2013 – 2014 Annual Report

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Letter from the Director

I am excited to report that, over the past year, solid progress has been made toward our goal of making PacTrans the research engine, applied technology showcase, workforce development base, educational leader, information center, and collaboration platform for Region 10. Highlights of our major activities in the 2013-2014 fiscal year are as follows:

PacTrans enhanced its regional leadership by organizing several important events including the Region 10 Transportation Conference, Region 10 Student Conference, and Region 10 Transportation Safety Workshop. A variety of issues were discussed at these events and critical transportation issues in Region 10 were identified. Additionally, three Region 10 Transportation Seminars were conducted with important transportation topics addressed by internationally recognized speakers. Hundreds of people attended these events collectively.

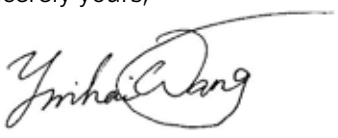
All of the 22 research projects funded in the 2012 – 2013 fiscal year were completed, and those funded in the 2013 – 2014 year are progressing as expected. We are now in the final stage of the 2012 – 2013 research report review and publication. Findings of these research projects will be presented and demonstrated at the upcoming 2014 Region 10 Transportation Conference scheduled on October 17. We expect the conference to offer a great platform for prospective technology users to interact with PacTrans researchers for potential technology transfer activities. Representatives from technology transfer offices of the PacTrans consortium universities are invited to join the conference so that they can interact directly with our PIs and the potential technology users. Technology transfer funds will be made available to facilitate the process for the most promising technologies.

Another important focus was student support. In addition to the continued support to PacTrans fellow students and student outreach activities, funds were allocated for student intern and travel support. For example, more than 30 students received travel support from PacTrans to attend the 2014 Transportation Research Board (TRB) Annual Meeting and PacTrans researchers delivered 85 technical presentations at the conference.

Furthermore, consistent efforts were made to grow our partnership network. Ten new industry and agency partners joined our network. Several international connections were made with countries in Europe and Asia for potential research and educational collaborations in transportation.

You will find more information about PacTrans' activities in this PacTrans Annual Report. Our goal is a report that is informative and useful to both internal and external readers. We also hope that it will bring to light every milestone we have reached with your great support. We welcome any suggestions or feedback you may have on our work and highly appreciate your continued support!

Sincerely yours,



Yinhai Wang, PhD, Professor
DIRECTOR OF PACTRANS

PacTrans Center

The Pacific Northwest Transportation Consortium (PacTrans) is the University Transportation Center (UTC) for Region 10. PacTrans continues to function as the UTC for Region 10 with the new grant of $5.2 million received in 2014 from the US Department of Transportation (USDOT) with a focus on transportation safety. We are a coalition of transportation professionals and educators from Oregon State University (OSU), the University of Alaska, Fairbanks (UAF), University of Idaho (UI), Washington State University, (WSU) and the University of Washington (UW).

PacTrans focuses on using technological advances to develop data-driven, sustainable solutions for the diverse transportation needs of the Pacific Northwest. Major goals and objectives of PacTrans include serving as Region 10's research engine, applied technology showcase, workforce development base, education leader, information center, and collaboration platform.

MANAGEMENT STRUCTURE

The University of Washington serves as the lead institution in the PacTrans consortium. The PacTrans Center is located at More 112 on the UW campus. Dr. Yinhai Wang, Professor of transportation engineering in the Civil and Environmental Engineering Department, serves as Director of PacTrans. The management structure of PacTrans includes the director and staff, Board of Directors, and an External Advisory Board.

The PacTrans Board of Directors includes the PacTrans center director and associate directors from all five consortium universities. The Board of Directors meets in person on a quarterly basis to discuss matters pertaining to PacTrans research, education, outreach, workforce development, and technology transfer.

The PacTrans External Advisory Board (EAB), which is composed of nine members, includes directors from the research offices of the state DOTs in Region 10 and representatives from other transportation agencies, private industries, and communities. The role of the EAB is to provide input on PacTrans' strategic planning and outreach activities.

PACTRANS OPERATIONS TEAM FOR 2013-2014 FISCAL YEAR

Yinhai Wang, Director; Professor, UW Civil and Environmental Engineering Department, (206) 616-2696, yinhai@uw.edu

Linda Boyle, Associate Director of Research; Professor, UW Industrial and Systems Engineering Department and UW Civil and Environmental Engineering Department, (206) 616-0245, linda@uw.edu

