WASHINGTON STATE
TRANSPORTATION CENTER

BIENNIAL REPORT **2004 to 2005**

2004 to 2005

Washington State Transportation Center

University of Washington
Washington State University
Washington State Department of Transportation

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Message from the Executive Director

Washington State's extensive multimodal transportation system is vital to the state's economy and the well being of its citizens:

- The system includes more than 7,000 centerline miles of state highways and over 75,000 centerline miles of county roads, city streets, and other state and federal roads. The state highways include 3,000 bridges, 34 tunnels, 43 safety rest areas, 54 weigh stations, and 97,500 acres of roadside land. Water drainage is managed through more than 42,500 culverts and 33,500 catch basins. In 2004, the number of daily vehicle miles traveled in the state was over 150 million. More than 4.3 million licensed drivers traveled Washington's roadways in 2005.
- Twenty-eight ferries travel 10 routes serving eight state counties and British Columbia, Canada, through 20 terminals. In 2004, the system moved over 24.4 million passengers and 10.9 million vehicles and drivers.
- Twenty-eight transit agencies, comprising 5,600 vehicles, 300 park-and-ride lots, 75 transit centers, and 102 maintenance facilities, provide service throughout the state to over 155 million passengers annually.
- Passenger rail service, provided by Amtrak, moved over 635,000 people in 2005.
- Washington's system of 129 airports annually serves 30 million passengers and generates 171,311 jobs, over $4 billion in wages, and over $18.5 billion in sales.
- This multimodal system moved over 466 million tons of freight in 1998. This volume is expected to grow to 834 million tons by 2020.

Research plays a key role in managing this complex and dynamic system. In the past two years, research produced results that will be used to accomplish the following:

- Continue seismic retrofitting of bridges, evaluation of bridges' response to earthquakes, and the construction of bridges that are resistant to seismic forces.
- Avoid or mitigate adverse environmental impacts. Research emphasized an improved understanding of stormwater runoff and the potential impacts of transportation on species listed under the Endangered Species Act.
- Measure congestion and system efficiency and reliability in order to develop strategies that improve highways in ways people can see and experience.
- Quantify changes in freight mobility resulting from roadway improvements, and maximize the security of, and efficiencies and benefits available from, the multimodal transportation system.
- Better understand liquefaction hazards and the performance of marginal, but available, fill materials. Geotechnical research also improved design guidelines for bridge foundations and for cable net systems for slopes.
- Improve pedestrian and driver safety by better understanding the complex factors that influence accidents and evaluating the effectiveness of design changes.
- Design pavements for longer life through the use of state-of-the-art test protocols and design tools.
- Incorporate factors into planning and design that influence quality of life and improve intermodal connectivity and use.
- Collect and analyze data to better understand and operate the state's multimodal transportation system.

The Washington State Transportation Center (TRAC) is an essential component of the state's transportation research program. TRAC is supported through a partnership among the Washington State Department of Transportation, University of Washington, and Washington State University to provide a link among the government, university researchers, and the private sector in support of transportation research.

TRAC researchers have worked with federal, state, regional, and local government transportation agencies to address critical issues in transportation, and their efforts have led to improved efficiency, longer system life, more context sensitive designs, and, through these benefits, cost savings. Many TRAC projects have also received national recognition and have had positive impacts on national transportation practices.

The research findings presented in this report represent the broad diversity of issues facing the management and operation of the state's transportation system. These findings have been achieved through substantial effort by university faculty and students, as well as industry professionals in both the private and public sectors. Their contributions have helped improve transportation facilities both within our state and nationwide. To all the participants in these projects, thank you for your efforts and to your commitment to improving the transportation system in Washington State.

Leni Oman
Executive Director, TRAC
Director, Office of Research and Library Services, WSDOT

Overview

Research at the Washington State Transportation Center (TRAC) is interdisciplinary, collaborative, and diverse.

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.

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 50 faculty and researchers in 13 UW and WSU departments for 18 sponsors and with over 30 public and private partners.

Project Funding and Support

From July 1, 2003, to June 30, 2005, TRAC researchers were involved in just over 100 research projects, for which the budgets totaled more than $13.2 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 support from

- Federal Highway Administration
- National Cooperative Highway Research Program
- Transportation Northwest (TransNow), one of 33 national university transportation research centers
- Transportation Research Board
- U.S. Department of Transportation.

A number of TRAC/WSDOT projects were supported by consortia or pooled funds in which the departments of transportation from other states were involved, including those of Alaska, Arizona, California, Colorado, Florida, Idaho, Illinois, Kansas, Maryland, Minnesota, Missouri, Montana, New York, North Dakota, Ohio, Oregon, Nebraska, Texas, and Wyoming.

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

- City of Bellevue
- City of Seattle
- City of Tacoma
- Community Transit
- Freight Mobility Strategic Investment Board
- Sound Transit
- Washington Department of Fish and Wildlife.

TRAC received private support from or worked as a subcontractor with

- Cambridge Systematics
- Fugro-BRE, Inc.
- PCS/LAW/MACTEC Engineering and Environmental Services
- Science Applications International Corp.

Cooperation and Collaboration

As part of their diverse projects, TRAC researchers worked with numerous partners from private consulting firms or product manufacturers, universities or other research facilities, cooperative 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. In addition to WSDOT, UW, and WSU, research partners included the following:

Universities and Research Institutes

Battelle Marine Sciences Laboratory
Royal Military College of Canada
Texas Transportation Institute
University of California, Berkeley
University of Washington Engineering Professional Programs
Western Transportation Institute

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
- Puget Sound Regional Council
- Snohomish County
- Sound Transit
- US Customs
- US Department of Agriculture
- Wasatch Front Regional Council, Utah

Private Companies

- ELogicity
- Go On Institute
- Maersk Sea-Land
- Keith Lawton and Associates
- Lawrence Frank and Company, Inc.

Associations

- Northwest Regional Modeling Consortium
- Washington Trucking Association

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. TRAC makes a special effort to ensure that research reports are understandable by developing project summaries and providing guidance to writers. During 2004-2005, TRAC processed numerous proposals and produced over 60 reports and other publications.

TRAC also continued 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.

In addition, over the past two years, researchers enhanced a computer-based pavement course and electronic tools to aid in communication and training about the design and construction of pavements, and they participated in a State Pavement Technology Consortium to allow inter-state sharing of pavement practices and a Pavement Tools Consortium that fosters the continued development and implementation of computer-based paving tools. TRAC researchers also continued to support a traffic systems management intern program at WSDOT to the mutual benefit of University of Washington civil engineering students and WSDOT Traffic Management.

Because Washington State is in an active seismic zone, earthquake-related issues are of major importance in bridge research.

The focus of bridge research has continued to be on seismic retrofitting, evaluation of bridges' response to earthquakes, and the construction of bridges that are resistant to seismic forces. The seismic retrofit program is active and is planned to continue through the next four to six years. This program typically retrofits bridges by type, and recent research has been able to evaluate the most cost-effective strategies for the next round of necessary retrofits. In addition, because Washington is in an active seismic zone, there have been concerns about constructing bridges with precast elements, but current and continuing research is evaluating the seismic resistance of new design and construction strategies.

Completed Projects

Development of Improved Design Procedures for Cotton Duck Bearing Pads.

Cotton duck pads have been used successfully on a limited basis as bridge bearings. These pads, manufactured under military standard, are known to have significant load capacity and are efficient, economical, and suitable for construction of small and moderate-size bridges. However, their rotational stiffness, durability, and deformation capacity had not been adequately characterized and codified through experimental testing. Expanding on previous tests, the researchers codified design provisions that will permit cotton duck pads to be used under increased load and rotational capacity and developed widely applicable design recommendations and tools that will allow their more extensive use as bridge bearings. These bearing pads may be used to replace more expensive spherical or disk bearings.

Principal Investigators: Roeder, C.W./Lehman, D.E., UW
Technical Monitor/Project Manager: Dornsife, R.J./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

Dynamic Response of Bridges to Near-Fault Forward Directivity Ground Motions.

Experimental evidence from and observations of the 1994 Northridge and 1995 Kobe earthquakes have shown that pulse-type earthquake ground motions can significantly damage structures. Furthermore, analytical models indicate that traditional analysis methods are insufficient to capture the full effects of pulse-type ground motions. This project is using the wealth of recent ground motion data to develop models that will improve understanding of the response of typical reinforced concrete and precast concrete bridges to pulse-type ground motions. Better understanding of the response of structures to this type of ground motion will result in direct benefits to communities across the United States exposed to nearby faults, including reduced seismic risk and the opportunity to more effectively allocate scarce resources in designing and retrofitting structures.

Principal Investigators: Cofer, W.F./Rodriguez-Marek, A., WSU
Technical Monitors/Project Manager: Kapur, J./Khaleghi, B./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

Robert F. Williams

A detailed "health monitoring" program developed for the existing Tacoma Narrows Bridge is intended to help the state design special repairs or structural modifications and will also include an evaluation of the influence of the new bridge on the structural performance of the old one.

FHWA-Supported Structures Research: Seismic Behavior of Micropiles.

An increased awareness of the performance of micropiles—very small foundation supports used to stabilize bridges and other structures under seismic conditions, in difficult ground conditions, or in limited space—has led to the widespread use of this technology. Through a comprehensive literature review, this study added to knowledge about the state-of-practice of micropile use. Researchers also conducted finite element modeling of single micropile and micropile groups under both static and dynamic loading. Several observations on micropile behavior were determined from an exhaustive parametric study. Results pointed to the importance of using appropriate nonlinear models of soil behavior. The researchers also concluded that numerical analyses can be used on complex pile geometries and complex soil behavior to obtain p-y curves for use by design professionals.

Principal Investigators: Rodriguez-Marek, A./ Muhunthan, B., WSU
Technical Monitor/Project Manager: Allen, T./Willoughby, K., WSDOT
Sponsor: FHWA

Post Earthquake Prioritization of Bridge Inspections.

National and world events have spurred Washington State to better prepare for natural disasters. As part of that preparation, researchers developed information tools to increase the speed and efficiency of WSDOT post-earthquake response and recovery efforts. The researchers upgraded the Pacific Northwest Seismograph Network (PNSN) ground-motion processing software to rapidly generate and disseminate maps of earthquake intensity. The researchers also implemented two procedures to estimate the likelihood of slight (or greater) bridge damage. Following an earthquake, these procedures will provide WSDOT personnel with preliminary earthquake data and a list of bridges for inspection, prioritized by likelihood of damage.

Principal Investigators: Eberhard, M.O./Malone, S., UW
Technical Monitor/Project Manager: Coffman, H./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

Structural and Construction Demands on Concrete in Floating Bridges.

Currently, WSDOT is replacing the east half of the Hood Canal floating bridge. Two important design considerations for floating bridges are concrete mix and watertight joints. Two concrete mix designs are available to this project, each one used for a previous floating bridge. Both mixes have performed well, even under exposure to salt water, winds and waves, freezing and thawing, and abrasion, but there is potential for improvement based on

Assessment and Retrofit of Outrigger Bents

Many raised highway structures are supported on bent columns that are not directly beneath the deck. Referred to as "outriggers" because their configuration resembles the outriggers used to stabilize canoes, they are built when a railroad, street, or other right-of-way prevents a column from being placed in the most logical location. Use of outrigger bents results in unusual internal forces, such as torsion, under all loads, but particularly under seismic loading. The SR 99–Spokane Street overcrossing in Seattle, built in the 1950s, represents an example of outrigger bents that could fail in a seismic event, and a previous study of the structure recommended retrofits, some of which have been implemented.

