

OPERATIONS

Organizing for Reliability (L01/L06/ L31/L34)

- **Guide to Integrating Business Processes to Improve Travel-Time Reliability (L01/L34)**
- **Guide to Organizing Transportation Agencies to Advance Systems Operations and Management (L06/L31)**
- **e-Tool for Business Processes to Improve Travel Time Reliability (L34)**

Assessing Programs and Processes to Better Manage Delay

Unexpected delays account for more than half of all congestion, increased safety risks, and costly disruptions. Transportation systems management and operations (TSMO) is a discipline devoted to reducing non-recurring congestion, including congestion from unpredictable or special events, such as crashes, roadway construction, inclement weather, and sporting or concert activities. A strong TSMO program requires not only technology solutions, but also business and technical processes, staffing, collaboration, performance measurement, and a strong culture of support. The SHRP2 Solution, ***Organizing for Reliability Tools***, helps agencies assess their TSMO programs and determine technical and organizational improvements to make them better able to manage unexpected congestion. Learn more about this SHRP2 Solution on page 7, including implementation efforts in the past year.

PROGRESS TO DATE

in use in **32** states
2,500 workshop participants
116 training sessions
24 peer exchanges

Reliability Data and Analysis Tools (L02/L07/L08/L05/C11)

- **Guide to Establish Monitoring Programs for Travel-Time Reliability (L02)**
- **Reliability by Design (L07)**
- **Incorporating Travel-Time Reliability into the *Highway Capacity Manual* (L08)**
- ***EconWorks* Wider Economic Benefits (W.E.B.) Tools (C11)**
- **Handbook for Incorporating Reliability Performance Measures into Transportation Planning and Programming (L05)**

Tools for Increasing Consistency in Travel Times

Inconsistent travel conditions are frustrating, costing the traveling public time and money, and putting motorists and traffic incident responders at greater risk. The SHRP2 Solution, ***Reliability Data and Analysis Tools,*** gives transportation agencies the data monitoring, analysis, and planning tools needed to understand fluctuations in traffic, identify problem areas, and reduce congestion and uncertainty in travel times. These tools provide guidance and analytical capabilities for travel-time data collection and analysis so agencies can consider the concept of reliability in their transportation project decision making. Learn more about this SHRP2 Solution on page 22, which highlights the Minnesota DOT's use of all five products.

PROGRESS TO DATE

in use in **17** states
80 peer exchange participants
30 hours technical assistance

Reliability in Simulation and Planning Models (L04)

More Efficient Travel Due to Designs that Incorporate Reliability Considerations

The SHRP2 Solution, ***Reliability in Simulation and Planning Models***, offers guidelines and pre- and post-processing tools (a scenario manager and a vehicle trajectory processor) that can be used to incorporate reliability performance measures and analysis into travel models. This SHRP2 product is designed to help state DOTs, MPOs, and other transportation agencies move reliability into their business practices, and help highway design engineers incorporate reliability into project alternative analysis. The new methods provided in this SHRP2 product are useful for project evaluation and many types of planning. Once planning decisions are implemented through completed transportation projects, the ultimate outcome is more consistent travel times and fewer incidents of congestion for the traveling public.

The FHWA worked with two metro regions to pilot test the tools in 2015–16 and gained valuable tips to share with future users. Starting in late 2016, five sites (three states and two MPOs) are piloting these tools through the SHRP2 Implementation Assistance Program.

PROGRESS TO DATE

2 pilot test completed
Analytical Framework Developed
5 proof of concept awards in Round 7 of the Implementation Assistance Program

National Traffic Incident Management Responder Training Program (L12/L32)

- **Train-the-Trainer Course (L32A)**
- **Web-based for Training Traffic Incident Responders and Managers (L32B)**
- **Post Course Assessment Tool (L32C)**

Training Incident Responders to Work as a Team Saves Lives

Effective traffic incident clearance is an important part of improving safety and reducing congestion delays. SHRP2's ***National Traffic Incident Management (TIM) Responder Training Program*** provides incident responders with a national curriculum developed by responders for responders. The training offers a set of practices and advanced standards to support safer and faster clearance of traffic crashes. Incident responders – police, firefighters, DOTs, vehicle towers, medical personnel and other emergency responders – are trained to work as a unified team, thereby improving communication and ensuring a well-coordinated response. Learn more on page 9.

In June 2016, the Towing and Recovery Association of America promoted National TIM Responder Training for its members, adding itself to the growing list of professional organizations that pushed the TIM program past the 200,000-trained milestone by August 2016.

PROGRESS TO DATE

in use in **50** states, District of Columbia, & Puerto Rico
8,524 train-the-trainer sessions
213,696 responders trained

SHRP2 Reliability Archive (L13A)

Archive Offers Data on More Than 45 SHRP2 Reliability Projects

The SHRP2 ***Reliability Archive*** is a rich resource available to the research community, traffic engineers, planners, data managers, and others interested in data related to transportation operations and travel-time reliability. SHRP2Archive.org provides more than 2 terabytes of structured and unstructured data from more than 45 SHRP2 Reliability-related projects. Users will find nearly 800 artifacts available for download, including raw datasets, analytical results, tools and models, and documentation that can be used as the basis of new analysis work. The *Reliability Archive* can help practitioners decide which SHRP2 Reliability products may be most useful and applicable to them. It also includes user experiences from SHRP2 pilot projects on work zone coordination analysis and incorporates reliability into design decisions and capacity analysis. Most importantly, the archive includes tools that make it easy to find specific data and to extract and visualize valuable information.