Maria Bayya, Assistant Director, (206) 685-6648, bayyam@uw.edu

Elysse Reyna, Communications Manager, (206) 685-3894 elysse@uw.edu

Melanie Paredes, Interim Program Assistant, (206) 221-9290 melqcp@uw.edu

Matthew Dunlap, PacTrans Student Taskforce Leader, mkdunlap@uw.edu

Kristian Henrickson, PacTrans Graduate Assistant, henr2237@uw.edu

BOARD OF DIRECTORS FOR 2013-2014 FISCAL YEAR

Yinhai Wang, Director at University of Washington

Linda Boyle, Associate Director of Research at University of Washington

Chris A. Bell, Associate Director at Oregon State University

Ken Casavant, Associate Director at Washington State University

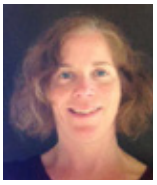
Billy Connor, Associate Director at the University of Alaska, Fairbanks

Mark Hallenbeck, Associate Director of Outreach, University of Washington

Anne Vernez-Moudon, Associate Director of Education, University of Washington

Ahmed Abdel-Rahim, Associate Director at the University of Idaho

EXTERNAL ADVISORY BOARD FOR 2013-2014 FISCAL YEAR



Carolyn Morehouse, Chief of Research, Development and Technology Transfer, Alaska Department of Transportation and Public Facilities

Michael Bufalino, Research Manager, Oregon Department of Transportation (ODOT)

Scott Drumm, Manager of Research & Strategic Analysis Dept., Port of Portland, Portland, Oregon

Charlie Howard, Director of Integrated Planning, Puget Sound Regional Council (PSRC)

Wayne Kittelson, Principal, Kittelson & Associates, Inc.

Edward Mantey, Vice President of Toyota Vehicle Planning, Corporate Strategy, Technical Administration

Rhonda Brooks, Acting Director of Research and Library Services, Washington State Department of Transportation

Ned Parrish, Research Program Manager for the Idaho Transportation Department (ITD)

Jerry Whitehead, Chairman of the Idaho Transportation Board

Highlights from 2013–14

PACTRANS AWARDED $5.2M TO CONTINUE AS USDOT REGION 10 UTC

The U.S. Department of Transportation announced June 18, 2014 that the University of Washington will receive $5.2 million in funding for the Pacific Northwest Transportation Center (PacTrans) to continue serving as the USDOT Region 10 University Transportation Center. The funding, which local and regional agencies matched for a total of $10.4 million, will support the center's focus on enhancing the safety of road users, transportation infrastructure and system operations in the Pacific Northwest.

PACTRANS REGION 10 CONFERENCE

The PacTrans Annual Conference on October 18, 2013, "Transportation Decision Making in the Big Data World," drew more than 160 participants representing Northwest transportation agencies, universities, and private-sector organizations from Alaska, Idaho, Oregon, and Washington. The conference allowed transportation leaders to review and update critical transportation issues for Region 10 and afforded PacTrans researchers a forum to share research ideas on data-driven solutions to transportation problems. PacTrans also showcased its research products for potential applications and technology transfer. Keynote speakers included Dr. Kumares Sinha, Purdue University, and Cam Gilmour, Deputy Secretary, Washington State Department of Transportation.

Clockwise from top left: Dr. Kumares Sinha, professor emeritus, Purdue University; Dr. Yinhai Wang, PacTrans director, welcomes conference attendees; Cam Gilmore, deputy secretary, Washington State Department of Transportation

REGION 10 STUDENT CONFERENCE

PacTrans and the University of Washington Student Chapter of the Institute of Transportation Engineers (ITE) jointly sponsored the Region 10 Student Conference on October 19, 2013. Organized by and for students from Region 10 schools, students selected three topic areas to focus on: data-based research, sustainability and the environment, and human factors in transportation. Randy McCourt, the president of DKS Associates, delivered the keynote speech, challenging student attendees to find and focus on aspects of transportation where their passions lie.

PACTRANS HOSTS TRANSPORTATION SAFETY WORKSHOP

More than 40 attendees representing the PacTrans Consortium universities and public and private agencies from Alaska, Idaho, Oregon, and Washington met on December 9, 2013 at the Talaris Conference Center near the University of Washington campus in Seattle. The program focused on safe road users, safe infrastructure, and safe operations. The goal was to gather input from all stakeholders to inform the direction of future PacTrans transportation safety research and workforce development activities.

PACTRANS AND WASHINGTON ITE HOST CO-SPONSORED SAFETY MEETING

On March 18, 2014 PacTrans and the Washington State chapter of the Institute of Transportation Engineers (ITE Washington) jointly hosted a meeting on the UW campus to discuss contemporary issues in transportation safety. Chris Madill, the Director of Program and Services at the Washington State Safety Commission spoke on Target Zero, Washington State's ambitious plan to reduce the number of annual traffic fatalities to zero by 2030. Matt Neely, WSDOT priority programming and scoping engineer, outlined the advantages of new techniques in analyzing stretches of road where collisions are frequent.

PACTRANS SEMINAR SERIES

PacTrans continued its seminar series to help generate discussions of important ongoing and future research and foster an exchange of information between transportation professionals and researchers. Each seminar talk is broadcast over the Internet as a webinar to offer cost-effective participation from remote sites in and beyond the region.