This project, conducted in concert with experimental research at Washington State University (see below), found the structure to be seismically vulnerable, especially to 72- and 475-year ground motions. Two main retrofit strategies were developed for the knee joints, which are the most critical components: a design to increase the strength and ductility of the components and a design to reduce the demands on the components. An evaluation of the knee joint and the retrofit strategies showed that the type of retrofit performed on the outrigger column greatly influences the performance of the bridge.

Principal Investigators: Stanton, J.F./Lehman, D.E./Kramer, S.L., UW
Technical Monitor/Project Manager: Henley, E./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

Behavior and Design of Joints in Bridge Substructures

The offset column in an outrigger bent is connected to the bridge support beam by a knee joint. Experience and research have demonstrated the vulnerability of the knee joints in outrigger bents in both older and more recent construction, and there is concern about the performance of knee joints in existing bridges during an earthquake. This project investigated the behavior of outrigger knee joints and developed and evaluated practical methods for retrofitting the joints to improve their performance. Although the focus of the research was the knee joints of the SR 99–Spokane Street overcrossing in Seattle, the results are applicable to other bridges as well.

Principal Investigator: McLean, D.I., WSU
Technical Monitor/Project Manager: Zhang, H./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

advancements in mix designs developed during the Strategic Highway Research Program. As for bridge joints, floating bridge pontoons are often constructed with horizontal construction joints between the bottom slab and exterior vertical walls. In past pontoon projects, these joints have leaked and have had to be sealed from the inside after the pontoons were floating. This method of achieving water tightness relies on a seal on the inside of the pontoon, which is expensive and undesirable. Improvements in construction methods or materials are needed to more efficiently and cost effectively achieve a watertight joint. This project is seeking ways for WSDOT to improve both these aspects of the Hood Canal Bridge, thus making the bridge more safe and its construction less costly.

Principal Investigators: Masad, E./Itani, R., WSU
Technical Monitor/Project Manager: Swett, G./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

Active Projects

Camber Prediction in Precast, Pretensioned Concrete Bridge Girders. Precast, prestressed concrete girders have been used in bridge construction for almost 50 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 feet. 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. In Washington State, three recent changes in construction practice have affected the accuracy of girder camber estimates. The goal of this project is to evaluate current methods for estimating camber and to develop improvements. Better methods of predicting camber will lead to more efficient design of prestressed girders and will decrease construction difficulties and thus also costs.

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

Composite Material Alternatives to Timber in the Construction of Wing Walls. The wing wall system is a critical structure of ferry terminals because it positions the vessel bow during its approach and impact for berthing. New wing walls are being designed and built with steel piles and wall supports, but large sections of timber remain the material of choice for the wear surface that contacts the ship. However, the use of biocide-treated wood products in harbors is under both regulatory and public scrutiny, so WSDOT is exploring the use of other materials for this application. The focus of this project is on developing thermoplastic wood composite materials to replace current timber elements for wing wall wear surfaces. This work will provide WSDOT with a better understanding of the feasibility of using such materials. If composite members can be used, they may result in both better energy dissipation and structure life, as well as provide environmental benefits.

Principal Investigators: Wolcott, M.P./McLean, D.I., WSU
Tech. Monitor/Project Manager: Bertucci, T./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

Effects of Long Duration Earthquakes on Bridge Structures. Recent geological evidence indicates that the potential exists for larger earthquakes in the Pacific Northwest than previously predicted. The seismic risk to bridges in such events may be strongly tied to the duration of significant ground motions. The current seismic design criteria for bridges in the Pacific Northwest have evolved from experiences with short duration earthquakes in California and Western Washington and, therefore, do not appropriately account for the potential damage that could occur. This project is investigating the expected performance of concrete bridges in large magnitude, long duration earthquakes. It consists of complementary experimental and analytical efforts that are contrasting the expected seismic performance of bridges subject to short duration events with that expected from the postulated long duration events. The findings will provide information about the adequacy or inadequacy of current seismic design provisions for protecting bridges in such events, and recommendations will be made for any necessary changes in the provisions. The result will be safer bridges in the Pacific Northwest and Alaska.

Principal Investigators: McLean, D.I./Cofer, W.F./McDaniel, C.C., WSU
Technical Monitor/Project Manager: Kapur, J./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

Nondestructive Evaluation of Prestressed Concrete Box Girders for the I-90/4th Avenue On-Ramp Bridge. The structural integrity of prestressed (PS) concrete bridges is dependent upon the condition of prestressed steel tendons/strands embedded in the concrete. Currently, no proven nondestructive evaluation (NDE) techniques exist for reliably detecting voids and corrosion in PS tendons. The scheduled demolition of a 12-year-old on-ramp bridge in Seattle is providing a unique opportunity to develop and apply

advanced NDE techniques (thermal imaging and ground-penetrating radar) for assessing the condition of post-tensioned PS tendons in a box girder bridge. In developing new non-destructive evaluation techniques, the project will give state and federal highway engineers ways to more accurately assess the condition and structural integrity of PS concrete box girder bridges. This will enhance public safety and improve the use of fiscal resources for the management and maintenance of public highways.

Principal Investigator: Pollock, D.G.,WSU
Technical Monitor/Project Manager: Khaleghi, B./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

Precast Systems for Rapid Construction of Bridges. WSDOT predominantly uses cast-in-place concrete construction to build many bridge substructure components and bridge decks. Although cast-in-place components have a long record of excellent durability and seismic performance, building on-site slows the construction process and often requires lengthy traffic restrictions and diversions. 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. This project is evaluating existing precast concrete systems, identifying those that are most promising, and developing new details and design procedures for typical bridge configurations in Washington State. Phase 2 will develop a testing plan to evaluate the practicality and seismic resistance of the proposed systems.

Principal Investigators: Eberhard, M.O./Stanton, J.F., UW
Technical Monitor/Project Manager: Kapur, J./Willoughby, K., WSDOT
Sponsors: 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. More specifically, the role of the deck of a prestressed girder bridge in resisting a blast is unknown. Thus, there is a need to conduct life-size blast experiments on prestressed girder bridges. 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 against damage that may result from potential acts of terrorism.

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

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 place steel jackets around 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 is assessing the seismic vulnerability of typical multi-column bent bridges in the state, assessing retrofit strategies to upgrade the structures to a safe performance level, and will provide recommendations for prioritization and selection of bridges for retrofit.

Principal Investigator: McDaniel, C.C., WSU
Technical Monitor/Project Manager: Lee, C.-S./Willoughby, K., WSDOT
Sponsor: WSDOT

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 is designing a detailed health monitoring program for the existing Tacoma Narrows Bridge and proceeding with initial stages of implementation on the existing structure. One of the benefits that will result from this project will be an evaluation of the influence of the new bridge on the structural performance of the old bridge.

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

Environmental research helps explain the interactions between transportation activities and ecosystem dynamics so that transportation agencies can be better stewards of the environment.

Acquiring permit approvals required by various federal and state natural resource agencies is a critical step in the transportation project delivery process. These approvals are based on the best available science on a particular topic, such as water quality or endangered species. Transportation research helps to further our understanding of the natural sciences and the affect of transportation activities in an ecosystem. Research also helps in identifying ways to avoid or mitigate adverse environmental impacts, helping transportation agencies manage transportation systems in a more environmentally compatible manner and improving information needed to secure needed permits in a timely manner.

Completed Projects

Assessing Overwater Structure-Related Predation Risk on Juvenile Salmon. To aid in the design of new ferry terminals, WSDOT needs to understand what effects ferry terminals and other over-water structures have on migrating juvenile salmon. To answer those questions, researchers from Battelle Memorial Institute conducted species surveys and identified attributes of ferry terminals (for example, light levels and dock characteristics) that influence abundance patterns or behavioral changes. The research results will be used to help design over-water marine facilities that will allow juvenile salmon to migrate successfully.

Principal Investigators: Williams, G.D./Thom, R.M. /Southard, J.A., Battelle Memorial Institute
Technical Monitor/Project Manager: Carey, M./Brooks, R., WSDOT
Sponsor: WSDOT

Evaluation of the Effects of Turbidity on Salmonids for Endangered Species Act Compliance. Stormwater runoff or disturbance of in-stream sediments caused by transportation projects can negatively affect water quality. One way of measuring that water quality is to measure turbidity, which occurs when matter such as clay silt, fine organic or inorganic matter, or macroscopic organisms becomes suspended in the water. The levels of turbidity that are critical at the most sensitive stages of salmonid life are not clearly understood. Knowing these critical levels and the best ways to measure turbidity will allow transportation professionals to devise temporary techniques to prevent erosion and sediment from causing turbidity to reach critical levels. This project reviewed these issues, and its findings will help improve protection of endangered species as well as improve the efficiency of transportation projects by preventing the need for extensive consultations and permit negotiations with resource agencies on this issue.

Principal Investigator: Bolton, S.M., UW
Technical Monitor/Project Manager: Molash, E./Brooks, R., WSDOT
Sponsor: WSDOT

Field Assessment and Mitigation of Potential Environmental Impacts of PCC Highway Grindings, Phase II. Very little information has been available on the environmental impact of highway grindings that result from re-surfacing portland cement concrete (PCC) pavements. The grinding slurry—a combination of water, concrete, and aggregate residue—is sometimes deposited along roadsides in Eastern Washington, but little is known about the effects, if any, of slurry disposal on the environment. For this study, researchers investigated the impact of PCC highway grinding slurry on soil pH in disposal areas in Eastern Washington, and they evaluated the effectiveness of using compost to at least partially neutralize slurry pH. The researchers found that PCC slurry does raise soil pH levels and that impacts on the soil may last as long as seven years. They also found that compost is effective at reducing slurry pH. This information will help guide future disposal methods. If the method of mixing the slurry and compost together to reduce the pH level is acceptable environmentally, it will be used on future PCC grinding projects to reduce the costs of collecting, hauling, and disposing of the slurry off-site.

Principal Investigator: Yonge, D.R., WSU
Technical Monitor/Project Manager: Pierce, L.M./Brooks, R., WSDOT
Sponsors: WSDOT/FHWA

Groin Design for Stream Bank Protection. Barbs are structures of stone, rock, or gravel built at an angle into a river to deflect flowing water away from critical zones and structures, to prevent bank erosion, to protect fish inhabiting the river, and to establish a more desirable channel for flood and erosion control. WSDOT has designed and used barbs at several locations to minimize streambank erosion and reduce scouring around bridge piers. However, the results have not always been consistent. This project investigated the appropriate design specifications for barbs in gravel streambeds, including the number of

barbs needed, flow patterns, barb length, scour, and criteria for defining rock size. New design procedures will improve WSDOT's ability to cost-effectively design barbs in streambeds. The benefits of the project will include reduced stream bank erosion and scour around bridge structures, thus preserving the life of the structures, as well as fewer potentially detrimental effects on stream ecology. In addition, the improved design procedures are anticipated to help WSDOT expedite its permitting process.

