Washington State Transportation Center—**TRAC**

2006 2007

BIENNIAL REPORT

Washington **State Transportation Center—TRAC**

BIENNIAL REPORT 2006 - 2007

University of Washington
Washington State University
Washington State Department of Transportation

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Transportation… we all use some mode of it each day, whether we take the bus or ferry to work, walk with our child to the library, ride a train to the ball game, drive to the hardware store, or fly to visit relatives. And we expect the transportation system to work smoothly every time we use it.

But sometimes it doesn't. Weather and accidents can cause delay, disrupt connections between modes, damage infrastructure, and, at the very worst, cost lives. Modal connections can present timing challenges. Aging infrastructure requires maintenance and construction that can affect our route. With the population growth in the state, more people are using the transportation system, contributing to delays during peak use periods. With all these challenges, it can sometimes seem difficult to get from here to there.

The Washington State Department of Transportation (WSDOT) and other transportation agencies in Washington are continually looking for tools and techniques to address these issues and improve the transportation system. The Washington State Transportation Center is a key partner in this effort, bringing knowledgeable and innovative researchers together with transportation managers to develop ways to address the system's complex challenges.

This partnership has served us well for 26 years. Through research we have extended the life of our infrastructure with improved materials and design. We more effectively manage traffic flow with the use of video, loop data, and ramp meters that allow us to move more vehicles on the existing system. The safety of the traveling public has been improved through design changes and added security features. And impacts on the environment have been reduced through better understanding of those impacts and the development of strategies to avoid and mitigate them.

You'll see in the following report that work continues in all of these areas and more. In addition to the partnership among the University of Washington, Washington State University, and WSDOT you'll see many other partners from academic institutions across the country, transportation organizations in the state, and industry partners. These partnerships are critical to our success, contributing knowledge and resources from a variety of disciplines to tackle the complex challenges we face.

My thanks to the partners, researchers, technical staff, and research managers identified in this report. It is through these collaborations that we are able to better understand and enhance the transportation system in Washington.

Sincerely,
Leni Oman
Executive Director
Washington State Transportation Center

Photo by Mark Hallenbeck

Research at the Washington State Transportation Center (TRAC) addresses the needs of today's transportation systems. The studies cover a variety of fields, and many require interdisciplinary contributions. These studies benefit from the collaborative work within and between research institutions in Washington, as well as other organizations. Through these partnerships, TRAC is able to leverage knowledge, funding, and other research resources to provide cost-effective and innovative solutions to transportation-related challenges.

In the 2005-2007 biennium TRAC received funding from 19 sources and worked with 41 partner organizations.

Project Funding and Support

From July 1, 2005, to June 30, 2007, TRAC researchers were involved in nearly 100 research projects, for which the budgets totaled over $11 million. This figure does not include TRAC's administrative budgets.

Research support came from a variety of sources. In the past two years, TRAC received national funding from

- Federal Highway Administration
- National Cooperative Highway Research Program
- Transportation Northwest (TransNow), one of 10 regional university transportation research centers
- Transportation Research Board
- U.S. Congress

A number of TRAC projects were supported by consortia or the Transportation Pooled Fund program in which the FHWA and departments of transportation from other states were involved. Through these activities, Washington researchers received funding from Alaska, California, Florida, Idaho, Illinois, Kansas, Maryland, Minnesota, Montana, Oregon and Texas.

In addition to WSDOT, in-state public supporters for TRAC projects included

- Community Transit
- Puget Sound Regional Council
- Sound Transit
- Urban League of Metropolitan Seattle
- Washington Department of Fish and Wildlife
- Washington State Legislature
- Whatcom Council of Governments
- Western Washington University

TRAC received private support from or worked as a subcontractor with

- Cambridge Systematics
- Florida's Turnpike Enterprise
- Fugro-Bre, Inc.
- PCS/LAW Engineering and Environmental Services
- Post, Buckley, Schuh & Jernigan, Inc.
- Science Applications International Corp.

Cooperation and Collaboration

The breadth of TRAC research topics over the past two years involved 37 faculty and researchers from the following 12 UW and WSU departments.

- Atmospheric Sciences-UW
- Civil and Environmental Engineering-UW
- Civil and Environmental Engineering-WSU
- Construction Management-UW
- Economic Sciences-WSU
- Electrical Engineering-UW
- Evans School of Public Affairs-UW
- Forest Resources-UW
- Information School-UW
- Landscape Architecture-UW
- Social and Economic Sciences Research Center-WSU
- Urban Design and Planning-UW

Through these research projects, TRAC researchers worked with numerous partners, including private consulting firms, product manufacturers, other universities and research facilities, associations, and public agencies. Most research would not have been possible without the cooperation of these partners, and the collaborations have resulted in more successful and valuable results. Over the biennium, TRAC collaborated with the 41 research partners listed below.

Universities and Research Institutes

- Battelle Memorial Institute
- Pennsylvania Transportation Institute
- Texas Transportation Institute
- University of Washington Engineering Professional Programs
- Volpe National Transportation Systems Center

Public Agencies

- City of Bellevue
- City of Des Moines
- City of Federal Way
- City of Issaquah
- City of Kenmore
- City of Kent
- City of Kirkland
- City of Lynnwood
- City of Portland
- City of Redmond
- City of SeaTac
- City of Seattle
- City of Shoreline
- King County
- King County Metro Transit
- Port of Seattle
- Port of Tacoma

TRAC is a cooperative transportation research agency. Its members, the University of Washington (UW), Washington State University (WSU), and the Washington State Department of Transportation (WSDOT), support TRAC to coordinate both public and commercial transportation research efforts and to develop research opportunities nationally and locally.

TRAC's most important function is to provide a link among the state and other research clients, university researchers, and the private sector. TRAC acts as a liaison, connecting those who need applied research at WSDOT or other agencies and those best suited to conduct it at the universities, as well as connecting researchers to data and other resources.

From its offices at the University of Washington in Seattle and Washington State University in Pullman, TRAC coordinates resources for research, serves as a focal point for student involvement in transportation research, and provides services such as report editing, production, and graphics. In fact, over the past two years, research at TRAC has been conducted by 37 faculty and researchers in 12 UW and WSU departments for over 20 sponsors and with 41 public and private partners. The office at WSDOT in Olympia serves as the central point of contact for agency managers interested in working with university researchers and students through a variety of programs. The WSDOT provides research funding and contracts and connects researchers to technical resources.

- Puget Sound Regional Council
- Snohomish County
- Sound Transit
- U.S. Customs
- U.S. Department of Agriculture

Private Companies

- Keith Lawton and Associates
- Demich Consulting
- EnviroIssues
- Heffron Transportation
- IBI Group
- Lawrence Frank and Company, Inc
- NohBell Group
- Perteet
- The Resource Group
- RNO Group
- Technology Service Corporation
- Wilbur Smith and Associates

Associations

- Northwest Regional Modeling Consortium
- Washington Trucking Associations

Through our partner organizations, TRAC also participated in the Region X Transportation Consortium that is working to strengthen the network between University Transportation Centers and state DOTs in the Northwest.

Technology Transfer

Research dollars are wasted if clients are unaware of research results, unable to understand research findings, or unable to implement them. That's why TRAC emphasizes technology transfer as part of its operations.

Research projects are entered into the national Research in Progress database (http://rip.trb.org/default.asp) managed by the Transportation Research Board so that others can find them. TRAC makes a special effort to ensure that research reports are understandable by providing guidance to writers. Over 60 research reports were produced during the biennium. Short Research Notes were also initiated in the last biennium to briefly describe the project need, findings, and planned implementation of the results. These project summaries were distributed within the funding organization, to state DOTs, and to other interested partners. Presentations, workshops, and training are also provided when appropriate to the research topic.

TRAC also continues to maintain and improve its website, www.trac.washington.edu, to inform visitors about TRAC work, provide access to research reports and project information, and guide researchers in producing work through TRAC.

Photo by Mary Marrah

Washington is in an active seismic zone, and because of that, much of the bridge research has focused on seismic-related issues.

The focus of the bridge research has continued to be on seismic retrofitting, rapid construction techniques for active seismic zones, and improving the design and construction of bridges. The seismic retrofit program, which is scheduled to conduct retrofits by bridge type and risk, will continue for the next four years. Research continues to evaluate the next type of bridges that are scheduled for retrofit. Research is also continuing on the rapid construction of bridges that can withstand seismic activity during construction. This work will reduce on-site bridge construction time, thereby causing less traffic disruption and fewer construction hazards, while having the ability to withstand an earthquake.

Photo by Laila S. Cohagen

This construction on an SR 520 ramp in Redmond, Washington, is using segmental construction.

Completed Projects

Camber Prediction in Precast, Pretensioned Concrete Bridge Girders

Precast, prestressed concrete girders have been used in bridge construction for almost fifty years and have proved economical and durable. In many states, prestressed girders, combined with a cast-in-place deck, constitute the superstructure system of choice for bridges that span 75 to 150 ft. Precast, prestressed concrete girders typically camber upwards when they are prestressed. If this curvature is significantly larger than expected, smaller than expected, or if adjacent girders have significantly different cambers, construction problems can result. The goal of this project was to evaluate current methods for estimating camber and to develop improvements. A computer program was developed to calculate camber as a function of time. Its long-term predictions were compared with the responses of 91 girders that were monitored during construction at the Keys Road Bridge site in Washington. The improved methods developed through this project will lead to more efficient design of prestressed girders and will decrease construction difficulties and cost.

Principal Investigators: Stanton, J. F./Eberhard, M.O., UW
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Khaleghi, B., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 669.1**

Precast Systems for Rapid Construction of Bridges

WSDOT predominantly uses cast-in-place concrete construction to build many bridge substructure components and bridge decks. The use of precast systems for bridges has the potential to substantially decrease on-site construction times and reduce the impact of construction activities on traffic flow. However, although precast systems have been used by other states, the practicality and seismic resistance of such systems have not been demonstrated. In response, this project developed force-based and displacement-based procedures for designing

economical and safe bridge piers out of precast concrete components. The expected level of damage to piers designed with the proposed procedures was also estimated. Both types of procedures were found to produce bridge designs expected to withstand an acceptable amount of damage in a design-level earthquake.

Principal Investigators: Eberhard, M.O./Stanton, J.F., UW
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Kapur, J., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 629.1**

Seismic Assessment and Retrofit of Existing Multi-Column Bent Bridges

WSDOT has implemented retrofit schemes to improve the seismic performance of bridges with single-column bents throughout Washington. However, numerous multi-column bent bridges are also in need of seismic upgrade. One option would be to steel jacket all the columns, the current retrofit strategy being used for single-column bent bridges. However, this approach would exceed the allowable retrofit budget. To provide guidance for efficiently and economically retrofitting multi-column bent bridges to improve public safety, this project assessed the seismic vulnerability of the state's typical pre-1975 prestressed concrete multi-column bent bridges. The project also assessed retrofit strategies for upgrading the structures to a safe performance level and provided recommendations for selecting bridges for retrofit. The researchers concluded that because each bridge is different, investing in better analyses will enable a more efficient use of the limited funds for bridge improvement, resulting in significant savings overall.

Principal Investigator: McDaniel, C.C., WSU
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Lee, C.-S., WSDOT
Sponsor: WSDOT **Report WA-RD 639.1**

Photo by D. Bender

Current timber elements in ferry terminal wing walls could be replaced with composite material components.

Wind Response and Health Monitoring of the Tacoma Narrows Bridge

"Health monitoring" of structures for predicting and responding to deficiencies in design or construction has been gaining recent acceptance. This process is intended to avert catastrophe and give owners and authorities a tool for designing special repairs or structural modifications. In recent years, several bridges have been instrumented and monitored, and the experience has been successful, particularly in the case of large, complicated structures. This project was intended to design a health monitoring and wind response program for the existing Tacoma Narrows Bridge, which did not happen because of scheduling challenges. However, this project developed and calibrated a detailed finite element model for the existing bridge to identify its structural properties and behaviors, and the report includes the frequency analysis results.

Principal Investigator: Itani, R., WSU
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Moore, T., WSDOT
Sponsors: WSDOT/FHWA

Active Projects

Composite Material Alternatives to Timber in the Construction of Wing Walls

The use of biocide-treated timber products in harbors is under both regulatory and public scrutiny. With the listing of salmon as an endangered species in Puget Sound, the continued installation of treated wood products in existing or new harbor facilities has become problematic. However, timber has a unique combination of stiffness, wear, frictional, and economic properties that make it the material of choice for wear surfaces in this environment, particularly for ferry terminal wing walls. The wing wall system positions the vessel bow and dissipates energy through impact during the ship's approach for berthing. New wing walls are designed and built with steel piles and wall supports, but timber remains the preferred material for the wear surface that contacts the ship. WSDOT is exploring the use of other materials for this application, and this project is developing composite material components to replace current timber elements for the wear surfaces of wing walls in ferry terminals.