On November 13, 2013, Dr. Asad J. Khattak, Beaman Professor of Civil & Environmental Engineering and director of Safety Programs, Center for Transportation Research, at the University of Tennessee Knoxville, presented on "What Is the Level of Volatility in Instantaneous Driving Decisions?" His lecture examined a framework for understanding instantaneous decisions and explored volatility with the aim of developing a fundamental understanding of decisions.

Dr. Ruth Steiner, professor and director of the Center of Health and the Built Environment in the Department of Urban and Regional Planning and an affiliate faculty in the School of Natural Resources and Environment and the University of Florida Transportation Institute (UFTI) at the University of Florida, presented on "School Siting and Children's Travel: Siting to Support Active Transportation" on February 5, 2014.

Dr. Joe Schofer, Professor of Civil and Environmental Engineering and Associate Dean for Faculty Affairs of the Robert R. McCormick School of Engineering and Applied Science at Northwestern University, spoke on May 30, 2014 on "Making Transportation Analysis Count: Bridging the Gap between Politics and Planning." Dr. Schofer gave suggestions of how to persuade politicians and members of the public to provide transportation projects funding, and explained the many factors that go into project funding decisions.

CUTC AWARDS AND PACTRANS RECEPTION AT THE 93RD TRB ANNUAL MEETING

At the 2014 TRB Annual Meeting, PacTrans actively supported UTC related activities, hosting a Region 10 UTC reception and showcasing 85 technical presentations by PacTrans Researchers.

The PacTrans reception, hosted in partnership with Alaska University Transportation Center (AUTC), Oregon State University, Washington State University, and TranLIVE, brought together professionals, public officials, and students from all over the world. University of Washington PhD student Jonathan Corey received the Michael Kyte Region 10 Outstanding Student Award.

PacTrans was also represented at the Council of University Transportation Centers (CUTC) banquet, where University of Idaho student Andrew Hooper received the PacTrans SOY (Student of the Year) award for 2013.

University of Idaho graduate student Andrew Hooper (second from left) received the SOY Award at the CUTC Banquet, surrounded by RITA and CUTC leaders.

Shown from left) Professor Karen Den Braven (UI), Jonathan Corey (UW PhD candidate and winner of the 2013 Michael Kyte Award), Andrew Hooper (UI grad student and 2013 Student of the Year award winner for Region 10), and Dr. Yinhai Wang, PacTrans director.

Exchange meeting between PacTrans STAR Lab and the China Ministry of Transportation's Big Data Delegation on Sept. 4, 2014.

EXCHANGE VISITS BRING TOP INTERNATIONAL SCHOLARS AND OFFICIALS TO PACTRANS

Collaboration and education exchanges bring transportation scholars and officials from countries such as Denmark, China, Luxembourg, and Israel, and the Valle Scholarship and Scandinavian Exchange Program fosters cooperative international education among the University of Washington and Scandinavian institutions.

PACTRANS COLLABORATES WITH LOCAL PARTNERS

PacTrans works closely with transportation agencies in research, education and workforce development, and technology transfer. Agency representatives' input contributes to the strong regional focus and alignment of PacTrans' research programs with the goals of local transportation agencies.

Washington State Department of Transportation (WSDOT) officials meet with PacTrans Collaborations on August 6, 2014.

CUTC 2014 SUMMER MEETING

PacTrans participated in the CUTC 2014 Summer Meeting held in Lincoln, Nebraska June 2-5. Over 200 attendees from different University Transportation Centers across the country participated. Transportation professionals, administrators and educators came together to discuss and share state-of-the-art ideas and methods to advance research, education and development in the transportation field.

L-R: Denise Dunn, Tamara Noble and David Block.

PacTrans Welcomes New Faculty

The University of Washington and University of Alaska Fairbanks are excited to welcome four new faculty members. They join their respective universities with a strong mix of research, teaching, and professional experience.

Dr. Nathan Belz joined the University of Alaska Fairbanks in August 2013 as an assistant professor in the Civil and Environmental Engineering Department. Dr. Belz has an MS degree in civil engineering from the University of Maine and earned his PhD in civil engineering at the University of Vermont. His dissertation focused on using video-based real-world data of traffic operations at roundabouts to identify types of driver behavior that are inconsistent with the traffic theories on which existing models are based. These observations informed the development of a new cellular automata model to assess how incorrect traffic negotiations affect the overall efficiency and performance of roundabouts. He also brings expertise in transportation applications of geographic information systems, transit planning and travel behavior studies, livability and transportation issues in small urban and rural communities, and analysis of driver behavior using GPS and in-vehicle instrumentation. Dr. Belz looks forward to continuing his work on roundabouts, further focusing on the problems inherent to transportation in rural and cold climates, and developing new partnerships and collaborations in the Pacific Northwest region.