Principal Investigators: Papanicolaou, T./Hotchkiss, R.H./Barber, M.E., WSU
Technical Monitor/Project Manager: Peralta, R./Brooks, R., WSDOT
Sponsors: WSDOT/FHWA

Infiltration Characteristics and Performance of Stormwater Facilities. To determine the size of ponds and stormwater facilities, previous design manuals and regulations mixed together hydraulic gradient and hydraulic conductivity for estimating infiltration rates. This research demonstrated the importance of working with these two parameters separately to accurately determine infiltration rates. Before this research, the tools available for estimating infiltration rates contributed to inaccuracy and misunderstanding. The resulting over- or under-designed facilities either were badly scoped or performed poorly. Furthermore, there was no agreement on how to estimate infiltration rates. Laboratory testing in this research provided new tools for estimating the hydraulic conductivity of soils, and simplified equations were developed to estimate the hydraulic gradient. The new tools were tested for accuracy in full-scale facilities. This research has enabled WSDOT and the state Department of Ecology to reach agreement on design standards for infiltration facilities, and the design guidelines have been adopted into WSDOT's Highway Runoff Manual and the DOE's Stormwater Manual for Western Washington.

Principal Investigator: Massman, J., Massman Consulting
Technical Monitor/Project Manager: Allen, T./Brooks, R., WSDOT
Sponsors: WSDOT/FHWA

Low Impact Stormwater Treatment Methods

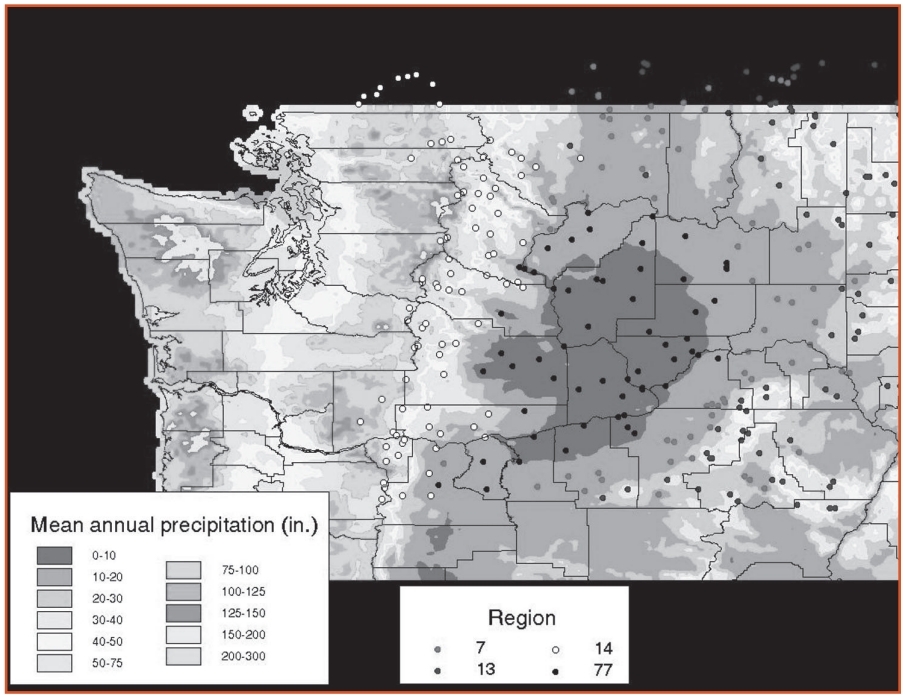
Management of stormwater quantity has long been a challenge for highway designers. Traditionally, centralized best management practice (BMP) designs have been cost prohibitive and inefficient for many rural highways. The use of existing vegetated rights-of-way as a method of treating stormwater has become a primary focus of WSDOT. However, to adequately design and utilize such stormwater management controls, further research and correlation between numerical infiltration/runoff models and field experiments were needed. This project focused on evaluating natural dispersion runoff infiltration performance and determined that WSDOT's current evaluation procedures were incorrectly eliminating vegetated areas that could provide acceptable levels of infiltration. As a result, a simplified, user-friendly design equation was developed that will help highway designers more efficiently and cost-effectively reduce the volume of highway runoff for diversion to BMP treatment systems.

Principal Investigators: Yonge, D.R., WSU/Reister, M., WSDOT
Technical Monitor/Project Manager: Navickis-Brasch, A./Brooks, R., WSDOT
Sponsor: WSDOT

Regional Precipitation Frequency Analysis and Spatial Mapping of Precipitation for 24-hour and 2-hour Durations in Eastern Washington.

Understanding the history of precipitation in Washington's diverse geographic areas can help WSDOT to design appropriate stormwater facilities. To improve engineers' understanding, this project collected and analyzed historical weather data and developed map layers in a geographic information system. This information will be available to WSDOT staff for use in project planning, design, and maintenance.

Principal Investigator: MGS Consultants
Technical Monitor/Project Manager: Peralta, R./Brooks, R., WSDOT
Sponsor: WSDOT



Collected, analyzed, and mapped historical weather data will help WSDOT personnel in project planning, design, and maintenance.

Active 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 their 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 approached these questions in two different ways, developing a literature review and conducting interviews with people who have specific knowledge or views of these issues. To summarize their findings, the researchers developed a decision framework that WSDOT district maintenance staff will be able to 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
Technical Monitor/Project Manager: Willard, R./Willoughby, K., WSDOT
Sponsor: WSDOT

Culvert Testing for Fish Passage at the Skookumchuck Test Bed.

As in many states, numerous barrier culverts in Washington will require repair or retrofit in the future. WSDOT estimates that it is responsible for over 1,200 needing retrofit. To find culverts that will effectively allow fish passage, a "one of a kind" research test bed is being developed through a partnership among the Washington Department of Fish and Wildlife, the states of Alaska, Oregon, and California, and the Federal Highway Administration. This research will help determine cost-effective designs for retrofitting culverts under highways and roads so that juvenile salmonids can survive their migration journeys.

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

Design of Fish Passage for Bridges and Culverts.

Most bridges and culverts, which play a critical role in the transportation network, contract the flow area at the crossing location because it is not economically feasible to span the entire width of the channel and

Because little is known about the effects on wildlife of driving piles through water, researchers are developing a plan to guide future research on this issue.

floodplain. Such contractions, or encroachments, constrict and narrow the channel through the bridge opening or culvert barrel. Because of these constrictions, many bridges and culverts act as barriers to juvenile and adult fish. Often, high quality upstream fish habitat is isolated and disconnected from downstream stream and river corridors by structures that are simply impassable for native fish. Unfortunately, there is no generalized approach for the design of fish passage for bridges and culverts that combines current practice, policy, and research results. This project is developing a manual to provide guidance for engineers and planners considering fish passage through bridges and culverts. The document will include information on current design practice and provide a coherent procedure that may be followed to consider differing hydraulic and fish species conditions. It will also include new research results for retrofitting existing culverts. In particular, such guidelines should greatly streamline the design process and decrease delays experienced by state departments of transportation on projects affecting fish.

Principal Investigator: Hotchkiss, R.H., WSU
Technical Monitor/Project Manager: Peralta, R./Brooks, R., WSDOT
Sponsors: WSDOT/FHWA

Effects of Pile Driving on Species. Driving large steel piles into soils under rivers or bodies of water generates underwater sounds and energy impacts that may adversely affect salmonids, other fish species, marine mammals, and diving sea birds. Currently, very little information exists to help WSDOT and regulatory agencies accurately predict the impact levels of driving steel piles through water and to determine methods to avoid or reduce the impacts. This project is developing a plan with the cooperation of representatives from federal and state resource agencies to guide future research on this issue.

Principal Investigators: Carlson, T./Thom, R.M., Battelle Memorial Institute
Technical Monitors/Project Manager: Carey, M., /Laughlin, J./Brooks, R., WSDOT
Sponsor: WSDOT

Endangered Species Listing Preparation and Response. Literature searches and inventories are conducted on various species under consideration for listing as "endangered." These studies have included the Oregon spotted frog, the streaked horned lark, the wild Canadian lynx, and the ground squirrel. WSDOT uses the information from these studies to minimize construction impacts on species and their habitats and to determine early in the project delivery process whether biological assessments will be necessary.

Principal Investigator: Washington Department of Fish and Wildlife
Technical Monitor/Project Manager: Carey, M./Brooks, R. WSDOT
Sponsor: WSDOT

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. Several efforts have recently been undertaken to map the state's impervious areas on the basis of remote sensing data, but these efforts have not addressed questions specific to WSDOT's needs. This project will develop a classification scheme for mapping the percent-

An innovative research facility located below the Ship Canal Bridge in Seattle is testing the quality of highway water runoff subjected to different stormwater treatments.

age of total impervious areas attributable to different types of transportation infrastructure based on current LANDSAT imagery. Such a system could help WSDOT more efficiently and effectively meet state regulations while designing and operating the state's highways.

Principal Investigator: Alberti, M., UW
Technical Monitor/Project Manager: Lanzer, E., Brooks, R., WSDOT
Sponsors: WSDOT/USDOT

Runoff Treatment BMP Design for Highway Runoff in Cold Climates. Regulations require significant reductions in pollution from stormwater runoff from all urban settings, including drainage from highways and bridge decks. Many Best Management Practices (BMPs) for stormwater runoff treatment have been based on model predictions developed for warm-weather climates subject to summertime thunderstorms and other rainfall events. However, in eastern Washington, most runoff is generated by rain-on-snow events or during fall months after a prolonged dry season. To address this problem, researchers are developing models to predict runoff treatment flow rates and volumes from short duration and long duration storms in Eastern Washington and northern Idaho. They are also analyzing the performance efficiency of runoff treatment BMPs in cold, semi-arid climates, including the effectiveness of filter strips, biofiltration swales, and compost amended vegetated filter strips in treating metals, nutrients, and deicers. With properly designed BMPs, transportation personnel will be able to better plan cost-effective controls for treating highway and bridge deck runoff. In addition, regulators will be able to more quickly assess performance, making permitting easier. Correctly designed BMPs may also prevent costly retrofits.

Principal Investigators: Barber, M.E./Buetel, M./Yonge, D., WSU
Technical Monitor/Project Manager: Peralta, R./Brooks, R., WSDOT
Sponsors: WSDOT/FHWA

Ship Canal Stormwater Research Facility. WSDOT and the cities of Tacoma and Seattle funded the construction of an innovative research facility below the Ship Canal Bridge in Seattle, Washington. The facility is testing the quality of highway water runoff subjected to various stormwater treatment products.

Principal Investigator: Taylor Associates
Technical Monitor/Project Manager: Stephens, M./Brooks, R. WSDOT
Sponsors: WSDOT, cities of Tacoma and Seattle

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

The Washington State economy loses an estimated $2 billion every year in wasted time, wasted fuel, and shippers' delays as a result of congestion. Cost effectively reducing congestion requires knowledge of its causes. In addition, the ability to measure congestion and the impact it has on the movement of people, the flow of goods to market, and regional air quality is of vital importance.