Principal Investigators: Bender, D./Wolcott, M.P., WSU
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Bertucci, T., WSDOT
Sponsor: WSDOT/FHWA

Prestressed Girder Blast Test

In response to a federal project to help states identify transportation structures vulnerable to terrorism, WSDOT has identified the 20 most vulnerable facilities in the State of Washington. A number of these are bridges. The logical next step is to evaluate each facility and recommend terrorism mitigation strategies. However, WSDOT has discovered that very little research has been conducted on the effects of blasts on bridges. Blast experts expect that the damage from a blast originating on top of a prestressed girder bridge will be restricted to damage to the deck and possibly one or two girders located near the blast. However, if the detonation occurs under the prestressed girder bridge, damage to the bridge may be much more substantial. In this case, the role of the deck in resisting the blast is unknown. Therefore, life-size blast experiments on prestressed girder bridges are needed. This study is experimentally and analytically examining the vulnerability of prestressed girder bridges to explosive loadings with various orientations. The results of this research will be beneficial in retrofitting prestressed bridges to prevent damage that may result from potential acts of terrorism.

Principal Investigators: McLean, D.I./McDaniel, C.C./Cofer, W.F., WSU
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Lewis, R., WSDOT
Sponsors: WSDOT/FHWA

Rapid Construction of Bridge Bents with Precast Concrete

Bridge construction can dramatically increase traffic delays and congestion, particularly in areas with heavy traffic volumes. Traffic disruption can be reduced if reinforced concrete columns and cross-beams can be precast offsite and then rapidly assembled together at the bridge site. To take advantage of the benefits of using precast bridge components in Washington State, precast concrete systems must be developed that not only can be constructed quickly but that also perform well under earthquake loading. A previous phase of this program addressed some of these issues. The extension of the use of precast concrete components to bridge bents could further reduce on-site construction time. Therefore, the overall goal of the this Phase 2 work is to develop methods of designing and constructing precast concrete bridge bents that can be built quickly, with the least possible impact on traffic, and that will perform well under earthquake loading. With the use of reliable precast bridge components, WSDOT will be better able to reduce on-site bridge construction time, thereby causing less traffic disruption and fewer construction hazards.

Principal Investigators: Stanton, J.F./Eberhard, M.O., UW
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Kapur, J., WSDOT
Sponsors: WSDOT/FHWA

Seismic Retrofit of Rectangular Bridge Columns

Bridges built before the implementation of modern seismic design codes have historically been vulnerable to the effects of seismic loading. Efforts have been made to develop and implement retrofit strategies to upgrade the seismic performance of existing bridges by enhancing the ductility of their substructure elements. A common method for improving the ductility of columns is to provide steel jacketing, typically circular or oval in cross-section. Composite materials have also been used as jacketing. Most of the previous research has focused on single-column bents. However, not only does WSDOT need guidelines on retrofit methods for improving the performance of bridges supported by multiple columns, but many of the columns in its existing bridge substructures are rectangular in cross-section. Therefore, the objective of this research is to develop practical and effective guidelines for the seismic retrofit of rectangular columns.

Principal Investigators: McLean, D.I./Sack, R./ElGawady, M., WSU
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Wilson, D., WSDOT
Sponsors: WSDOT/FHWA

Research to improve project scoping, budgeting, and management is critical for improving the success of and accountability for the hundreds of major transportation projects that are constructed every year. Project scope, time, and cost estimates for these projects are critical in making decisions about planning, monitoring, and budgeting and for maintaining accurate accountability to the taxpayers for effective project delivery.

Maintenance at night may make operations more cost and time effective.

Completed

Data Access for Trusted Partners

The University of Washington Information School (iSchool), in collaboration with Creation Logic, LLC, assisted WSDOT in evaluating methods for enabling trusted partners, such as contractors, vendors, and staff from other government agencies, to have secure, Web-based access to WSDOT databases. The UW team sought understanding of the special circumstances of the WSDOT environment, processes, and procedures by interviewing key individuals in the organization and gathering relevant, available information and documentation; researched and evaluated appropriate alternative solutions; compared these options according to WSDOT criteria and current best practices; and worked with WSDOT staff to assist them in their final evaluation of alternatives. With information provided by the project, WSDOT will be able to make knowledgeable decisions about making data sharing more flexible while maintaining security with trusted partners.

Principal Investigator: Mason, R., UW
Research Manager: Lindquist, K., WSDOT
Technical Monitor: Kemp, C., WSDOT
Sponsor: WSDOT

Highway Project Delivery Requirements

Delivery of a highway project in Washington State is a complex process that is dependent upon numerous entities for review, approval, cooperation, and coordination. Myriad federal, state, and local laws and regulations govern all aspects of project delivery—the planning process, environmental review, design, utility relocation, right-of-way acquisition, contracting, construction, maintenance, and operations. The complexity of these various regulations and the relationships of legal requirements are frequently cited as causes for delays in project delivery. Researchers worked with WSDOT to help make these requirements more transparent to highway project teams. The project included documentation of WSDOT's project delivery stages, the federal and state requirements relevant to each stage, and the roles and responsibilities of stakeholders throughout the delivery of WSDOT highway projects. The results were delivered as a series of Web pages that illustrate each process in flow charts and allow users to link the process steps in the flow charts to relevant regulatory information.

Principal Investigators: Poe, C./Machek, E./Bryan, J., Volpe National Transportation Systems Center
Research Manager: Oman, L., WSDOT
Technical Monitor: Smith, R., WSDOT
Sponsor: WSDOT **Report WA-RD 632.1**

Program Scoping State of Practice

A critical phase in the development of transportation projects is the scoping of the project before authorization or construction. After the transportation planning process has identified system deficiencies and assigned possible solutions, scoping is then used to identify the scope, schedule, and budget of project phases. If the scoping process is curtailed by schedule or budget, the projected budget and schedule can be inaccurate and lead to unrealistic expectations. The goal of this project was to identify ways to program project scoping, with adequate time and budget, earlier in the process in order to improve initial estimates and enhance the information provided for legislative consideration and authorization. Such scoping will include full cultural resource assessment, complete geo-technical investigations and other risk factors assessment, as well as traditional environmental and construction determinations of cost and requirements. Identifying the time needed to develop a complex but complete scope before legislative considerations and project implementation will set the stage for more ac-

curate and reliable scoping documents.

Principal Investigators: Jessup, E./Yoder, J./Casavant, K.L., WSU
Research Manager: Lindquist, K., WSDOT
Technical Monitor: Gabel, M., WSDOT
Sponsor: WSDOT **Report WA-RD 680.1**

Performance Analysis and Forecasting for WSDOT Highway Projects

The time and cost of highway projects are important for highway agencies to control. The objectives of this research were to develop tools to improve the prediction of time and cost for highway projects in order to reduce overruns, and to develop tools to monitor the contractor's performance during construction to detect unsatisfactory progress. Researchers developed minimum performance bounds and average performance bounds for a set of successfully completed projects and for clusters of projects grouped in categories based on quantities of asphalt, contract value, project duration, and project miles. The researchers also developed time and cost prediction models based on a number of major variables in pavement projects, including project duration, final contract value, asphalt quantity, grading, surfacing, and the number of project highway miles. These new tools will better enable WSDOT construction managers to more accurately estimate construction duration and cost before projects are bid, as well as to check the time and cost status of projects and take corrective actions to prevent overruns.

Principal Investigator: Abdel Aziz, A.M., UW
Research Manager: Lindquist, K., WSDOT
Technical Monitor: McDaniel, C., WSDOT
Sponsor: WSDOT **Report WA-RD 675.1**

Photo by MaryMarrah

Researchers developed tools to improve predicted time and costs for highway projects, such as this round-about construction near Spokane, Washington.

Environmental research in Washington is contributing to the best available science in understanding the effects of transportation on the physical environment. WSDOT is committed to delivering transportation projects and services while also protecting and enhancing the natural environment. Best practices in transportation programs and services are continually being developed through research so that Washington's valuable natural resources are protected and enhanced.

Completed Projects

Assessment of Alternatives in Roadside Vegetation Management

The WSDOT has traditionally used herbicides, along with mechanical means such as mowing, trimming, and grading, to manage vegetation along highways. Some citizens are concerned with herbicide use because of its possible impacts on human health and the environment. This study explored both the need for and the variety of alternatives to the use of an annual application of herbicides for removing vegetation next to the pavement edge. The study both developed a literature review and conducted interviews with experts. To summarize their findings, the researchers developed a decision framework that WSDOT district maintenance staff can use in formulating vegetation management plans. The decision framework differs from current practice primarily in that it begins with the assumption that maintenance of the area next to the pavement is not necessary unless some particular, observable condition triggers the need for such maintenance. This decision framework should help WSDOT maintain roadsides more safely, efficiently, and cost effectively.

Principal Investigators: Hill, K./Horner, R.R., UW
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Willard, R., WSDOT
Sponsor: WSDOT **Report WA-RD 621.1**

Determination of Hydraulic Conditions and Eddy-Like Motions in the Culvert Test Bed and Their Effects on Upstream Juvenile Salmon Passage

This study sought to determine whether the culvert retrofits recommended by the Washington Department of Fish and Wildlife, sloped-weir baffles, limit juvenile salmon passage. Culvert slope, baffle spacing, and baffle height were varied, and an Acoustic Doppler Velocimeter (ADV) was used to measure all three components of velocity. A separate, concurrent biological study was conducted by Battelle Memorial Institute. The study results will provide professionals with guidance for retrofitting culverts.

Principal Investigator: Horner-Devine, A., UW
Research Manager: Brooks, R., WSDOT
Technical Monitor: Petersen, J., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 687.1**

Environmental Investigation of Heavy Metals in Highway Runoff

Stormwater runoff from highways is a growing concern across the country. The Federal Highway Administration currently identifies cadmium, chromium, copper, iron, lead, nickel, and zinc as the heavy metals typically associated with highway runoff. The U.S. Environmental Protection Agency states that the primary sources of these metals are wear and tear of various vehicle components such as tires, engine parts, and brake pads; auto body rusting; lubricants; and fuel combustion. However, although attempts have been made to relate stormwater runoff quality to average daily traffic (ADT) loads, the relationship between metals in stormwater runoff and levels of traffic has proved to be complex, and simply treating highway runoff from roads with high ADT is not the answer. This research helped develop methodologies for testing highway stormwater for metals so that appropriate treatments can be found to protect any receiving bodies of water.

Principal Investigators: Barber, M.E./Yonge, D.R., WSU
Research Manager: Brooks, R., WSDOT
Technical Monitor: Stephens, M., WSDOT
Sponsor: WSDOT **Report WA-RD 661.1**

Remote Sensing Solutions for Estimating Total Impervious Surface Areas

Washington State's land-use planning and clean water regulations often make reference to target levels of total impervious area—land that is developed or paved and, rather than absorbing rainfall, creates runoff. The WSDOT must work within these regulations, as highways and freeways significantly contribute to the state's total amount of impervious surface area. This project developed a model for predicting the percentage of total impervious areas attributable to different types of transportation infrastructure based on current LANDSAT imagery. The researchers found that higher resolution satellites do not necessarily provide more accuracy to justify their added expense and that, in most cases, LANDSAT performed as well, if not better than, higher resolution imagery for determining regional-scale roadway impervious surface area. These results can help WSDOT more efficiently and effectively meet state regulations while designing and operating the state's highways.

Principal Investigator: Alberti, M., UW
Research Manager: Brooks, R., WSDOT
Technical Monitor: Lanzer, E., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 653.1**

Research on Upstream Passage of Juvenile Salmon through Culverts: Retrofit Baffles

Road culverts located on federal, state, and private lands may block upstream passage of juvenile salmon to suitable juvenile rearing habitat. The WSDOT is leading a cooperative program to study juvenile salmonid passage through culverts by conducting experiments in a full-scale culvert system at the Culvert Test Bed (CTB) at the Washington Department of Fish and Wildlife (WDFW) Skookumchuck Hatchery near Tenino, Washington. The overall goal of the CTB program is to identify culvert configurations and associated hydraulic conditions that facilitate successful upstream passage of juvenile salmonids. This study focused on retrofitted culverts. The main objective was to determine the passage success of juvenile salmon swimming through a culvert configured with WDFW weir baffles and to relate fish passage success to culvert slope, flow, water velocity, turbulence intensity, water depth, and other hydraulic parameters. The results demonstrated that juvenile coho salmon have remarkable abilities to adapt their behavior to accomplish upstream passage in different system configurations and under different flows.

Principal Investigators: Pearson, W./Southard, S./May, C., Battelle Memorial Institute
Research Manager: Brooks, R., WSDOT
Technical Monitors: Wagner, P./Petersen, J., WSDOT
Sponsors: Washington, Alaska, Oregon, and California DOTs, FHWA, Washington Department of Fish and Wildlife
Report WA-RD 644.1

Photo by David Thurman

Different culvert configurations and associated hydraulic conditions are being tested for their effects on salmon passage.

Research faces the challenge of congestion and its impacts on the environment and economy.