For more information about his research, contact Dr. Belz, **npbelz@alaska.edu**.

Dr. Don MacKenzie joined the Civil and Environmental Engineering Department at the UW as an assistant professor in 2013. His research focuses on the interactions of emerging transportation technologies and public policies, and their effects on energy consumption. He is working in three related areas: (1) modeling the charging decisions of electric vehicle drivers and implications for electric grid loads and generation emissions, (2) assessing prospective energy efficiency and travel demand implications of vehicle automation, and (3) evaluating the effects of services such as car sharing and online shopping on total travel demand.

Dr. MacKenzie previously did research and advocacy work on clean vehicles for the Union of Concerned Scientists in Washington, D.C., and worked as a researcher on biofuel technologies at a startup in Vancouver, B.C., Canada. He holds a PhD in engineering systems and a master's degree in technology and policy, both from MIT. He also holds a bachelor of applied science in chemical and biological engineering (environmental option) from the University of British Columbia.

For more information about his research, contact Dr. MacKenzie, **dwhm@uw.edu**.

Dr. Amy Kim joins the Civil and Environmental Engineering Department at the UW from Texas A&M University, where she earned her PhD. Earlier in her career she was a project engineer at Primera Engineers and an architect at DLA Architects, Ltd. Amy's research interests include investigating construction management issues for transportation projects. Her current research work investigates long-range strategic issues affecting preservation, maintenance, and renewal of highway infrastructure. Another research project involves developing a comprehensive and scalable scoping process to assist transportation agencies to improve on time and on budget delivery of highway projects.

For more information about her research, contact Dr. Kim, **amykim@uw.edu**.

Dr. Jessica Kaminsky joined the Civil and Environmental Engineering Department at the UW in January 2014. After receiving her BS in civil engineering from Rice University, she spent six years working in private industry in Montgomery, Chicago, and Sydney. Her PhD is from the Department of Civil, Environmental, and Architectural Engineering at the University of Colorado Boulder. While there Jessica won an EPA STAR Graduate Fellowship, a Mortenson Center of Engineering for Developing Communities Fellowship, a departmental fellowship and a dean's fellowship. Jessica's research focuses on the social sustainability of constructed infrastructure systems in the context of developing or otherwise underserved communities.

For more information about her research, contact Dr. Kaminsky, **jkaminsk@uw.edu**.

Research Success Stories

IMPROVING ARTERIAL OPERATIONS FOR ALL USERS – URBAN STREET PERFORMANCE MEASUREMENT FOR THE AUTO, BICYCLE, AND PEDESTRIAN

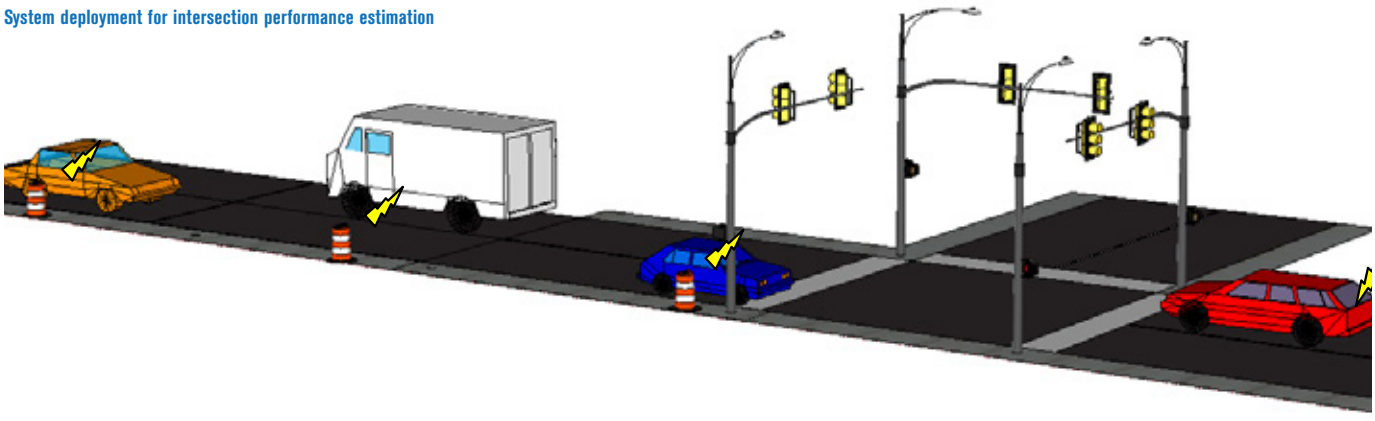
Analyzing transportation system performance to optimize users' travel experiences occupies a major part of transportation professionals' time and effort. Historically, performance measurement has been largely an off-line, labor intensive endeavor. This is gradually changing to leverage widespread communication systems and technological resources for sensing, data processing, and systems management. PacTrans researchers from University of Idaho, University of Washington, and Oregon State University collaborated to develop methods and technologies to gather data from multiple sources in order to enable a more complete understanding of arterial traffic safety and systems efficiency.