PROGRESS TO DATE

nearly 3,500 downloads of data sets and other artifacts since launch of the site

Communicating Traveler Information and Estimating Its Value to Travelers (L14)

Improving the Way Agencies Communicate with the Public

Travel-time reliability information provides travelers with pre-trip information to help them make informed decisions about their trips, thereby increasing mobility. With better public awareness and understanding of the variability of travel time, road users can plan their trips for routes and times that are more reliable or allow extra time if they need to travel on a route with unpredictable congestion. This can improve the predictability of trips and help travelers arrive on time. Researchers for the SHRP2 Solution, ***Communicating Traveler Information and Estimating Its Value to Travelers***, conducted human behavior research that resulted in a new inventory of terms and approaches agencies can use to convey travel-time reliability information to the public. This SHRP2 Solution also includes a series of strategies for improving the way agencies disseminate that information. The FHWA worked with three metro areas to field-test several different options for phrasing and delivering the travel-time reliability information. The results of the field tests and guidance for future deployments will be shared in reports and a webinar in early 2017.

PROGRESS TO DATE

3 field tests conducted in **3** states
14 peer exchange participants
20 hours of technical assistance

Enhanced Knowledge Transfer System (L17)

Center Offers Resources and Services to Operations Community

The National Operations Center of Excellence (NOCoE) is an expansion of SHRP2's ***Enhanced Knowledge Transfer System***. The center's mission is to improve surface transportation system reliability by lending exceptional support to transportation systems management and operations (TSMO) practitioners. A comprehensive website contains case studies, technical resources, recorded webinars for on-demand learning, discussion forums, links to an array of information, and a calendar of TSMO-related events. According to the *NOCoE 2015 Annual Report*, more than 20 NOCoE webinars were hosted, including a 6-part Capability Maturity Model webinar series. The series covered state-of-the-practice information from more than 30 workshops implementing the *Guide to Organizing Transportation Agencies to Advance Systems Operations and Management* (L06). In-person peer exchanges were conducted, including those related to the *National Traffic Incident Management Responder Training Program* (L12/L32A/L32B) and the *Regional Operations Forum* (L36). This center is a joint effort of FHWA, AASHTO, the Institute of

Transportation Engineers, and the Intelligent Transportation Society of America. The NOCoE also includes a knowledge center of more than 1,200 key TSMO resources, including the SHRP2 Reliability products. In 2016, the resources and services available from the NOCoE has continued to grow.

PROGRESS TO DATE

January 2015 site launched
2,454 average website visitors/month
2,250 reicpients of biweekly newsletter

Regional Operations Forums (L36)

Equipping Agencies and Practioners for TSMO

With tighter budgets, growing demands to move people and goods, and new operations data and strategies, many state DOTs are increasing their emphasis on effectively managing and operating their existing facilities. SHRP2's ***Regional Operations Forums*** advance transportation systems management and operations (TSMO) by providing agencies and their partners education and training on strategies; business processes; organizational capabilities; operations and planning; and technical and analytical tools. By design, the forums bring together representatives from several states for training, peer exchange, and practical exercises. Participants leave with a new understanding of TSMO, awareness of techniques and tools, and a network of peers to call when questions and issues arise. Through the Implementation Assistance Program six states are using the forum to establish or advance a TSMO training program in their states.

PROGRESS TO DATE

in use in **49** states, District of Columbia, & Puerto Rico
17 forums
400+ forum participants
6 states using materials to develop/ advance state training programs

WISE: Work Zone Impacts and Strategies Estimator Software (R11)

Mitigating Work Zone Impacts Through Corridor-Level Planning

More than half of all traffic congestion is unexpected – and one primary cause of this unexpected delay is work zones. In addition, work zones can change road conditions -- such as lane closures -- increasing the probability of certain types of crashes. Historically, agencies have scheduled construction projects on a project-by-project basis and have not always considered the combined effects of multiple work zones within a corridor or region. SHRP2's ***Work Zone Impacts and Strategies Estimator Software (WISE)*** – is a planning tool that helps agencies schedule work zones at the regional level along multiple roadways within a corridor or network. The tool allows agencies to evaluate traffic impacts due to work zones and determine which sequencing of projects will reduce overall traffic impacts. The planning tool can also help agencies identify strategies that will lead to less delay. Several *WISE* resources are available to transportation agencies, including the *WISE* software, user's guide, pilot test files, and the *WISE Software Validation and Pilot Test Report*. Through the SHRP2 Implementation Assistance Program, two state DOTs and two MPOs are currently piloting the *WISE* software and will enhance the software and integrate it into their work zone processes.

PROGRESS TO DATE

in use in **4** states
14 peer exchange participants
20 hours of technical assistance

4. SHRP2 Across the Country

Source: *Managing Utilities in Kentucky SHRP2 Case Study.*

Source: Kathy Frankle

Source: *C19 Assessment Workshop Summary Report*

SHRP2 encourages peer-to-peer knowledge sharing. Visit the GoSHRP2 website for contact information for agencies implementing these SHRP2 Solutions.

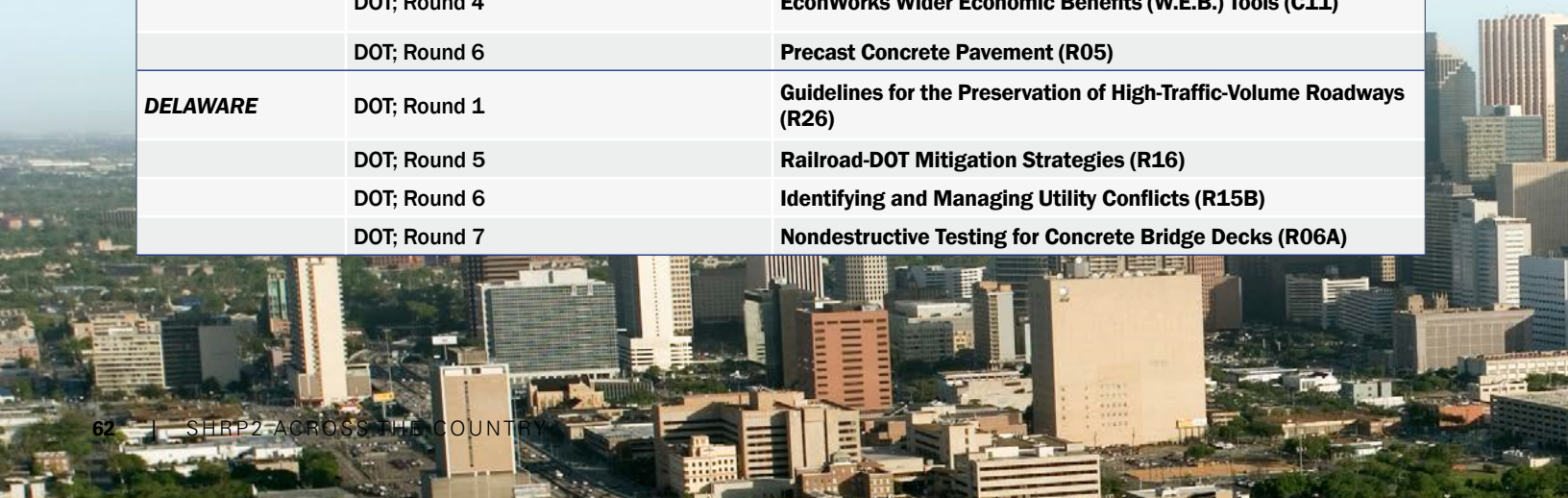
In January of 2013, FHWA and AASHTO launched the SHRP2 Implementation Assistance Program (IAP) designed to assist federal, state, and local transportation agencies in deploying the SHRP2 products. Under the IAP, a wide range of product implementation activities is made available to transportation agencies by providing both financial and technical incentives as well as subject matter expertise. IAP recipients include state DOTs, local highway agencies, metropolitan planning organizations, tribal agencies, FHWA Federal Lands offices, and resource agencies.