The free flow of people and goods is vital to Washington and the families that live here. That's why traffic congestion one of the state's top three transportation priorities, along with preserving road systems and ensuring safe travel. In 2003 the annual estimated cost of delays caused by traffic congestion was $486 million. In 2005, the congestion price tag rose to $598 million, an increase of 23 percent.

For years Washington has worked to manage highway congestion with tools such as high-occupancy vehicle (HOV) lanes; metered on-ramps; variable-direction express lanes; traffic cameras, variable message signs and traffic management centers; Incident Response Teams; and signal optimization. Now the state is taking the challenge to a new level. By studying the most cutting-edge and successful traffic management advances in the world, Washington is developing smarter highway systems. With an eye toward the future, the state is exploring new congestion-reducing innovations that are making our highways more efficient, less congested, and safer for all.

Research in the state is developing measurements and benchmarks to present a clear, more accurate picture of congestion on the state's most affected freeways. The research is focusing on developing ways of measuring efficiency and reliability and on producing improvements that people can see and experience.

Photo by Mark Hallenbeck

Research seeks to reduce congestion on and coordinate traffic between both freeways and arterials.

Completed Projects

The Automated Use of Uncalibrated CCTV Cameras as Quantitative Speed Sensors, Phase III

The WSDOT has a network of several hundred closed-circuit television (CCTV) traffic surveillance cameras deployed on the freeways and arterials around Seattle for congestion monitoring. The goal of this project was to create software to allow these cameras to be used to quantitatively measure vehicle speed. Building on the algorithms developed in phases 1 and 2 of this project, researchers developed ways to estimate the cameras' parameters and calibrate them. They also created a Java prototype application based on the developed algorithms that will allow users to select from a list of cameras, examine the camera view, calibrate the camera, and record speed data to a file. Successful deployment of such an application will allow WSDOT to estimate freeway speeds from existing camera equipment and freeway loop data. This will save WSDOT from having to install alternative speed estimating systems, and the resulting information can be used in programming ramp meters, detecting incidents, and counting vehicles.

Principal Investigator: Dailey, D.J., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Jacobson, E., WSDOT
Sponsors: WSDOT/FHWA **Reports WA-RD 635.1 & 635.2**

Evaluation of the Effects of Changes in HOV Lane Hours of Operation

Washington State modified HOV lane operating policy on the Puget Sound region's freeway system to allow general purpose vehicles to use HOV lanes between 7:00 PM and 5:00 AM on some freeways. To help the state understand whether these changes should be adopted permanently, researchers analyzed the combined effects of HOV safety improvements and the revised HOV operating hours on a variety of operational measures, including accident rates, HOV violation rates, and changes in the frequency of congestion that occur during the shoulders of the peak periods. They also assessed the public's opinions of the changed hours. The researchers found basically no differences in driving behavior or speeds after the operational changes. As in other parts of the country, HOV lane usage is a politically important topic with both the public and government bodies, such as the Washington State Transportation Commission. This project addressed their need to know whether changes in HOV policy were successful, and the results will help policy makers in deciding how best to operate the HOV lanes and the public in better understanding the lanes' purpose and effectiveness.

Principal Investigators: Hallenbeck, M.E./Ishimaru, J.M./Kang, J., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Briglia, P., WSDOT
Sponsor: WSDOT **Report WA-RD 643.1**

General Automata Model for Use with Real Freeway Data to Perform Congestion Prediction, Phase 3

The overall goal of this ongoing project is to create a method for predicting traffic congestion on freeway corridors. When implemented, it will provide a traffic service, like that of "pin-point Doppler" weather radar, that can predict growing or dissipating congestion. Phase 3 of this project calibrated the model and demonstrated its accuracy by testing it across full days and along a freeway length of 10 miles. It also demonstrated the utility of the model by testing its ability to simulate vehicle behavior under unusual freeway conditions. When the model is completely implemented, it will be able to predict recurring congestion, non-recurring congestion once an incident has been identified and located, and dissipation of congestion. It will also be able to estimate the effects of lane and road closures on freeway congestion. By predicting 20 to 30 minutes into the future, the model will allow WSDOT to improve its traffic control strategies and traveler information.

Principal Investigator: Dailey, D.J., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Trepanier, T., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 633.1**

HOT Lane Buffer and Mid-Point Access

By dedicating a lane of travel to buses, carpools, and vanpools, high-occupancy vehicle (HOV) lanes improve the overall person-moving capacity of a roadway. High-occupancy toll (HOT) lanes are similarly dedicated to HOVs, but they also allow solo drivers willing to pay a toll to use the surplus capacity in the lane. Tolls are adjusted to ensure that these lanes keep flowing even when general purpose lanes are congested. HOT lanes are managed by creating buffers and/or barriers and access restrictions along the roadway. This project documented information about the buffer and midpoint access designs and enforcement measures of other states' HOT lane projects and evaluated the safety, cost and performance of the different methods. The resulting design guidance for WSDOT should help the agency design safer and more effective HOT lanes on SR 167.

Principal Investigator: Burgess, C., Wilbur Smith Assoc.
Research Manager: Brodin, D., WSDOT
Technical Monitor: Forte, D., WSDOT
Sponsor: WSDOT **Report WA-RD 651.1**

HOV Lane Evaluation and Monitoring Phase VIII

Surveys have shown considerable support for the construction of HOV lanes in the Puget Sound region. In this ongoing study researchers are conducting a multi-faceted evaluation of the effectiveness of HOV lanes. The evaluation includes analysis of data collected to describe the number of people and vehicles that use the HOV lanes, the reliability of the HOV lanes, travel time savings in comparison to general purpose lanes, violation rates, and public perceptions. These statistics are available at http://depts.washington.edu/hov/.

The resulting information is intended to help transportation decision makers and planners evaluate the impact and adequacy of the existing Puget Sound HOV lane system and plan for other HOV facilities.

Principal Investigators: Hallenbeck, M.E./Ishimaru, J.M./Kang, J., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Jacobson, E., WSDOT
Sponsors: WSDOT/FHWA

Improving Dual Loop Truck Data

Real-time traffic data are essential for modern traffic control and management systems, and the WSDOT has made an enormous investment in the installation of loop detectors in the Seattle metropolitan area freeway network. Dual-loop systems provide valuable speed and truck data. However, previous research found that WSDOT's dual-loop detection system was not consistently reporting accurate truck volumes. The majority of the dual-loop detectors had significant under-count errors. In response, this project developed an algorithm, based on high-resolution loop detector data and vehicle length distribution statistics, to help identify and correct dual-loop sensitivity problems. The algorithm was implemented in a new computer application called the Advanced Loop Event Data Analyzer (ALEDA). Once they have been correctly configured, dual-loop detectors should be reliable sources for speed and truck volume data.

Principal Investigators: Nihan, N. L./Wang, Y., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Jacobson, E., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 647.1**

Improving Truck and Speed Data Using Paired Video and Single-Loop Sensors

Many freeway networks contain numerous single-loop detectors, which collect vehicle volume and lane occupancy data. However, they do not directly measure vehicle speeds or truck volumes. This study investigated a way to pair video from surveillance cameras and single-loop sensor data to produce better speed and truck data estimates. To estimate speed from single-loop measurements alone, an algorithm must assume a constant value for average vehicle length; however, given the different lengths of cars and trucks, this value can never be accurate enough. To enable more accurate speed estimation, video was used to provide truck counts, which were then applied to improve the value for vehicle length. The resulting Video-based Vehicle Detection and Classification (VVDC) system was shown to provide a cost-effective way to collect traffic data with the help of surveillance video cameras. Developing a way for single-loop detectors to support accurate measurement of speeds and truck volumes will provide highway agencies with valuable

Photo by Mark Hallenbeck

HOV lanes are considered important components of traffic management on both freeways and arterials.

data without having to install costly dual-loop systems.

Principal Investigators: Wang, Y./Nihan, N.L., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Briglia, P., WSDOT
Sponsors: WSDOT/TransNow **Report WA-RD 656.1**

ITS Program Assessment Support (IPAS)

The federally sponsored operational test called National Traffic Management Center Applications of Archived Data examined the effects of building a data archive that integrated multiple sources of data to enhance the operation of a traffic management center (TMC). The test included the development and application of a data archive at the Smart Traffic Center for Hampton Roads, Virginia. TRAC researchers provided support to SAIC in the evaluation of the TMC Test, including preparing an evaluation plan, collecting data, and analyzing results. The full report for this evaluation is available through the USDOT's Joint Programs Office Electronic Document Library.

Principal Investigator: Hallenbeck, M.E, UW
Technical Monitor: Register, D., SAIC
Sponsors: Science Applications International Corp./USDOT

NCHRP 7-16: Recommended Revisions to the AASHTO Guidelines for Traffic Data Programs

The first edition of the AASHTO Guidelines for Traffic Data Programs, published in 1992, was a highly regarded and much utilized guidebook that helped state departments of transportation and other transportation agencies in designing and operating traffic monitoring programs. However, as the years passed, the usefulness of the Guidelines diminished as the technology and reasons for data collection, processing, analysis, dissemination, and management dramatically changed. As a subcontractor to Cambridge Systematics, TRAC researchers helped develop an update to this Guide by incorporating modern technology, improved computational procedures, and updated data requirements. At the same time, the recommendations in the Guidelines were coordinated with the FHWA's recently revised Traffic Monitoring Guide. The revised AASHTO Guidelines provide practical "how-to" information for updating and enhancing current traffic monitoring procedures. It also recommends ways for traffic data programs to take advantage of modern technology to improve accuracy, efficiency, effectiveness, and responsiveness to users needs.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor: McCready, R., Transportation Research Board
Sponsors: Cambridge Systematics/NCHRP

NCHRP Project 3-68: Guide to Effective Freeway Performance Measurement

The National Cooperative Highway Research Program (NCHRP) produced a guide to help state and local highway agencies develop and utilize freeway performance measurement systems. To accomplish this, NCHRP selected a team led by Cambridge Systematics that included TRAC researchers. TRAC's role in the project included interviewing agency personnel in Seattle and Portland about their performance monitoring systems, recommending performance measures, and providing case studies illustrating the use of these measures. The report for this project has been published by the Transportation Research Board as Web-Only Document 97: Guide to Effective Freeway Performance Measurement: Final Report and Guidebook, available at http://trb.org/news/blurb_detail.asp?id=7477.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor: Derr, R., Transportation Research Board
Sponsors: Cambridge Systematics/NCHRP

Photo by MaryMarrah

Numerous projects are looking at different ways to better measure and predict congestion.

Northwest Region FLOW Analysis Support

As part of WSDOT's continuing efforts to manage the central Puget Sound region's transportation network and enhance traveler mobility, WSDOT's Northwest Region has an ongoing need for timely, detailed technical information on traffic conditions, historical trends, and emerging transportation issues associated with the area's roadways. Since 1995, TRAC has developed data collection tools and analyses intended to provide this information. This project continued to update those freeway monitoring analyses, evaluation tools, and technical support. This included conducting analyses for the fifth and sixth editions of the WSDOT Central Puget Sound Freeway Usage and Performance Report, now published as interactive graphics on-line at http://depts.washington.edu/hov, as well as analyses for an updated HOV lane evaluation. The information provided by these analyses helps WSDOT improve freeway operations, conduct planning studies, and analyze alternative policy changes in order to improve the Puget Sound transportation network.

Principal Investigators: Hallenbeck, M.E./Ishimaru, J.M./Kang, J., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Leth, M., WSDOT
Sponsor: WSDOT **Report WA-RD 623.1**

Radar for Traffic Monitoring

In remote areas, installing and maintaining embedded roadway sensors can be too expensive. However, data from such sensors could be used to predict travel time, provide driver alerts, and analyze congestion. This project investigated the technical feasibility of building a modestly priced traffic monitoring sensor based on a police speed radar that would be mounted on towers at selected locations to measure the count and speed of moving vehicles. Researchers analyzed the road visibility from candidate radar locations, designed a radar system configuration for future implementation, and identified required components and costs.

Principal Investigators: Corbeil, A./Pieramico, A./Shipley, C., Technology Service Corporation
Research Manager: Brodin, D., WSDOT
Technical Monitor: Jacobson, E., WSDOT
Sponsor: WSDOT **Report WA-RD 630.1**

Smart Highways Network Manager

The presence of Smart highways technology—modern sensors, communications, and control technology—makes it possible for a modern roadway authority to optimize the operational performance of its roadway system. "Optimization" can include maximizing the number of vehicles served, maximizing the revenue generated, minimizing the delays experienced by facility users, or a variety of other agency goals. As conditions change, operational controls and the management plans that direct them must change. The person in charge of making those control decisions and developing the management plans is the highway network manager (HNM). Under subcontract to Post, Buckley, Schuh & Jernigan, Inc., TRAC researchers developed a paper defining and describing the necessity of the HNM, the roles of the HNM, tools required for success, and data management possibilities. Findings were presented to staff of the Florida Turnpike and at a workshop in conjunction with the 73rd annual meeting of the International Bridge, Tunnel and Turnpike Association.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor: Austin, S., PBS&J
Sponsors: Post, Buckley, Schuh & Jernigan, Inc./Florida's Turnpike Enterprise

Statewide Database Design for Performance Monitoring

The WSDOT operates one of the nation's most successful archived data user service (ADUS) systems. The

ADUS gathers Puget Sound freeway operations data, generates an archive, and analyzes the archived data to produce key performance measures for use by WSDOT and other regional transportation agencies. This project improved on the ADUS by creating an archiving system that helps integrate different data collection statistics into a more accessible database, converts raw statistics into useful summary traffic statistics, and allows retrieval of statistics from multiple data sources through a single, Web-accessible, geographic information system. The improved ADUS will enhance freeway performance monitoring by covering more geographic areas, reporting additional types of performance measures, and making more data easily accessible to more WSDOT and other public agency staff.

