WASHINGTON STATE TRANSPORTATION CENTER

BIENNIAL REPORT

2002 - 2003

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University of Washington • Washington State University • Washington State Department of Transportation

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MESSAGE FROM THE EXECUTIVE DIRECTOR

RESEARCH THAT MATTERS

Transportation research has come a long way in 110 years. Organized transportation research efforts began in 1893 with the creation of the Office of Road Inquiry within the U.S. Department of Agriculture to investigate the best methods of building roads. Since that time, transportation research has evolved to address a broad range of issues affecting the performance and delivery of transportation systems. Transportation research today includes investigation of

- congestion and traffic management
- protection of roadways and bridges from earthquakes
- smoother and more durable roadways
- management of the environmental impacts of transportation construction and successful mitigation techniques
- improvement of roadway safety and design
- planning for a transportation system that meets the needs of Washington's citizens.

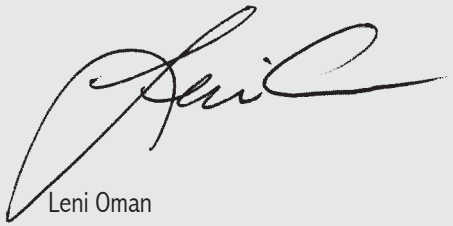
In 1983, the Washington State Department of Transportation (WSDOT), University of Washington, and Washington State University formed the Washington State Transportation Center (TRAC). TRAC was created to provide a link among the government, university researchers, and the private sector. This partnership continues to successfully connect those who need applied research at the state and federal levels with those best suited to conduct it at Washington's research universities and the private sector.

Research is a tool that helps transportation agencies continuously improve their performance. The results of the applied research conducted by TRAC for WSDOT solve real problems that affect the everyday operation of the state's transportation system. A crucial emphasis of the research is implementation of the findings to improve transportation processes and products.

The TRAC research program reflects the changing needs of the transportation system in the state and around the nation. Over the past several years, trends show that the percentage of TRAC funding has shifted to include more research on planning and environmental issues while maintaining research on bridges, structures, construction, and materials. Funding for highway operations, including traffic and intelligent transportation systems, has seen a significant increase because of the need to address congestion and highway operational issues. Continued research is needed in these areas, as well as in emerging areas such as security. Overall, TRAC is reviewing transportation business needs to determine how research can help deliver transportation options to the public in an effective, efficient, and accountable way.

TRAC's research results have led to cost savings, improvements in construction methods, improved pavement durability, and improved environmental practices in Washington state. Many TRAC projects have also received national recognition and have had national impacts.

The research findings presented in this report represent substantial effort by university faculty and students, as well as industry professionals in both the private and public sectors, who are committed to making our transportation system more reliable. I applaud their efforts, thank them for their contributions to better transportation facilities both within our state and nationwide, and look forward to a continued, fruitful partnership.



Leni Oman
Executive Director, TRAC
Director of Transportation Research, WSDOT

TRAC MISSION

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

PROJECT FUNDING AND SUPPORT

From July 1, 2001, to June 30, 2003, TRAC researchers were involved in just over 100 research projects, for which the budgets totaled more than $14.8 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

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

In addition to WSDOT, TRAC researchers received support from the Montana and Oregon departments of transportation. In-state public supporters included

- City of Bellevue
- Freight Mobility Strategic Investment Board
- Sound Transit
- Whatcom County.

TRAC received private support from or worked as a subcontractor with

- Cambridge Systematics
- Fugro-BRE, Inc.
- ERES Consultants
- PCS/LAW Engineering and Environmental Services
- Science Applications International Corp.
- Technology Service Corp.
- Texas Transportation Institute
- TranSystems 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.

Universities and Research Institutes

Battelle Marine Sciences Laboratory
University of Washington Engineering Professional Programs

Public Agencies

City of Bellevue
City of Everett
City of Issaquah
City of Kirkland
City of Lynnwood
City of Redmond
City of Seattle
Community Transit
King County
King County Metro Transit
Port of Seattle
Port of Tacoma
Puget Sound Regional Council
Snohomish County
US Customs
Washington State Patrol
Wasatch Front Regional Council, Utah

Private Companies

AAA Washington
Earth Design Consultants, Inc.,
eLogicity
G.T. Engineering
Maersk Sea-Land

Associations

Northwest Regional Modeling Consortium
Washington State Tow Truck Association
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 2002-2003, TRAC processed numerous proposals and produced over 50 reports and other publications. In addition to standard study reports, TRAC documentation projects included updating FHWA's Traffic Monitoring Guide and providing FHWA with training materials for workshops on its application. Researchers also developed a computer-based pavement course and electronic tools to aid in communication and training about the design and construction of pavements, and they helped organize a State Pavement Technology Consortium to allow inter-state sharing of pavement practices. 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.

TRAC continued to publish its one-page newsletter, the TRAC Research Review <http://depts.washington.edu/trac>, which emphasizes research successes and is distributed to a broad audience within Washington and across the United States. TRAC staff also aided WSDOT in the publication of its on-line newsletter covering road/weather information issues, the rWeather Newsletter < http://www.wsdot.wa.gov/biz/ATB/rwisnews/frames.html>.

EARTHQUAKE POTENTIAL FOCUSES RESEARCH ON SEISMIC DESIGN, RETROFITTING AND PREPAREDNESS

In the 1980s bridge research in Washington focused on bridge decks. Nationally there was concern about the corrosive effects of salt on the reinforcing bars in bridge decks. In October 1989 the Loma Prieta earthquake in California shifted not only the ground around Oakland and San Francisco but also the direction of state bridge research. The Washington legislature began to allocate state funds to support an aggressive program of seismic retrofitting. Projects to develop retrofit strategies for a variety of bridge types were initiated and continue to the present. During the late 1990s and early 2000s the bridge program received support from FHWA to build and monitor the performance of a high performance bridge. The successful conclusion of this research resulted in the inclusion of higher strength girders that allow for longer girders as a design option. Several of these longer girder bridges have been designed and will be built on projects where keeping the foundation elements out of a river floodplain is environmentally warranted.

In the past two years, most of the current research has remained focused on seismic related issues. This includes the retrofitting of existing structures, the development of plans and specifications for emergency repair of bridges damaged by earthquakes, and computer programs to analyze bridges for seismic risk. Other issues addressed include a new type of bridge bearing, micropiles, wind and wave loads on floating bridge anchor cables, and high performance concrete for floating bridges.

COMPLETED PROJECTS

Alaskan Way Viaduct Seismic Risk Mitigation System

The Alaskan Way Viaduct, which runs along the Seattle waterfront, is highly susceptible to earthquake damage. Previous studies have shown that extensive soil liquefaction could cause sections of the Viaduct to collapse. Potential collapse would be expected at some time after earthquake shaking began, thus providing a period of time in which motorists could potentially be kept from entering the Viaduct. The purpose of this project was to evaluate the feasibility of instrumenting the Viaduct to (1) provide warning of potentially unsafe conditions and (2) reduce post-earthquake closure times by speeding the process of evaluating the condition of the Viaduct after an earthquake. In fact, although the February 2001 Nisqually earthquake was not strong enough to threaten lives on the Viaduct, detected damage did require closure for repairs over several congestion-challenged weeks. This project developed recommendations for performance monitoring instrumentation, warning system triggering levels, and response levels for inspection and closure. These will improve public safety after an earthquake and reduce post-earthquake closure times.

Project Managers: Kramer, S.L./Eberhard, M.O., UW
Tech. Coord.: Henley, E., WSDOT
Sponsors: WSDOT/FHWA

Displacement Methods for Bridge Seismic Analysis

Although engineers have traditionally used linear static analysis procedures to evaluate seismic bridge response, more often today they are using displacement-based analysis. Such analysis can determine damage that would result from bridge movement and suggest appropriate retrofits to mitigate the damage. This project sought to identify which analysis methods and computer software are most effective for practical displacement-based seismic analysis of highway bridges. A survey of state departments of transportation and engineering consulting firms, as well as evaluation of four analysis programs, led the researchers to recommend the SAP2000 software because it has several features that make it particularly useful for practical displacement-based seismic analysis of simple highway bridges.

Project Managers: Symans, M.D./McLean, D.I./Cofer, W.F., WSU
Tech. Coord.: Zeldenrust, R., WSDOT
Sponsors: WSDOT/FWHA

High Performance Concrete in Bridge Girders

The Federal Highway Administration and WSDOT are interested in the potential savings in cost and time that appear possible through the use of high performance concrete (HPC) bridges. One feature of such bridges is that the girders in them may be spaced farther apart than in bridges made of conventional concrete, thus lowering costs. This comprehensive, long-term project produced three reports: one on a three-year program of girder design, monitoring and evaluation; one on a three-year materials testing program; and a third on an evaluation of live-load distribution factors for a series of three-span, prestressed concrete girder bridges. WSDOT has already applied findings from the research to construction of a freeway interchange.

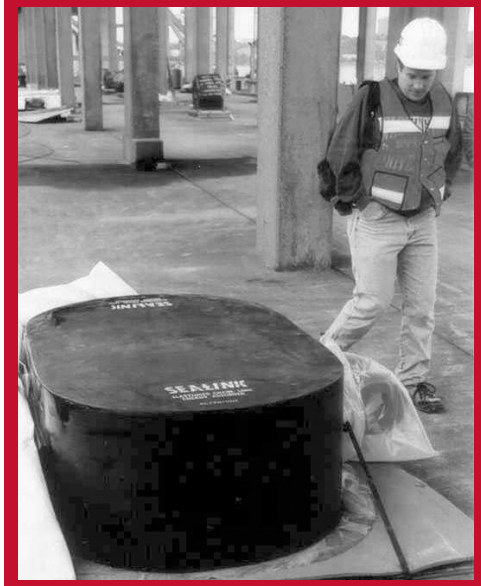
Project Managers: Stanton, J.F./Eberhard, M.O., UW
Tech. Coord.: Roper, T., FHWA
Sponsors: WSDOT/FHWA

EVALUATION OF CABLE FORCES AND BRIDGE RESPONSE IN THE EVERGREEN POINT FLOATING BRIDGE

In January 1993, a heavy storm caused structural damage to the Evergreen Point Floating Bridge in Seattle. Two damaged end mooring cables were later replaced by larger cables with Sealink elastomeric devices, essentially large rubber doughnuts attached to the cables, to resist higher cable loads and to provide energy absorption and reduce cable stiffness. The study measured the forces on those cables during the winter of 2001-2002 to evaluate the effectiveness of the Sealink devices.

Because there are only eight floating bridges in the world—and Washington State owns four of them—less is known about them than about other types of bridges. This project produced valuable knowledge about storm loads from wind and waves as well as bridge anchor cable response, and that information will contribute to better design of anchor cable systems and tensioning for floating bridges. The end result will be safer bridges in Washington and elsewhere.

Project Manager: McLean, D.I., WSU
Tech. Coord.: Anderson, M., WSDOT
Sponsors: WSDOT/FHWA



Sealink elastomer used in the Evergreen Point Floating Bridge. The elastomers were installed on the submerged end of a number of the anchor cables and are designed to decrease cable force and absorb energy in a storm.

ACTIVE PROJECTS

Assessment and Retrofit of Outrigger Bents

Many raised highway structures are supported on bents that are not concentric with 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 crossing in Seattle, built in the 1950s, represents a particularly egregious example of outrigger bents, 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, is assessing the seismic vulnerability of the existing structure and evaluating further retrofit strategies.