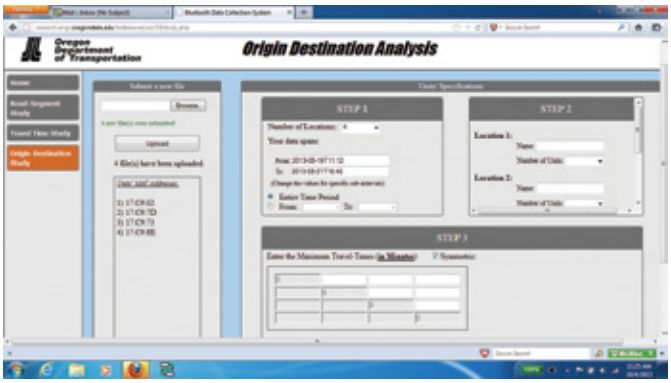
This PacTrans multi-institutional research effort documents development on five fronts for multi-modal transportation system performance measurement. Researchers developed a performance measurement development tool that leverages the advent of high resolution controller data. The research targets the use of high resolution controller data output from simulation to shorten the performance measurement development cycle. Researchers developed and tested a GIS tool to process sparse bicycle counts and estimate network wide link bicycle counts, enabling transportation agencies to predict bike usage throughout the network. Additionally, researchers developed a portable wireless Bluetooth data collection system that is much more cost effective for short-term studies than existing products on the market. Pedestrian performance measurement is so elusive that obtaining counts is challenging. Researchers developed an application for an off-the-shelf product to count pedestrians using the Microsoft Kinect video game sensor. Finally, researchers developed a method to estimate turning movement counts for most signalized intersections and some unsignalized intersections from lane-by-lane counts. This last development leverages common matrix analysis techniques to assess data collection plans for solution feasibility and provide a viable solution.

The outcome of the research project covered several product areas: 1) an open-source tool to monitor dynamic performance measures from high resolution traffic controller data, 2) a practical and accurate tool for estimating bike volumes, 3) cost-effective pedestrian detection, 4) inexpensive and quickly applied tools to extract probe vehicle data, and 5) a pragmatic approach to accurately estimate signalized intersection turning movements.

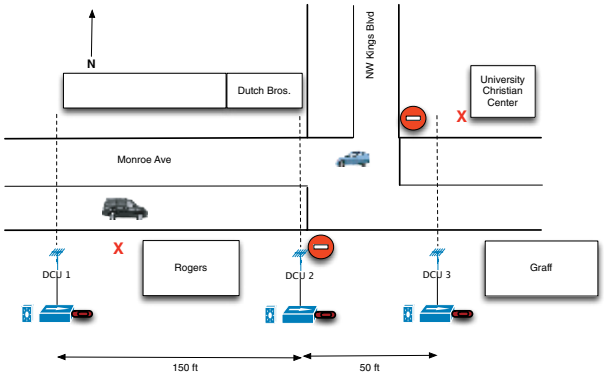
Chapter 2 of the project's final report proposes a tool that facilitates future performance measurement research related to traffic signal systems. The tool imports data from a simulation data source for experimentation in varied ideal settings or from field traffic signal systems for more rigorous application testing. Currently, imported traffic controller data are combined to produce dynamic performance measures, including the Purdue Coordination Diagram (PCD), Green Time Utilization (GTU), phase termination, and queue length/delay. These are integrated to be visualized with the PCD acting as the background. Additional measures and tasks can be supported by the tool's data import and various database functions.

System deployment for intersection performance estimation





Web application screen shot showing origin-destination data entry



Test setup for intersection performance data collection test

Chapter 3 uses origin-destination centrality to estimate directional bicycle volumes. Limited input data, simple site specific calibration, trivial modeling requirements, and practical accuracy make this method very attractive relative to proposed alternatives. This research also provides the tools to import and process input data, estimate bicycle volumes, and visualize results with add-on applications created for industry-standard off-the-shelf software.

Chapter 4 proposes an efficient pedestrian detection method for crowded scenes by combining RGB and depth images from Microsoft's® Kinect. While traditional image-based pedestrian detectors provide very rich information, their performance quickly degrades with increased occlusion. The 3D sensing capabilities of Microsoft's Kinect present a potential cost-effective solution for occlusion-robust pedestrian detection. The results of the study demonstrate the feasibility of using the low-cost Kinect device as a detection method for real-world pedestrian detection in crowded scenes.

Chapter 5 documents the research and development of an inexpensive portable wireless roadside data collection system using probe vehicles whose movements are monitored using Bluetooth technology. The system addresses industry needs for low-cost portable traffic monitoring and supports travel time, origin-destination, and delay performance measures. The research also reviewed the potential of Dynamic Short Range Communications (DSRC) to accomplish the same tasks and found that DSRC advantages include low-latency communications, broadcast messages, greater communication range (+200 m), and greater bandwidth. Limited availability and expense of supporting hardware are major disadvantages of the system, which will subside as technology adoption spreads.