Principal Investigators: Hallenbeck, M.E./Sanderson, A., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Briglia, P., WSDOT
Sponsor: WSDOT **Report WA-RD 627.1**

The Use of Weather and Weather Model Data to Predict Nonrecurring Traffic Congestion

While it is often asserted that there is a causal relationship between weather and roadway delays, this relationship has not been quantified. This project sought to find ways to correlate the effects of weather with both non-recurring traffic congestion and conditions that may increase incidents or accidents. Data from two databases maintained at the University of Washington were combined to evaluate the quantitative relationship between freeway speed reduction (as measured by freeway inductance loops) and rainfall rate (as measured by Doppler radar). An algorithm was developed to use rainfall radar measurements in predicting traffic speed reduction. This research has the potential to enable transportation professionals to (1) predict non-recurring traffic congestion caused by weather and (2) predict conditions under which incidents or accidents may have a significant impact on the freeway system. Thus, the system could be deployed at traffic management centers to allow for proactive metering, maintenance facilities to help in providing better roadside assistance, and incident response facilities to assist in proactively deploying incident response equipment.

Photo by MaryMarrah

Researchers developed an algorithm to use rainfall radar measurements in predicting traffic speed reduction.

Principal Investigators: Dailey, D.J./Mass, C.F., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Trepanier, T., WSDOT
Sponsors: WSDOT/TransNow **WA-RD 655.1**

Active Projects

Arterial FLOW Methodology

As a result of the WSDOT's research efforts, a freeway performance monitoring methodology and tool set, which use the WSDOT's FLOW system of loop detectors and data archiving processes, have been developed and deployed to monitor freeways. However, for a traveler considering a trip over both freeways and arterials, the distinction between the two is an artificial one; ultimately, performance of an overall trip is the prime concern. Therefore, a method of monitoring arterial performance that complements the existing freeway monitoring techniques would be desirable. The objectives of this research are to explore potential methods for monitoring arterial performance by using basic loop sensors and signal data; develop a prototype method for arterial monitoring and test it by using simulated data calibrated for a real-world corridor; and evaluate the feasibility for deployment of the signal and sensor systems required to make the method workable in practice. If successfully developed, such a method for monitoring arterial performance will benefit not only traveler information but also roadway operations and planning.

Principal Investigators: Hallenbeck, M.E./Ishimaru, J.M./Kang, J., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Trepanier, T., WSDOT
Sponsor: WSDOT

Quantifying Incident-Induced Travel Delays on Freeways Using Traffic Sensor Data

On freeways, it is generally believed that more than 50 percent of congestion is the result of incidents. Particular attention should be paid to travel delays caused by non-recurring congestion, such as that caused by incidents, because non-recurring congestion may be effectively alleviated through traffic management, control,

and incident response. To better understand non-recurring congestion in the Puget Sound, researchers are developing a database of loop detector and incident data to support delay estimation studies and decision making, developing an algorithm for quantifying incident-induced travel delay on freeways with traffic sensor data, and creating a computer system that will automate the proposed algorithm's delay calculations. The result should be a better understanding of incident delays that helps WSDOT in choosing the most effective incident response strategies and congestion countermeasures.

Principal Investigator: Wang, Y., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Trepanier, T., WSDOT
Sponsors: WSDOT/FHWA

Statewide Operations Data Archive

To improve the performance of the state's roadway system, WSDOT needs to have accurate measures of roadway system performance. To meet that need, the Department requires a robust and flexible system that collects, stores, summarizes, and makes available roadway data. A number of efforts are already under way within the WSDOT to collect, archive, and distribute data. However, the Department has lacked guidance on how to gather the data it is collecting so that they may be combined with other WSDOT data sets, and make the combined data available in a useful manner. The primary objective of this research effort is to recommend cost-effective ways to make existing WSDOT data sources more readily available. The intent is to allow previously collected data to be easily located by users throughout WSDOT, who can then quickly understand, obtain, and integrate them with data from other sources. When the archive protocol and other recommendations are implemented, they should reduce the cost of archive development, decrease the number of data that must be collected to meet "special" analysis needs, and increase the number of data available for use by WSDOT staff

Principal Investigators: Hallenbeck, M.E./Sanderson, A., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Trepanier, T., WSDOT
Sponsors: WSDOT/FHWA

Photo by Mark Hallenbeck

Systems developed to monitor freeways are being modified to also monitor arterial performance in order to improve traveler information, roadway operations, and planning.

Traffic Management Center Design

WSDOT's Northwest Region has been operating a freeway management system in the Seattle metropolitan area since the early 1980s. The system has now expanded beyond the original Traffic Management Center's (TMC) capability. Additional staff and associated workstations, video monitors, media viewing rooms,

and other facilities are needed. In addition, the Region's Emergency Operations Center (EOC) needs to be upgraded and provided with a permanent facility, probably one that is integrated with the TMC. This project is allowing TRAC researchers familiar with TMC operations to help WSDOT develop a request for proposals to hire a consultant to design a new Northwest Region Traffic Management Center. This project will allow the RFP and agency consultation process to begin immediately, providing WSDOT savings in time and money.

Principal Investigator: Briglia, P., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Balogh, M., WSDOT
Sponsor: WSDOT

Washington Incident Response Tracking System

The Washington Incident Tracking System (WITS) database is currently written in a database language that prevents it from being readily accessed by other computerized WSDOT applications. This project is rewriting the WITS database with Microsoft SQL Server, in order to make the data more accessible within WSDOT. At the same time, the project team is updating the functional capabilities of WITS. This will include a better user interface, additional reporting capabilities, improved incident location referencing systems, and the ability to enter data directly into the WITS database from remote devices. With these changes, WSDOT will be better able to access WITS data, combine that data with other operational datasets to better manage roadway operations, and develop more integrated decision support tools.

Principal Investigators: Hallenbeck, M.E./Sanderson, A., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Bremmer, D., WSDOT
Sponsor: WSDOT

WSDOT Incident Response Evaluation: Measurement of Recurring versus Non-recurring Congestion, Phase III

To enable deeper analysis of the relative importance of different causes of congestion on urban freeways, this project is developing new data analysis tools and techniques and making improvements to the ways in which WSDOT identifies and handles invalid or missing freeway data. These improvements will be used to provide insight into urban freeway congestion and the effectiveness of various operational improvement strategies.

Principal Investigator: Hallenbeck, M.E., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Trepanier, T., WSDOT
Sponsors: WSDOT/FHWA

Researchers' work to improve databases and data analysis tools for tracking and analyzing incidents and their causes will help WSDOT better manage roadway operations.

Research in freight mobility supports the state's economy and improves security

The value and volume of goods moving in the Washington State freight system are large and growing. This system consists of three components. The first is international and national trade through Washington ports, airports, and other gateways. About 70 percent of international goods entering Washington's gateways continue on to the larger U.S. market. The second component consists of the state's own producers and manufacturers. Over 519,000 jobs in regional manufacturing, agriculture, construction, and forestry depend on Washington's freight system; these industries accounted for $145.7 billion or 36 percent of all state gross business in 2005. The third component is the retail and wholesale distribution system that produces up to 80 percent of all truck trips in the state's metropolitan areas.

The state's freight policy goal is to ensure reliable freight movement and transportation investments that support Washington's strategic freight advantage. Current areas of freight research include quantifying changes in freight mobility resulting from roadway improvements; development of a Washington State Freight Data System, a comprehensive look at the freight delivery supply chain of three industries in the Central Puget Sound region; understanding the impact of variability in border crossing times on regional supply chains; improved freight mobility for economic vitality; reducing congestion at ports and borders; and increasing the security of containerized cargo movements.

Completed Projects

Development of a Washington State Freight Data System

Data on goods movements are needed to identify and evaluate options for mitigating congestion, improving regional and global economic competitiveness, improving land-use planning, enhancing transportation safety and security, and reducing fuel consumption and improving air quality. However, it is evident, at all levels of government and the private sector, that data collection activities are not coordinated, and data development and the results are not dispersed among the agencies needing the data. In order to support economic activity in the state, this project sought to create a blueprint for efficiently and effectively collecting timely and complete state freight data. This included determining gaps, redundancies, inaccuracies, and weaknesses in current data collection (such as in data on supply chains, corridors, modes, industry trade flows) and developing a plan to fill those data gaps. The resulting systematic, coordinated data collection system will help decision makers base policy proposals on complete data.

Principal Investigators: Jessup, E./Casavant, K.L., WSU
Research Manager: Brodin, D., WSDOT
Technical Monitor: Ivanov, B., WSDOT
Sponsor: WSDOT **Report WA-RD 690.1**

Freight Efficiency and Competitiveness, Phase I

Improving any freight delivery system requires knowing who uses the system, what aspects of the system users most value, and where the largest inefficiencies in the system exist. This study provided a comprehensive look at the freight delivery supply chains of three major industries—building and construction, processed food, and aerospace—to aid WSDOT in improving freight delivery in the central Puget Sound region. Research included in-depth interviews with key freight personnel in the state, industry research, and market analysis. These methods allowed a better understanding of the freight and supply chain issues of these three industries. From this, the study was able to identify and quantify bottlenecks and deficiencies in the existing transportation system, and it provided data to support the creation of a strategic investment plan for Washington State's freight transportation system.

Principal Investigator: Jones, T., Wilbur Smith and Associates
Research Manager: Brodin, D., WSDOT
Technical Monitor: Ivanov, B., WSDOT
Sponsor: WSDOT **Report WA-RD 646.1**

Identification and Evaluation of Traffic Data Gaps/ Redundancies at Washington PTR WIM Sites

To produce heavy truck data, the WSDOT Transportation Data Office (TDO) has 150 permanent traffic reporting (PTR) weigh-in-motion (WIM) sites located on state highways throughout Washington State. WSDOT evaluated PTR site needs in 1985. However, since the 1980s, the needs of TDO clients, state and regional traffic patterns, and freight shipping characteristics have evolved and changed. Therefore, this project sought to produce an updated evaluation of the PTR WIM locations throughout the state that would determine whether these sites are sufficient (or redundant) and in the proper locations to provide the freight data that the WSDOT TDO and its clients require. The project resulted in a more efficient and streamlined methodology for determining PTR WIM site organization and better transportation/traffic data for WSDOT clients. State and regional public planners and policy makers will also benefit from improved information about specific highway segments to shape infrastructure investment prioritization and guide transportation policy.

Principal Investigators: Jessup, E./Casavant, K.L., WSU
Research Manager: Brodin, D., WSDOT
Technical Monitor: Bushnell, D., WSDOT
Sponsor: WSDOT

Understanding the Impact of Variability in Border Crossing Times1 on Regional Supply Chains

When service times at vehicle processing facilities such as border stations are variable, they cause transportation planning challenges for shipping companies. These companies must either build in more time than is necessary, thus underutilizing their equipment, or risk missing delivery windows, which can incur penalties. This study examined variability in border crossing times at the facility in Blaine, Washington, and the impacts of that variability on regional supply chains. Directional, daily, hourly, and seasonal variations were examined. The researchers also interviewed regional carriers based in British Columbia and Washington. As expected, variability increases with wait times, but overall the crossing times were reported to be reasonably consistent. The primary response from shippers is to increase buffer times, which reduces the carriers' productivity. Although, the size of the inefficiency is small in comparison to trip times, the pressure for carriers to more efficiently utilize that time is expected to increase with changes in technology, new security regulations, and increasing driver scarcity.

Principal Investigator: Goodchild, A.V., UW
Technical Monitor: Davidson, D., WWU
Sponsor: Western Washington University

Active Projects

Electronic Container Seal Expansion Project

This is a Federal Highway Administration-sponsored Field Operational Test of a transponder-based system, located in electronic door seals of cargo containers, for ensuring the security of cargo containers transported by truck. This effort, which expands on an existing field test, is evaluating the efficacy of these seals as a tool for increasing the security of containerized cargo movements, for tracking shipping containers both in ports and along roadways, and for reducing roadway congestion at ports and borders. The seal is one element in a larger WSDOT effort to facilitate the movement of commercial vehicles on the state's highways by providing enforcement agencies with regulatory and management information from transponder technology.