SHRP2 SOLUTIONS
TOOLS FOR THE ROAD AHEAD

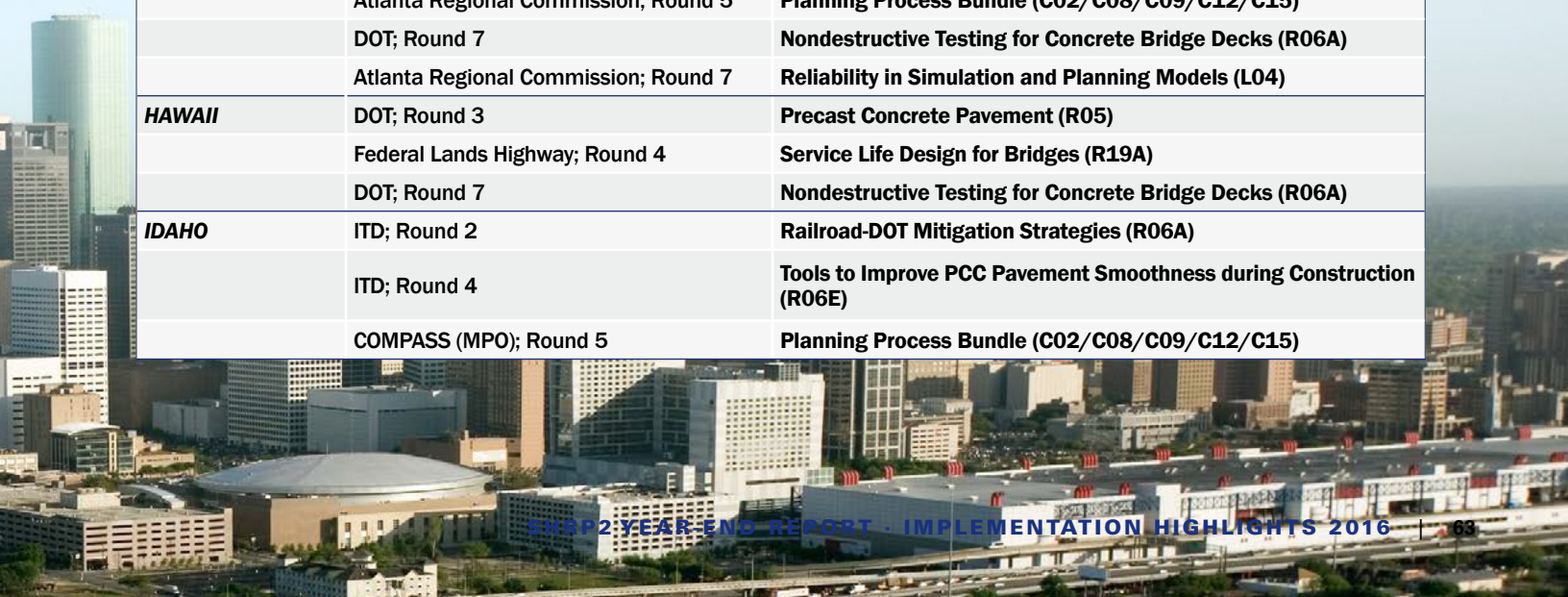
www.fhwa.dot.gov/GoSHRP2

State	IAP Recipient Agency and IAP Round	SHRP2 Product Name
ALABAMA	DOT; Round 2	Performance Specifications for Rapid Renewal (R07)
	DOT; Round 4	Technologies to Enhance Quality Control on Asphalt Pavements (R06C)
	DOT; Round 4	Tools to Improve PCC Pavement Smoothness during Construction (R06E)
	DOT; Round 6	Precast Concrete Pavement (R05)
	DOT; Round 7	Nondestructive Testing for Concrete Bridge Decks (R06A)
	DOT; Round 7	Techniques to Fingerprint Construction Materials (R06B)
ALASKA	DOT & PF; Round 4	Technologies to Enhance Quality Control on Asphalt Pavements (R06C)
	DOT & PF; Round 4	Managing Risk in Rapid Renewal Projects (R09)
	DOT & PF; Round 4	Project Management Strategies for Complex Projects (R10)
ARIZONA	DOT; Round 1	Organizing for Reliability (L01/L06)
	AZTech (Regional Partnership); Round 1	Organizing for Reliability (L01/L06)
	Gila River Indian Community DOT; Round 1	Innovative Bridge Designs for Rapid Renewal (R04)
	DOT; Round 1	Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)
	Maricopa Association of Governments; Round 2	Expediting Project Delivery (C19)
	DOT; Round 2	Expediting Project Delivery (C19)
	Maricopa Association of Governments; Round 3	Freight Demand Modeling and Data Improvement (C20)
	DOT; Round 3	GeoTechTools (R02)
	DOT; Round 3	Pavement Renewal Solutions (R23)
	DOT; Round 4	Managing Risk in Rapid Renewal Projects (R09)
	Federal Lands Highway; Round 4	Managing Risk in Rapid Renewal Projects (R09)
	DOT; Round 4	Project Management Strategies for Complex Projects (R10)
	DOT; Round 7	Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)
ARKANSAS	SHTD; Round 2	Expediting Project Delivery (C19)
	SHTD; Round 2	Railroad-DOT Mitigation Strategies (R16)
	SHTD; Round 6	Utility Locating Technologies (R01B)
	SHTD; Round 6	PlanWorks (C01)
	SHTD; Round 7	Nondestructive Testing for Concrete Bridge Decks (R06A)
	SHTD; Round 7	Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)
CALIFORNIA	Caltrans; Round 1	Implementing Eco-Logical (C06)
	Association of Monterey Bay Area Governments; Round 1	Implementing Eco-Logical (C06)
	Southern California Association of Governments (MPO); Round 1	Implementing Eco-Logical (C06)
	Caltrans; Round 1	Organizing for Reliability (L01/L06)
	Caltrans; Round 1	Innovative Bridge Designs for Rapid Renewal (R04)
	Caltrans; Round 2	Expediting Project Delivery (C19)
	Association of Monterey Bay Area Governments; Round 2	Expediting Project Delivery (C19)
	Caltrans; Round 2	Railroad-DOT Mitigation Strategies (R16)