Project Managers: Stanton, J.F./Lehman, D.E./Kramer, S.L., UW
Tech. Coord.: Zhang, H., WSDOT
Sponsors: WSDOT

Behavior and Retrofit of Knee Joints in Bridges

A number of bridges in Washington state are supported on columns that are offset from the superstructure because of geometric or right-of-way constraints, creating what is referred to as an outrigger bent. The offset column 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 is investigating the behavior of outrigger knee joints and will develop and evaluate practical methods for retrofitting the joints to improve their performance. Although the focus of the research

Outrigger bent and knee joint support the Alaskan Way Viaduct, Seattle.

will be the knee joints of the SR 99 Spokane Street overcrossing in Seattle, the results are expected to be applicable to other bridges as well.

Project Manager: McLean, D.I., WSU
Tech. Coord.: Zhang, H., WSDOT
Sponsors: WSDOT/FHWA

Behavior of Micropile Networks

An increased awareness of the sound 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 is adding to knowledge about the state-of-practice of micropile use. Through physical modeling and analysis, it is developing tools for analyzing micropile networks under static and dynamic loads for non-liquefied ground, liquefied ground, and lateral spreads; validating numerical analysis of micropile networks; and developing design guidelines for micropile networks. Micropiles are often more cost-effective to use.

Project Managers: Rodriguez-Marek, A./Muhunthan, B., WSU
Tech. Coord.: Allen, T., WSDOT
Sponsors: FHWA

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 have not been adequately characterized and codified through experimental testing. Expanding on previous tests of cotton duck pads, the researchers are codifying design provisions that will permit cotton duck pads to be used under increased load and rotational capacity and are developing widely applicable design recommendations and tools that will allow their more extensive use as bridge bearings.

Project Managers: Roeder, C.A./Lehman, D.E., UW
Tech. Coord.: Dornsife, R., WSDOT
Sponsors: WSDOT/FHWA

High Performance Concrete in Floating Bridges

Floating bridges constitute a major investment in the region's infrastructure by state and federal governments. This project is investigating the potential use of high performance concrete (HPC) in floating bridges because of its strength, durability, and other material characteristics that are favorable for use in such a structure in a marine environment. Researchers are developing techniques to optimize the concrete microstructure (air void distribution) to improve the bridges' resistance to salt water, pursuing methods to limit or eliminate shrinkage cracking, and studying ways to minimize creep and pontoon distortions after post-tensioning.

Project Managers: Masad, E.A./Itani, R.Y., WSU
Tech. Coord.: Swett, G., WSDOT
Sponsors: FHWA

The Lacey V. Murrow Memorial Bridge, better known as the I-90 floating bridge, is one of two floating bridges that cross Lake Washington near Seattle.

Post-Earthquake Evaluation of Retrofitted versus Non-retrofitted Bridges

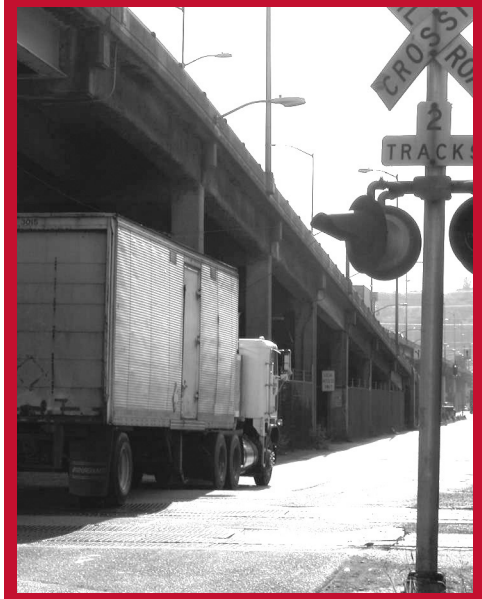
This study is testing, evaluating, and comparing the performance of retrofitted and non-retrofitted bridges after an earthquake. The study is concentrating on the Nisqually earthquake of 2001 and is using non-destructive examination (NDE) methodologies appropriate for such analysis. Researchers are assessing damage to piers and other damage that occurred near the epicenter of the Nisqually earthquake. The performance of structures in the region will determine recommendations for additional studies.

Project Manager: Itani, R.Y., WSU
Tech Coord.: Pietz, M., WSDOT
Sponsors: WSDOT/FHWA

Siesmic retrofitting to the Spokane Street Bridge, Seattle

RAPID REPAIR DESIGN OF TEMPORARY SUPPORT SYSTEMS FOR BRIDGES DAMAGED BY EARTHQUAKES IN THE STATE OF WASHINGTON

This completed project produced valuable results that will have a big impact on WSDOT's speed in responding to an earthquake and on public safety. Although the timely restoration of earthquake-damaged bridges to a serviceable level is in the best interest of emergency crews, the public, and the state's economy, no plans or procedures were in place to quickly shore up such bridges. This project sought to provide a general set of pre-engineered shoring plans for the three types of standardized bridges commonly found in Washington state.



On the basis of a broad range of loading criteria and bridge geometries, several shoring systems were developed; these will rely on the steel and wood materials commonly found in contractor's stockyards. Because of the developed system, in the event of an earthquake WSDOT engineers will not have to spend precious time calculating numbers for sizes of shoring members such as posts and mudsills. A handbook, with a flowchart and detailed construction drawings, was developed to aid WSDOT inspection engineers. This reference will allow WSDOT personnel to provide temporary repairs to earthquake-damaged bridges most quickly and efficiently.

Project Managers: Itani, R.Y./Fridley, K.J., WSU
Tech. Coord.: Szewcik, M., WSDOT
Sponsors: WSDOT/FHWA

ENVIRONMENTAL RESEARCH IS KEY TO PROJECT DELIVERY, PERMITTING, AND ENVIRONMENTAL HEALTH

The impacts of environmental issues on transportation agencies have become more significant as the public has made more demands to protect the environment. Roadway construction and maintenance may affect water quality and many species of plants and animals, including endangered salmon. Washington's extensive ferry system is also affected by the increase in information requested to meet environmental requirements related to aquatic plants and animals.

Lack of early agreement on environmental impacts and appropriate mitigation may result in project delays and untimely design changes, adding to costs. Better understanding of those impacts and how to avoid or mitigate them allows transportation agencies to obtain permits more quickly and complete projects more successfully.

COMPLETED PROJECTS

Determination of the Effects of Anti-Icer Compounds on the Rare Plant Hackelia Venusta

Over the last ten years, WSDOT's methods for managing ice on its eastern highways have changed from the application of sand to the application of anti-icer compounds.

Because they are applied before a storm event, they can actually decrease the amount of chemical needed to be fully effective, but over time, these compounds dissolve into solution with melted water and drain to the sides of the roads. Of concern to several government agencies is the effect of these compounds on the decline of an increasingly rare plant, showy stickseed (Hackelia venusta). One possible cause for its decline is exposure to anti-icer compounds. This project investigated the effect of such compounds on showy stickseed along Highway 2 in Chelan County, Washington. The project was not completed due to an arson fire at the lab that destroyed all the files.

Project Manager: Chalker-Scott, L., UW
Tech. Coord.: Wagner, P., WSDOT
Sponsor: WSDOT

Ecological Effects of Shoreline Armoring Phase I—Workshop to Identify Issues and Study Design

Shoreline armoring, used to control erosion in Washington waters, has both physical and biological effects. It involves the placement of erosion-resistant materials (such as boulders and cement) in areas of high river, estuary, or marine current flow to reduce or eliminate erosion of native shorelines. It has been shown to be an effective and economical method for controlling erosion and local scour in coastal areas, shorelines of bays, and along streams near bridges. However, armoring can radically alter the characteristics of a natural riverine, estuarine, or marine habitat, causing erosion in other locations, and it can also eliminate or significantly diminish ecological functions. This project surveyed the state of knowledge about the effects of armoring on habitat and conducted a workshop for WSDOT staff on its ecological effects. This information will be used to develop a study plan that will identify specific areas for monitoring and testing.

Project Manager: Simenstad, C.A., UW
Tech. Coord.: Carey, M., WSDOT
Sponsors: WSDOT/FHWA

TRAC researchers have conducted a series of projects on the effects of ferry terminals on salmon and other aquatic life.

Impacts of Ferry Terminals on Migrating Juvenile Salmon Phase III: Field Assessment of Epibenthic Prey Impacts

Because the current Endangered Species Act lists fifteen stocks of salmon and steelhead as threatened or endangered, WSDOT is seeking scientific evaluation of the potential

effects of its ferry terminals on those fish. Previous research has found that shading associated with shoreline structures such as ferry terminals has the potential to both impede juvenile salmon migration and disrupt important attributes of their nearshore migration and rearing habitat. Conclusions from testing conducted for this phase III study were that vessel traffic, reduced or compromised vegetation, and alterations of physical and biological habitat at ferry terminal locations decrease or change the density, diversity, and assemblage of epibenthic animals and plants (on the sea bottom between low tide and 100 fathoms), including salmon prey. This knowledge will be used to mitigate the impacts of ferry operations on salmon habitat.

Project Managers: Simenstad, C.A./Cordell, J.R., UW
Tech. Coord.: Stoltz, T., WSDOT
Sponsors: WSDOT/FHWA

FIELD EVALUATION OF A COST-EFFECTIVE WAY TO RETROFIT STORM WATER DRY WELLS USING PERMEABLE REACTIVE BARRIERS

In Eastern Washington, which has very different storm water management conditions than Western Washington, storm water injection wells, or dry wells, are widely used as storm water management facilities. However, these wells also act as a filter for contaminants transported by storm water into groundwater.

This project tested a Storm Water Permeable Rapid Infiltration Barrier (SPRIB) as a potential way to retrofit storm water injection wells (as required by the underground injection well regulations in the Safe Drinking Water Act) in Spokane to filter contaminants. During a series of simulated storm events the SPRIB reduced concentrations of total metals by 99 percent and soluble metals by 91 to 98 percent. However, surface clogging could limit the lifespan of the barrier to 20–22 storms (about 6 months in Spokane) unless the system is pretreated for suspended solids or periodically maintained. WSDOT will now be studying the project's results to determine where maintenance would be easiest and thus the locations where use of this technique would be most appropriate. The use of SPIRIBs is included in the new draft WSDOT Highway Runoff Manual as a specification.

Project Manager: Yonge, D.R., WSU
Tech. Coord.: Molash, E., WSDOT
Sponsor: WSDOT

Infiltration Characteristics, Performance and Design of Storm Water Facilities, Phase II

Storm water infiltration facilities help reduce the hydrologic impacts of residential and commercial development, including highways. The design of these facilities has been particularly challenging because until now reliable ways to predict both short-term and long-term infiltration rates—how much water will soak through a given soil in a given time—have not been available. This study developed a scientific way to estimate infiltration rates, providing a realistic design procedure that WSDOT field engineers can use when construction projects require infiltration ponds. The resulting field manual will make mitigation of storm water that runs off state highways more effective. The Washington State Department of Ecology has already incorporated some of the project's information into its Stormwater Manual for Western and the Stormwater Manual for Eastern Washington.