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. Freeway and arterial management research is focusing on developing ways of measuring efficiency and reliability, and on producing improvements that people can see and experience.

Completed Projects

The Automated Use of Uncalibrated CCTV Cameras as Quantitative Speed Sensors, Phase 2.

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 ongoing project is to create algorithms and prototype software to allow these cameras to be used to make continuous quantitative measurements of vehicle speed. This Phase 2 project investigated ways to use roadway features to augment camera calibration. Successful deployment of these algorithms 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
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

A Cellular Automata Model for Use with Real Freeway Data for Congestion Prediction, Phase 2.

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 "Pinpoint Doppler" weather radar, that can predict growing or dissipating congestion. Preliminary versions of the model developed in Phase 1 used real-time inductance loop data to successfully reproduce traffic behavior under moderately congested conditions. To improve the model for heavily congested conditions, it had to be calibrated, but the calibration process revealed that inductance loop errors were preventing accurate results. So this Phase 2 project developed an algorithm to correct data provided by improperly functioning loops. The resulting algorithm, and the eventual traffic prediction model, will allow WSDOT to improve its freeway management efforts.

Principal Investigator: Dailey, D.J., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

Evaluation of FAME.

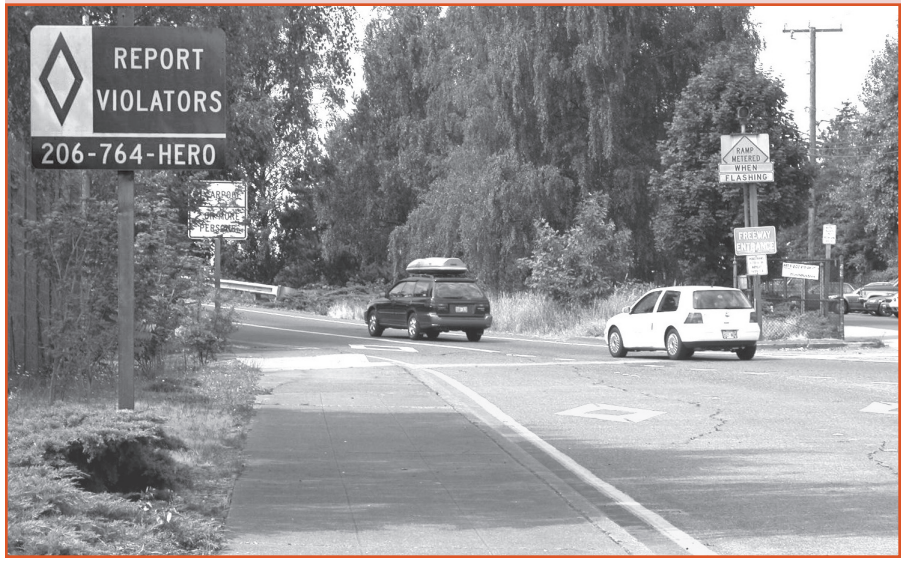
The Freeway and Arterial Management Effort (FAME) was a broad program that oversaw research and deployment of new and more effective methods of reducing traffic congestion in Washington State. FAME projects were funded through a variety of sources; between 1988 and 2004, 23 FAME projects received at least partial funding from the Oil Rebate Program, a fund created as the result of a dispute settlement between the federal government and major U.S. oil companies. This project evaluated those Oil Rebate expenditures. Its findings were that FAME projects improved the way that incidents are detected, cleared, and communicated to travelers; improved the state's ability to control and manage traffic; decreased the financial risk associated with investigating non-traditional approaches to traffic flow improvements; and allowed WSDOT to begin quantifying the extents of both the problem and the benefits that could be gained from new approaches for dealing with congestion. All of these projects contributed to smoother, less congested vehicle flow, resulting in decreased fuel use and fewer emissions generated by cars and trucks.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Legg, B./Brodin, D., WSDOT
Sponsor: WSDOT

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

Washington State recently decided to modify 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 are analyzing 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 are also assessing the public's opinions of the changed hours. 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 report addresses their need to know whether changes in HOV policy are successful. The results will help policy makers in deciding how best to operate the HOV lanes and the public in better understanding their purpose and effectiveness.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsor: WSDOT



Flow Archive Analysis Support. As part of WSDOT's continuing efforts to manage the central Puget Sound region's transportation network and enhance traveler mobility, WSDOT 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 fourth edition of the WSDOT "Central Puget Sound Freeway Usage and Performance Report," analyses for an updated HOV lane evaluation, and analyses on changes in freeway performance that resulted from WSDOT roadway improvement projects such as the completion of the latest HOV lane expansion project on I-5. The information provided by these analyses helps WSDOT improve freeway operations, perform planning studies, and analyze alternative policy changes in order to improve the Puget Sound transportation network.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Leth, M.P./Brodin, D. WSDOT
Sponsors: WSDOT/FHWA

F-SHRP. For this project, TRAC researchers, in a subcontract to Cambridge Systematics, helped design a detailed research program for the portion of the federal Future Strategic Highway Research Program (F-SHRP) that will address improvements in highway travel time reliability. The project team identified the needs and expectations for reliability of various highway customers, such as the traveling public, freight carriers and shippers, and manufacturers and producers. They then developed performance measures and indicators that describe reliability for those customers and identified the research that will be necessary to improve the transportation profession's ability to deliver products and services that meet those reliability needs. The recommended research program is part of the Strategic Highway Research Program II (SHRP II) recently funded by Congress.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor: Margiotta, R., Cambridge Systematics
Sponsors: Cambridge Systematics/NCHRP

HOV Evaluation VII. Surveys have shown considerable support for the construction of HOV lanes in the Puget Sound region. In this phase of a multi-year study, researchers collected considerable data on the use and performance of the Puget Sound region's HOV

lanes and conducted a multi-faceted evaluation of the effectiveness of HOV lanes. The evaluation included analysis of 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. 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 Investigator: Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

Improvements to the FLOW Archive and Analysis Process. Since 1995, TRAC has been developing and enhancing a methodology and tool set for WSDOT to use in estimating usage and performance of the central Puget Sound freeway network. During this ongoing effort, new algorithms, performance measures, and improvements in tool design and efficiency have enhanced the analysis process and resulted in more useful products for users. This most recent project enhanced the methodology's algorithms, including developing a way to fill data holes by making estimations from surrounding data. This project also created new analysis tools and improved the system interface. WSDOT is using the analyses that these tools support to produce regularly updated estimates of urban freeway travel times for the public and for operations, planning, and policy analyses and decision making.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

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

Measurement of Recurring and Non-recurring Congestion, Phase IIB. TRAC researchers are continuing to help WSDOT better understand the causes of congestion in the Puget Sound region. This project, the second phase of this effort, examined the effects of special events, lane blocking incidents, incidents that did not block lanes, and weather between January and April 2003 for three corridors, I-90, SR 520, and the southern half of I-405. One major finding of the study was that considerable congestion cannot be directly associated with any of the causes noted above, nor the existence of "routine" traffic volumes. The study also showed that many of the congestion effects of traffic disruptions (accidents, incidents, special events) occur far away from the actual cause of the disruption. A less obvious finding was that lane blocking incidents can cause multiple backups: primary congestion directly behind the incident and secondary congestion downstream of the incident after it has been cleared. Another finding of the study was that the effect of light rain on traffic is quite variable. Considerable work remains to be done to understand the complex interaction of all of the factors that affect traffic performance. Improving this understanding is key to developing cost-effective strategies for keeping our roadways flowing optimally.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Bremmer, D./Brodin, D., WSDOT
Sponsors: WSDOT/Cambridge Systematics

Traffic Systems 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 Systems Management Center to students from the UW's Department of Civil 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.

Principal Investigator: Rutherford, G.S., UW
Technical Monitor/Project Manager: Balogh, M./Brodin, D., WSDOT
Sponsor: WSDOT

Active Projects

Arterial FLOW Methodology. Over the course of eight years, the FLOW evaluation project has produced numerous useful analytical results related to regional freeway performance for WSDOT as well as other regional and state agencies and commissions.

This project is using the FLOW evaluation methodology as a model for developing a performance measurement approach for arterials. It is examining the use of various data sets that already exist to provide base-line arterial performance information. Several types of arterial performance improvement projects implemented in the Puget Sound region will benefit from such an evaluation approach. These include coordinated signal timing systems intended to improve general-purpose arterial flow, transit signal priority systems intended to improve transit performance and reliability on surface streets, and new efforts to combine freeway and arterial management control. Adapting the FLOW methodology for arterials will allow routine, inexpensive review of arterial network operation, benefiting operational engineers, planners, and the traveling public.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

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 on the freeways and arterials around Seattle for monitoring congestion. The goal of this ongoing project is to create algorithms and prototype software to allow these cameras to be used to measure vehicle speed. Building on work in phases 1 and 2 of this project, researchers are developing ways to estimate the cameras' parameters and calibrate them. They are also creating a Java application prototype 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
Technical Monitor/Project Manager: Jacobson, E./Brodin, D. WSDOT
Sponsors: WSDOT/FHWA

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 "Pinpoint 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
Technical Monitor/Project Manager: Trepanier, T./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

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

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitors/Project Manager: Trepanier, T./ Bolotin, L./Brodin, D., WSDOT
Sponsor: WSDOT

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 is developing a dual-loop 'tune-up" algorithm based on high-resolution loop detector data and vehicle length distribution statistics. The algorithm will be implemented in a new computer system that can be used to identify and correct dual-loop sensitivity problems. Once they have been correctly configured, dual-loop detectors should

be reliable sources for speed and truck data..