Principal Investigator: McCormack, E.D., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Legg, B., WSDOT
Sponsors: WSDOT/FHWA

Photo by Amy O'Brien

Electronic seals for cargo container doors are being tested for their ability to increase security and track container movements.

Strategic Freight Transportation Analysis—Phase 2

Because a need exists to accurately determine how changes in intermodal technologies, energy prices, air quality concerns, and environmental efforts will affect the state's multimodal transportation system, infrastructure, and economic development, $1.4 million in federal funds was provided to continue this project. As a follow-up to Phase 1, the objectives of this study are to identify freight corridors by vehicle volume, type, and commodity; assess the operation of selected modes of the current transportation system, evaluate infrastructure adequacy, and identify deficiencies and investment needs; conduct analyses of mode cost structure and competitive mode shares as ownership and government policies change; and research opportunities for public/private partnership investments in infrastructure to stimulate and support rural economic development. The results will aid decision makers in formulating strategic, coordinated investment decisions for the multimodal system. For more information, see the project website at http://www.sfta.wsu.edu/.

Principal Investigator: Casavant, K.L., WSU
Research Manager: Brodin, D., WSDOT
Technical Monitor: Lenzi, J., WSDOT
Sponsors: WSDOT/FHW

Dealing effectively with marginal soils that contribute to slides, erosion, and liquefaction is a key focus of research.

The construction of pavements and bridges on or around marginal soils has been an important area of recent geotechnical research. Projects have looked at the use of marginal soils for fill, marginal soils underneath a structure, and the evaluation of liquefaction hazards. In addition to research on liquefaction and marginal soils, work has continued on mechanically stabilized earth walls with marginal quality backfill and the evaluation of micropiles.

Completed Projects

Investigation of Soil-Interaction and Performance of Micropiles for Retrofits

Infrastructures such as bridges, road embankments, and viaducts require sound deep foundation substructures. Because many older foundation systems have been found to be inadequate to meet the increasing demand of larger static or seismic load, great demand exists to retrofit existing deep foundations. Micropile technology has proved to be effective for retrofitting deep foundations. However, micropiles are commercialized and marketed with their own designs, and their effectiveness and performance are, at best, qualitatively based on judgment and experience. This project developed analytical models to quantitatively analyze the performance of micropile systems in relation to soil/concrete interaction, soil capacity, and deformations. This will aid WSDOT engineers in estimating their long-term performance and producing more cost-effective designs.

Principal Investigators: Rodriguez-Marek, A./Muhunthan, B., WSU
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Allen, T., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 604.1**

Active Projects

Compaction Control of Marginal Soils in Fills

One of the most pressing geotechnical issues is the use of marginal soils (such as silts and soft rock) as fill and backfill material for walls and bridge abutments. The current availability of high quality materials will become limited in the future, and costs for them will likely increase. This combination of factors will force engineers to use marginal soils. The two major issues with using marginal soils are finding a suitable compaction control method for such materials and the long-term performance of these soils. To address these issues, this project is developing effective compaction methods and control measures to ensure the sound engineering performance of fills constructed with marginal soils. The resulting guidelines on the use of marginal soils will help state and federal highway engineers improve public safety and more effectively spend resources on the management and maintenance of the highway infrastructure.

Principal Investigator: Muhunthan, B., WSU
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Allen, T., WSDOT
Sponsors: WSDOT/FHWA

Evaluation of Liquefaction Hazards in Washington State, Phase III

Soil liquefaction, caused by earthquakes, commonly occurs in loose, saturated, cohesionless soils, the types of soils often encountered in and adjacent to rivers and bodies of water n Washington State. As a result, liquefaction is frequently an important factor in the design of new bridges and has a significant impact on the seismic vulnerability of existing bridges. A number of outstanding issues need to be addressed to improve the evaluation of liquefaction hazards and the design of remedial measures in Washington. This project, continuing the work of two previous phases, developed improved procedures for evaluating liquefaction hazards specific to Washington State. The result will be a manual of practice describing those procedures and a computer program that will produce a map of liquefaction hazards across the state. Such information will help bridge designers more cost effectively build and retrofit state bridges, tunnels, and roadways whose seismic features will most accurately reflect the liquefaction hazards of the soils in which they are constructed.

Principal Investigator: Kramer, S.L., UW
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Allen, T., WSDOT
Sponsors: WSDOT/FHWA

Investigation of the Performance and Effectiveness of Ground Improvement Using Vibro-Densification

Deep foundations play a significant role in maintaining the structural integrity of highway bridges. Unfortunately, many older foundation systems have been found to be inadequate to meet the increasing demand of larger static or seismic loads, and they require remediation. Advanced geotechnical practice for retrofitting deep foundations includes vibro-densification and vibro replacement, which densify the soil or change the "soil state" to a new one, increasing soil capacity/stiffness and bearing capacity. This research is developing state parameter-based ground models for in situ densification by vibro-compaction and is analyzing field experiment and laboratory tests to validate the theoretical/analytical models. Design guidelines will be developed on the basis of the findings. Such guidelines will give engineers greater flexibility in improving the safety of bridges.

Principal Investigators: Muhunthan, B./Itani, R., WSU
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Allen, T., WSDOT
Sponsors: WSDOT/FHWA

Strength and Deformation Analysis of MSE Walls at Working Loads

The work performed under this transportation pooled fund study has developed an improved method for designing the internal stability of mechanically stabilized earth (MSE) retaining walls: the K-Stiffness method. This method appears to produce more cost-effective designs of MSE walls than the AASHTO Simplified Method. The K-Stiffness method has been developed and validated only for high quality, sandy backfill soils. The next two phases of the study will extend the applicability of the K-Stiffness method to marginal quality backfill materials and full-scale field walls, which will be monitored for validation. Such validation is necessary to incorporate the K-Stiffness method into the AASHTO Load and Resistance Factor Design (LRFD) specifications. WSDOT's partners on this project are the Alaska, Arizona, California, Colorado, Idaho, Minnesota, Missouri, New York, North Dakota, Oregon, and Wyoming departments of transportation.

Principal Investigator: Bathurst, R., Royal Military College of Canada
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Allen, T., WSDOT
Sponsors: WSDOT and State Partners

Photo by MaryMarrah

Soil liquefaction during an earthquake may damage existing structures, such as the Alaskan Way Viaduct in downtown Seattle. Researchers are studying ways to better evaluate liquefaction hazards.

Paula Hammond, Secretary of Transportation for the State of Washington, said in 2007, "More than 600 people per year died in collisions on our highways and local roads in Washington State last year, and that's far too many. We must continue to work with the Washington State Patrol, local jurisdictions, and others to help keep drivers safe. Traffic data indicate that we need to reduce the risk of collisions on rural two-lane roads and to continue efforts to stop drivers from getting behind the wheel when they're impaired."

Completed Projects

In-Service Evaluation for Landscaped Medians on Urban Roadways

To increase road safety, create a more aesthetically pleasing local environment, and enhance the economic vitality and attractiveness of their communities, several cities north and south of Seattle are implementing redevelopment plans of the major State Routes that run through them. These redevelopment proposals include landscaped medians, many with trees placed close to the roadway in either the median or shoulder areas. However, WSDOT's clear zone width criterion may not always be met when trees are placed within curbed medians. To address the potential conflicts, WSDOT adopted an in-service evaluation process that would study collision, environmental, operational, and maintenance experiences in the field. This project completed evaluation of two of 13 median treatment projects, and the multi-year in-service evaluation of the remaining 11 sites will continue. The result should be a better understanding of the costs of specific median designs, safety factors, possible redesigning, and future plans for development of landscaped medians.

Principal Investigators: Hallenbeck, M.E./St. Martin, A., UW
Research Manager: Brooks, R., WSDOT
Technical Monitor: Leth, M.P., WSDOT
Sponsor: WSDOT **Report WA-RD 636.1**

Managing Pedestrian Safety

Collisions involving pedestrians take place more frequently at some roadway locations than at others. Differences in the frequencies and severity of pedestrian–motor vehicle collisions are related to many environmental conditions. However, the limited amount of information available on the environmental conditions associated with such collisions has impeded agency efforts to develop effective pedestrian safety programs. This study investigated factors correlated with injury severity and measures of their relative effects on fatal or severe injury collisions. The correlates consisted of both individual-level factors and attributes of the environments at or near pedestrian collision sites. The models developed will help predict the likelihood of future collisions occurring on the basis of specific environmental conditions. Such predictive power will aid WSDOT in targeting pedestrian safety improvement programs and developing treatments and countermeasures.

Principal Investigator: Vernez Moudon, A., WSDOT
Research Manager: Hanson, T., WSDOT
Technical Monitor: Reeves, P., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 671.1**

Motorist and Pedestrian Behavioral Analysis – SR 7

The objective of this research was to evaluate motorist and pedestrian behavioral changes resulting from federally funded engineering treatments on SR 7 through Spanaway in Pierce County, Washington. The project installation included a median with a pedestrian refuge island, allowing pedestrians to cross the roadway one direction at a time. Nearby transit stops were also relocated to concentrate pedestrians at a single crossing point. The goal of these changes was to increase safety for pedestrians, with particular focus on pedestrians and motorists over the age of 65. A before-and-after analysis was conducted. The main performance measures included pedestrian crossing locations, wait times, changes in pedestrian behaviors, and changes in motorist behaviors. An evaluation of these factors will help WSDOT determine the successful elements of safety treatments and develop design guidance, which can be used to provide cost-effective pedestrian improvements for other highway locations.

Principal Investigators: Hallenbeck, M.E./Kang, J., UW
Research Manager: Hanson, T., WSDOT
Technical Monitor: Reeves, P., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 631.1**

NCHRP Report 350 Test of Long-Span Guardrail Installation

There are many locations where it is difficult to install guardrail posts at the normal 6.25-ft spacing because of underground obstacles such as culverts. Designs for omitting one or two posts have been crashed tested in accordance with National Cooperative Highway Research Program (NCHRP) Report 230 criteria. These designs require 12.5 to 18.75 ft of layered W-beams to compensate for the increased post spacing. The objective of this project was to develop a long-span guardrail design that meets NCHRP Report 350 evaluation criteria while being less expensive to construct than the existing design. Researchers reviewed design details of previously developed long-span guardrails and used the BARRIER VII computer program to evaluate the expected performance of a proposed design. However, in a full-scale crash test, the proposed long-span guardrail failed to meet the evalua-

tion criteria of NCHRP Report 350 test 3-11.
Principal Investigator: Buth, C.E./Bullard, D.L./Menges, W.L., Texas Transportation Institute
Research Manager: Brooks, R., WSDOT
Technical Monitor: Albin, D., WSDOT
Sponsors: WSDOT/NCHRP **Report WA-RD 662.1**

Safety Evaluation Testbeds—an Assessment of Safety Project Prioritization in the WSDOT I2 Program

Washington has one of the lowest fatal accident rates per hundred million vehicle miles traveled in the country. To further improve roadway safety, this project assessed WSDOT's current system of prioritizing and programming safety projects through its I2 program, with a special focus on high-accident locations. The goals were to improve the reliability of accident risk predictions and to identify methods for analyzing the efficiency of safety programming on the basis of multiple safety performance measures. The study identified analysis methodologies that will produce more reliable accident predictions and more robustly identify sites with safety improvement potential. In using these methodologies, WSDOT will be able to implement procedures that better prioritize potential improvement locations, while addressing a larger number of locations in terms of identified and funded safety improvements.
Principal Investigator: Shankar, V., Pennsylvania Transportation Institute
Research Manager: Brooks, R., WSDOT
Technical Monitor: Milton, J., WSDOT
Sponsor: WSDOT **Report WA-RD 654.1**

Active Projects

Analysis of Pedestrian Safety Treatments by Functional Class

Transportation issues have historically focused on the mobility and safety of motor vehicles, while overlooking pedestrian concerns. Pedestrian safety treatments and countermeasures have not been thoroughly monitored, tested, and analyzed for effectiveness on various types of roadways. This study is evaluating motorist and pedestrian behaviors at locations where pedestrian safety treatments such as medians, signage, and lighting have been implemented. Data on motorist and pedestrian movements are being collected with field video and a digital video recorder. These data are being analyzed to compare the impacts of the treatments on pedestrian and motorist behaviors. A better understanding of the effectiveness of pedestrian treatments on various roadway types will help ensure the best investment of limited safety resources and will aid WSDOT in providing appropriate guidance to cities and counties.
Principal Investigators: Hallenbeck, M.E./Davis, K., UW
Research Manager: Hanson, T., WSDOT
Technical Monitor: Reeves, P., WSDOT
Sponsors: WSDOT/FHWA

GIS Data Coding

University of Washington researchers are aiding WSDOT in assigning geographic information system (GIS) coordinates for collision data. The data include fatal and disabling injury collisions on county roads (3,906 records) and city streets (5,005 records) within Washington State from 2002 to 2006. The purpose of the project is to complement ongoing WSDOT efforts to assemble a complete geospatial database on collisions. This will allow WSDOT to identify groupings of high severity crashes across jurisdictional boundaries (city, county, state). This capability will provide WSDOT with another way to identify areas of need and could provide an additional way to prioritize safety projects.
Principal Investigator: Vernez Moudon, A., UW
Research Manager: Lindquist, K., WSDOT
Technical Monitor: Enders, M., WSDOT
Sponsor: WSDOT

Roadside Safety Pooled Fund

Washington, Alaska, California, Minnesota, Tennessee, Pennsylvania and Louisiana have pooled funds to conduct research on roadside safety features such as guardrails, median barriers, rumble strips, sign posts, and more. The work, conducted by the Texas Transportation Institute (TTI), provides important information on the performance of various designs and configurations that are deployed to keep motorists safe.
Principal Investigators: Bligh, R./Bullard, L., TTI
Research Manager: Brooks, R., WSDOT
Technical Monitors: Albin, D./Olson, D., WSDOT
Sponsor: FHWA

Two-Lane Rural Safety

Two-lane rural roads in Washington State account for less than a quarter of the total yearly miles traveled but account for 56 percent of the fatal and disabling accidents each year. However, the state's funding structure tends to target major improvements in urban areas or on multilane facilities. Expenditures on rural roadways tend to target pavement preservation and minor safety improvements. This leaves a gap in addressing collisions on rural two-lane facilities. This research will suggest cost-efficient solutions for reducing the frequency and severity of crashes on rural two-lane roadways.
Principal Investigator: van Schalkwyk, I., Arizona State University
Research Manager: Brooks, R, WSDOT
Technical Monitor: Olson, D, WSDOT
Sponsor: WSDOT

Research in intelligent transportation systems (ITS) helps support smarter travel choices

Transportation professionals agree that congestion problems cannot be simply built away; additional, innovative solutions are needed. Intelligent transportation systems, or ITS, provide technologies that enable people to make smarter travel choices.