Project Manager: Massmann, J.W., UW
Tech. Coord.: Allen, T. WSDOT
Sponsors: WSDOT/FHWA

Intertidal Habitat Structure in the Vicinity of the Eastern End of the Hood Canal Floating Bridge

To minimize the impacts of upcoming repair and replacement of portions of the Hood Canal Floating Bridge, Wash., WSDOT requested spatial evaluation of the location of biological resources near the bridge. A collaborative team comprising researchers from the University of Washington School of Aquatic and Fisheries Sciences' Wetland Ecosystem Team and Earth Design Consultants, Inc., utilized high-resolution remote sensing imagery to map the intertidal habitat of the shoreline within one half kilometer of the eastern end of the bridge. The data were merged with Battelle Science Laboratory's videography map of the adjacent subtidal habitat. The final intertidal-subtidal habitat characterization provides detailed information about the distribution of eelgrass and other habitats such as seaweeds and kelps, grasses, woody riparian vegetation, and unvegetated sand and cobble important to migrating salmon, especially summer chum.

Project Manager: Simenstad, C.A., UW
Tech. Coord.: Swayer, J., WSDOT
Sponsor: WSDOT

Modeling Hydrology for the Design of Fish Passage Structures

Recently the Washington Department of Fish and Wildlife (WDFW) established statewide guidelines for incorporating fish migration into culvert design. The method in the guidelines is called the hydraulic design option. This project developed a procedure for estimating design flows to allow fish passage for the hydraulic design option for streams without flow gauges in Eastern Washington. The model is founded on two key concepts: a unique definition of fish passage design flow, which ensures that fish will not be delayed any more than three days during their natural migration, and a GIS-based approach for estimating this flow. The WSDOT, WDFW, and other interested parties will be able to use the procedure to design new culverts with the hydraulic design option, as well as retrofit older ones, to ensure adequate passage for migrating fish.

Project Managers: Hotchkiss, R.H./Barber, M.E./ Papanicolaou, T., WSU
Tech. Coord.: Wagner, P., 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 even 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.

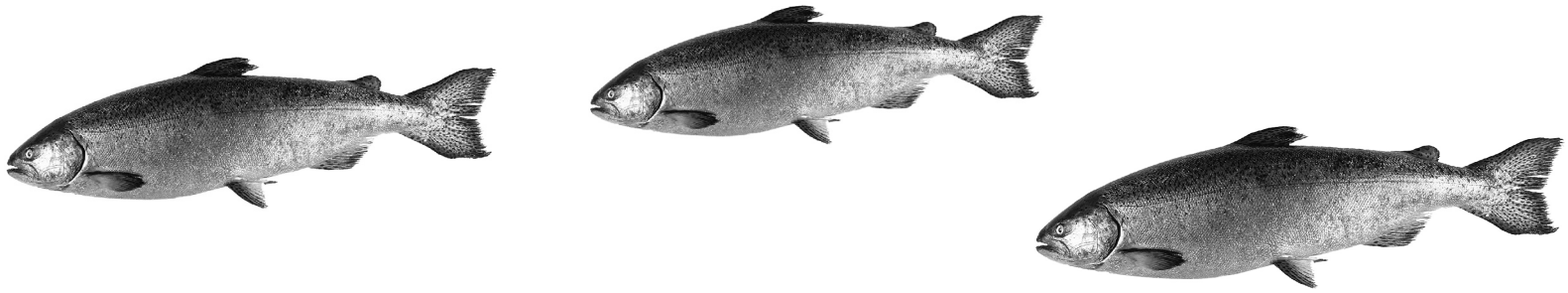
This project investigated the appropriate design specifications for barbs in gravel streambeds, including the number of barbs needed, flow patterns, barb length, scour, and criteria for defining rock size. New design procedures will improve WSDOT's ability to cost-effectively design barbs in streambeds. 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 is anticipated to help WSDOT expedite its permitting process.

Project Managers: Papanicolaou, T./Hotchkiss, R.H./Barber, M.E., WSU
Tech. Coord.: Peralta, R., WSDOT
Sponsors: WSDOT/FHWA

PCCP Slurry Disposal Impacts, Phase I

An extensive literature review was conducted for this project to identify the potential adverse environmental and human health effects of leachate from portland cement concrete (PCC) highway grindings. Under laboratory conditions, PCC leachate has been documented to be toxic to aquatic ecosystems. However, with natural remediation processes using vegetation, the toxicity is completely eliminated. Therefore, PCC highway grinding leachate likely has a negligible impact on aquatic ecosystems. In addition, leachate from PCC highway grindings has been found to have no adverse impact on human health. WSDOT can prevent potential environmental impacts by following mitigation practices that promote natural uptake processes. This will allow the agency to complete necessary pavement projects while remaining sensitive to environmental effects.

Project Managers: Loge, F.J./Yonge, D.R., WSU
Tech. Coord.: Pierce, L., WSDOT
Sponsors: WSDOT/FHWA



Courtesy Robert F. Williams

Researchers studied ecological and habitat issues associated with streams and riverbank corridors, such as at this stream near Sultan, Washington.

Salmon Habitat Protection and Restoration Standards and Guidelines for Floodplain and Riparian Corridor Issues

In partnership with the Washington Department of Ecology and the Washington Department of Fish and Wildlife, this project developed a white paper that reviews ecological and habitat issues associated with streams and riparian zones (riverbank corridors) in Washington State and the Pacific Northwest. The findings of the literature review include information on the ecological and habitat effects of channelization, channel confinement, and construction. The paper also includes a section on habitat protection and mitigation techniques. Alternative management strategies such as passive (vs. active) restoration, streamside vegetation retention or promotion, and modified in-channel vegetation removal are reviewed. In recent years there has been a societal push to rehabilitate and/or restore streams and rivers degraded by channel modifications. The information reviewed in this project will be used to develop appropriate impact analysis and mitigation methods.

Project Manager: Bolton, S.M., UW
Tech. Coord.: Lynch, P., WSDOT
Sponsor: WSDOT

Spring Fish Movements and Culvert Passage

Although recent studies have shown that juvenile salmonids move both upstream and downstream during their fall and spring migrations, upstream fish passage has not been considered in culvert design. This project conducted field studies of spring in-stream fish behavior by marking and recapturing fish and noting their upstream and downstream movements. Researchers also analyzed data regarding relationships between fall movement into Washington tributaries and mainstem river flow. The information obtained will lead to improvements in culvert design that will allow fish to pass through culverts during critical migration periods.

Project Manager: Bolton, S.M., UW
Tech. Coord.: Wagner, P., WSDOT
Sponsors: WSDOT/FHWA

ACTIVE PROJECTS

Evaluation of the Effects of Turbidity on Salmonids for Endangered Species Act Compliance

Storm water runoff or disturbance of in-stream sediments caused by transportation projects can negatively affect water quality. Turbidity occurs when matter such as clay silt, fine organic or inorganic matter, or plankton and other 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 will allow transportation professionals to devise temporary techniques to prevent erosion and sediment from causing turbidity to reach critical levels. This project's findings will help improve protection of endangered species and will improve the efficiency of transportation projects by preventing the need for extensive consultations and permit negotiations with resource agencies.

Project Manager: Bolton, S.M., UW
Tech. Coord.: Molash, E., WSDOT
Sponsor: WSDOT

Field Assessment and Mitigation of Potential Environmental Impacts of PCC Highway Grindings, Phase II

Very little information is available on the environmental impact of highway grindings that result from re-surfacing portland cement concrete (PCC) pavements. The grinding slurry is typically deposited along the roadside, but little is known about the fate, transport, and effects of slurry disposal methods on the environment. For this study, researchers are investigating the impact of PCC highway grinding slurry on soil pH in disposal areas, and they are evaluating efficient and affordable methods to neutralize slurry pH before or during disposal. This information will guide future disposal methods.

Project Managers: Yonge, D.R./Loge, F.J., WSU
Tech. Coord.: Pierce, L., WSDOT
Sponsors: WSDOT/FHWA

THE VALUE OF STORM WATER MANAGEMENT PRACTICES

Many construction projects require storm water management measures designed to prevent or reduce water and soil pollution and to attenuate peak flows and volumes. Although the costs of treatment are known, the monetary value of benefits from treatment is not well understood. This problem distorts the selection of economically feasible construction projects among the many projects eligible for scarce transportation funding.

To address this problem, this project conducted a literature review of storm water treatment benefits and is developing a method to estimate the monetary benefits of storm water management measures. The resulting models will help improve the efficiency of WSDOT's project funding decision process.

Project Manager: Brown, G.M., UW
Tech. Coord.: Morin, P., WSDOT
Sponsors: WSDOT/FHWA

CONGESTION AND ITS IMPACT ON THE ENVIRONMENT AND ECONOMY POSE CHALLENGES

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

Archived Data Analysis Methods

The purpose of this project was to develop new methods for freeway performance analysis. To that end, researchers developed a multiyear database of frequently requested freeway performance measures to allow WSDOT to quickly respond to common user requests. They also developed a methodology, based on the existing freeway loop system, to produce enhanced traffic data by vehicle category. In addition, the project team began to develop an analytical procedure based on traffic flow and incident response data that can describe the effects of incidents on traffic flow.

Project Manager: Ishimaru, J., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsor: WSDOT

A Cellular Automata Model for Use with Real Freeway Data for Congestion Prediction

Traffic models developed to address different traffic problems have historically been divided into two classes, microscopic and macroscopic. Microscopic modeling considers the individual vehicle's physical state and driver's behavior. Macroscopic models describe traffic with aggregate variables such as traffic density, mean speed, and volume. This project extended and tested a hybrid model to combine the best features of both micro- and macroscopic models and validated the model using freeway traffic data from the I-5 corridor in North Seattle. The software resulting from this project is capable of modeling regional freeway corridors and predicting volume, occupancy, and speed 20 minutes into the future. This information can be used to predict travel times for the public, as well as plan for freeway capacity improvements.

Project Manager: Dailey, D.J., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsors: WSDOT/FHWA

Evaluation of Dual Loop Errors in Measurement of Freeway Traffic Composition

The WSDOT has installed dual loop detectors at many sites in the pavement of the Seattle area freeway system. Data from these dual loop systems can indicate vehicle speeds and volumes. Unfortunately, these systems often do not function correctly, preventing WSDOT from collecting useful data. This project focused on identifying and diagnosing dual loop problems and data errors. Video imaging was used to collect the base-line data necessary to identify dual loop errors. The project concluded that defects in the underlying algorithm for the dual-loop detectors or its implementation program can cause data errors even when equipment is functioning accurately, and future work should focus on scrutinizing the dual-loop algorithm and implementation code.

Project Managers: Nihan, N.L./Wang, Y., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsors: WSDOT/TransNow

Evaluation of the Service Patrol Program in the Puget Sound Region

A Service Patrol pilot demonstration in Seattle and Tacoma examined how the similarities and differences among different methods of aiding disabled vehicles—Washington State Patrol cars, contracted tow trucks, and WSDOT service patrol trucks—affected the impact of the Service Patrol operation on traffic conditions and motorist satisfaction. The factors investigated included the level of response, equipment choices, and costs. The program was managed by WSDOT and operated by Washington State Patrol cadets and contracted registered tow truck operators. The pilot project resulted in a variety of intangible benefits, such as improved interagency coordination and cooperation, more efficient utilization of personnel, and a better understanding of each partner's roles in and contributions toward congestion relief. The public's positive view of the Service Patrol was uniform, regardless of service mode.

Project Managers: Nee, J./Hallenbeck, M.E., UW
Tech. Coord.: Althauser, G., WSDOT
Sponsor: WSDOT

WSDOT is now using revised and enhanced software for analyzing freeway data to produce regularly updated estimates of freeway travel times for the public.