Finally, chapter 6 presents a method that solves for turning movement volumes using Gauss-Jordan elimination row operations (e.g., row swapping, multiplying rows by non-zero constants, and adding a factor of one row to another row). The input data are phase status, lane-by-lane detector counts, and limited exit detector counts. The method evaluates existing intersection detector locations for their combined suitability to estimate turning movements and selects detection plans that minimize data requirements. It accommodates varying lane configurations, varying detector locations, and includes or excludes phase status. Because the method is founded on direct implementation of basic matrix analysis row operations, the solution is easy to implement. Three data sets validate the method's accuracy, with and without detection error, showing the method can be sufficiently accurate for professional applications in planning, design, and operations.

Arterial system performance measurement is important for assessing steps considered or taken to accomplish goals for greater community livability. Several tools and methods were developed to collect data, import data, process data, and to estimate performance measures. These tools were tested to prove their feasibility and each chapter provides an insightful and detailed evaluation of these products.

Contact: Dr. Ahmed Abdel-Rahim Email: **ahmed@uidaho.edu**

PACTRANS RESEARCH LEADS TO DIGITAL PLATFORM FOR TRANSPORTATION EDUCATION MATERIALS

There is national interest in reforming engineering education to improve global economic competitiveness. Agencies such as the National Science Foundation, the National Academies, and the Accreditation Board for Engineering and Technology have made substantial effort and progress towards improving educational methods in undergraduate engineering programs. An abundance of empirical research from multiple perspectives suggests that students should be engaged in activity during the lecture period; doing something other than listening. Students should be engaged with their peers in challenging conceptual exercises for a portion of each lecture period. Despite broad national interest and extensive empirical evidence, however, most faculty have made little or no changes to the way they design and offer courses.

The PacTrans Education Team is engaged in three coupled efforts to facilitate the improvement of transportation education. The first is the iterative development of the PacTrans Education Resource Center (PTERC), the second is research on how transportation faculty make decisions on educational resources they implement in their classrooms, and the third is to collect high quality educational materials that will be placed in the PTERC. The PTERC will be a web-based platform where faculty can share and search for materials they can utilize in their classroom.

We have conducted multiple rounds of feedback on the usability of the PTERC and developed an understanding of what size and type of materials faculty are interested in, and how users want to share, search for, and comment on curricular materials. Research on faculty decision-making utilizes established interview methods from educational psychology. We ask faculty about where they found or received materials that they considered for use in a transportation course they have taught, which portion of these materials they decided to use, and why they did or did not decide to use the materials. Findings indicate that faculty have a set of beliefs that affect the way they teach their courses and that dictate how they make decisions to adopt some materials and not others.

We have collected approximately 300 example educational materials from transportation faculty throughout the country that will be uploaded to the PTERC prior to launch. Users will be able to browse and search for these materials in a multitude of ways.

Utilizing all of the information gathered in the usability tests and our research on faculty decision making, we have collaboratively developed a full design specification for the PTERC. We are currently working on the design of the first widely shared version of the PTERC and it will be ready for use by the end of the calendar year.

Contact: Dr. Shane Brown Email: **shane.brown@oregonstate.edu**

EDUCATING TEENAGE DRIVERS IN THE PACIFIC NORTHWEST REGARDING THE DANGERS OF DISTRACTED DRIVING

Driver distraction describes the diversion of attention away from the driving task and is of particular concern among teenage drivers who exhibit greater crash risks when compared to drivers in other age groups. The goal of the PacTrans outreach project was to examine driver distraction among teenagers in the Pacific Northwest to identify tasks they consider to be distracting and compare that to their self-reported engagement in these same tasks while driving.

The research team included faculty from all five PacTrans member institutions: David Hurwitz (PI) Oregon State Univ., Ahmed Abdul-Rahim (Co-PI) Univ. of Idaho, Linda Boyle (Co-PI) Univ. of Washington, William Cofer (Co-PI) Washington State Univ., and Ghulam Bham (Co-PI) Univ. of Alaska Anchorage. Additionally, no fewer than five graduate students were funded and mentored throughout the course of the project.

The research team developed and administered an interactive presentation of distracted driving to high school and college students in the Pacific Northwest. Pre and post knowledge surveys were collected from approximately 3000 teenage drivers (750 students in each of the four states Oregon, Idaho, Washington, and Alaska). The interactive presentation and a facilitator's guide will be made available through the PacTrans website for further dissemination across the Pacific Northwest.