Intelligent transportation systems encompass a broad range of wireless and traditional communications-based information, control, and electronics technologies. They provide transportation professionals with tools to collect, analyze, and archive data about the performance of the system. Having these data enhances traffic operators' ability to respond to incidents, adverse weather, or other capacity constricting events.

When ITS are integrated into the transportation system infrastructure, and in vehicles themselves, these technologies help monitor and manage traffic flow; reduce congestion; provide alternative routes to travelers; enhance productivity; and save lives, time and money.

Completed Projects

Development of a Virtual Sensor System Based on Probes in an Operational Traffic Management System

The WSDOT operates a central traffic management system (TMS) for both day-to-day surveillance and traveler information. This project developed a way to provide real-time congestion information from Seattle area arterials and freeways to the WSDOT TMS. This system gathers existing automatic vehicle location (AVL) data from within King County Metro Transit and transmits the raw data to the University of Washington, where they are converted into roadway speed information. This speed information is color coded on the basis of specific, localized conditions for the arterials and freeways to reflect traffic congestion. The resulting traffic data are then provided to WSDOT as a virtual sensor data source. A comparison of statistics between virtual sensors based on transit vehicles as probes and those from inductance loops suggested that this virtual sensor technology can be used to identify both recurring and non-recurring congestion with the same accuracy associated with inductance loops. This means that roadways that do not currently have inductance loops could be monitored without installing new equipment in the roadway.

Principal Investigators: Dailey, D. J., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Trepanier, T., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 660.1**

Development of Weather Information Resources for Yakima County Public Services

The Automated Real-time Road Weather System (ARROWS), developed at the University of Washington, provides WSDOT with access to a variety of weather information resources, including road-weather information system (RWIS) observations, high-resolution ensemble weather model forecasts, highway camera images, satellite imagery, weather radar imagery, National Weather Service forecasts, private vendor forecasts, and automatically generated weather warnings. This project incorporated a database of Yakima County roads into the ARROWS system to provide county-specific forecasts to highway maintenance personnel and included county-run RWIS observations in ARROWS to calibrate the forecasts for local conditions. A Web application was developed to permit Yakima County Public Services (YCPS) personnel to customize the information they receive from ARROWS, and a functional prototype of the Yakima-ARROWS system was made available, in real time, to YCPS road maintenance personnel.

Principal Investigator: Mass, C., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Trepanier, T., WSDOT
Sponsor: WSDOT

A database of Yakima County roads was incorporated into WSDOT's Automated Real-time Road Weather System to provide county-specific forecasts to highway maintenance personnel.

Intelligent Transportation Systems Backbone 05-07

The WSDOT and other partners have invested in the development of an architecture and infrastructure for a Puget Sound intelligent transportation systems (ITS) backbone. This backbone has been used to obtain traffic data from disparate sources, combine those data, and make them available over a standard interface to transportation-related organizations and the public. In this way it supports traveler information applications for traffic and transit information, real-time access to WSDOT data by a variety of public and private groups, research activities within WSDOT and at universities and agencies nationwide, and a standard way to include new data sources into the existing traffic management system. This project supported and augmented the continuing personnel, equipment, maintenance, software, and communications links for the ITS backbone. http://www.its.washington.edu/bbone/

Principal Investigator: Dailey, D. J., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Jacobson, E., WSDOT
Sponsor: WSDOT **Report WA-RD 676.1**

ITS Evaluation Framework: Phase II

The Phase I ATIS Evaluation Framework project developed a standard evaluation method that is applicable to a range of advanced traveler information system (ATIS) projects. The primary purpose of an evaluation is to give planners an understanding of intelligent transportation system (ITS) deployments during various project stages. The framework focuses on quantifying the benefits and costs of ITS projects by looking at technical and institutional issues that arise; the measures or strategies taken by project partners to address and resolve those issues; and lessons learned that might be applicable to future ITS deployments. Since the Phase I project, WSDOT had developed 19 additional ITS projects that also required local evaluation. During Phase II, these new projects were evaluated within the adopted framework, which enabled the framework methodology and tools to be refined and generalized to encompass additional ITS factors.

Principal Investigators: Hallenbeck, M.E./Kang, J., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Briglia, P., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 672.1**

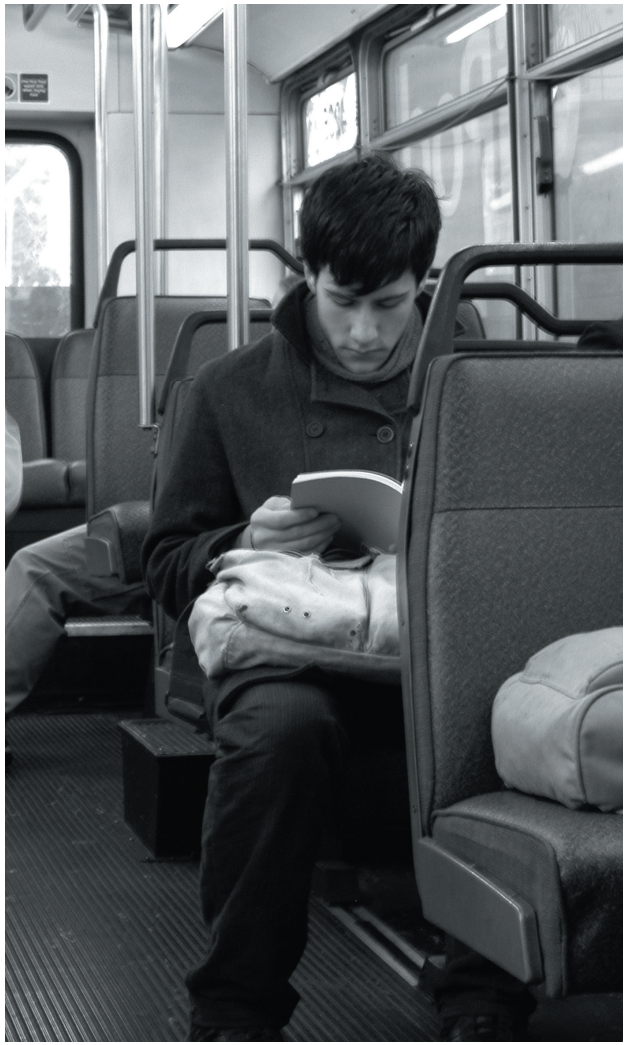

Photo by MaryMarrah

The successful MyBus and BusView real-time transit information systems developed as TRAC research projects have been transferred to King County Metro for operation and maintenance.

MyBus, BusView and Associated Applications Transfer and Training

Sound Transit, King County Metro, and the University of Washington have collaborated on the development of various applications associated with the successful MyBus and BusView real-time transit information systems. A number of these applications have been moved from the UW to King County Metro computer servers for day-to-day operation. This project enabled UW researchers to complete the transfer of these applications and to train King County Metro engineers and programmers to maintain and update them.

Principal Investigator: Dailey, D. J., UW
Technical Monitor: Marquardt, N., Sound Transit
Sponsor: Sound Transit

Software Support for the Border Data System

A coalition of U.S. and Canadian public and private organizations known as the International Mobility and Trade Corridor (IMTC) project was formed to address the challenge of maintaining efficient traffic movement—and thereby facilitating trade, transportation, and tourism—through the border crossings between lower British Columbia and Whatcom County, Washington. As part of the IMTC project, the Whatcom Council of Governments received federal, state, and provincial funding to develop a bi-national border data management system (DMS) to archive border crossing data that are currently collected but not stored. The ultimate goal of the system is to provide an online query tool and border crossing information to the public. The DMS will archive historic wait times at the border, cross-border traffic volumes and queue lengths, and other data collected from U.S. and Canadian in-road detector systems located at the Peace Arch and Pacific Highway ports-of-entry. Engineers at TRAC provided software and programming support to the DMS project.

Principal Investigator: McCormack, E.D., UW
Technical Monitor: Conroy, H., Whatcom Council of Governments
Sponsors: Whatcom Council of Governments

Testing the ITS Lessons Learned Resource

The U.S. Department of Transportation's Joint Program Office (JPO) is charged with collecting information about public agency experiences with state and local intelligent transportation system (ITS) projects. One of its databases is the ITS Lessons Learned Resource, designed to provide better access to information about stakeholder experiences with ITS planning, deployment, operations, and maintenance. Because WSDOT had completed 13 ITS projects that included detailed evaluations, the JPO asked WSDOT and TRAC to test and proof its database information entry template by provid-

The Whatcom County, Washington, Council of Governments has funded the development of a U.S./Canadian border data management system for the Peace Arch and Pacific Highway border crossings to provide the public with an online query tool and border crossing information.

ing the lessons learned from these 13 ITS projects. The resulting website (www.itslessons.its.dot.gov/) should help agencies around the country deploy and operate ITS more effectively.

Principal Investigator: McCormack, E.D., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Trepanier, T., WSDOT
Sponsors: WSDOT/FHWA

TrafficTV: Phase 2

TrafficTV is an automated source of traffic and traveler information that aired on UWTV2 (University of Washington) and a Seattle cable channel beginning in June 1998. The TrafficTV system combines regional traffic congestion data with live traffic video, adds digital video effects, and supplies the resulting presentation to the cable TV provider for broadcasting. This project updated the hardware and software that run the application. In addition, new functionality for communicating incident information, voice-over information, and AMBER Alerts was designed and implemented in coordination with WSDOT operations.

Principal Investigator: Dailey, D. J., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Trepanier, T., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 659.1**

Active Projects

Puget Sound In-Vehicle Traffic Map Demonstration

Traveler information has long been one of the intelligent transportation system technologies expected to have significant benefit to both travelers and public transportation agencies. However, current studies have shown that available travel information does not result in actual time savings during most commute trips; that significant route diversion can result in congestion on alternative routes, thus increasing delays throughout a region; and that few businesses providing travel information have yet to succeed in making a profit. To investigate this issue in detail, Congress requested and funded a test of the effects of in-vehicle traffic information and measurement of its benefits. With the help of subcontractors Battelle Memorial Institute and Volpe National Transportation Systems Center, this project is examining the benefits that can be gained from using in-vehicle traffic information devices. Two sets of analyses are being conducted. One analysis focuses on the benefits perceived by travelers who use the devices, and the other is determining changes in roadway performance that occur as travelers use the devices.

Principal Investigators: Hallenbeck, M.E./Wang, Y./Rutherford, G.S., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Trepanier, T., WSDOT
Sponsors: WSDOT/U.S. Congress

RWIS Phase III

Researchers at the UW have developed innovative, Web-based applications to provide current and forecast weather conditions for state highway routes to WSDOT personnel and the traveling public. The resulting websites combine complex meterological and roadway data from a number of sources and present them through user-friendly, intuitive Web interfaces. These websites have received strong positive feedback, and in fact, during inclement weather, it has not been unusual for WSDOT's travel route Web pages to receive several hundred thousand visitors in a single day. This project is continuing work to make a wide range of weather and roadway information available. This work includes removing biases from weather data output, testing a new weather prediction model, and applying ensemble forecasting techniques, which help determine the reliability of weather forecasts. Such information is already helping WSDOT to more cost-effectively maintain state highways, particularly during the winter months, and enabling the public to plan their routes for safer travel.