Freeway Performance Analysis

For this project, TRAC researchers provided analytical support for freeway performance monitoring activities related to operations, planning, and policy analyses. They revised and enhanced the freeway data analysis software that TRAC has developed since 1995; it now has greatly expanded analytical options as well as a more robust performance. They also provided training and support to WSDOT engineers to allow their use of the software. In addition, they developed new methods to measure freeway performance and reliability based on analyses of traveler delay and recurrent versus non-recurrent traffic conditions. WSDOT now uses these methods to produce regularly updated estimates of urban freeway travel times for the public.

Project Manager: Ishimaru, J., UW
Tech. Coord.: Shanafelt, J., WSDOT
Sponsor: WSDOT

North Seattle Advanced Traffic Management System Evaluation

This evaluation was originally designed to analyze the potential transportation benefits and costs of a regional arterial traffic data sharing system that would obtain traffic signal system information from participating agencies and then share the data among them. The operational goal was to allow each agency to make better control decisions by providing it with real-time knowledge of traffic conditions outside of its own control system boundaries. However, because of numerous technical and jurisdictional issues, the system as originally envisioned was not successfully implemented. As a result, the evaluation documented expected institutional benefits, as well as extensive "lessons learned." Of particular note were the importance of effective and ongoing lines of communication, and the critical need to properly evaluate the fundamental nature of the project and provide a well-matched project management structure.

Project Managers: Ishimaru, J./Hallenbeck, M.E., UW
Tech. Coord.: Balogh, M., WSDOT
Sponsor: WSDOT

A Queuing Analysis at the U.S./Canadian Peace Arch Border Crossing

A coalition of U.S. and Canadian public and private organizations known as the International Mobility and Trade Corridor (IMTC) project is investigating ways to maintain efficient movement through the border crossings between British Columbia, Canada, and Whatcom County, Wash. For the IMTC, this project explored potential analytical approaches that could provide a better understanding of the interactions between traffic demand, border crossing strategies, and border traffic conditions. A prototype analytical model of the border crossing in both directions was developed and tested, and the model output was compared with theoretical results and field

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. To help the state understand whether these changes should be adopted permanently, TRAC 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 occurs in the shoulders of peak periods. They are also assessing the public's opinion 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, and the results will be helpful to policy makers in deciding how best to operate the HOV lanes and to the public in better understanding their purpose and effectiveness.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Leth, M., WSDOT
Sponsor: WSDOT

data. A series of hypothetical scenarios was analyzed to illustrate the potential uses of such a tool. The researchers concluded that such a model could provide useful information for evaluating operations and policy decisions, identifying ways to enhance border services, and developing strategies to improve traffic mobility.

Project Managers: McCormack, E./Nee, J./Ishimaru, J., UW
Tech. Coord.: Haslam, H., WSDOT
Sponsors: WSDOT/Whatcom County

Use of Uncalibrated CCTV for Measuring Speed

Image processing techniques have been applied to traffic scenes for a variety of purposes, including queue and incident detection, vehicle classification, and vehicle counting. However, despite the fact that roadside cameras are relatively inexpensive and many departments of transportation have installed them, few efforts have been made to measure speed by using video images from uncalibrated cameras. Researchers first tested a new approach for estimating traffic speed on the basis of a sequence of real-time freeway video images from closed-circuit TV cameras. The approach, which the project demonstrated to be valid, requires neither direct camera control nor placement of an object in the environment to calibrate the camera. With such an algorithm, many more transportation departments could estimate, and share, traffic speed information.

Project Manager: Dailey, D.J., UW
Tech. Coord.: Legg, B., WSDOT
Sponsors: WSDOT/TransNow

WTP Travel Time and Reliability Performance Measure Development

The Washington Transportation Plan (WTP) includes highway travel times and delay as congestion performance measures. However, WSDOT does not currently collect the data necessary to produce accurate measures of travel time on most of its highways. Available data collection and travel time estimation techniques do not accurately estimate the size, duration, and frequency of recreational trip, incident, and accident delays. In response, this project produced a white paper discussing the technologies available, including global positioning system receivers, vehicle tags and roadside readers, and cellular telephone E-911, to provide accurate travel time and delay measurements for all state highways.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Al-Memar, F., WSDOT
Sponsor: WSDOT

ACTIVE PROJECTS

The Automated Use of Uncalibrated CCTV Cameras as Quantitative Speed Sensors

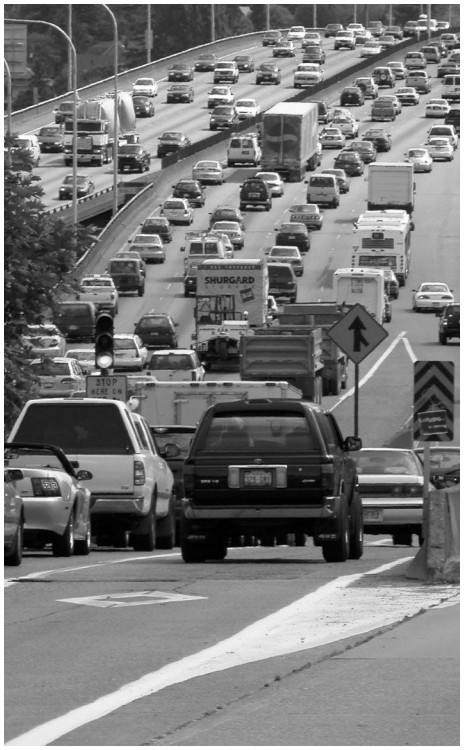
TRAC researchers have developed and published algorithms that can estimate traffic speed by using video images from uncalibrated closed-captioned TV cameras. However, these algorithms must be automated if they are to be useful as a tool for traffic management operations. In actual deployment, the algorithms must detect camera motion that would require the camera to be re-calibrated. This project is investigating ways to identify when the camera scene has changed, thus requiring camera re-calibration. Success will allow freeway speeds to be estimated from the department of transportation's existing camera equipment. This will save the department from having to install alternative speed estimating systems, and the resulting information can be used in programming ramp meters, detecting incidents, and counting vehicles.

Project Manager: Dailey, D.J., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsors: WSDOT/FHWA

HOV Evaluation VI

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 timesavings 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.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Shanafelt, J., WSDOT
Sponsor: WSDOT



Results from an ongoing study of HOW lane effectiveness are helping decision makers and planners evaluate the impact and adequacy of the Puget Sound HOV lane system.

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 used by WSDOT and other regional transportation agencies. This project is improving on the ADUS by creating an archiving system that can integrate different data collection statistics into a more seamless database, convert raw statistics into useful summary traffic statistics, and allow retrieval of statistics from multiple data sources through a single geographic information system. The improved ADUS will enhance freeway performance monitoring by covering more geographic areas and reporting additional types of performance measures.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsor: WSDOT

WSDOT INCIDENT RESPONSE EVALUATION: MEASUREMENT OF RECURRING VERSUS NON-RECURRING CONGESTION

Cost effectively reducing congestion requires an understanding of its causes, but WSDOT is uncertain about how much congestion on the Puget Sound freeway system is caused by having more demand than roadway lanes and geometry can serve and how much is caused by temporary reductions in capacity resulting from incidents and other singular events. To provide more answers, this project measured the amount of delay on the Seattle metropolitan freeway system and determined how much is generated by recurring and non-recurring causes, with special emphasis on the amount of delay caused by lane blocking incidents.

In Seattle, as in many areas, capacity is constrained and construction is too costly, so dealing with congestion, particularly that caused by incidents, has become more important. Agencies need to be able to measure congestion, decrease it through operational changes, clear incidents faster, and better predict incident causes, including adverse weather and special events. Agencies also need to find more effective ways to communicate with the public about congestion, particularly in terms of incidents. The project results were useful enough to WSDOT that continuing research phases are being planned.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Rickman, T., WSDOT
Sponsor: WSDOT

FREIGHT MOVEMENT IN WASHINGTON STATE HAS STRATEGIC IMPACT

Freight and freight mobility are of utmost importance to Washington State. Washington has many strategic advantages in foreign import and export markets, as well as domestic markets. This is due in part to its geographic location, natural deep-water harbors, and a developed river system. One in four jobs in Washington State is trade-related. Freight and goods tonnage moved by roads in the state has increased 116 percent since 1980 and is expected to keep growing. Trucks haul 283 million tons of freight and goods on state roads each year. In 1998, 75 million tons of commodity moved in or through Washington by rail. In addition, air freight movement in Washington state is significant and growing.

The state's freight policy goal is to ensure that freight movement is reliable and that transportation investments support Washington's strategic trade advantage. Current areas of freight research include rail line abandonment, freight security issues, lack of available freight data and performance criteria, inefficient port access, delays at the U.S./Canadian border, and conflicts between rail and roadway traffic.

COMPLETED PROJECTS

Functions and Benefits of Rural Airports in Washington

Of the 129 airports in Washington state, most are small and are based in rural and often remote locations. The survival of many of these airports is threatened, while the economic viability of many of their nearby communities is also in trouble. Through qualitative analysis, this project identified the many ways in which the presence of a nearby airport benefits rural communities, including improving economic development; providing access for emergency medical services and increasing quality of health care; supporting local business and commerce; providing facilities for public safety efforts and disaster/emergency response; and enriching community life.

Project Managers: Casavant, K.L./Newkirk, J.R., WSU
Tech. Coord.: Smith, T., WSDOT
Sponsor: WSDOT

Intermodal Freight Data Project Support

As congestion increases, transportation agencies are seeking regional travel time data to determine exactly when, how, and where congestion affects freight mobility. Concurrently, a number of regional intelligent transportation systems (ITS) are incorporating various technologies to improve transportation system efficiency. This research explored the ability of these operational systems—including transponder-equipped trucks, GPS-equipped trucks, and WSDOT's extensive loop-based freeway surveillance and control system—to be used as tools for developing useful historical, and perhaps real-time, traffic flow information. Such information will be useful in improving freight movement and estimating delivery times more accurately.

Project Managers: McCormack, E./Nee, J., UW
Tech. Coord.: Legg, B., WSDOT
Sponsor: WSDOT

Researchers analyzed the ways in which local airports benefit rural communities.

Methodology for Determining Washington State Value-Added Freight Moved in Washington

Washington State has adopted annual tonnage as the measure for identifying its strategic freight corridors, primarily because the data can be readily obtained for roadways, waterways, and railways. However, to prioritize freight projects by total benefit to the state, planners have to move past physical tonnage to better quality information. A fuller set of descriptors might also include the dollar value of freight movements, the dollar value of transportation services in moving these products, and the value-added characteristics of those products and commodities.

Of these, state value-added is likely to most realistically reflect public benefits to the state. This project identified a practical methodology for estimating the value-added component of freight moving on Washington's transportation system.

Project Manager: Casavant, K.L., WSU
Tech. Coord.: Harger, A., WSDOT
Sponsors: WSDOT/FHWA

ACTIVE PROJECTS

Freight Mobility Strategic Investment Board Benchmark 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 that will quantify changes in freight mobility resulting from efforts to remove those impediments. TRAC researchers are providing guidance on the development of a data collection methodology that can be used to measure truck movements along specific roadway corridors. They will also analyze the collected data and provide input into the creation of benchmarks for measuring the effectiveness of roadway projects intended to improve freight mobility.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Schmidt, K., FMSIB
Sponsors: Freight Mobility Strategic Investment Board

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 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 is developing an applied methodology to determine the potential economic viability of intermodal truck-rail facilities. The resulting framework will 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.