State	IAP Recipient Agency and IAP Round	SHRP2 Product Name
CA *(continued)*	Caltrans; Round 3	**Pavement Renewal Solutions (R23)**
	San Diego Association of Governments; Round 4	**Improving our Understanding of How Highway Congestion and Price Affect Travel Demand (C04) and Understanding the Contribution of Operations, Technology, and Design to Meeting Highway Capacity Needs (C05)**
	Metropolitan Transportation Commission; Round 4	**Partnership to Develop an Integrated, Advanced Travel Demand Model and a Fine-Grained, Time-Sensitive Network (C10) [part of TravelWorks]**
	Caltrans; Round 4	**Tools for Assessing Wider Economic Benefits of Transportation (C11) [part of EconWorks]**
	Caltrans; Round 5	**3D Utility Location Data Repository (R01A)**
	Caltrans; Round 6	**Utility Locating Technologies (R01B)**
	Caltrans; Round 6	**Identifying and Managing Utility Conflicts (R15B)**
	Caltrans; Round 6	**New Composite Pavement Systems (R21)**
	Association of Monterey Bay Area Governments; Round 6	**WISE: Work Zone Impacts and Strategies Estimator Software (R11)**
	Caltrans; Round 6	**PlanWorks (C01)**
	Caltrans; Round 7	**Utility Locating Technologies (R01B)**
	Caltrans; Round 7	**Nondestructive Testing for Concrete Bridge Decks (R06A)**
	Caltrans; Round 7	**Advanced Methods to Identify Pavement Delamination (R06D)**
	Caltrans; Round 7	**Nondestructive Testing for Tunnel Linings (R06G)**
	Caltrans; Round 7	**Service Limit State Design for Bridges (R19B)**
	Caltrans; Round 7	**Regional Operations Forum (L36)**
COLORADO	Pikes Peak Area Council of Governments (MPO); Round 1	**Implementing Eco-Logical (C06)**
	DOT; Round 1	**Organizing for Reliability (L01/L06)**
	DOT; Round 2	**Railroad-DOT Mitigation Strategies (R16)**
	DOT; Round 4	**Nondestructive Testing for Tunnel Linings (R06G)**
	Denver Regional Council of Governments; Round 5	**Planning Process Bundle (C02/C08/C09/C12/C15)**
	DOT; Round 7	**Nondestructive Testing for Tunnel Linings (R06G)**
	DOT; Round 7	**Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)**
	DOT; Round 7	**PlanWorks (C01)**
	DOT; Round 7	**Regional Operations Forum (L36)**
CONNECTICUT	DOT; Round 3	**GeoTechTools (R02)**
	DOT; Round 4	**EconWorks Wider Economic Benefits (W.E.B.) Tools (C11)**
	DOT; Round 6	**Precast Concrete Pavement (R05)**
DELAWARE	DOT; Round 1	**Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)**
	DOT; Round 5	**Railroad-DOT Mitigation Strategies (R16)**
	DOT; Round 6	**Identifying and Managing Utility Conflicts (R15B)**
	DOT; Round 7	**Nondestructive Testing for Concrete Bridge Decks (R06A)**