Contact: Dr. David Hurwitz Email: **david.hurwitz@oregonstate.edu**

UTC Spotlight

PACTRANS SPONSORED UNIVERSITY OF IDAHO'S NIATT STUDENT TEAMS: A WORKFORCE DEVELOPMENT AND TECHNOLOGY TRANSFER TOOL

After the University of Idaho (UI) Vandal Formula Hybrid Racing Team won a number of the 2014 National Formula Hybrid Competition's top awards, team members were asked to leave resumes with GM representatives and were invited by the Chrysler team for a site visit and job interviews, said the team's faculty adviser Dan Cordon. Over the past five years, the team has had seven students go on to work in the automobile industry. The University of Idaho's Clean Snowmobile Team, sponsored by PacTrans, has also seen three members go on to work in the automotive industry and ten work in the powersports industry in the last five years.

One of the reasons that the UI's National Institute for Advanced Transportation Technology (NIATT) team initiatives are such impressive and effective workforce development and career building tools is that these aren't simply a few weeks spent working on a project for a professor. A spot on the Formula Hybrid Racing Team or the Clean Snowmobile Team means working with students and professors from multiple disciplines for a year or more. Many students become involved as undergraduates and then carry on working with the team as graduates. This kind of sustained, focused involvement means students become familiar not only with the technology they are working with, but also with the tenor of the industry.

NIATT student Andrew Hooper, MS in Mechanical Engineering '13, was with UI's Clean Snowmobile Team for five years. During an interview following his team's win in 2013, Hooper, now a project engineer for Polaris, stated that working on the team is a "very big career-opportunity maker for a student."

The Clean Snowmobile team also continues to create new technology for a cleaner, quieter and more fuel efficient snowmobile, with several patents as a result. This technology is needed to support the winter economy in rural areas of the inland Northwest and Alaska, and has shown that it is possible to maintain environmental excellence in pristine areas while permitting winter motorized recreation.

The success of the UI's Snowmobile team reflects the transfer of PacTran's own technology in several ways, primarily through the hiring of its own students. Often the projects they work on when first hired are highly related to the projects they worked on as students with PacTran's research platforms. Some of the ideas that are implemented arise from discussions with the R&D personnel from the major powersports manufacturers. Once a proof of concept has been demonstrated on the vehicle, those manufacturers hire UI graduates who work on implementing those lessons learned in the next generation of powersports models currently in the design phase.

Working with a NIATT-sponsored team not only provides students with in-depth involvement with the transportation and automotive industry, it also encourages them to persist in that industry. Because of team members' early and often industry-level instruction in the practical aspects of their field, students feel confident to take on professional projects and enter the job market in their field.

Contact: Dr. Dan Cordon Email: **dcordon@uidaho.edu**

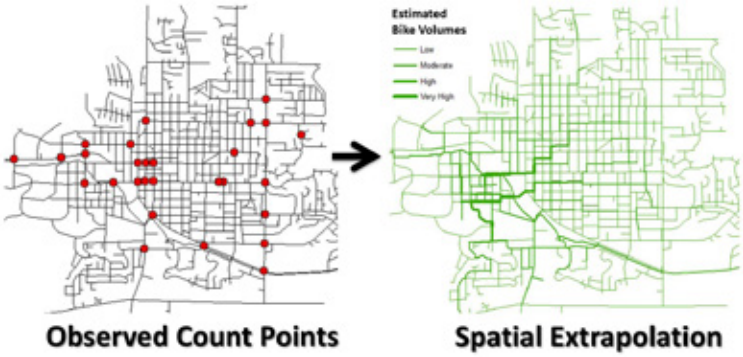
Research Highlights

DATA COLLECTION AND SPATIAL EXTRAPOLATION OF BICYCLE AND PEDESTRIAN DATA

This project, led by Dr. Michael Lowry at the University of Idaho, has developed a method to estimate Average Annual Daily Bicyclists (AADB) throughout a street network by spatially and temporally extrapolating observed two-hour bicycle counts that are collected through citizen-volunteer count programs.

The method can be used to compare different bi-cycle improvement scenarios. In addition, a framework has been created to compare improvement scenarios in terms of exposure to dangerous situations. This involves creating "dangerous situation metrics" through a public involvement process. For example, in the case study a metric was devised to study a dangerous situation known as the "right hook" a situation in which a high number of bicyclists are going straight through an intersection and a high volume of vehicles are turning right.

The proposed bicycle master plan presented to the case-study community would decrease the right hook exposure metric by 5%.



These tools are being tested in Moscow, Idaho, Bellingham and Seattle, Washington.