Principal Investigators: Nihan, N.L./Wang, Y., UW
Technical Monitor/Project Manager: Jacobson, E./Brodin, D. WSDOT
Sponsors: WSDOT/FHWA

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

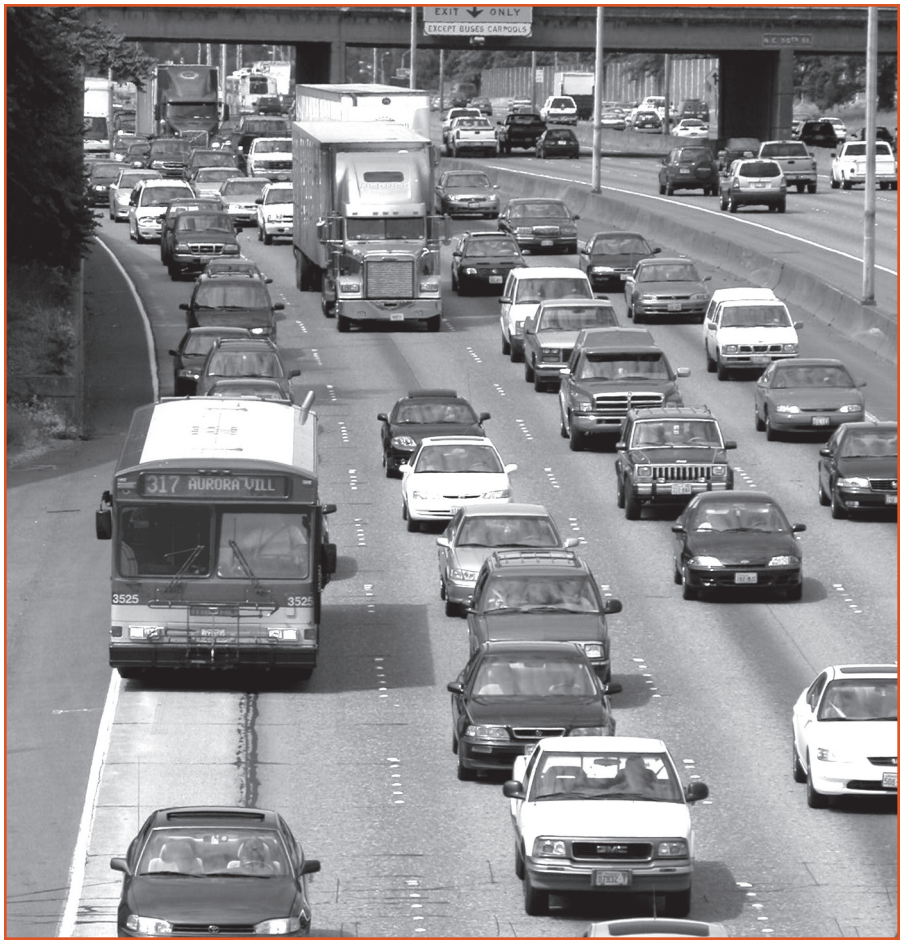
Many freeway networks contain numerous single-loop detectors, which collect vehicle volume and lane occupancy data. However, they do not directly measure vehicle speeds or truck volumes. Given that over 250 surveillance video cameras have been installed along the freeways in the greater Seattle area, this study is investigating a way to pair video 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 vastly different lengths of cars and trucks, this value can never be accurate enough. To allow more accurate speed estimation, video will be used to provide reasonably accurate truck counts, which will then be applied to improve the value for vehicle length. Finding a way for single-loop detectors to support accurate measurement of speeds and truck volumes will provide highway agencies with valuable data without having to install costly dual-loop systems.

Principal Investigators: Wang, Y./Nihan, N.L., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

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

The National Cooperative Highway Research Program (NCHRP) is producing 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 includes TRAC researchers. TRAC's role in the project includes suggesting performance measures, interviewing agency personnel in Seattle and Portland about their performance monitoring systems; and contributing to the initial and final reports. The report for this effort will be published by NCHRP upon conclusion of the project.

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



Two projects are investigating the use of freeway loop detectors to produce better speed and truck volume estimates.

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 is improving 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 Investigator: Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsor: WSDOT

The Use of Weather and Weather Model Data to Predict Non-recurring Traffic Congestion. The aviation and maritime industries use weather measurements and predictions as a normal part of operations. While it is generally asserted that there is a causal relationship between weather and roadway system delays, this relationship has not been quantified in a way that allows the effects of weather on roadway systems to be predicted. This project seeks to find ways to correlate the effects of weather with both non-recurring traffic congestion and conditions that may increase incidents or accidents. If this project is successful and a reliable method for predicting traffic congestion on the basis of weather conditions can be created, the method could be deployed at traffic management centers to allow proactive metering, maintenance facilities to help in providing better roadside assistance, and incident response facilities to assist in proactively deploying incident response equipment.

Principal Investigators: Dailey, D.J./Mass, C.F., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

Researchers are investigating ways to correlate the effects of weather with both non-recurring traffic congestion and conditions that may increase incidents and to develop a reliable way to predict traffic congestion on the basis of weather conditions.

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 450,000 jobs in regional manufacturing, agriculture, construction, and forestry depend on Washington's freight system; these industries accounted for $118.5 billion or 29 percent of all state gross business in 2003. 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, identifying the benefits of proposed intermodal truck-rail facilities, maximizing the efficiencies and benefits available from the multimodal transportation system, reducing congestion at ports and borders, and increasing the security of containerized cargo movements.

Completed Projects

Freight Mobility Strategic Investment Board Benchmarking Study. The Freight Mobility Strategic Investment Board (FMSIB) has undertaken a program to identify impediments to freight mobility and to develop a set of benchmarks, or standards, that will quantify changes in freight mobility resulting from roadway improvements. Such quantification will require extensive data, but unfortunately, data specific to truck movements can be difficult to collect, especially on urban arterials. This project tested two technologies for collecting robust performance data specific to trucks. One data collection technology tested was electronic truck transponders mounted on truck windshields. The second involved global positioning systems placed in volunteer trucks to collect truck movement data at 5-second intervals. Although both data collection methods were found to be potentially useful, the researchers reported that the key to both is whether enough instrumented vehicles pass over the roadways for which data are required. This basic condition will determine whether the technologies will be effective at collecting required data.

Principal Investigators: McCormack, E./Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Stuart, J./Brodin, D., WSDOT
Sponsors: FMSIB/WSDOT

Methodology for Determining the Potential Economic Viability of Intermodal Truck-Rail Facilities in Washington State. Intermodal truck-rail facilities, where goods are transferred from truck to rail or vice versa for shipment to domestic markets, or through gateways to international markets, are one potential means of improving the efficiency of freight movement. However, it can be difficult to determine the benefits that would result from public investment in freight-related infrastructure. This project developed a methodology for determining the potential economic viability of intermodal truck-rail facilities. The focus was on discerning the attributes, characteristics, or market situations associated with successful projects. The resulting framework is being used to help state, regional, and local agencies identify the public and private benefits of proposed facilities and analyze whether further development of and investment in a given truck-rail facility is justified.

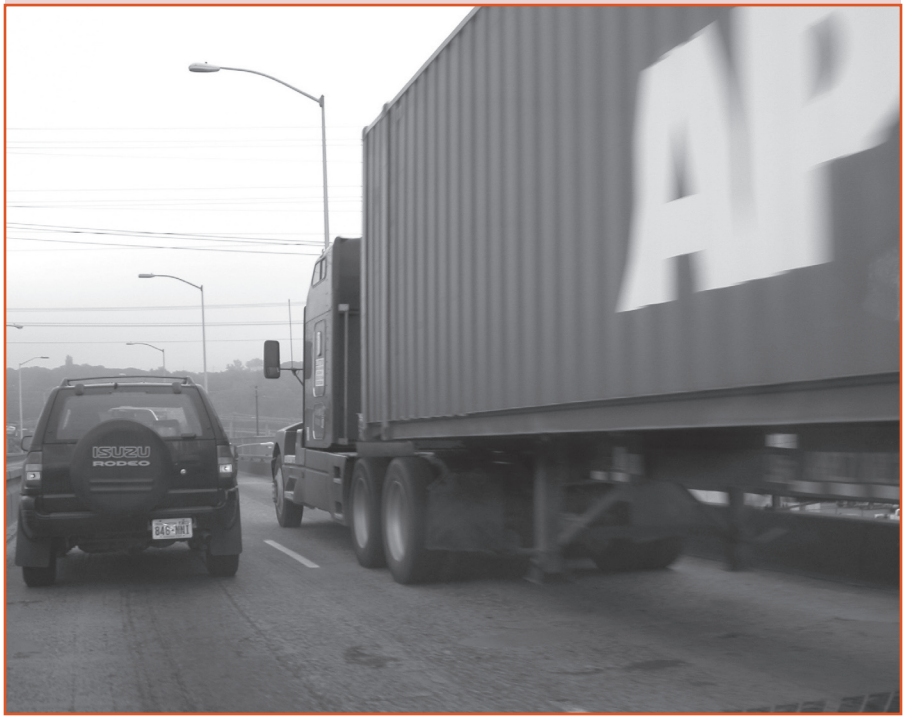
Principal Investigators: Casavant, K.L./Jessup, E.L., WSU
Technical Monitor/Project Manager: Fredrickson, K./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

Strategic Freight Transportation Analysis. Washington State's multimodal transportation system is fundamentally necessary to support the state's economy, affecting agriculture, manufacturing, and all other businesses. Many intermodal technologies have been changing, and energy prices, air quality concerns, and environmental efforts are causing changes in not only the competitive advantages among modes but the ability of the freight mobility sector to continue operating practices that are complementary among modes. A need exists to accurately determine how these changes will affect the multimodal transportation system, the infrastructure, and the state's desired economic development. The purpose of this project was to strategically maximize the efficiencies and benefits available from the multimodal transportation system. By addressing several specific objectives, the researchers strove to aid decision makers in formulating strategic, coordinated investment decisions

Electronic Container Seal Expansion Project

This is an FHWA-sponsored Field Operational Test of a transponder-based system, located in electronic door seals, for ensuring the security of marine 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., UW
Technical Monitor/Project Manager: Legg, B./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA



for the multimodal system. Information from the study has been used to better understand freight movement in the update of the Washington Transportation Plan. Because of the importance of freight mobility issues, this project received national interest, as well as federal funds to continue the project (see below).

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

Active Projects

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 desired economic development, an additional $1.4 million in federal funds was earmarked to continue this project. As a follow-up to Phase 1, the objectives of this study are to identify past, present and prospective 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 discrete analyses of mode cost structure and competitive mode shares as ownership and government policies change; assess the potential for economic development opportunities as it pertains to supporting the overall multimodal transportation system; examine case studies to establish a baseline of private and public contributions to individual modes; 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 *www.sfta.wsu.edu/*.

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

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 in the subgrade layer underneath a pavement structure, and the evaluation of liquefaction hazards. Other recent geotechnical research has included the design and construction of micropiles and design guidelines for wiremesh and cable net systems for slopes.

Completed Projects

Bucoda Test Section Phase III. This was Phase III of field investigations carried out over 12 years to quantify the contribution of geotextile separators, special fabrics often used to separate pavement base courses from the underlying subgrade, to the long-term performance of pavement sections. Knowing when and where geotextile separators are most appropriate, and how well they will perform, will help WSDOT more cost-effectively use geotextiles in constructing better performing and longer lasting pavements. Five different geotextile separators and a control (soil-only) section were installed in a test section covering two lanes with different base course thicknesses on a low volume but heavily loaded rural highway west of Bucoda, Washington. Phase I evaluated the performance of the separators during construction. Phases II and III evaluated the performance of the separators 5 and 12 years after construction, respectively. Laboratory tests indicated that the geotextiles successfully performed their separation function over the 12-year period. Final implementation of this research is dependent on finding that the geogrid behaves consistently regardless of the geosynthetic type for this application. Partial implementation of the Bucoda findings may result in less over-excavation for certain soil conditions. If over-excavation depths can be reduced with no sacrifice in pavement life or performance, the result may be reduced pavement costs.

Principal Investigator: Holtz, R.D., UW
Technical Monitors/Project Manager: Allen, T./Pierce, L.M./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

Design Guidelines for Wiremesh and Cablemesh Slope Protection. Draped wiremesh and cablemesh slope protection has been used for many years to control rockfall. Through on-site experience, WSDOT developed protection systems for slopes shorter than 75 feet. However, these systems are now being installed regularly on slopes much higher than 75 feet, for which design guidance is non-existent. In addition, certain problems WSDOT has experienced indicate that some system elements may be under-designed. In short, there is no clear understanding of what design elements are critical to the wiremesh and cablemesh systems because their design is empirical and has never been quantified. To address this problem, this study developed design guidelines for these systems based on research that characterized existing performance, tested critical system components, back-analyzed system failures, evaluated typical loading conditions, and developed analytical models to refine the systems' engineering.