State	IAP Recipient Agency and IAP Round	SHRP2 Product Name
DISTRICT OF COLUMBIA	DOT; Round 1	Organizing for Reliability (L01/L06)
	DOT; Round 1	Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)
	DOT; Round 5	3D Utility Location Data Repository (R01A)
	DOT; Round 5	Railroad-DOT Mitigation Strategies (R16)
	DOT; Round 6	Precast Concrete Pavement (R05)
FLORIDA	DOT; Round 1	Organizing for Reliability (L01/L06)
	DOT; Round 1	Managing Risk in Rapid Renewal Projects (R09)
	DOT; Round 2	Expediting Project Delivery (C19)
	DOT; Round 2	Managing Risk in Rapid Renewal Projects (R09)
	DOT; Round 3	Freight Demand Modeling and Data Improvement (C20)
	DOT; Round 3	GeoTechTools (R02)
	DOT; Round 4	Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)
	DOT; Round 4	Nondestructive Testing for Concrete Bridge Decks (R06A)
	DOT; Round 4	Managing Risk in Rapid Renewal Projects (R09)
	DOT; Round 4	Concept to Countermeasure – Research to Deployment Using the SHRP2 Safety Data
	DOT; Round 5	Railroad-DOT Mitigation Strategies (R16)
	DOT; Round 6	Precast Concrete Pavement (R05)
	MetroPlan Orlando (MPO); Round 6	WISE: Work Zone Impacts and Strategies Estimator Software (R11)
	DOT; Round 7	Advanced Methods to Identify Pavement Delamination (R06D)
	DOT; Round 7	Reliability in Simulation and Planning Models (L04)
GEORGIA	Atlanta Regional Commission; Round 1	Implementing Eco-Logical (C06)
	DOT; Round 1	Organizing for Reliability (L01/L06)
	DOT; Round 1	Managing Risk in Rapid Renewal Projects (R09)
	DOT; Round 1	Project Management Strategies for Complex Projects (R10)
	DOT; Round 1	Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)
	Atlanta Regional Commission; Round 4	Partnership to Develop an Integrated, Advanced Travel Demand Model and a Fine-Grained, Time-Sensitive Network (C10) [part of TravelWorks]
	Atlanta Regional Commission; Round 5	Planning Process Bundle (C02/C08/C09/C12/C15)
	DOT; Round 7	Nondestructive Testing for Concrete Bridge Decks (R06A)
	Atlanta Regional Commission; Round 7	Reliability in Simulation and Planning Models (L04)
HAWAII	DOT; Round 3	Precast Concrete Pavement (R05)
	Federal Lands Highway; Round 4	Service Life Design for Bridges (R19A)
	DOT; Round 7	Nondestructive Testing for Concrete Bridge Decks (R06A)
IDAHO	ITD; Round 2	Railroad-DOT Mitigation Strategies (R06A)
	ITD; Round 4	Tools to Improve PCC Pavement Smoothness during Construction (R06E)
	COMPASS (MPO); Round 5	Planning Process Bundle (C02/C08/C09/C12/C15)



State	IAP Recipient Agency and IAP Round	SHRP2 Product Name
ILLINOIS	Illinois Tollway; Round 3	**Precast Concrete Pavement (R05)**
	DOT; Round 4	**EconWorks Case Studies (C03)**
	DOT; Round 4	**Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)**
	DOT; Round 4	**Technologies to Enhance Quality Control on Asphalt Pavements (R06C)**
	DOT; Round 5	**Planning Process Bundle (C02/C08/C09/C12/C15)**
	Champaign County Regional Planning Commission; Round 6	**PlanWorks (C01)**
INDIANA	Ohio/Kentucky/Indiana Regional Council of Governments (MPO); Round 1	**Implementing Eco-Logical (C06)**
	DOT; Round 1	**Organizing for Reliability (L01/L06)**
	DOT; Round 4	**EconWorks Case Studies (C03)**
	DOT; Round 4	**EconWorks Wider Economic Benefits (W.E.B.) Tools (C11)**
	DOT; Round 4	**Nondestructive Testing for Concrete Bridge Decks (R06A)**
	DOT; Round 4	**Tools to Improve PCC Pavement Smoothness during Construction (R06E)**
	DOT; Round 6	**Precast Concrete Pavement (R05)**
	DOT; Round 6	**Identifying and Managing Utility Conflicts (R15B)**
	DOT; Round 7	**3D Utility Location Data Repository (R01A) and Utility Locating Technologies (R01B)**
IOWA	DOT; Round 1	**Organizing for Reliability (L01/L06)**
	DOT; Round 3	**GeoTechTools (R02)**
	DOT; Round 3	**Identifying and Managing Utility Conflicts (R15B)**
	DOT; Round 4	**Nondestructive Testing for Concrete Bridge Decks (R06A)**
	DOT; Round 4	**Project Management Strategies for Complex Projects (R10)**
	DOT; Round 4	**Service Life Design for Bridges (R19A)**
	DOT; Round 4	**Concept to Countermeasure – Research to Deployment Using the SHRP2 Safety Data**
	DOT; Round 7	**Nondestructive Testing for Concrete Bridge Decks (R06A)**
	DOT; Round 7	**Service Life Design for Bridges (R19A)**
	DOT; Round 7	**Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)**
	DOT; Round 7	**Regional Operations Forum (L36)**
KANSAS	DOT; Round 1	**Organizing for Reliability (L01/L06)**
	DOT; Round 3	**Precast Concrete Pavement (R05)**
	DOT; Round 7	**Regional Operations Forum (L36)**
KENTUCKY	Ohio/Kentucky/Indiana Regional Council of Governments (MPO); Round 1	**Implementing Eco-Logical (C06)**
	KYTC; Round 1	**Innovative Bridge Designs for Rapid Renewal (R04)**
	KYTC; Round 1	**Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)**
	KYTC; Round 3	**GeoTechTools (R02)**
	KYTC; Round 3	**Identifying and Managing Utility Conflicts (R15B)**
	KYTC; Round 3	**Pavement Renewal Solutions (R23)**