Project Managers: Casavant, K.L./Jessup, E.L., WSU
Tech. Coord.: Fredrickson, K., 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 strived to aid decision makers in formulating strategic, coordinated investment decisions for the multimodal system. Because of the importance of freight mobility issues, this project received national interest, as well as funds for a follow-up study.

Project Manager: Casavant, K.L., WSU
Tech. Coord.: Lenzi, J., WSDOT
Sponsors: WSDOT/FHWA

BETTER UNDERSTANDING OF SLOPE FAILURE AND SOIL LIQUEFACTION RESULTS IN SAFER HIGHWAYS

In the middle 1990s the focus of TRAC geotechnical research shifted from problem solving to long-term investment in the use of geosynthetic fabrics for reinforcing walls. In the late 1990s TRAC researchers began a multi-year investigation of liquefaction hazards prompted by WSDOT's growing concerns for the safety of bridges built on such soils. As fate would have it, these studies coincided with the Nisqually Earthquake in February of 2001, which triggered a number of liquefaction failures throughout the Puget Sound area.

The remainder of the current program focuses on construction issues. The wiremesh and cablemesh slope protection project addresses recent and past failures of these protection systems with the development of more sophisticated design criteria. New standards for these systems should be able to accommodate higher and longer slopes and slopes that include additional loads imposed by accumulated snow.

COMPLETED PROJECTS

Dynamic Stiffness of Piles in Liquefiable Soils

Pile foundations used to support bridges and highway structures are often placed in saturated deposits of loose sand and soft silt and clay, which are subject to liquefaction from seismic and non-seismic loading. This research developed more accurate and versatile tools for estimating the stiffness of pile foundations in liquefiable soils. These tools were created by updating and extending the capabilities of two computer programs developed during previous WSDOT research studies, WAVE and DYNOPILE. A new WAVE model allows estimation of the response of typical sands to the stresses induced by earthquake shaking. The model has the important advantage of being easily calibrated with commonly available data. More complex soil-pile interaction analyses can be performed with a new Windows-based version of DYNOPILE. Additional efforts are now under way at WSDOT to develop an additional software program based on a different approach to the issue. Once this is completed WSDOT will have a set of programs suitable for designing pile foundations for liquefiable soils.

Project Manager: Kramer, S.L., UW
Tech. Coord.: Cuthbertson, J.G., WSDOT
Sponsor: WSDOT/FHWA

New models will allow WSDOT to better design pile foundations for liquefiable soils, such as that under the Alaskan Way Viaduct along the Seattle waterfront.

ACTIVE PROJECTS

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 slope protection systems in the late 1950s for slopes shorter than 75 feet. However, they 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, researchers are developing design guidelines for these systems based on an analysis of the influence of various types of loads on the global stability of the systems, as well as on individual components.

Project Manager: Muhunthan, B., WSU
Tech. Coord.: Lowell, S., WSDOT
Sponsor: WSDOT/FHWA

Evaluation of Liquefaction Hazards in Washington State

Soil liquefaction commonly occurs in loose, saturated, cohesionless soils, the types of soils commonly encountered in and adjacent to rivers and bodies of water. As a result, liquefaction frequently plays an important role 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. In two related projects, researchers have been developing improved procedures for evaluating liquefaction hazards specific to Washington State, and the result will be a manual of practice describing those procedures.

Project Manager: Kramer, S.L., UW
Tech. Coord.: Allen, T., WSDOT
Sponsors: WSDOT/FHWA

GOOD HIGHWAY DESIGN AND CAREFUL TRAFFIC ENGINEERING INCREASE SAFETY

Roadway and roadside issues related to safety have historically been the subjects of intense research. As long as death and injury accidents continue to occur on our roads, they will remain important. TRAC research has sought to improve safety for the traveling public while finding effective safety methods at lower costs that are equivalent to FHWA standards. Areas of emphasis include roadside and roadway safety, context sensitive design, and pedestrian and bicycle safety.

COMPLETED PROJECTS

Motorist and Pedestrian Behavioral Analysis Relating to Pedestrian Safety Improvements

The objective of this project was to evaluate motorist and pedestrian behavioral changes that resulted from changes in the roadway environment, traffic enforcement activities, and a public information campaign. A "before" and four-phased "after" analyses were conducted at two study sites along a major highway arterial in Shoreline, Wash. The results of the study showed that the safety treatments had a positive effect on pedestrian behavior in that pedestrians used an installed refuge island for crossing. The safety treatments also significantly improved vehicle compliance in yielding for pedestrians, although driving behavior could still be improved. Other treatments in the study included marked crosswalks, push-button activated "roving eyes" signs, and yield bars. This information will be used to design and install more effective pedestrian crossing treatments on multilane roadways—particularly arterials with transit stops.

Project Manager: Nee, J., UW
Tech. Coord.: Matlick, J., WSDOT
Sponsor: WSDOT

Pedestrian Safety and Transit Corridors

Many state-owned highways and urban arterials are important metropolitan transit corridors with large numbers of bus stops. This research examined the relationship between pedestrian accident locations and transit bus stops and found that bus stop usage is strongly associated with pedestrian collisions along state facilities. The research also examined the association between pedestrian collisions and other pedestrian travel generators, such as concentrations of retail activity and housing, as well as environmental conditions such as wide roadways, high traffic volumes, and high speed limits. The findings suggest that roadways that carry high numbers of bus riders must be considered multi-modal facilities and make safe accommodations for pedestrians. They will provide data to support the construction of pedestrian facilities based on the benefit of the facilities in reducing the societal costs of collisions.

Ways to ensure the safey of pedestrians along state-owned highways and arterials with transit stops may include refuge islands and other measures.

Project Manager: Vernez Moudon, A., UW
Tech. Coord.: Matlick, J., WSDOT
Sponsor: WSDOT

ASSESSING THE ECONOMIC IMPACTS OF ACCESS MANAGEMENT

Access management includes the planning, design, and implementation of land-use and transportation strategies that control the flow of traffic between roads and surrounding land. Vehicular, pedestrian, and bicycle traffic is managed and controlled through various forms of access, including traffic signals, turning lanes and restrictions, driveway spacing management, and intelligent transportation systems. This study investigated how merchants view access management, documenting their thoughts and perceptions about its economic impacts on their businesses.

The results will help WSDOT personnel who work with property owners to explain WSDOT's access management policies. In dialogues between public development reviewers and private land developers about design requirements, such information can help WSDOT make changes or purchases more easily.

Project Manager: Shankar, V., UW
Tech. Coord.: Milton, J., WSDOT
Sponsors: WSDOT/FHWA

INTERACTION BETWEEN ROADWAY AND ROADSIDE ACCIDENTS

The purpose of this research was to explore the relationship between roadway and roadside accident rates for Washington State highways, with the larger goal of improving WSDOT's processes for modeling roadway and roadside accident rates and thus the agency's safety project programming process.

The project tested the use of the seemingly unrelated regression estimation (SURE) model to model the roadway and roadside simultaneously. However, empirical results indicated that the correlation between roadway and roadside accident rates was insignificant. This meant that use of SURE to simultaneously model the roadway and roadside would not make the state's process of programming roadway safety improvements more efficient and that WSDOT's current practice of modeling the accident rates separately is appropriate and accurate. This result will prevent WSDOT from spending unnecessary funds on new procedures and will allow it to carry out its safety project programming process with greater confidence.

Project Manager: Shankar, V., UW
Tech. Coord.: Milton, J., WSDOT
Sponsors: WSDOT/FHWA

ACTIVE PROJECTS

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 is identifying the set of geometric factors that increase the probability of a median cross-over and the probability of fatalities.

Project Manager: Shankar, V., UW
Tech. Coord.: Olson, D., WSDOT
Sponsors: WSDOT/FHWA

In-Service Evaluation for Landscaped Medians on Urban Roadways

Interest has been growing in the landscaping of 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 needed appropriate performance criteria and a data collection plan to evaluate whether the landscaping achieves its objectives. For this project, researchers are developing a standardized framework for evaluating landscaped medians and are conducting an evaluation with that framework of an in-service landscape treatment. The result should be a better understanding of the cost of specific median designs, safety factors, possible redesigning, and future plans for development of landscaped medians.

Project Managers: Nee, J./Hallenbeck, M.E., UW
Tech. Coord.: Leth, M., WSDOT
Sponsor: WSDOT

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 is to develop degradation curves for the reflectivity of roadway pavement markings. These degradation curves will provide information to decision-makers about the frequency with which different types of pavement markings should be replaced. The research will determine the best time to reapply pavement markings and will help identify the pavement markings that are most cost effective.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Jacobson, E., WSDOT
Sponsor: WSDOT

PROVIDING ITS FOR 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

Analysis of Web-Based WSDOT Traveler Information: Testing Users' Information Retrieval Strategies

What types of information do motorists seek out when traveling in Washington? When searching for specific information on WSDOT's Traffic and Weather Web site, can visitors find what they seek? Once they find information, is it easy to understand? Could additional types of information at the site be useful? Researchers conducted a 1,700-participant, Web-based survey and detailed usability tests to answer these questions. Beyond determining that users find the Traffic and Weather Web site (http://www.wsdot.wa.gov/traffic/) to be a valuable resource, the study provided detailed and specific recommendations for making the site more appropriate, user friendly, and helpful to visitors.

Project Managers: Sauer, G. /Kolko, B.E./Haselkorn, M.P., UW
Tech. Coord.: Legg, B., WSDOT
Sponsors: WSDOT/FHWA

Intelligent Transportation System Backbone Infrastructure

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, as well as associated applications. <http://www.its.washington.edu/bbone/ >

Project Manager: Dailey, D.J., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsor: WSDOT

Intelligent Transportation System Backbone Infrastructure II

Within this project the intelligent transportation systems (ITS) backbone continued to perform several important tasks for ongoing efforts at WSDOT and the University of Washington. The backbone supported existing traveler information applications for both traffic and transit information; sup-

TRAC is involved in projects to discover what information travelers need, and how to best deliver it, when they use Washington State highways.

ported real-time access to WSDOT data for a variety of public and private groups; reduced WSDOT workload by allowing backbone staff to handle the interaction and support of data users external to WSDOT; provided a standard interface so that all roadway data were available equally to outside agencies and groups; supported research activities within WSDOT, research funded by WSDOT at the UW, and research at universities and agencies nationwide; and provided a standard interface to include new data sources into the existing traffic management system.

Project Manager: Dailey, D.J., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsor: WSDOT

A demonstration of "smart bus" technologies has led to their deployment and further evaluation on some King County Metro buses.

Next-Generation Land Surface Model for the Prediction of Pavement Temperature

To meet the needs of WSDOT highway maintenance managers for information about weather and pavement, researchers at the University of Washington developed a system for predicting real-time pavement temperatures. This system utilizes the NOAH land surface model (National Center for Environmental Prediction, Oregon State University, Air Force, Hydrologic Research Lab) to estimate fluxes of energy to and from the pavement surface and resulting pavement surface temperatures. Data from real-time MM5 weather prediction model forecasts, performed twice daily at the UW, were used as initial and boundary conditions in pavement temperature simulations. The results of these simulations were compared with observations to verify the system's forecasting accuracy.

Project Manager: Mass, C.F, UW
Tech. Coord.: Brown, B., WSDOT
Sponsor: WSDOT

Regional Multi-Modal Automatic Vehicle Location Demonstration Project, Phase I: Alternatives Analysis

Sound Transit initiated this project to test the ability of newly emerging commercial wireless telecommunications systems to provide reliable information, based on the global positioning system (GPS), for automatic vehicle location (AVL) of transit vehicles. Under contract to Sound Transit, TRAC researchers provided alternatives analysis and prepared specifications for the recommended approach. The ultimate goals of the larger project are to demonstrate the value of automatic vehicle location information for Sound Transit and its partner agencies and to identify the cost implications of a possible full-scale implementation.