The design guidance on site suitability, characterization of external loads, fabric selection, anchorage requirements, and system detailing will help WSDOT build safer and more cost-effective slope protection.

Principal Investigator: Muhunthan, B., WSU
Technical Monitors/Project Manager: Badger, T./Lowell, S./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

A study developed guidelines for using draped wiremesh and cablemesh slope protection systems, such as this mesh system north of Vancouver, B.C., installed to direct falling rock into an accumulation ditch.

Evaluation of Liquefaction Hazards in Washington State, Phase III

Soil liquefaction, caused by earthquakes, is hazardous to many existing transportation structures and can add considerable cost to the design and construction of new structures in Washington State. Liquefaction commonly occurs in loose, saturated, cohesionless soils, the types of soils often encountered in and adjacent to rivers and bodies of water. 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, is developing 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, such as the Alaskan Way Viaduct (shown above), whose seismic features will most accurately reflect the liquefaction hazards of the soils in which they are constructed.

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

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 lack of availability of higher quality materials and the added costs for these materials will eventually force engineers to use marginal soils, whereas in the past these marginal soils were replaced with materials of better quality. 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 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
Technical Monitor/Project Manager: Allen, T./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

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, there is currently a great demand to retrofit existing deep foundations. Micropile technology has proved to be effective for retrofitting deep foundations. However, micropiles are commercialized and aggressively marketed with their own designs, and their effectiveness and performance are, at best, qualitatively based on judgment and experience. This project is developing analytical models to quantitatively analyze the performance of micropile systems in relation to soil/concrete interaction, soil capacity, and deformations. This will aid engineers in estimating their long-term performance and producing more cost-effective designs.

Principal Investigators: Muhunthan, B./Itani, R., WSU
Technical Monitor/Project Manager: Allen, T./Willoughby, K., 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
Technical Monitor/Project Manager: Allen, T./Willoughby, K., 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 in order 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: Bathhurst, R., Royal Military College of Canada
Technical Monitor/Project Manager: Allen, T./Willoughby, K., WSDOT
Sponsors: WSDOT and State Partners

Walls were built to test and verify the use of an improved method for designing the internal stability of mechanically stabilized earth retaining walls.

A primary goal of the transportation program is to improve safety for the traveling public

The number of deaths on Washington's roadways has declined over the past several years. Even so, more than 600 people die in collisions in Washington State each year – an unacceptable number despite our progress. The societal cost of motor vehicle collisions for all roadways (state, county, city, tribal, and federal) is estimated at $5.6 billion annually. Although fatal collisions make up only 2.5 percent of the total number of collisions, they account for 54 percent of the total societal costs.

Washington continues to strive to improve safety for the traveling public. While research is only one aspect of the strategies we employ to reduce accidents, the findings do contribute to changes in policy and design.

Completed Projects

Aesthetic Roadside Safety Barriers for the Deception Pass State Park.

Several attempts to replace an old log and rock support barrier system that was constructed in 1935 with a crashworthy barrier were unsuccessful because of the public's concerns for historic and visual impacts. In an attempt to develop a context sensitive solution, a replica barrier of the old rail was design and constructed. The new wooden rail was then crash tested at the Texas Transportation Institute. This design may be applicable to other areas where historical context or aesthetics are a concern to the application of a roadside barrier.

Principal Investigator: Texas Transportation Institute
Technical Monitor/Project Manager: Albin, D./Brooks, R., WSDOT
Sponsor: WSDOT

Motorist and Pedestrian Behavioral Analysis - SR7.

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 Investigator: Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Reeves, P./Hanson, T., WSDOT
Sponsors: WSDOT/FHWA

Reflectivity of Pavement Markings.

The reflective quality of pavement markings is important to motorists, and research indicates that properly maintained pavement markings minimize run-off-the-road accidents. The intent of this project was to develop degradation curves for the reflectivity of roadway pavement markings that would help engineers more accurately determine the frequency with which different types of pavement markings should be replaced. To accomplish this objective, the study utilized a vehicle-mounted Laserlux ret-

A new roadside barrier was designed and tested for use in locations where historical context or aesthetics are a concern.

roreflectometer to take measurements of approximately 80 test sections throughout Washington State. The resulting retroreflectivity values from roadways with similar traffic volumes and environments displayed a significant amount of variability, so the project was unable to develop striping performance predictions that had a high level of statistical confidence. For this reason, the researchers could not recommend any changes to WSDOT's current restriping schedule, which is to repaint once to twice a year.

Principal Investigators: Hallenbeck, M.E./Kopf, J., UW
Technical Monitor/Project Manager: Jacobson, E./Willoughby, K., WSDOT
Sponsor: WSDOT

Active Projects

In-Service Evaluation for Landscaped Medians on Urban Roadways. Interest has been growing in landscaping medians along arterials with speed limits of 35 to 45 mph to both enhance safety and improve aesthetic characteristics. The WSDOT has been working with selected local agencies to landscape medians along SR 99 from SeaTac to Federal Way and needs appropriate performance criteria and a data collection plan to evaluate whether the landscaping achieves those objectives. For this project, researchers developed a standardized framework for evaluating landscaped medians and are conducting an evaluation within that framework of in-service landscape treatments. 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 Investigator: Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Leth, M.P./Brooks, R., WSDOT
Sponsor: WSDOT

Pacific Northwest Snowfighters. The Pacific Northwest Snowfighters Association serves the traveling public by evaluating and establishing specifications for products used in winter maintenance. These specifications emphasize safety, environmental preservation, infrastructure protection, cost-effectiveness, and performance. In this project the consortium is working to create and improve specifications for winter maintenance chemicals and the optimization of their application on the roadway. WSDOT's partners for this project are British Columbia, Colorado, Idaho, Montana, and Oregon.

Principal Investigator: Shi, X., Western Transportation Institute
Technical Monitor/Project Manager: Root, T./Willoughby, K., WSDOT
Sponsors: WSDOT and Partners

Evaluation of Factors That Contribute to Median Crossover Accidents

The conventional rule is that if a divided highway has a median wider than 30 feet and average daily traffic under 5,000 vehicles per lane, then median barriers are not necessary. However, under high speed conditions, medians wider than 30 feet without a barrier can still pose a problem; the probability of fatal consequences from a vehicle crossing the median and colliding with oncoming traffic is high.

To improve public safety and help WSDOT more systematically determine where medians are necessary along high speed roadways, this project identified a set of geometric, environmental, and traffic factors that affect the probability of a median cross-over and the probability of fatalities. It also examined the impacts of barriers and recommended that medians narrower than 50 feet include a barrier, while those wider than 60 feet not include one. Those 50 to 60 feet wide should be considered case by case.

Principal Investigator: Shankar, V., UW
Technical Monitor/Project Manager: Olson, D./Lindquist, K., WSDOT
Sponsors: WSDOT/FHWA

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

ATIS Evaluation Framework and Project Evaluation. Over the last few years, WSDOT implemented five new advanced traveler information system (ATIS) projects encompassing a range of devices in both urban and rural environments, all intended to assist travelers in making informed route, mode, and trip time decisions. To help evaluate these projects, TRAC researchers created a standardized framework for evaluating ATIS projects that focuses on technical, management, and organizational lessons learned. The evaluations produced lessons learned and guidelines for planning and operating ATIS programs, and the framework was effective in providing useful information about ATIS benefits and deployment issues. These results add to the industry's understanding of the impact of ATIS investments on transportation systems and users, as well as the efficacy and cost effectiveness of different ATIS. A Phase 2 project will use the framework to evaluate an additional 19 ATIS projects.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

AVL-Equipped Vehicles as Speed Probes for Traffic Management and Traveler Information. The project Transit Vehicles as Probes began developing technology and software to allow WSDOT to use King County Metro's automatic vehicle location- (AVL) equipped bus fleet as a set of probe vehicles on both freeways and arterials. That project created the ability to capture AVL data on the fly and to measure individual transit vehicles' travel times, as well as to estimate speeds on freeways. In this project, researchers worked to integrate freeway travel times and speeds estimated from AVL-equipped probe vehicles with travel time and speed estimates derived from WSDOT freeway inductance loop sensors. In addition, this project created several user interfaces for traveler information. The goal is to produce a freely available data stream, based on probe vehicles, that provides speed estimates for a variety of arterial and freeway segments. Made available on the Internet, such speed estimates will enhance information to the public about their travel times.

Principal Investigators: Dailey, D.J./Cathey, F.W., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA/TransNow

Documentation of User/Agency Benefits for Information-Based ITS Strategies. Information-based intelligent transportation systems (ITS) strategies are generally believed to be among the most cost-effective investments that a transportation agency can make. These strategies include highway advisory radio systems; PC-based websites; traffic information on personal data assistants; and real-time transit information at bus stops, on the Internet, and on mobile PDAs. However, to date no reliable and defensible method has been available to evaluate the benefits of these strategies. Without information showing user and agency benefits, projects to implement these strategies have difficulty competing with more traditional transportation projects to obtain funding. This research investigated and recommended a method, called the ITS Deployment Analysis System (IDAS), for evaluating, screening, and prioritizing ITS projects. The researchers also suggested adjustments that WSDOT should make to the program and its assumptions to most successfully apply it to ITS within Washington State.

Principal Investigator: Rutherford, G.S., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsors: WSDOT/TransNow

Intelligent Transportation System Backbone Infrastructure 03-05. The U.S. Department of Transportation, WSDOT, and other Washington State 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 and traveler information 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 existing traveler information applications for both traffic and transit information, supports real-time access to WSDOT data by a variety of public and private groups, supports research activities within WSDOT and at universities and agencies nationwide, and provides a standard way to include new data sources into the existing traffic management system. This project supported the continuing personnel, equipment, maintenance, software, and communications links for the ITS backbone. *www.its.washington.edu/bbone/* It also augmented the backbone to include data from Lynnwood and Bellevue, virtual speed and travel time sensors on King county arterials, and non-recurring traffic congestion predictions based on weather information. It was also expanded to include a new interface to meet WSDOT data sharing requirements.

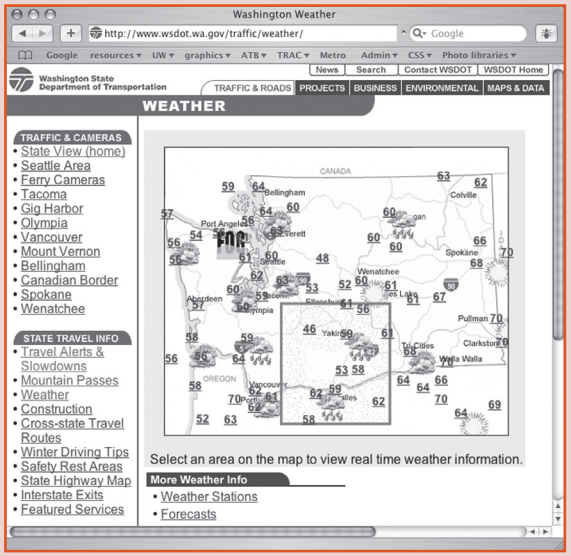
Principal Investigator: Dailey, D.J., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsor: WSDOT

MyBus Software Interface—Multi-Modal Traveler Information. MyBus is a real-time information system, developed by researchers at the UW, that predicts bus departure times for the King County Metro bus fleet throughout the county region based on automatic vehicle location data collected from the Metro bus fleet. The service operates as a Web page, *www.mybus.org*, and is available for cellular Internet connection and personal digital assistants. Sound Transit, King County Metro, and researchers at the UW have also collaborated to develop a new type of variable message sign that will interface with the MyBus application to provide real-time bus location information to transit riders waiting at bus shelters. This project involved testing, implementation, and evaluation of the signs.