Principal Investigator: Mass, C., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Briglia, P., WSDOT
Sponsor: WSDOT

South Snohomish Regional Transit Signal Priority Evaluation

By reducing the amount of time that transit vehicles are stopped at intersections, transit signal priority (TSP) can improve the speed and on-time reliability of service. However, enthusiasm for TSP has been tempered with concerns that overall traffic performance may be compromised when signal timing plans intended to optimize traffic flow are overridden to provide a travel advantage to transit vehicles. To improve levels of Community Transit service, the South Snohomish Regional Transit Signal Priority (SS-RTSP) project is implementing TSP at selected locations in Snohomish County. To guarantee the overall benefit of the project, researchers at the UW are evaluating the impacts of the SS-RTSP project on both transit vehicles and automobiles that use the affected local networks. While WSDOT does not directly control the signals involved in the evaluation, the Department does operate a number of signal systems for which TSP is being considered. The results of this evaluation will help WSDOT determine the optimal TSP operating parameters for those locations.

Principal Investigator: Wang, Y., UW
Research Manager: Lindquist, K., WSDOT
Technical Monitor: Senn, L., WSDOT
Sponsors: WSDOT/Community Transit

Photo by J. Stimberis

Unmanned aerial vehicles are becoming small and inexpensive enough that WSDOT is investigating their potential use for avalanche control and search and rescue operations.

Transportation Applications of an Unmanned Aerial Vehicle

Unmanned aerial vehicles (UAVs) are becoming smaller and less expensive. These aircraft are small enough to be launched from a pickup truck but still large enough to be equipped with cameras and sensors that can provide low-cost aerial information. This situation holds considerable promise for WSDOT, since a UAV could be used for data collection and aerial surveillance in areas where the geographic locations of potential transportation-related problems are only crudely known. Potential transportation applications include avalanche control, search and rescue, accident scene photography, land-use mapping, surveying, security inspections, hazardous material monitoring, construction inspections, and roadway condition and congestion monitoring. This project is testing the utility of the UAV within two WSDOT programs, snow avalanche control and search and rescue operations. This limited test will help WSDOT better understand the institutional and other issues involved in employing UAVs, such as Federal Aviation Administration requirements and liability, and will guide its policies in their future use.

Principal Investigator: McCormack, E.D., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Trepanier, T., WSDOT
Sponsors: WSDOT/FHWA

Transportation planning guides decisions and investments needed to develop Washington's transportation system

Transportation is key in the daily lives of people and supports our quality of life. Delivery of an appropriate and efficient transportation system is an important priority for government and other providers of the facilities and services that make up the transportation system. The issues on which recent research has focused include quality of life, community livability and cohesion, environmental quality, land use and transportation, and economic, social and cultural values and trends. Collaboration at all levels to better coordinate planning of land use, transportation, and the environment is ongoing. The coordination of transportation and the needs of special groups—such as homeless students—is an important new focus.

Completed Projects

Evaluation of Washington State's Homeless Student Transportation Project

The McKinney-Vento Homeless Education Assistance Act of 2001 requires states to ensure that homeless children and youth have equal access to the same free public education as is provided to other children and youth. In an effort to test a variety of homeless student transportation options, a pilot program funded eight school districts around Washington state to implement a range of transportation methods during 2005 and 2006. This project evaluated how the variety of transportation options employed met the objectives of the McKinney-Vento Act. The evaluation looked at age- and location-appropriate transportation services; their delivery and administrative costs; and their effectiveness in getting students to/from school in a consistent, timely, and safe manner. The study also addressed policy assumptions about whether staying in the school of origin affects students' academic performance. This project provides information useful for determining the most effective use of continued funding for homeless student transportation in Washington state and nationally.

Principal Investigators: Carlson, D./ Reder, S., UW
Research Manager: Lindquist, K., WSDOT
Technical Monitor: Chartock, D., WSDOT
Sponsor: WSDOT **Report WA-RD 665.1**

Financing Options for an Extended Seattle Streetcar System

The Urban League of Metropolitan Seattle and the Seattle Streetcar Alliance propose the expansion of Seattle's new South Lake Union Streetcar line to other portions of downtown Seattle and the inner Seattle neighborhoods. However, before Seattle agrees to study the streetcar system expansion in greater detail, it wants a better understanding of how the capital and operating costs for this expansion could be met. This project investigated how cities across the U.S. fund the operation of streetcar systems and examined the potential for the use of those funding sources in Seattle, particularly whether the feasible funding sources could generate sufficient revenue to meet all or a substantial portion of the operating expenses of the Seattle streetcar network. The study also explored the social and economic characteristics of neighborhoods and districts that would affect the funding and use of the planned network of streetcar lines. The study results will help Seattle policy makers and citizens make more informed decisions about extending Seattle's streetcar lines.

Principal Investigator: Vernez Moudon, A., UW
Technical Monitor: Kelly, J., Urban League of Metropolitan Seattle
Sponsor: Urban League of Metropolitan Seattle

On-Line Commute Trip Reduction Survey

WSDOT conducts a Web-accessible survey about Commute Trip Reduction (CTR) that was written and implemented, and has been hosted and maintained, by researchers at Washington State University. The survey is intended for employees of companies that are working to meet the state's Commute Trip Reduction Act. This project continued work on the survey by developing a customizable version with a library of questions to choose from and translations into nine languages. The survey was also redesigned to make it easier to use and more aesthetically appealing. The purpose of the CTR Act is to reduce traffic congestion, air pollution, and fuel consumption through employer-based commute programs by reducing drive-alone commute trips made to major employer sites by 35 percent over a 12-year period. The survey is a means of measuring companies' progress toward meeting the state's CTR goals, and conducting the survey on-line is intended to make the state's measurement of progress faster and more efficient.

Principal Investigator: Tarnai, J., WSU
Research Manager: Lindquist, K., WSDOT
Technical Monitor: Hillsman, E., WSDOT
Sponsor: WSDOT

Travel Behavior, Emissions, and Land-Use Correlation Analysis in the Central Puget Sound

This research was undertaken to document and validate connections between land use and transportation. Such information can help WSDOT and local agency partners in transportation planning activities. The project generally corroborated research showing a connection between land use and travel behavior, and added detail to the specific aspects of land use that may affect travel behavior. The findings of the study indicated that 1) time is the most important consideration in travel; 2) land use

Photo by MaryMarrah

In preparation for studying expansion of Seattle's streetcar system, the city asked TRAC researchers to investigate ways to fund necessary capital and operating costs.

is a stronger predictor of trip chaining patterns than demographic factors; 3) a working environment conducive to walking is associated with reduced auto use for trips to and from work and increased mid-day walking trips; and 4) increased levels of mixed-use development, retail density, and street connectivity are significantly associated with lower per capita emissions and an increased tendency to walk and take transit. This information can be used by cities and counties in making land-use decisions that support lower emissions, walking, biking, and transit.

Principal Investigators: Frank, L., Lawrence Frank and Company, Inc./ Bradley, M./Lawton, K., Keith Lawton and Associates
Research Manager: Lindquist, K., WSDOT
Technical Monitors: Mabry, J./Kavage,S., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 625.1**

Options for Making Concurrency More Multimodal

The Washington State Growth Management Act (GMA) introduced the idea of "concurrency" to Washington. Concurrency is the policy goal of ensuring that development not outpace the provision of infrastructure. The GMA directs jurisdictions to define and establish level of service (LOS) standards for their transportation systems. If new development will cause the transportation system to exceed the established LOS standards, the jurisdiction must deny the development unless transportation improvements and strategies are implemented that will accommodate the development within six years. This study's purpose was to examine and propose improvements to the concurrency process that would support multimodal transportation. These include both alternative ways to measure the availability and effectiveness of multimodal transportation systems, and ways to use those measurements to implement more effective multimodal transportation systems. The project report recommends adopting a two-tiered concurrency system that provides a more flexible incentive and disincentive system at the

Photo by MaryMarrah

By combining information about the future of Washington forests with data on roadways and transload facilities, researchers will produce estimates of current and future use of the state's roadways by the forest products sector.

regional level, while applying more multimodal transportation system measures at the local level.

Principal Investigators: Hallenbeck, M.E./Carlson, D./Vernez Moudon, A., UW
Technical Monitors: Cushman, K., PSRC/Phillips, E., WSDOT
Sponsors: Washington State Legislature, WSDOT, Puget Sound Regional Council

Prioritization of Transportation Security Projects

To increase security, state planners have undertaken and produced a vulnerability assessment for the state's transportation infrastructure, which has determined the steps necessary to improve security for different assets and facilities of the system: highways, bridges, tunnels, rail facilities, ferries, and more. The next steps are to determine the benefits of the security improvements and then to use the resulting benefit/cost ratios as part of the funding prioritization process. The difficulty is in determining the costs and benefits of damage or impacts that do not occur and in comparing those costs and benefits among very diverse projects. The objective of this project was to determine a method for reliably and accurately estimating the societal or operating costs and benefits of system security projects. With defendable and reliable estimates of cost/benefit ratios for security measures and projects, economic feasibility can be achieved, and the projects can be prioritized in the planning, programming, and policy processes along side all other projects under consideration.

Principal Investigators: Jessup, E./Casavant, K.L., WSU
Research Manager: Brooks, R., WSDOT
Technical Monitor: Himmel, J., WSDOT
Sponsor: WSDOT

Active Projects

Forest Products' Use of Roadways and Transload Facilities in Washington

Washington's forest products sector has changed dramatically over the past several decades, and with it the movement of timber and forest products over the state's roadways. In fact, the movement of raw material resources and products will likely continue to adjust as timber resources change, and milling and processing facility investments respond to those changes. By combining information from recent studies on the future of Washington forests with data on roadways and transload facilities, researchers will provide WSDOT with an estimate of the current and future use of roadways and transload facilities by Washington's forest products sector. Estimates of current and projected use by wood product manufacturers will allow the WSDOT to better plan its infrastructural needs to move goods across the state efficiently.

Principal Investigator: Perez-Garcia, J., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Ivanov, B., WSDOT
Sponsor: WSDOT

The goal of pavement research is to produce longer lasting pavements and to manage them effectively.

The focus over the past few years has been on improvements to pavement design, construction, prediction, and Washington State's pavement management system. Research focusing on pavement construction techniques has included the evaluation of tack coat, dowel bar retrofit, construction analysis software, and determining the best practices for portland cement concrete pavements and bituminous surface treatments. The mechanistic-empirical pavement design guide has been a part of multiple projects over the past few years, as well as updating the pavement management system. The overriding goal of these research projects has been to produce longer lasting pavements through cost-effective decision-making.

Completed Projects

Bituminous Surface Treatment Protocol

A bituminous surface treatment (BST), often referred to as a chip seal or seal coat, is a thin surface treatment of liquid asphalt covered with an aggregate that has an applied thickness of about 0.5 inch or less. BSTs are normally applied to pavements with lower traffic volumes, but it is possible to successfully apply a BST on high speed, high traffic roads when precautions are taken. This study used the Highway Development and Management System (HDM-4) software to test the average annual daily traffic and equivalent single axle load levels appropriate as criteria for selecting the application of BSTs to WSDOT pavements. It verified the feasibility of using BSTs to maintain pavements with higher traffic levels. The study also determined the validity of alternating the application of BST resurfacings and 45-mm HMA overlays. In addition, it estimated the impacts that increased use

Researchers investigated the influence of several factors on the adhesive bond provided by a tack coat at the interface between pavement layers.

of BST surfaces would have on the performance of the state-owned route system.

Principal Investigator: Mahoney, J.P., UW
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Pierce, L.M., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 652.1**

Development of a Tack Coat Protocol

A tack coat is a light application of an asphaltic emulsion between pavement layers. The role of a tack coat is to provide adequate adhesive bond between layers so that they behave as a whole structure. The inadequacy or failure of this bond can cause slippage between the layers, which results in a significant reduction in shear strength, making the pavement more susceptible to distresses such as cracking, rutting, and potholes. This study investigated the influence of several factors on the adhesive bond provided by tack coat at the interface between pavement layers. These factors included surface treatment, curing time, residual application rate, and coring location. The research found that milling generally provided a significantly better bond at the interface between the existing surface and the new overlay right after construction. In addition, the absence of a tack coat did not significantly affect the bond strength at the interface for milled sections, but for non-milled sections there was no bond at all. WSDOT is monitoring these test sections over time to determine the change in bond strengths, if any.