Project Manager: Boon, C.B., UW
Tech. Coord.: Roach, N. /Marquart, N., Sound Transit
Sponsor: Sound Transit

Regional Smart Bus Demonstration Project, Phase I: Evaluation

Sound Transit and King County Metro participated in a demonstration of an integrated set of "off-the-shelf," on-board technologies for transit. These smart bus technologies included, among others, automatic vehicle location; on-board comparison of actual versus scheduled time and location; interior next stop displays and announcements; and automatic report of engine, transmission, and braking system fault conditions. The technologies were installed on one Sound Transit bus and one King County Metro bus, which operated for four months. TRAC researchers evaluated the demonstration, assessing the implications of the project for future investments by Sound Transit and its regional partners. As a result of the evaluation, many of the technologies were incorporated into the regional transit technology plan, which will be implemented in two corridors.

Project Manager: Boon, C.B., UW
Tech. Coord.: Plaskon, T., Sound Transit
Sponsor: Sound Transit

Road Weather Information System Cost/Benefit Study

The WSDOT's rWeather program has significantly integrated and expanded the capabilities of road/weather information systems (RWIS) in the state, enabling proactive winter maintenance practices and better-informed winter travel decisions. This project reviewed

the potential benefits of a comprehensive, integrated RWIS, including cost-efficient snow and ice control strategies and improved safety and mobility. Use of, and attitudes toward, RWIS by WSDOT maintenance personnel were examined, and barriers to the expanded use of RWIS technologies were identified. Public response to the rWeather traveler information web site was found to be overwhelmingly positive. The researchers concluded that expanding the use of RWIS and advanced winter maintenance practices will require continued investment in equipment reliability, demonstration of forecast credibility, targeted training, and implementation planning.

Project Manager: Boon, C.B., UW
Tech. Coord.: Brown, B., WSDOT
Sponsors: WSDOT

TDAD—Traffic Data Acquisition and Distribution

Although a number of agencies collect data describing real-time traffic conditions, these data are not in forms easily accessible to transportation planners and managers, particularly given the various methods by which the data are collected and the disparate computer systems of different agencies. In this project, researchers designed, specified, and demonstrated a prototype of a regional data collection and distribution system. This prototype makes available real-time travel and traffic operations data in a format usable by planners, for instance, at the Puget Sound Regional Council and at WSDOT. Researchers can collect data from Western Washington intelligent transportation system projects and WSDOT- and UW-sponsored projects. <http://www.its.washington.edu/tdad/ >

Project Manager: Dailey, D.J.,UW
Tech. Coord.: Briglia, P., WSDOT
Sponsors: WSDOT/FHWA

Technology Service Corporation Remote Sensing

TRAC provided technical support on topics such as modeling parameters and statistical traffic analysis to a small business concern investigating civilian applications of military remote sensing technology and radar databases. The project's intent was to use military airborne remote sensing technology to identify traffic and congestion and provide information for law enforcement, emergency response, and other purposes.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Corbeil, A., TSC
Sponsor: Technology Service Corporation

Transit Vehicles as Probes

Although many agencies would like access to real-time travel times and speeds in major urban corridors, corridor travel time is difficult to estimate accurately. While probe vehicles can be used to estimate the duration of a single vehicle's trips, continuously available travel-time and speed estimates from a variety of locations require a large number of probe vehicles. The King County Metro transit fleet, equipped with an automatic vehicle location (AVL) system and operating nearly 1,000 vehicles simultaneously, could potentially provide the large pool of vehicles necessary to make a probe vehicle strategy viable. In this project, the researchers developed a framework for modeling the data provided by Metro's transit AVL system. They then applied a mathematical filtering method to estimate speed as a function of space and time, and they used this speed function to estimate travel time Future phases of this project may enable WSDOT to estimate travel speeds and construct travel times through corridors by collecting data from transit vehicles equipped with AVL. These results could then be used to augment the existing sensor network of loops, cameras, and radar.

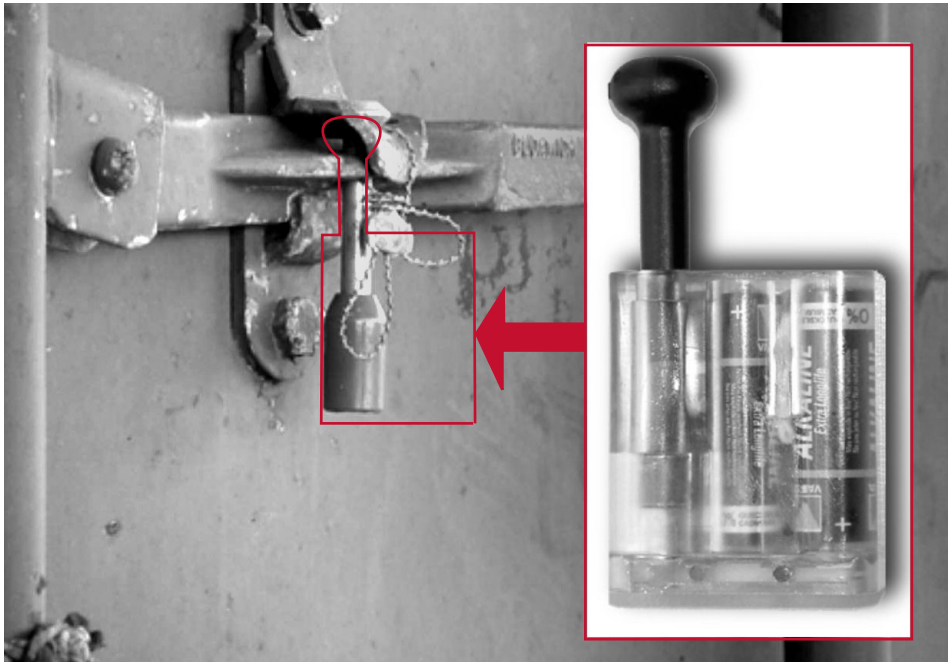
Project Manager: Dailey, D.J., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsors: WSDOT/TransNow

AVL-EQUIPPED VEHICLES AS SPEED PROBES FOR TRAFFIC MANAGEMENT AND TRAVELER INFORMATION IN ADDITION TO PERFORMANCE MONITORING

The project Transit Vehicles as Probes began developing technology and software for using 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 are working 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.

The goal is to produce a freely available data stream, based on probe vehicles, that provides speed estimates for a variety of arterial segments. These speed estimates will complement travel time information now available for the Interstate system. Available on the Internet, such speed estimates will enhance information to the public about their travel times.

Project Manager: Dailey, D.J., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsors: WSDOT/FHWA/TransNow



Electronic door seals are being tested for their ability to help track inter-modal cargo and increase cargo security.

ACTIVE PROJECTS

ATIS Evaluation Framework and Project Evaluation

WSDOT has implemented five new advanced traveler information system (ATIS) projects, all intended to assist travelers in making informed route, mode, and trip time decisions. These projects will need to be evaluated, but the question will not necessarily be whether the technologies might be helpful but whether investment in their deployment would be most beneficial given other demands for state funding. To help evaluate these projects from that perspective, TRAC researchers are creating a standardized framework for evaluating ATIS projects that focuses on quantifying their benefits and costs, and they are testing the framework as part of the coordinated evaluation of each of the new projects. They will also identify key characteristics of ATIS applications that contribute to positive benefit/cost ratios and make recommendations for investment decision criteria appropriate to ATIS.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsor: WSDOT

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 Web sites; traffic information on personal data assistants; and real-time transit information at stops, on the Internet, and on mobile PDAs. However, to date no reliable and defensible method is available to evaluate the benefits of these strategies. Without information showing user and agency benefits, projects to implement these strategies will have difficulty competing with more traditional transportation projects, such as highway capacity expansion or safety projects, to obtain funding. This research will develop a way to measure information-based ITS strategies with data now available or easily collected.

Project Manager: Rutherford, G.S., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsors: WSDOT/FHWA

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 U.S.-Canadian collaboration, which expands on an existing field test, will evaluate 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 highway by providing enforcement agencies with regulatory and management information from transponder technology.

Project Manager: McCormack, E. UW
Tech. Coord: Legg, B., WSDOT
Sponsor: WSDOT/FHWA

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

Traffic flow modeling is an integral part of any traffic control system. Cellular automata-based microscopic models have shown promise in their ability to reproduce many complex traffic phenomena. This project is extending a cellular automata model to create a general automata model that can use freeway traffic data from the I-5 corridor in North Seattle to predict congestion. It is demonstrating the ability of that model to accurately reproduce both traffic distribution parameters and time dependent factors. The model is being validated against real freeway data in a variety of congestion conditions. If the model is successful it would be used to assist with

traffic management efforts.
Project Manager: Dailey, D.J., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsor: WSDOT

ITS Program Assessment Support

The National TMC Applications Archived Data Operational Test is measuring the effects of integrating archived data to enhance the operations of traffic management centers. The National TMC Test includes development of operational models for using archived data for traffic forecasting and incident management, development of algorithms to execute the models, and application of those algorithms to advanced traffic management and traveler information systems at the Smart Traffic Center in Hampton Roads, Virginia. TRAC researchers are providing support to SAIC in the evaluation of the TMC Test, including preparing an evaluation plan, collecting data, and analyzing results.
Project Manager: Hallenbeck, M.E, UW
Tech. Coord.: Register, D., SAIC
Sponsors: Science Applications International Corp./USDOT

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 Web site, <www.wsdot.wa.gov/traffic>.

Phase II is continuing the work of Phase I to make a wide range of weather and roadway data resources available to WSDOT and the public.

Project Manager: Mass, C.F., UW
Tech. Coord.: Brown, B. /Briglia, P., WSDOT
Sponsors: WSDOT/FHWA

Traffic TV: Updates and Improvements Based on User Feedback

TrafficTV is an automated source of traffic and traveler information that has aired on UWTV2 (University of Washington) and a Seattle cable channel since June 1998. The TrafficTV system fuses regional traffic congestion data with live traffic video, adds digital video effects, and supplies the resulting presentation to the cable TV provider for broadcasting. Focus groups and an evaluation identified several problems and recommended improvements. This project is updating TrafficTV with those changes and adding corridor travel-time information to the overall package.
Project Manager: Dailey, D.J., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsor: WSDOT

WSDOT Electronic Information and Supporting Systems: Challenges to Effective Practice and Policy

This project is identifying and addressing issues that affect WSDOT's ability to derive benefits from its extensive investment in information and communication technology. The emphasis is on electronic information and supporting systems (EISS), that is, information and its use, rather than technological issues such as compatibility and bandwidth. This work is developing 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.
Project Managers: Kolko, B.E./Haselkorn, M.P./Sauer, G., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsor: WSDOT

BUILDING BETTER PERFORMING, STRONGER, LONGER-LASTING PAVEMENTS

Over the years TRAC's research in pavements, and specifically asphalt pavements, has concentrated on developing mix design systems (Superpave) and pavement design systems (AASHTO 2002 Design Guide) that essentially refine the process of producing the best possible mix and thickness designs for the climates and expected traffic on the state's roadways. A more recent study investigated the factors that lead to better pavement performance and longer life. The conclusion of the study was the construction process is the main factor in producing superior or inferior performance in a pavement, given that the mix and thickness designs are correct. TRAC researchers are also involved in implementing performance-based specifications for high performance concrete.