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

Road Weather Information Systems (RWIS) Phase III

Over the past five years, 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 metero-logical 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— *www.wsdot.wa.gov/traffic/weather/*—to receive several hundred thousand visitors in a single day.



The subsequent phases of this project are 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
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsor: WSDOT

Researchers are working with Sound Transit and other Puget Sound transit agencies to improve bus location tracking and public dissemination of real-time bus movement information.

Sound Transit Multi-Modal BusView and MyBus Support. The Mobile Data Communications Demonstration Project provides a functional test and demonstration of a multi-agency, GPS-based, automatic vehicle location (AVL) system. This multi-agency system includes vehicles and data from Sound Transit bus service operated by Community Transit and Pierce Transit; Community Transit and Pierce Transit internal transit service; and Sounder Commuter Rail service. Spatial and temporal schedule data are obtained from all the agencies and are combined with software developed at the University of Washington called MyBus/ Busview. The original MyBus application *www.mybus.org* predicts arrival and departure times and presents them in a publicly available Web page. The application created in this project *www.its.washington.edu/multi-modal/* performs these functions with data from all the participating agencies. In addition, it provides the functionality of Busview, a Web-based transit vehicle location display, for all the participating transit agencies and their customers.

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

Sound Transit SR 99 Signage. Researchers at the UW have developed software for calculating and publicly disseminating real-time bus movement information for the King County region based on automatic vehicle location data collected from the King County Metro bus fleet. At some bus shelters, Metro would like to place variable message signs that will tell riders where their approaching bus is. These signs would connect to the developed data feed to provide each of the signs with bus movement information relevant only to that sign location. This project tested the connection between one such sign and the Metro data server for a one-week period. The connection and resulting bus location information were deemed successful.

Principal Investigatorx: Dailey, D.J./Cathey, F.W., UW
Technical Monitor: Marquardt, N., Sound Transit
Sponsor: Sound Transit

Traffic TV: Updates and Improvements Based on User Feedback. TrafficTV was a traffic and traveler information program developed by University of Washington researchers that aired on UWTV2 (University of Washington) and a Seattle cable channel beginning in June 1998. The TrafficTV system fused regional traffic congestion data with live traffic video, added digital video effects, and supplied the resulting presentation to the cable TV provider for broadcasting. A series of meetings with WSDOT personnel in 2003 produced a set of recommended changes, to which this project responded by improving TrafficTV's hardware, software, and user interface. A subsequent focus group and market penetration audit indicated that viewers found TrafficTV to be a useful information tool, but its public exposure and marketing were insufficient.

Principal Investigator: Dailey, D.J., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

A Weather Information System for Washington State Transportation Needs, Phases I and II. Detailed information about weather along the state's highways helps WSDOT manage and maintain the roadways and gives the public a detailed picture of current and expected driving conditions. This project developed a way to gather atmospheric weather data from all available resources, both observed and forecast, and disseminate them to WSDOT and the public. This collection of real-time data was also integrated with road condition models developed for use in Washington. These two elements facilitate high-

resolution weather forecasting over Washington and enable the creation of a new generation of weather display products, adapted for transportation needs, that are being distributed through a dedicated website, *www.wsdot.wa.gov/traffic/weather/*.

Principal Investigator: Mass, C.F., UW
Technical Monitors/Project Manager: Brown, B./Briglia, P./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

WSDOT Electronic Information and Supporting Systems: Challenges to Effective Practice and Policy. This project identified and addressed issues that affect WSDOT's ability to derive benefits from its extensive investment in information and communication technology. The emphasis was on electronic information and supporting systems (EISS), that is, information and its use, rather than technological issues such as compatibility and bandwidth. This work developed strategies for EISS practice and policy that will help WSDOT and other transportation departments evolve from organizations driven by localized, project-based acquisition and implementation of technology to organizations guided by the coordinated use of EISS to accomplish strategic, enterprise-wide missions.

Principal Investigatorx: Kolko, B.E./Haselkorn, M.P./Sauer, G., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsor: WSDOT

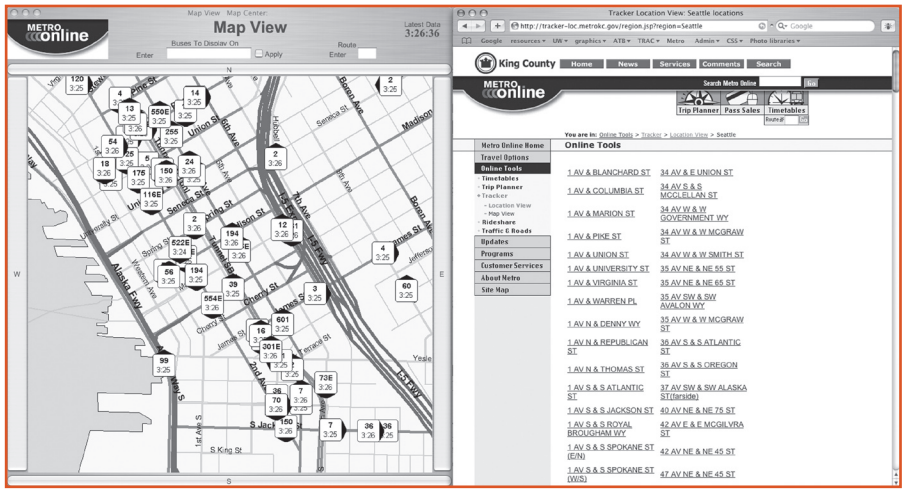
Active Projects

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 has developed 19 additional ITS projects that also require local evaluation. These new projects will be evaluated within the framework during Phase II, which will not only benefit those and future projects but will also enable the framework methodology and tools to be refined and generalized to encompass additional ITS factors.

Principal Investigator: Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Briglia, P./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

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 is enabling 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



Researchers are helping to transfer the MyBus and BusView applications to King County Metro computer servers for daily operation, and to train Metro engineers and programmers in their maintenance.

South Snohomish Regional Transit Signal Priority Evaluation. Transit signal priority (TSP) helps in-service buses move more efficiently through traffic controlled intersections. By reducing the amount of time that transit vehicles are stopped at intersections, 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 select 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 Investigators: Wang, Y./Hallenbeck, M.E., UW
Technical Monitor/Project Manager: Senn, L./Brodin, D., WSDOT
Sponsors: WSDOT/Community Transit

Researchers are evaluating the impacts of transit signal priority (TSP) implementation on both transit vehicles and automobiles to help determine optimal TSP operating parameters.

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

The focus over the last few years in pavement research has been on improvements to design tools for mix design (Superpave), pavement design (Evercalc and AASHTO's Mechanistic-Empirical Pavement Design Guide), and Washington State's pavement management system. The overriding goal of these research projects has been to produce longer lasting pavements through the use of state-of-the-art test protocols and design tools. These protocols and tools will enhance the pavement management system so that retrieving information and making decisions about pavement maintenance and rehabilitation are straightforward and cost effective.

Completed Projects

EVERCALC II: Advanced Back-Calculation Procedures Based on Dynamic FWD Response Data. One of the ways that WSDOT evaluates the structural performance of pavement systems is by using the Falling Weight Deflectometer (FWD). With the FWD, a large weight is raised off the ground and dropped onto a rubber loading pad. The pulse from the FWD simulates traffic loading more realistically than any other commercially available system. The traditional method for interpreting FWD data to back-calculate structural pavement properties is efficient when the depths of the pavement layers are known and their properties are homogeneous, but under other circumstances the method may not yield reliable results. This project attempted to develop alternative back-calculation procedures for the FWD test that use dynamic response data to overcome some of the limitations of current procedures. It also determined that WSDOT's current back-calculation procedures for determining structural pavement properties are state-of-the-art, and WSDOT will continue to use its current back-calculation program, Evercalc.

Principal Investigators: Turkiyyah, G./Kramer, S.L./Mahoney, J.P., UW
Technical Monitor/Project Manager: Pierce, L.M./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

Improving Traffic Characterization to Enhance Pavement Design and Performance: Load Spectra Development. This research addressed the understanding of, and need for, load spectra in future pavement design procedures and as a stepping stone toward more complete pavement design. The primary objective of this project was to develop truck axle load spectra for Washington State. Achieving this objective would allow WSDOT, or any state highway agency with analogous traffic patterns, to accommodate the requirements of the *Mechanistic-Empirical Pavement Design Guide* developed through NCHRP Project 1-37A. A secondary objective of this project was to determine whether equivalent single axle loads calculated from the developed load spectra were significantly different from historical values, and the researchers determined that they were not. This study resulted in an extensive review of how traffic data are collected, provided significant recommendations for improving the calibration of weigh-in-motion stations, and suggested that WSDOT could potentially simplify the process for characterizing traffic loads on state highway pavements that would result in significant cost savings.

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

Integration of Maintenance Information into the Washington State Pavement Management System. For WSDOT, pavement maintenance involves about 18,000 miles of pavement, 3,300 bridges, and 100,000 acres, and it requires an annual expenditure of about $110 million. A software tool called the Highway Development and Management System (HDM-4), developed for the World Bank, could help WSDOT make pavement maintenance more cost effective and enhance the preservation and maintenance budget development process. However, its effectiveness is dependent on its ability to accurately model and predict pavement performance, which is affected by numerous factors, including structural design, materials, construction variability, traffic, and maintenance and rehabilitation practices. To make the HDM-4 models suitable for use in Washington State, this study collected data from the state's Pavement Management System and calibrated the models for flexible pavements. They were then applied successfully to the WSDOT road network.

Principal Investigators: Mahoney, J.P./Muench, S.T., UW
Technical Monitor/Project Manager: Pierce, L.M./Willoughby, K., WSDOT
Sponsors: WSDOT/FHWA

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

Researchers are conducting laboratory tests to develop a database of dynamic modulus values for Superpave hot mix asphalt mixes that are widely used in Washington.

Software developed by the State Pavement Technology Consortium, of which WSDOT is a member, will estimate how much pavement can be rehabilitated under different traffic closure strategies and other factors.

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

Active Projects

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

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

Montana Pavement Design Program Assistance. Through a subcontract to Fugro-Bre, Inc., TRAC researchers are providing technical assistance in the development of traffic load estimates for Montana Department of Transportation pavement test sections. They are analyzing traffic characteristics in accordance with procedures proposed for adoption in the AASHTO *Mechanistic-Empirical Pavement Design Guide* for roadways, with sufficient data to confirm the default values recommended in the *Design Guide*.