State	IAP Recipient Agency and IAP Round	SHRP2 Product Name
KY *(continued)*	KYTC; Round 4	**Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)**
	KYTC; Round 5	**3D Utility Location Data Repository (R01A)**
	KYTC; Round 5	**Railroad-DOT Mitigation Strategies (R16)**
	KYTC; Round 7	**Nondestructive Testing for Concrete Bridge Decks (R06A)**
LOUISIANA	DOTD; Round 3	**GeoTechTools (R02)**
	DOTD; Round 3	**Pavement Renewal Solutions (R23)**
	DOTD; Round 4	**Nondestructive Testing for Concrete Bridge Decks (R06A)**
	DOTD; Round 6	**Precast Concrete Pavement (R05)**
MAINE	DOT; Round 1	**Implementing Eco-Logical (C06)**
	DOT; Round 1	**Innovative Bridge Designs for Rapid Renewal (R04)**
	DOT; Round 1	**Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)**
	DOT; Round 2	**Performance Specifications for Rapid Renewal (R07)**
	DOT; Round 4	**Technologies to Enhance Quality Control on Asphalt Pavements (R06C)**
	DOT; Round 5	**Performance Specifications for Rapid Renewal (R07)**
	DOT; Round 7	**Techniques to Fingerprint Construction Materials (R06B)**
	DOT; Round 7	**Service Life Design for Bridges (R19A)**
MARYLAND	DOT; Round 1	**Organizing for Reliability (L01/L06)**
	DOT; Round 3	**Freight Demand Modeling and Data Improvement (C20)**
	DOT; Round 4	**Partnership to Develop an Integrated, Advanced Travel Demand Model and a Fine-Grained, Time-Sensitive Network (C10) [part of TravelWorks]**
	DOT; Round 4	**Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)**
	DOT; Round 6	**Identifying and Managing Utility Conflicts (R15B)**
	DOT; Round 6	**WISE: Work Zone Impacts and Strategies Estimator Software (R11)**
	DOT; Round 7	**Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)**
	DOT/SHA/Baltimore Metropolitan Council; Round 7	**Reliability in Simulation and Planning Models (L04)**
MASSACHUSETTS	DOT; Round 1	**Project Management Strategies for Complex Projects (R10)**
	DOT; Round 1	**Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)**
	DOT; Round 2	**Expediting Project Delivery (C19)**
	DOT; Round 3	**GeoTechTools (R02)**
	Southeastern Regional Planning and Economic Development District; Round 4	**EconWorks Wider Economic Benefits (W.E.B.) Tools (C11)**
	DOT; Round 5	**Planning Process Bundle (C02/C08/C09/C12/C15)**
	DOT; Round 7	**Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)**
	Southeastern Regional Planning and Economic Development District; Round 7	**PlanWorks (C01)**

Maryland Bay Bridge

State	IAP Recipient Agency and IAP Round	SHRP2 Product Name
MICHIGAN	DOT; Round 1	Implementing Eco-Logical (C06)
	DOT; Round 1	Organizing for Reliability (L01/L06)
	Federal Lands Highway; Round 1	Innovative Bridge Designs for Rapid Renewal (R04)
	DOT; Round 1	Project Management Strategies for Complex Projects (R10)
	DOT; Round 3	Identifying and Managing Utility Conflicts (R15B)
	DOT; Round 4	Concept to Countermeasure – Research to Deployment Using the SHRP2 Safety Data
	DOT; Round 7	3D Utility Location Data Repository (R01A)
MINNESOTA	DOT/MnRoad; Round 1	Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)
	DOT; Round 2	Managing Risk in Rapid Renewal Projects (R09)
	DOT; Round 3	GeoTechTools (R02)
	DOT; Round 3	Pavement Renewal Solutions (R23)
	DOT; Round 4	Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)
	DOT; Round 4	Concept to Countermeasure – Research to Deployment Using the SHRP2 Safety Data
	DOT; Round 7	Advanced Methods to Identify Pavement Delamination (R06D)
	DOT; Round 7	Reliability in Simulation and Planning Models (L04)
MISSISSIPPI	DOT; Round 3	GeoTechTools (R02)
MISSOURI	DOT; Round 1	Implementing Eco-Logical (C06)
	DOT; Round 1	Organizing for Reliability (L01/L06)
	DOT; Round 1	Innovative Bridge Designs for Rapid Renewal (R04)
	DOT; Round 1	Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)
	DOT; Round 2	Performance Specifications for Rapid Renewal (R07)
	Mid-America Regional Council (MPO); Round 3	Freight Demand Modeling and Data Improvement (C20)
	DOT; Round 3	GeoTechTools (R02)
	DOT; Round 4	Nondestructive Testing for Concrete Bridge Decks (R01A)
	DOT; Round 4	Technologies to Enhance Quality Control on Asphalt Pavements (R06C)
	DOT; Round 7	Regional Operations Forum (L36)
MONTANA	Federal Lands Highway; Round 1	Project Management Strategies for Complex Projects (R10)
	DOT; Round 7	Utility Bundle (R01A/R01B/R15B)
NEBRASKA	NDOR; Round 1	Innovative Bridge Designs for Rapid Renewal (R04)
	NDOR; Round 2	Expediting Project Delivery (C19)
	NDOR; Round 4	Technologies to Enhance Quality Control on Asphalt Pavements (R06C)
	DOT; Round 7	Regional Operations Forum (L36)
	DOT; Round 7	Nondestructive Testing for Concrete Bridge Decks (R06A)
NEVADA	DOT; Round 1	Organizing for Reliability (L01/L06)
	DOT; Round 4	Concept to Countermeasure – Research to Deployment Using the SHRP2 Safety Data

State	IAP Recipient Agency and IAP Round	SHRP2 Product Name
NEW HAMPSHIRE	DOT; Round 1	Implementing Eco-Logical (C06)
	DOT; Round 1	Organizing for Reliability (L01/L06)
	DOT; Round 3	Identifying and Managing Utility Conflicts (R15B)
	DOT; Round 4	Project Management Strategies for Complex Projects (R10)
	Strafford MPO; Round 6	PlanWorks (C01)
NEW JERSEY	DOT; Round 1	Organizing for Reliability (L01/L06)
	DOT; Round 3	GeoTechTools (R02)
	DOT; Round 3	Pavement Renewal Solutions (R23)
	DOT; Round 4	Technologies to Enhance Quality Control on Asphalt Pavements (R06C)
	DOT; Round 7	Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)
NEW MEXICO	DOT; Round 1	Project Management Strategies for Complex Projects (R10)
	DOT; Round 7	Nondestructive Testing for Concrete Bridge Decks (R06A)
	DOT; Round 7	Advanced Methods to Identify Pavement Delamination (R06D)
NEW YORK	International Transportation Technology Coalition; Round 1	Organizing for Reliability (L01/L06)
	Capital District Transportation Committee; Round 3	Freight Demand Modeling and Data Improvement (C20)
	DOT; Round 3	GeoTechTools (R02)
	DOT; Round 3	Pavement Renewal Solutions (R23)
	DOT; Round 4	Concept to Countermeasure – Research to Deployment Using the SHRP2 Safety Data
	DOT; Round 5	Railroad-DOT Mitigation Strategies (R16)
	DOT; Round 7	Nondestructive Testing for Concrete Bridge Decks (R06A)
NORTH CAROLINA	Winston-Salem MPO; Round 3	Freight Demand Modeling and Data Improvement (C20)
	Durham-Chapel Hill-Carrboro MPO; Round 4	The Effect of Smart-Growth Policies on Travel Demand (C16) [part of TravelWorks]
	DOT; Round 4	Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)
	DOT; Round 4	Technologies to Enhance Quality Control on Asphalt Pavements (R06C)
	DOT; Round 4	Project Management Strategies for Complex Projects (R10)
	DOT; Round 4	Concept to Countermeasure – Research to Deployment Using the SHRP2 Safety Data
	DOT; Round 5	Railroad-DOT Mitigation Strategies (R16)
	High Point Urban Area MPO; Round 5	Planning Process Bundle (C02/C08/C09/C12/C15)
	DOT; Round 7	Nondestructive Testing for Concrete Bridge Deck (R06A)
NORTH DAKOTA	DOT; Round 3	Pavement Renewal Solutions (R23)
	DOT; Round 7	Nondestructive Testing for Concrete Bridge Decks (R06A)