In response to a need for more complete and accurate information, an extensive guide to pavement information has been developed and enhanced, and will soon be available on CD. Researchers have also created a Web-enabled version of the WSDOT's Pavement Management System that gives users access to pavement condition data regardless of their geographic location.

By linking physical, quantitative roadway measures with subjective measures of driver-perceived pavement roughness, researchers concluded that the International Roughness Index is the single best predictor of road roughness and driver acceptability.

COMPLETED PROJECTS

Assessment of Highway Roughness

This study linked physical, quantitative roadway measures with subjective, driver-perceived measures of roughness on urban highways. Driver evaluations were collected from participants placed in normal traffic conditions and asked their opinions about pavement roughness on 40 predetermined highway test segments. Results from an ordered logit model indicated that the International Roughness Index (IRI) is the single best predictor of driver-perceived road roughness and driver acceptability. Other factors statistically associated with driver-perceived measures of road roughness included maintenance of the pavement, the presence of joints or bridge abutments, the age of the pavement surface, and vehicle type.

Project Manager: Shafizadeh, K., UW
Tech. Coord.: Pierce, L., WSDOT
Sponsors: WSDOT/FHWA

Enhancements to the EverFE Finite Element Program

Most of the rigid pavement on WSDOT's roadways is 20 to 30 years old and in need of rehabilitation or reconstruction. WSDOT requires an enhanced system to analyze the causes of various types of distress in these pavements and the effects of various rehabilitation options on pavement response. This project enhanced the EverFE finite element pavement modeling software to analyze a larger variety of rigid pavement systems, as well as flexible pavements. The researchers improved the modeling capabilities of the system and enhanced its efficiency, interactivity, and ease of use.

Project Managers: Turkiyyah, G./Mahoney, J.P., UW
Tech. Coord.: Pierce, L., WSDOT
Sponsors: WSDOT/FHWA

DEVELOPMENT AND IMPLEMENTATION OF PAVEMENT TOOLS

The purpose of this project was to develop separate but integrated tools that aid in communication and training in the areas of pavement design and construction. The reasons for developing such tools included better access to information, enhanced collaboration among state departments of transportation and national pavement organizations, improved training, better information sharing, and enhanced connection between pavement design and construction. This project produced a Web-based catalog for hot-mix infrared images, an on-line hot-mix database for quality assurance data, and an integrated pavement guide, available on CD, that can be used for training and as a delivery system for pavement advancements.

The products from this project are important not only for Washington but for many other states that would like to have the pavement information included on the CD—everything from design to construction, testing, and management of both asphalt and concrete—readily available to their engineers and field inspectors. In fact, the CD has already been distributed to research directors in about 17 western states and to the materials engineers in all 50 states. In addition, whereas many textbooks on these topics are nearly obsolete by the time they are published, this information is up to date and can be more easily maintained.

Project Managers: Mahoney, J.P./Turkiyyah, G., UW
Tech. Coord.: Pierce, L., WSDOT
Sponsors: WSDOT

Implementation of High Performance Concrete in Washington State

The Federal Highway Administration defines high performance concrete (HPC) with eight parameters, including freezing/thawing durability, chloride permeability, abrasion resistance, scaling resistance, strength, elasticity, shrinkage, and creep. Associated with each parameter are performance criteria, testing procedures to measure performance, and recommendations to relate performance to field conditions. WSDOT is implementing performance-based specifications for concrete on the basis of FHWA's definition of HPC. Determining the performance levels of existing concrete mixes is the first step toward fully implementing these specifications. To this end, researchers evaluated the performance grades of existing mixes in Washington. They investigated the effects of the various constituents of each mix on its performance grade, and they proposed recommendations and developed guidelines for improving the durability and compressive strength of existing mixes.

Project Manager: Masad, E.A., WSU
Tech Coord.: Anderson, M., WSDOT
Sponsors: WSDOT/FHWA

NCHRP 1-39: Traffic Data Collection, Analysis, and Forecasting for Mechanistic Pavement Design

NCHRP project 1-37A has proposed a new pavement design guide for adoption by AASHTO to provide engineers with practical and realistic pavement design procedures that use existing mechanistic-empirical principles.

For WSDOT, pavement maintenance involves about 18,000 miles of pavement, 3,300 bridges, and 100,000 acres and requires an annual expenditure of about $110 million.

STATE OF WASHINGTON STUDDED TIRE STUDY

Whereas a number of states have banned studded tires, others, including Washington, have restricted their use and passed legislation to require lighter-weight studs. This project, conducted by GT Engineering, reviewed recent studies of the performance and safety of the current generation of studded tires, as well as new "studless" winter tires, on late-model vehicles. The resulting report presents a thorough picture of the performance capabilities of studded and studless tires.

The report states that from the standpoint of traction alone, studded tires, when new, can provide more benefit than other tire types, but only on ice-covered roads when the temperature is near freezing. In fact, the advent of new studless tires has diminished the marginal benefit of studs, and recent studies suggest that the infrequent, narrow range of conditions necessary to produce benefit from studded tires may not outweigh their detrimental effect on traction in dry or wet conditions on certain pavement types. This information has valuable implications for the state's studded tire policy and will be presented to the state legislature for its use in decision making.

Project Managers: Scheibe, R./Hallenbeck, M.E., UW
Tech. Coord.: Kirkland, K.C., WSDOT
Sponsors: WSDOT/FHWA

The prediction models developed for this new guide require more detailed data on vehicle axle weights than are currently used by most pavement design procedures. Recognizing the constraints on resources available in most state and local highway agencies, the new pavement design guide will allow for various levels of traffic data collection and analysis. To help prepare states to use the guide, this project created procedures and documentation for collecting and forecasting the required traffic load data, as well as guidance on selecting, installing, and operating the equipment required to collect those data.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Weinblat., H., Cambridge Systematics
Sponsor: Cambridge Systematics

Technical Assistance for the Development of the AASHTO 2002 Pavement Design Guide, NCHRP 1-37A

As a subcontractor to ERES Consultants, Inc., and Fugro-BRE, Inc., TRAC provided advice on which data state highway agencies are able to collect or are otherwise available for use in designing new and rehabilitated pavement structures. This information was gathered as input to a National Cooperative Highway Research Program pavement design guide, developed under project NCHRP 1-37A, "Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures."

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Von Quintus, H.L., Fugro-BRE
Sponsors: NCHRP/ERES Consultants, Inc./Fugro-BRE, Inc.

Web-Based Pavement Management System

WSDOT has maintained a PC-based software application, the Washington State Pavement Management System (WSPMS), to help engineers examine and evaluate system-wide roadway conditions for managing the state's roadway network. This project created a new Web-enabled version of the WSPMS that gives users access to pavement condition data regardless of their geographic location. Besides including all of the existing functionality of the PC-based software, the Web-based PMS includes new features such as walk-through tutorials and a mapping interface that allows users to view the data spatially. The Web application also catalogs WSDOT employee comments about roadway conditions from locations around the state and reflects those comments immediately to all other users.

Project Managers: Mahoney, J.P./White, G.C., UW
Tech. Coord.: Pierce, L., WSDOT
Sponsors: WSDOT/FHWA

ACTIVE 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. This project is developing back calculation procedures for the FWD test that use dynamic response data to overcome some of the limitations of current procedures. The project will implement these improved methods in the Evercalc II computer program to provide WSDOT with the ability to easily use them.

Project Managers: Turkiyyah, G./Kramer, S.L., UW
Tech. Coord.: Pierce, L., WSDOT
Sponsors: WSDOT/FHWA

Integration of Maintenance Information into the Washington State Pavement Management System

WSDOT conducts pavement maintenance on about 18,000 miles of pavement, 3,300 bridges, and 100,000 acres It requires an annual expenditure of about $110 million. The application of maintenance treatments preventively rather than reactively should lead to more cost-effective pavement performance. However, WSDOT currently applies maintenance treatments on a "worst first" basis. This is partly because WSDOT has several pavement data systems, and there is little direct connection between maintenance treatments and the state's Pavement Management System (WSPMS). To make pavement maintenance more effective, and to enhance the preservation and maintenance budget development process, researchers are working to incorporate pavement maintenance information into the WSPMS.

Project Manager: Mahoney, J.P., UW
Tech. Coord.: Pierce, L., WSDOT
Sponsors: WSDOT/FHWA

LTPP: Pavement and Traffic Engineering Technical Support Services

As subcontractors to PCS/LAW, TRAC researchers continue to provide technical support to the Federal Highway Administration in conducting its Long-Term Pavement Performance research program. TRAC work includes 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.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Rada, G., PCS/LAW
Sponsors: FHWA/PCS/LAW Engineering and Environmental Services

Montana Pavement Design Program Assistance

Through a subcontract to Fugro-Bre, Inc., TRAC researchers 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 2002 AASHTO Pavement Design Guide for roadways, with sufficient data to confirm the default values recommended in the Design Guide. TRAC is also helping to estimate historical traffic for test sections with minimal traffic data. They will also recommend additional data collection sites if necessary to measure traffic characteristics across the state.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Killingsworth, B., Fugro-Bre
Sponsors: Fugro-Bre/Montana Department of Transportation

State Pavement Technology Consortium

The State Pavement Technology Consortium (SPTC) is a pooled fund activity among the state transportation departments of California, Minnesota, Texas, and Washington, which has been the lead state for the project. The purpose of the SPTC is to establish a working relationship among the four organizations, and each state has allocated funding to allow selected DOT personnel and university researchers to participate in a series of technical meetings. The semi-annual SPTC technical meetings, held since July 1999, have allowed the four 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 Web site, <http://pavements.ce.washington.edu/sptc>.

Project Manager: Mahoney, J.P., UW
Tech. Coord.: Pierce, L., WSDOT
Sponsors: WSDOT/FHWA

A Web-enabled version of the Washington State Pavement Management system, which helps engineers examine and evaluate the roadway network, will give users access to pavement condition data regardless of their location.

TECHNOLOGY TRANSFER IS CORE ELEMENT OF TRAC MISSION

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

TRAC researchers conducted several documentation and training projects over the biennium, including work on FHWA's Traffic Monitoring Guide and a program to help educate future transportation engineers. Other technology transfer projects were specifically pavement related (see Pavement, pg 30) and included making WSDOT's Pavement Management System available on the Web; developing separate but integrated tools to aid in communication and training in the areas of pavement design and construction; and participation in the State Pavement Technology Consortium to share information on pavement practices and discuss the conduct of pavement-oriented research.

TRAC also continued to publish its one-page newsletter, the TRAC Research Review <http://depts.washington.edu/trac>, which emphasizes research successes and is distributed to a broad audience within Washington and across the United States. In addition, TRAC staff also aided WSDOT in the publication of its on-line newsletter covering road/weather information issues, the rWeather Newsletter <http://www.wsdot.wa.gov/biz/ATB/rwisnews/frames.html>.

COMPLETED PROJECTS

Traffic Monitoring Guide Training

TRAC researchers aided the Federal Highway Administration in updating and rewriting its Traffic Monitoring Guide. FHWA then asked TRAC to develop training materials for use in FHWA-sponsored workshops and courses on application of the new Guide. TRAC researchers both created presentation materials and assisted in training workshops.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsor: WSDOT/FHWA

Traffic Systems Management Center Intern Program

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 and analysis tasks.