Principal Investigator: Tashman, L., WSU
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Pierce, L.M., WSDOT
Sponsor: WSDOT **Report WA-RD 645.1**

LTPP: Pavement and Traffic Engineering Technical Support Services

As subcontractors to PCS/LAW/MACTEC Engineering and Environmental Services. TRAC researchers provided technical support to the Federal Highway Administration in conducting its Long-Term Pavement Performance research program. TRAC work included providing technical assistance on the collection and processing of data that are required to estimate traffic loads applied to pavement test sections, maintenance of LTPP experiments, and regional operations.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor: Rada, G., PCS/LAW
Sponsors: FHWA/PCS/LAW Engineering and Environmental Services

Montana Pavement Design Program Assistance

Through a subcontract to Fugro-Bre, Inc., TRAC researchers provided technical assistance in the development of traffic load estimates for Montana Department of Transportation pavement test sections. They analyzed 15 months of Montana truck volume and weight data in accordance with procedures proposed for adoption in the AASHTO Mechanistic-Empirical Pavement Design Guide for roadways.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor: Killingsworth, B., Fugro-Bre
Sponsors: Fugro-Bre/Montana Department of Transportation

Photo by MaryMarrah

The Washington State Pavement Management System, which helps engineers examine and evaluate state roadways, was enhanced to group roadway segments together for better overall analysis and management.

PCCP Models for Rehabilitation and Reconstruction Decision-Making

The majority of WSDOT portland cement concrete (PCC) pavements have far exceeded their original design lives and have carried several times the traffic loading originally anticipated. WSDOT is undertaking a major effort to identify both rehabilitation and reconstruction projects to improve its PCC pavements. To estimate WSDOT's concrete pavement performance and analyze current PCC pavement conditions, this project systematically studied two major groups of concrete pavement deterioration models: the Highway Development and Management System (HDM-4) model developed for the World Bank and those of NCHRP 1-37A. The NCHRP 1-37A models proved to be more suitable for WSDOT conditions. The calibrated faulting and roughness models were able to represent the typical performance of WSDOT PCC pavements. These models can be used to assist WSDOT in developing more effective plans for rehabilitating or reconstructing these pavements.

Principal Investigators: Muench, S.T.,UW
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Pierce, L.M., WSDOT
Sponsors: WSDOT/FHWA **Report WA-RD 588.2**

Rapid Pavement Construction Tools, Materials and Methods

To address the need to deliver cost-effective pavement projects while minimizing traffic impacts, WSDOT has begun to use rapid construction techniques. These techniques for designing and building roadway projects are based on fast-paced construction operations and more aggressive scheduling to reduce roadway user impacts. To improve WSDOT's awareness, understanding, and utilization of these techniques, this project investigated WSDOT's emerging use of four different rapid construction tools or methods: Constructibility Analysis for Pavement Rehabilitation Strategies (CA4PRS), a software program for predicting construction productivity for highway rehabilitation and construction; rapid portland cement concrete panel replacement; fast-setting polymer concrete overlays; and traffic closure windows. The report includes an analysis of each method, records of key WSDOT decisions during use, and recommendations for future use in an attempt to capture and improve WSDOT institutional knowledge.

Principal Investigator: Muench, S.T., UW
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Pierce, L.M., WSDOT
Sponsors: WSDOT/FHWA/UW Engineering Professional Programs
Report WA-RD 670.1

WSPMS Phase 2

The current Washington State Pavement Management System (WSPMS), a program to help engineers examine and evaluate system-wide roadway conditions for managing the state's roadway network, was converted to a Web-based system under Phase 1 of this work. Besides including all of the existing functionality of the PC-based software, the Web-based PMS includes walk-through tutorials, a mapping interface that allows users to view the data spatially, and on-line viewing of digital pavement distress video logs. Phase 2 enhanced the system with network visualization tools so that it can be used to analyze the entire state route system and/or group roadway segments together for better overall analysis. WSDOT can now analyze the effects of funding changes or other maintenance efforts for a network of highways, rather than individual state routes or sections. Phase 2 also served as a catalyst for identifying exciting new possibilities for additional development and system features that would directly benefit WSDOT.

Principal Investigator: Mahoney, J.P., UW
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Sivaneswaran, N./Pierce, L.M., WSDOT
Sponsors: WSDOT/FHWA

Active Projects

Best Practices for the Design and Construction of Portland Cement Concrete Pavements in Washington State

Current portland cement concrete pavement (PCCP) conditions in key state transportation corridors require a large-scale reconstruction and rehabilitation effort. This will be the state's largest PCCP rehabilitation/reconstruction effort ever, and if it is done well, it should last 50 years or more. Before embarking on this effort, WSDOT would like to identify and quantify design methods, materials, and construction practices that (1) provide for the most efficient and effective use of public funds and (2) provide long-lasting, high performance pavements. Although much expertise and research on "typical" U.S. PCCP has been done elsewhere in the country, because of local variations, this research is helping WSDOT form a comprehensive rehabilitation and reconstruction plan that will use the most effective set of design, materials, and construction techniques possible for local conditions.

Principal Investigator: Muench, S.T., UW
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Pierce, L.M., WSDOT
Sponsors: WSDOT/FHWA

Dynamic Modulus Test—Laboratory Evaluation and Future Implementation in the State of Washington

A national effort is under way to implement performance tests for the Superpave mix design criteria for hot

mix asphalt (HMA). This project developed a database of dynamic modulus values for typical Superpave HMA mixes that are widely used in Washington. The database is being used to investigate the sensitivity of the dynamic modulus to HMA mix properties and its relationship to field performance. It is also being used to evaluate the Mechanistic-Empirical Pavement Design Guide released recently by NCHRP Project 1-37A. The results are providing WSDOT with the necessary HMA input parameters for the Guide. In addition, this database is providing WSDOT with valuable information about the use of dynamic modulus in forensic studies and other research.

Principal Investigator: Tashman, L., WSU
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Pierce, L.M., WSDOT
Sponsors: WSDOT/FHWA

Evaluation of Dowel Bar Retrofitting for Long-Term Life in Washington State

Since 1993, WSDOT has been rehabilitating its aged portland cement concrete pavements by retrofitting the transverse joints with dowel bars. WSDOT has found that this procedure is a cost effective rehabilitation option; however, questions remain about its situational appropriateness, long-term performance, and ultimate failure mechanism. WSDOT has some of the oldest significant stretches of DBR pavement in the U.S. Researchers are taking advantage of WSDOT's careful documentation of construction and performance to assess the extended pavement life offered by DBR, determine the life-cycle cost of DBR projects, and establish criteria for selecting DBR projects in Washington state. The research findings will likely become standard DBR practice in the state. And at current costs of nearly $350,000 per lane-mile for DBR and perhaps 1,000 lane-miles in need of retrofitting, this work will have direct impact on over $350 million of work in the next two decades.

Principal Investigators: Muench, S.T./Turkiyyah, G., UW
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Baker, T., WSDOT
Sponsors: WSDOT/FHWA

I-5 Seattle Corridor—Pavement Deterioration Study

The portland cement concrete pavements (PCCP) constructed on I-5 through Seattle were built as part of the original Interstate Highway System but have not been rehabilitated or completely reconstructed. The first pavement reconstruction project within this corridor is scheduled to begin in 2013, but there is concern that pavement deterioration will require action by WSDOT before then. To address such concerns, this study is assessing how much longer each segment within the 28-mile I-5 Seattle urban corridor will survive before rehabilitation/ reconstruction is required. Researchers are also developing improved PCCP performance analysis tools and procedures. In addition, the project is creating a visual means of conveying the current and future conditions of this corridor to decision makers and the general public. The information provided by this project will be crucial in helping WSDOT budget the funds needed for pavement rehabilitation. Additionally, WSDOT will receive updated analysis tools that will allow it to better identify future rehabilitation needs.

Principal Investigators: Mahoney, J.P./Turkiyyah, G., UW
Research Manager: Willoughby, K., WSDOT
Technical Monitor: Hunter, C., WSDOT
Sponsors: WSDOT/FHWA

Long-Term Corrosion Impacts from Highway Snow and Ice Control Chemicals

Several types of snow and ice control chemicals are available to WSDOT maintenance for improving road safety under winter conditions. While the short-term operational costs of using different chemicals are fairly easy to identify, information about the long-term costs of corrosion from chemical use is lacking. The effects of corrosion on motor vehicles, bridge structures, and steel rebar in pavements and bridge decks are of particular concern. This project is investigating the corrosion of steel in pavements and bridge decks by subjecting samples embedded in concrete to three different deicers that WSDOT commonly uses (both corrosion inhibited and non-corrosion inhibited) through accelerated testing. The results will be used to make cost-effective selections of snow and ice chemicals, as well as to determine the long-term performance of pavements and bridges.

Principal Investigator: Shi, X., Montana State University Western Transportation Institute
Research Manager: Willoughby, K., WSDOT
Technical Contact: Baroga, R./Wilson, D./Pierce, L., WSDOT
Sponsor: WSDOT

Pavement Tools Consortium

The Pavement Tools Consortium fosters the continued development and implementation of computer-based paving tools, such as the Pavement Guide, Media Library, HMAView, Stockpile Blender, XPactor, and EverFE. The major focus of the pavement tools is to enhance pavement-related training and construction operations. WSDOT's partners are the California, Florida, Idaho, Illinois, Kansas, Maryland, Minnesota, and Texas departments of transportation, and the Federal Highway Administration.

Principal Investigators: Mahoney, J.P., UW
Research Manager: Willoughby, K., WSDOT
Sponsors: WSDOT and PTC Member States

Technology Transfer is a core element of the TRAC mission.

Research dollars are wasted if clients are unaware of research results, unable to understand research findings, or unable to implement them. For that reason, TRAC has always emphasized technology transfer as part of its operations.

To enhance access to TRAC research, projects are entered into the national Research in Progress database managed by the Transportation Research Board. Reports are also available from TRAC's website, www.trac.washington.edu. In addition, Short Research Notes were initiated in the last biennium to briefly describe the project need, findings, and planned implementation of the results. Specific transfer projects over the past two years included enhancing a computer-based pavement course and electronic tools to aid in communication and training about the design and construction of pavements; participating in a Pavement Tools Consortium that fosters the continued development and implementation of computer-based paving tools; continuing to support a traffic management center intern program at WSDOT; and establishing a Student Research Program to stimulate student interest in transportation issues and address the ad hoc study needs of WSDOT management.

Active Projects

Student Studies Program

WSDOT established a Student Research Program to supplement its capabilities to perform research and to provide educational opportunities to students at the University of Washington and Washington State University. TRAC coordinated the effort and provided oversight. Student work within this program included highway system performance evaluation and traffic operations analysis; a review of Puget Sound transportation governance agencies and their best practices; development of a design for a permanent water quality sampling station along SR 270 in Eastern Washington; preparation of WSDOT's existing weigh-in-motion data for use with the Mechanistic-Empirical Pavement Design Guide; investigation of the accuracy and consistency of Superpave Gyratory Compactors; and improved freight modeling of containerized cargo shipments for regional policy making and planning.

Principal Investigator: Hallenbeck, M.E., UW; McLean, D.I., WSU
Research Manager: Brooks, R., WSDOT
Sponsor: WSDOT

Traffic Management Center Intern Program Supplement

This project allowed the University of Washington and WSDOT to cooperatively provide professional experience, training, and research opportunities at WSDOT's Traffic Management Center to students from the UW's Department of Civil and Environmental Engineering. Under the supervision of WSDOT engineers, students learned about and helped to operate ramp meters, closed-circuit TV incident identification, variable message signs, highway advisory radio, and traffic condition update reports on regional phone lines. They also helped conduct research and analysis tasks.

Principal Investigator: Rutherford, G.S., UW
Research Manager: Brodin, D., WSDOT
Technical Monitor: Dang, V., WSDOT
Sponsor: WSDOT

Transportation Synthesis Reports

The WSDOT transportation synthesis reports (TSRs), brief summaries of literature on issues of current priority to WSDOT, grew out of WSDOT executives' desire for "just-in-time" summaries of current practice and literature. WSDOT, with support from TRAC-WSU, prepares summaries of current literature and publications. Online and print sources may include newspaper and periodical articles, ongoing or completed research, surveys of practice, and more. Synthesis projects completed in the 2005-2007 biennium included summaries of research on highway improvement costs; inflation estimating models and state DOT practices; state laws that allow container fees; sobriety checkpoints; contractor quality assurance and control; estimation of highway toll facility demand and revenue; characteristics of state research programs; the benefits of public transportation in Washington state; and automated enforcement techniques.

Principal Investigators: Lindquist, K./Wendt, M., WSDOT; Lewis, S., WSU
Research Manager: Lindquist, K., WSDOT
Sponsor: WSDOT

Photo by MaryMarrah

WSDOT and the University of Washington cooperatively provided professional experience at WSDOT's Traffic Systems Management Center to students from the UW's Department of Civil Engineering.

Many of the following reports can be obtained electronically at the TRAC or WSDOT Web sites. WA-RD numbers are given to WSDOT reports (see www.trac.washington.edu and www.wsdot.wa.gov/research/). Paper copies are available through the National Technical Information Service (NTIS).

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University of Washington Faculty

July 1, 2005 - June 30, 2007

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Civil and Environmental Engineering

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Alexander R. Horner-Devine, Assistant Professor
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