State	IAP Recipient Agency and IAP Round	SHRP2 Product Name
OHIO	Ohio/Kentucky/Indiana Regional Council of Governments (MPO); Round 1	**Implementing Eco-Logical (C06)**
	DOT; Round 1	**Organizing for Reliability (L01/L06)**
	NE Ohio (NOACA MAP); Round 1	**Organizing for Reliability (L01/L06)**
	DOT; Round 4	**Partnership to Develop an Integrated, Advanced Travel Demand Model and a Fine-Grained, Time-Sensitive Network (C10) [part of TravelWorks]**
	DOT; Round 4	**Tools to Improve PCC Pavement Smoothness during Construction (R06E)**
	DOT; Round 6	**Utility Locating Technologies (R01B)**
OKLAHOMA	DOT; Round 3	**Identifying and Managing Utility Conflicts (R15B)**
	DOT; Round 5	**3D Utility Location Data Repository (R01A)**
	DOT; Round 7	**Regional Operations Forum (L36)**
OREGON	DOT; Round 1	**Organizing for Reliability (L01/L06)**
	DOT; Round 2	**Managing Risk in Rapid Renewal Projects (R09)**
	Portland Metro MPO; Round 3	**Freight Demand Modeling and Data Improvement (C20)**
	DOT; Round 4	**Effect of Smart Growth Policies on Travel Demand (C16)**
	DOT; Round 4	**Nondestructive Testing for Concrete Bridge Decks (R01A)**
	DOT; Round 4	**Service Life Design for Bridges (R19A)**
	DOT; Round 6	**Utility Locating Technologies (R01B)**
	DOT; Round 6	**Identifying and Managing Utility Conflicts (R15B)**
	DOT; Round 7	**3D Utility Location Data Repository (R01A)**
	DOT; Round 7	**Nondestructive Testing for Concrete Bridge Decks (R06A)**
	DOT; Round 7	**Nondestructive Testing for Tunnel Linings (R06G)**
	DOT; Round 7	**Railroad-DOT Mitigation Strategies (R16)**
	DOT; Round 7	**Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)**
PENNSYLVANIA	DOT; Round 1	**Organizing for Reliability (L01/L06)**
	DOT; Round 1	**Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)**
	DOT; Round 2	**Managing Risk in Rapid Renewal Projects (R09)**
	DOT; Round 2	**Railroad-DOT Mitigation Strategies (R16)**
	Delaware Valley Regional Planning Commission; Round 3	**Freight Demand Modeling and Data Improvement (C20)**
	Delaware Valley Regional Planning Commission; Round 4	**Effect of Smart Growth Policies on Travel Demand (C16)**
	DOT; Round 4	**Nondestructive Testing for Concrete Bridge Decks (R06A)**
	DOT; Round 4	**Tools to Improve PCC Pavement Smoothness during Construction (R06E)**
	DOT; Round 4	**Nondestructive Testing for Tunnel Linings (R06G)**
	DOT; Round 4	**Managing Risk in Rapid Renewal Projects (R09)**
	DOT; Round 4	**Service Life Design for Bridges (R19A)**
	DOT; Round 5	**Performance Specifications for Rapid Renewal (R07)**
	DOT; Round 6	**Precast Concrete Pavement (R05)**
	DOT; Round 7	**3D Utility Location Data Repository (R01A) and Identifying and Managing Utility Conflicts (R15B)**

State	IAP Recipient Agency and IAP Round	SHRP2 Product Name
RHODE ISLAND	DOT; Round 1	Organizing for Reliability (L01/L06)
	DOT; Round 1	Innovative Bridge Designs for Rapid Renewal (R04)
	DOT; Round 1	Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)
	Rhode Island Statewide Planning Program; Round 4	Econworks Case Studies (C03)
	Rhode Island Statewide Planning Program; Round 4	EconWorks Wider Economic Benefits (W.E.B.) Tools (C11)
SOUTH CAROLINA	DOT; Round 2	Expediting Project Delivery (C19)
	DOT; Round 7	Identifying and Managing Utility Conflicts (R15B)
SOUTH DAKOTA	DOT; Round 1	Organizing for Reliability (L01/L06)
	DOT; Round 2	Expediting Project Delivery (C19)
	DOT; Round 2	Railroad-DOT Mitigation Strategies (R16)
	DOT; Round 3	Freight Demand Modeling and Data Improvement (C20)
	DOT; Round 3	Identifying and Managing Utility Conflicts (R15B)
	DOT; Round 7	Regional Operations Forum (L36)
TENNESSEE	DOT; Round 1	Organizing for Reliability (L01/L06)
	DOT; Round 1	Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)
	DOT; Round 4	Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)
	DOT; Round 4	New Composite Pavement Systems (R21)
	DOT; Round 5	Planning Process Bundle (C02/C08/C09/C12/C15)
	DOT; Round 6	WISE: Work Zone Impacts and Strategies Estimator Software (R11)
	DOT; Round 7	Techniques to Fingerprint Construction Materials (R06B)
	DOT; Round 7	PlanWorks (C01)
	DOT; Round 7	Regional Operations Forum (L36)
TEXAS	North Central Texas Council of Governments (MPO); Round 1	Implementing Eco-Logical (C06)
	DOT; Round 2	Railroad-DOT Mitigation Strategies (R16)
	DOT; Round 3	Precast Concrete Pavement (R05)
	DOT; Round 3	Identifying and Managing Utility Conflicts (R15B)
	DOT; Round 4	New Composite Pavement Systems (R21)
	DOT; Round 5	3D Utility Location Data Repository (R01A)
	DOT; Round 5	Planning Process Bundle (C02/C08/C09/C12/C15)
	North Central Texas Council of Governments (MPO); Round 6	PlanWorks (C01)
	DOT; Round 7	Advanced Methods to Identify Pavement Delamination (R06D)
	DOT/Houston-Galveston Area Council; Round 7	Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)
	DOT; Round 7	Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)