Project Manager: Rutherford, G.S., UW
Tech. Coord.: Balogh, M., WSDOT
Sponsors: WSDOT

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

Update of the Federal Highway Administration's Traffic Monitoring Guide

TRAC researchers updated FHWA's Traffic Monitoring Guide. This Guide provides general guidance on the development of traffic monitoring programs for highway agencies. Its focus is on the collection of traffic volume, vehicle classification, and weight information. It also provides statistical procedures that allow managers to determine how much traffic monitoring is needed to achieve a desired level of statistical precision. The Guide is available on the Web at <http://www.fhwa.dot.gov/ohim/tmguide/index.htm>.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Briglia, P., WSDOT
Sponsors: WSDOT/FHWA

TRANSPORTATION PLANNING IS A REFLECTION OF SOCIETAL VALUES

Transportation is a vital service for citizens and businesses. Delivery of an appropriate and efficient system of transportation is a top priority for many levels of government and other providers of the facilities and services that make up this system. Planning for the transportation system that is necessary to so many people involves numerous considerations and complex choices and decisions, as well as multi-faceted coordination. Among the issues that planners consider are societal values such as quality of life, community livability and cohesion, environmental quality, land use governance, and economic and other trends. Planning for the transportation system with these in mind, in turn, may lead to policies that reflect society's values and consequent investment in the system to provide the transportation service that is so valued.

TRAC projects have revolved around several primary planning issues: land use and governance; project trade-offs among travel modes; and multimodal travel, including funding mechanisms, performance measures, and development of priorities.

COMPLETED PROJECTS

Development of a Multimodal Investment Choice Analysis for Use in Statewide Transportation Planning

Making budget decisions across various modes of transportation, each with differing characteristics and possibly serving different markets, is a difficult undertaking. Most state departments of transportation arrive at major program budget decisions on the basis of past expenditures, analysis of new needs, and policy considerations. WSDOT has traditionally identified needs by mode, then financially constrained the plan to a target funding level linked to revenue for that mode. For this project, researchers developed a methodology to improve the decision-making tradeoff process. This tool, based on transportation economics and defined goals, could assist WSDOT management, the Washington State Transportation Commission, and the state legislature in the timely analysis of program budget options

Project Manager: Rutherford, G.S., UW
Tech. Coord.: Howard, C., WSDOT
Sponsor: WSDOT

Researchers have found that local land-use regulations are very important in guiding transportation-efficient development.

Transportation Investment Decision-Making

Transportation-efficient development is development that supports the use of alternative transportation modes while reducing the need to drive alone. This project assumed that transportation-efficient development is effective at changing people's travel behavior. To study implementation of transportation-efficient development, relationships between local regulations and approved project proposals were examined in 19 study areas along two major state highway corridors in the central Puget Sound. Findings highlighted the importance of local land-use regulations in successfully guiding transportation-efficient development. Design review programs had also been particularly effective, and several study areas had produced success with incentive programs. This information will be useful in guiding future land-use decisions so that they better support the use of alternative modes of transportation.

Project Manager: Vernez Moudon, A., UW
Tech. Coord.: Mabry, J., WSDOT
Sponsor: WSDOT

Intellectual Foundation to Support the Establishment of Transportation Operation as a Transportation Core Mission

As subcontractors to the Texas Transportation Institute, TRAC researchers contributed to an FHWA white paper focused on a number of issues. These included changes and trends in congestion, how perceptions of congestion affect travel, the kinds and effectiveness of various traffic operations and management strategies that transportation agencies are pursuing, the benefits to be expected from different management systems, and the role of public transportation in easing congestion. This paper is targeted to transportation officials and public decision makers and is available at <www.fhwa.dot.gov/congestion/cgstpapr.htm>.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Lomax, T., TTI
Sponsor: Texas Transportation Institute/FHWA

A series of research projects is aimed at helping local jurisdictions and WSDOT more closely tie together land-use development and transportation during the investment decision-making process.

Research Travel Time Reliability

As a subcontractor to Cambridge Systematics, TRAC helped develop a detailed research plan for the portion of the future national Strategic Highway Research Program (F-SHRP) that seeks to improve the reliability of highway travel times. TRAC researchers contributed ideas and expertise in the areas of the scope and nature of travel time reliability, the economic consequences of congestion and travel time reliability, product orientation, and integration with other research. This information was then combined with knowledge of ongoing research to develop the proposed national plan.

Project Manager: Hallenbeck, M.E., UW
Tech. Coord.: Derr, R., TRB/Margiotta, R., Cambridge Systematics
Sponsor: Cambridge Systematics/NCHRP

Targeting Pedestrian Infrastructure Improvements

Several research projects for WSDOT have indicated that opportunities exist in the Puget Sound region to increase pedestrian travel in suburban areas beyond recognized employment centers. This project developed a methodology and tools that can assist state and local jurisdictions in identifying suburban locations where investments in pedestrian infrastructure would yield the highest potential increases and benefits in pedestrian travel. The Pedestrian Location Identification Tool identifies such locations, and the Pedestrian Infrastructure Prioritization Decision System indicates to which areas improvement funds should be allocated first.

Project Manager: Vernez Moudon, A., UW
Tech. Coord.: Matlick, J , WSDOT
Sponsors: WSDOT/TransNow

Tools were developed to assist the state and local jurisdictions in identifying suburban locations where investments in pedestrian infrastructure would yield the highest benefits.

ACTIVE PROJECTS

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 is thoroughly documenting 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 are working with the Wasatch Front Regional Council in Utah to describe the process and results of database development, calibration, sensitivity testing, and application of the model system.

Project Managers: Waddell, P.A./Borning, A.H., UW
Tech. Coord.: Mabry, J., WSDOT
Sponsors: WSDOT/FHWA

Transportation Efficient Land Use and Development Patterns

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. This phase of the program is developing a reference manual of strategies and tools for linking transportation and land-use decisions. The manual will guide WSDOT and local jurisdictions in coordinating land-use actions and transportation investments to best support transportation system efficiency.

Project Manager: Vernez Moudon, A., UW
Tech. Coord.: Mabry, J. , WSDOT
Sponsors: WSDOT/FHWA

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. This study is a two-year assessment of how the transportation element of concurrency is managed in the four cities of Bellevue, Issaquah, Kirkland, and Redmond, Wash. The Washington State Growth Management Act (GMA, RCW 36.70A.070) requires that public transportation services—which may include increased 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 roadways in their comprehensive plans.

This study is evaluating the extent to which meeting concurrency requirements assists the four cities in complying with the intent of the GMA. Researchers are investigating alternative measures of transportation concurrency and suggesting what changes, if any, to state and local laws would provide more effective ways of dealing with concurrency issues. The cities will be able to use the results to better plan development and transportation systems, both within and among their jurisidictions.

Project Managers: Hallenbeck, M.E./Carlson, D.L./Vernez Moudon, A./Blanco, H.J., UW
Tech. Coord.: Loewenherz, F., City of Bellevue
Sponsor: City of Bellevue

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FACILITIES

A number of laboratories and other facilities are available to TRAC researchers at the UW and WSU. Below is a select list:

Albrook Hydraulics Laboratory, WSU

For nearly 50 years the Albrook Hydraulics Laboratory has provided engineering services to solve a wide array of hydraulics-related problems. Major studies have been completed in fluid mechanics, hydrology, hydraulic model studies, and fisheries engineering. These include the effects of turbulence on body drag, storm water runoff and management, riverbed scour, fish passage facility performance, sediment removal from streams, and restoration of impacted stream habitats. The laboratory contains flumes of various sizes, flow capacities, and functions; and computing facilities for test control and analysis.

Environmental Science and Hazardous Waste Research, UW

Over 7,000 sq. ft. of lab space are well equipped with sophisticated research instruments, including gas, liquid, and ion chromatographs; total organic carbon and total organic halide analyzers; inductively coupled plasma and atomic absorption spectrophotometers; state-of-the-art particle size and particle mobility analyzers; and up-to-date instrumentation for conventional environmental engineering analyses. The labs are also equipped with several walk-in controlled temperature areas for experimentation.

Geotechnical Engineering Laboratory, UW

This laboratory contains standard soil mechanics laboratory testing equipment, including soil classification, permeability, consolidation, direct shear, and triaxial testing devices. Specialized research equipment includes a microcomputer-controlled GDS pressure control system and Bishop-Wesley cell for stress path testing, a recently developed cuboidal shear device, 250 mm on a side, with complete computer control of stresses and deformations, as well as data acquisition and control, CKC cyclic triaxial, and an SBEL (Stokoe) resonant column device.

Harris Hydraulic Laboratory, UW

This laboratory is fully equipped for both teaching and research in environmental fluid mechanics. The lab's five major research facilities are a three-dimensional water wave facility (used for edge-wave research and tsunami run-up research); a two-dimensional water wave facility (used for tsunami sediment research); a flow exchange facility (used for tsunami run-up research and internal wave/gravity current research); a wind-wave facility; and a tidal flow facility (used for harbor flushing research). Three other water flumes are used for experiments in hydraulics and fluid mechanics ranging from fish-screen hydrodynamics to swash-zone mechanics.

Quaternary Research Center, UW

Cooperating faculty members come from fields as diverse as anthropology, chemistry, civil engineering, forest resources, geophysics, and zoology to study the processes that currently shape the environment and those that have operated on it for several million years. The center's Periglacial Laboratory contains cold rooms equipped for manipulating and studying the freezing and thawing of soils, rocks, and building materials. A large, unique tilt table permits the study of ground surfaces under controlled conditions of slope, temperature and moisture.

Structural Research Laboratory, UW

The Structural Research Laboratory contains a 2.4-million-lb capacity Baldwin universal hydraulic testing machine, together with two smaller Baldwin testing machines of 300,000- and 120,000-lb capacities. A modern MTS Testing system includes 60-GPM pumping capacity and numerous controllers and actuators of various sizes. The laboratory also includes a strong floor, a reaction wall, and an earthquake simulator. A wide range of electronic and mechanical equipment is available to measure load and response in structures. This includes fully computerized data acquisition and processing systems.

University of Washington Aeronautical Laboratory, UW

The Department of Aeronautics and Astronautics offers several facilities used by companies, individuals, and the government for testing the aerodynamics of various models. The main facility is the F.K. Kirsten Wind Tunnel, a subsonic, closed circuit, double return wind tunnel. The test section is 8-feet high, 12-feet wide and 10-feet long. It is vented to the atmosphere and can be viewed from all sides. Two 500 hp dc motors drive two 14-ft 9-in-diameter, seven-blade fans to provide the test section with airspeeds of 200 MPH for a typical-sized wind tunnel model.

Washington Center for Asphalt Technology, WSU

WCAT was established through partnership among WSU, WSDOT, and the Washington Asphalt Paving Association. The National Science Foundation also contributed by funding the acquisition of a material testing system. The asphalt materials laboratory has the equipment and capabilities to test absolute viscosity, kinematic viscosity, flash point, rolling thin film oven, penetration, asphalt extraction, kneading compaction, Hveem stability, specific gravities, percentage of air voids, and more. WSU also has facilities for testing portland cement concrete and other materials.

Wood Materials and Engineering Laboratory, WSU

This interdisciplinary research facility develops new building materials from a range of recycled and virgin resources and develops innovative structural systems to effectively utilize new materials while maintaining economic viability and public safety. The laboratory is equipped with equipment for materials and structural testing; thermal and surface analysis; spectroscopic and microscopic analysis; composite manufacture analysis; sorting, drying, blending and forming; furnish generation; nondestructive evaluation; and computer-based modeling and data analysis.

CREDITS

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