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

Pavement Reconstruction Scheduling Software. This project was formed through the State Pavement Technology Consortium (SPTC) to develop a software simulation tool for considering pavement design options. The CA4PRS software is a construction and scheduling analysis tool that will help engineers make sound construction project management decisions at each stage of planning, designing, and constructing a highway rehabilitation project. CA4PRS will estimate how much pavement can be rehabilitated or reconstructed under different traffic closure strategies with given constraints of pavement design, lane closure tactics, schedule interfaces, and contractor logistics and resources. WSDOT's partners are the California, Minnesota, and Texas departments of transportation.

Principal Investigator: Lee, E-B., University of California, Berkeley
Project Manager: Willoughby, K., WSDOT
Sponsors: WSDOT and SPTC Member States

Pavement Tools Consortium. The Pavement Tools Consortium fosters the continued development and implementation of computer-based paving tools, such as the Pavement Guide, Virtual Superpave Laboratory, Media Library, HMAView, PMSView, 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.

Principal Investigators: Mahoney, J.P./Muench, S.T./Turkiyyah, G./White, G., UW
Project Manager: Willoughby, K., WSDOT
Sponsors: WSDOT and PTC Member States

State Pavement Technology Consortium. The State Pavement Technology Consortium (SPTC) is a pooled fund group of the state transportation departments of California, Minnesota, Texas, and Washington, which has been the lead state for the project. Through the SPTC, each state has allocated funding to allow selected DOT personnel and university researchers to participate in semi-annual technical meetings. These SPTC technical meetings, held since July 1999, have allowed the five states to share information on pavement practices, discuss the conduct of pavement-oriented research, and identify topics of mutual interest, which has resulted in additional studies of special interest to the SPTC members. More information can be found on the SPTC website, *http://sptc.ce.washington.edu/*.

Project Manager: Willoughby, K., WSDOT
Technical Monitor: Pierce, L.M., WSDOT
Sponsors: WSDOT/FHWA

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, and the researchers will continue to work with WSDOT to promote and demonstrate the extensive capabilities of the WebWSPMS to the national pavement and transportation communities.

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

Robert F. Williams

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 modes, and the environment is ongoing.

Completed Projects

Bellevue, Redmond, Kirkland, and Issaquah Concurrency Study. Concurrency is the requirement that infrastructure to support development be planned and funded before development can be built or improved. Such infrastructure includes facilities for water, sewage, and transportation. The Washington State Growth Management Act (GMA) requires that public transportation services—which may include roadway capacity, transit services, ride-sharing programs, demand management, and other transportation management—be in place within six years from "the time of development" to accommodate the impacts of new development. Local governments planning under the GMA must establish level of service standards for their transportation systems in their comprehensive plans. This study assessed how the transportation element of concurrency is managed in the four cities of Bellevue, Issaquah, Kirkland, and Redmond, Washington. Researchers evaluated the extent to which meeting concurrency requirements assists the four cities in complying with the intent of the GMA. They also investigated alternative measures of transportation concurrency. The results will help cities better plan development and transportation systems, both within and among their jurisdictions.

The state requires that transportation infrastructure be in place within six years from the time of development to accommodate the impacts of new development. Researchers studied how well four Puget Sound cities are meeting that requirement.

Principal Investigators: Hallenbeck, M.E./Carlson, D.L./Vernez Moudon, A./Blanco, H.J., UW
Technical Monitor: Loewenherz, F., City of Bellevue
Sponsor: City of Bellevue

Commute Trip Reduction Survey. To assist WSDOT in deploying and maintaining its Commute Trip Reduction (CTR) survey on-line, researchers at WSU wrote software for, implemented, and is hosting and trouble-shooting a Web-accessible CTR survey. The survey is intended for employees of companies that are working to meet the state's Commute Trip Reduction Act by encouraging commuters to consider transportation alternatives such as ridesharing or taking the bus. 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
Technical Monitor/Project Manager: Hillsman, E./Lindquist, K., WSDOT
Sponsor: WSDOT

CTR Performance Grants: Continuing Innovations. Through the Commute Trip Reduction (CTR) Performance Grant program, WSDOT is breaking new ground by testing whether the state can obtain transportation capacity by purchasing single occupant vehicle trips as well as roadway infrastructure. UW researchers examined the program's design and

market structure to identify ways both could be modified to better achieve program goals. The research team concluded that WSDOT is a true innovator in seeking ways to increase capacity and reduce congestion but that the CTR Performance Grant program could be more effective if WSDOT clarified whether its primary goal is trip removal or innovation. Furthermore, the state could more easily remove high impact trips from the transportation system if the program focused more narrowly on peak hour trips in high-use corridors.

Principal Investigator: Carlson, D.L., UW
Technical Monitor/Project Manager: Lagerberg, B./Hanson, T., WSDOT
Sponsor: WSDOT

Documentation of the Application of UrbanSim to the Wasatch Front Area, Utah. Recognizing the effects of transportation on land use and the environment, national legislation has mandated that metropolitan planning organizations better coordinate planning of land use, transportation, and the environment. In that context, the UrbanSim land-use model was developed at the University of Washington in the mid-1990s. It has been successfully applied and integrated with traditional travel models in several cities and states around the country and has been selected for application by the Puget Sound Regional Council. This research thoroughly documented a case study of the application of UrbanSim, from beginning to operational use. The FHWA selected the Salt Lake City region as the site for the case study. Researchers worked with the Wasatch Front Regional Council in Utah to describe and evaluate the process and results of database development, calibration, sensitivity testing, and application of the model system.

Principal Investigators: Waddell, P.A./Borning, A.H., UW
Technical Monitor/Project Manager: Mabry, J./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

Transportation Demand Management Study. WSDOT has posed several questions about its role in transportation demand management (TDM), including how it defines TDM, what its strategic interest in TDM is, how TDM relates to its transportation goals, what responsibilities it should assume, and how it ought to structure itself to implement TDM. To help answer these questions, this study involved describing the current TDM environment, interviewing key stakeholders, and recommending approaches in each area. The research team concluded that TDM measures can enable the movement of more people and goods over existing and future state roads at far less capital, political, and environmental cost than

Transportation Efficient Land Use and Development Patterns (Phase 2) and GIS Land Use Analysis Tool (Phase 3)

The efficiency of the transportation system in urban areas has been compromised by a disconnection between land-use decisions made at the local level and transportation decisions made at the regional and state levels. This project is part of a larger research program to develop tools to help local jurisdictions and WSDOT more closely tie together the relationship between land use and transportation during the investment decision-making process

The second phase of the program developed a reference manual of regulatory and financial strategies and tools for linking transportation and land-use decisions. It is a valuable tool for WSDOT in working with local agencies to better link transportation and land-use decisions. It references strategies and tools used to foster transportation-efficient land-use patterns (development that supports the use of alternative transportation modes while reducing the need to drive alone). It also documents state-of-the-art best practices at the national level, in addition to practices that are specific to Washington State and the Puget Sound region.

The final phase of the program integrated findings from phases 1 and 2 with other data to develop the Transportation Efficient Land Use Mapping Index (TELUMI), a set of maps that depicts how the region's urban form affects overall transportation system efficiency. Not only does the TELUMI show how to rate areas of the Puget Sound for their existing transportation efficiency, it can also be used to set goals for future efficiency and to monitor progress. Because TELUMI can assess the impact of land use on travel behavior and transportation systems, it can be used to support WSDOT decision-makers in prioritizing and programming transportation investments.

Principal Investigator: Vernez Moudon, A., UW
Tech. Monitors: Mabry, J./Kavage, S., WSDOT
Project Manager: Lindquist, K., WSDOT
Sponsors: WSDOT/FHWA

construction of new highways.

Principal Investigator: Carlson, D.L., UW
Technical Monitor/Project Manager: Lagerberg, B./Hanson, T., 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 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.

Principal Investigators: Frank, L, Lawrence Frank and Company, Inc./
Bradley, M./Lawton, K., Keith Lawton and Associates
Technical Monitors/Project Manager: Mabry, J./Kavage, S./Brodin, D., WSDOT
Sponsors: WSDOT/FHWA

Washington State Trends in Commuting. The goal of this project was to better understand how the travel indicators for Washington State fare in relation to those from other states. In other words, how similar or different is Washington State from others? A second goal was to review the state's travel indicators over time to detect changes or special conditions that should be considered in the future. This work will help WSDOT and local agency partners in developing general transportation policies and future state-level transportation plans. The researchers found that none of the travel indicators reviewed strongly suggest that travel conditions in the state stand out in the national context. Overall, Washington State needs to stay tuned to national projections about the likely impacts on travel demand and transportation of general economic trends, the slow down in household formation, growth in car ownership among new immigrants, an aging population with changing driving patterns, and population growth in densely populated areas, where transportation systems investments and land-use policies can affect future travel behavior.

Principal Investigator: Vernez Moudon, A., UW
Technical Monitor/Project Manager: Robbins, E./Lindquist, K., WSDOT
Sponsors: WSDOT/FHWA

WTP Tribal Transportation Survey. The most recent update of the Washington Transportation Plan (WTP) includes minimal information on tribal transportation systems in Washington, primarily because of a lack of readily accessible data and the fragmentation of data among the main jurisdictions operating on any given reservation. To integrate Washington State tribal transportation information into the WTP and create a more comprehensive and accurate Tribal Transportation Needs Chapter, researchers developed a tribal transportation survey to collect data from state tribes. The survey collected information in the following areas: administrative capacity, safety, economy and tourism, system preservation, non-motorized transportation, special needs, building communities, freight, security, environment, cultural resources, and workforce development. This information was analyzed and compiled into a report that is consistent with the WSDOT Transportation Framework. A report of the results was also prepared and presented at several meetings in 2004.

Principal Investigator: Galloway, R., Go On Institute
Technical Monitor/Project Manager: Jollie, C./Lindquist, K., WSDOT
Project Sponsors: WSDOT/FHWA

Active Projects

Software Tools for Sharing and Integrating GIS Data. A significant need exists to collect and combine location referencing and GIS data from multiple agencies in order to create a complete transportation network and associated location referencing systems. A consortium of public and private entities has been established to develop computer-based tools that will facilitate geo-spatial transportation data sharing and integration for a variety of purposes and uses. WSDOT leads this Transportation Pooled Fund (TPF) project with Ohio, Oregon, Nebraska, and Texas. A new project solicitation has been posted to begin work on Phase 2 of the project.

Principal Investigator: Griffin, T., WSDOT
Technical Monitor/Project Manager: Leierer, M./Lindquist, K., WSDOT
Sponsors: WSDOT/ODOT/TxDOT/OhioDOT/NDOR/FHWA

Reports

Below is a list of reports published by TRAC between July 1, 2003, and June 30, 2005. Many of these reports can be obtained electronically at the TRAC or WSDOT websites. WA-RD numbers are given to WSDOT reports. See *www.trac.washington.edu* and *www.wsdot.wa.gov/research/*. Hard copies are available from the National Technical Information Service.

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Inouye, B., D.E. Lehman, J.F. Stanton, S.L. Kramer. *Seismic Analysis and Retrofit Study of the SR 99–Spokane Street Over-Crossing*. Washington State Department of Transportation. October 2004. WA-RD 596.1

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