State	IAP Recipient Agency and IAP Round	SHRP2 Product Name
UTAH	DOT; Round 1	Organizing for Reliability (L01/L06)
	DOT; Round 3	GeoTechTools (R02)
	DOT; Round 3	Pavement Renewal Solutions (R23)
	DOT; Round 4	EconWorks Case Studies (C03)
	DOT; Round 4	EconWorks Wider Economic Benefits (W.E.B.) Tools (C11)
	DOT; Round 4	Concept to Countermeasure – Research to Deployment Using the SHRP2 Safety Data
	DOT; Round 5	3D Utility Location Data Repository (R06A)
	DOT; Round 5	Railroad-DOT Mitigation Strategies (R16)
	DOT; Round 5	Planning Process Bundle (C02/C08/C09/C12/C15)
	DOT; Round 6	Identifying and Managing Utility Conflicts (R15B)
	DOT; Round 6	PlanWorks (C01)
	DOT; Round 7	Identifying and Managing Utility Conflicts (R15B)
	DOT; Round 7	Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)
	DOT; Round 7	Reliability in Simulation and Planning Models (L04)
VERMONT	AOT; Round 2	Expediting Project Delivery (C19)
	AOT; Round 2	Performance Specifications for Rapid Renewal (R07)
	AOT; Round 3	Identifying and Managing Utility Conflicts (R15B)
	AOT; Round 7	Identifying and Managing Utility Conflicts (R15B)
VIRGINIA	Charlottesville-Albemarle MPO; Round 1	Implementing Eco-Logical (C06)
	DOT Virginia Center for Transportation Innovation and Research; Round 4	EconWorks Wider Economic Benefits (W.E.B.) Tools (C11)
	DOT Virginia Center for Transportation Innovation and Research; Round 4	Nondestructive Testing for Concrete Bridge Decks (R06A)
	DOT Virginia Center for Transportation Innovation and Research; Round 4	Technologies to Enhance Quality Control on Asphalt Pavements (R06C)
	Federal Lands Highway; Round 4	Technologies to Enhance Quality Control on Asphalt Pavements (R06C)
	DOT Virginia Center for Transportation Innovation and Research; Round 4	Service Life Design for Bridges (R19A)
	DOT; Round 6	Utility Locating Technologies (R01B)
	DOT; Round 6	New Composite Pavement Systems (R21)
	DOT; Round 6	PlanWorks (C01)
	DOT; Round 6	Precast Concrete Pavement (R05)
	DOT; Round 7	Nondestructive Testing for Tunnel Linings (R06G)
	DOT; Round 7	Railroad-DOT Mitigation Strategies (R16)
	Charlottesville-Albemarle MPO; Round 7	PlanWorks (C01)

State	IAP Recipient Agency and IAP Round	SHRP2 Product Name
WASHINGTON	DOT; Round 1	Organizing for Reliability (L01/L06)
	Whatcom Council of Governments (MPO); Round 1	Organizing for Reliability (L01/L06)
	DOT; Round 1	Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)
	DOT; Round 3	Freight Demand Modeling and Data Improvement (C20)
	Western Federal Lands Highway Division; Round 3	GeoTechTools (R02)
	DOT; Round 4	Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)
	DOT; Round 4	Project Management Strategies for Complex Projects (R10)
	DOT; Round 4	Concept to Countermeasure – Research to Deployment Using the SHRP2 Safety Data - 2 separate projects
	DOT; Round 5	Planning Process Bundle (C02/C08/C09/C12/C15)
	DOT; Round 7	3D Utility Location Data Repository (R01A) and Identifying and Managing Utility Conflicts (R15B) [part of Utility Bundle]
	DOT; Round 7	Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)
	DOT; Round 7	Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)
	DOT; Round 7	Regional Operations Forum (L36)
WEST VIRGINIA	DOT; Round 3	GeoTechTools (R02)
	DOT; Round 4	Technologies to Enhance Quality Control on Asphalt Pavements (R06C)
	WVDOT for KYOVA Interstate Planning Commission (KY, OH, WV); Round 5	Planning Process Bundle (C02/C08/C09/C12/C15)
	DOT; Round 7	Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)
	DOT; Round 7	Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)
	DOT; Round 7	PlanWorks (C01)
WISCONSIN	DOT; Round 1	Innovative Bridge Designs for Rapid Renewal (R04)
	DOT; Round 1	Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)
	DOT; Round 3	Freight Demand Modeling and Data Improvement (C20)
	DOT; Round 3	Precast Concrete Pavement (R05)
	DOT; Round 4	Managing Risk in Rapid Renewal Projects (R09)
	DOT; Round 4	Project Management Strategies for Complex Projects (R10)
	DOT; Round 7	Reliability Data and Analysis Tools (L02/L05/L07/L08/C11)
WYOMING	DOT; Round 4	Concept to Countermeasure – Research to Deployment Using the SHRP2 Safety Data

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SHRP2 SOLUTIONS

TOOLS FOR THE ROAD AHEAD

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