Contact: Dr. Michael Lowry Email: **mlowry@uidaho.edu**

TRADE-OFFS BETWEEN PUBLIC-PRIVATE PARTNERSHIPS (P3'S) AND DESIGN BID BUILD (DBB)

With the adoption of Moving Ahead for Progress in the 21st Century Act (MAP-21) and an almost ten-fold increase of the Transportation Infrastructure Finance and Innovation Act (TIFIA) lending program, the U.S. Congress signaled that the transport community should look to the private sector for transportation finance. But is this the right direction for our roads? Or, as others have suggested, might there be unintended consequences to public-private partnerships (P3's)?

photo courtesy of WSDOT

Today's value-for-money, shadow bid, or return on investment equations have not been designed to factor in the consequences of multiple shifts in legal rights and responsibilities commonly written into P3 agreements. This project uses a transaction cost economic measurement framework to make sense of trade-offs between P3's and the more traditional design bid build (DBB) option.

The fruit of a joint collaboration between two regional University Transportation Centers, this research will produce a methodology for comparatively evaluating the relative merits and disadvantages of projects procured through P3 and DBB in California, Oregon, Washington, Idaho, and Alaska. The study findings are intended to appeal to a broad audience including policymakers, their staff, and the public in order to help assist public discussions regarding transportation project finance.

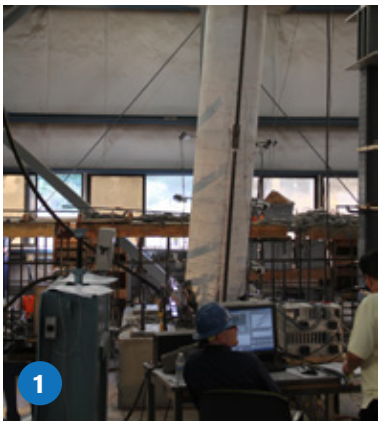
The two-year project targets research to the State of California and the Pacific Northwest States of Region 10, including Oregon, Washington, Idaho, and Alaska, making use of results from existing completed cases of side-by-side projects delivered traditionally and delivered through partnership agreements.

Contact: Dr. Jan Whittington Email: **janwhit@uw.edu**

SEISMIC PERFORMANCE OF CONCRETE BRIDGE COLUMNS MADE WITH HIGH-STRENGTH REINFORCEMENT

Although high-strength steel (HSS) reinforcement is commercially available, its use in transportation infrastructure systems, specifically bridges, is limited. Current bridge design codes in the West and Pacific Northwest (PNW) allow the use of HSS reinforcement in bridge decks, girders, and bents but do not allow HSS in members designed to develop a plastic hinge (i.e., bridge columns). In general, higher steel strengths lead to lower ductility values and this causes concern. Some reports have found that HSS reinforcement (ASTM A706 Grade 80) exhibits ductile properties similar to conventional reinforcement, but the American Association of State Highway and Transportation Officials (AASHTO) has concerns with the ductility in structural elements and other design challenges. Ductility concerns relate to lack of data on steel performance. Design challenges include lack of data for characterizing the reinforcing steel stress-strain models, lack of models for predicting low-cycle fatigue of the materials, and lack of confined concrete models, all of which are important issues in seismic regions in the West and PNW. Ground motions resulting from seismic events can have catastrophic consequences for transportation infrastructure systems. Of particular concern is the possible effect of future seismic ground motions (e.g., the Cascadia Subduction Zone). Subduction zone ground motions (i.e., long-duration motions) increase the probability that structures will be subjected to more inelastic cycles, which may in turn be subjected to low-cycle fatigue and early failures.

The current research is investigating the performance of six (6) reinforced concrete columns made with conventional and HSS reinforcement (3 each) subjected to cyclic loading simulating seismic events. The researchers are comparing the performance of these when subjected to cyclic loading. Figure 1 shows a concrete column reinforced with HSS and subjected to cyclic lateral loads—note that the column is exhibiting significant drift. Figure 2 shows the applied force versus drift of a column made with conventional reinforcement (C1) and a column made with HSS reinforcement (C2). Preliminary results indicate that columns containing HSS reinforcement exhibit similar structural capacity, a larger drift ratio before reinforcement fracture, and overall similar performance when compared to columns containing conventional reinforcement. HSS may be an effective alternative to conventional steel reinforcement for design of columns located in seismic regions.



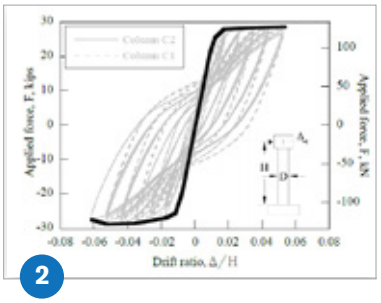


Figure 1: Reinforced concrete column with HSS subjected to lateral loads.

Figure 2: Applied force versus drift ratio for reinforced concrete columns containing conventional reinforcement (C1) and HSS reinforcement (C2).

Contact: Dr. David Trejo Email: **David.Trejo@oregonstate.edu**

BICYCLE AND PEDESTRIAN RESEARCH PROJECTS

The two projects, "Second Generation Accessible Pedestrian Systems" and "A Framework for Improved Safety and Accessibility through Pedestrian Guidance and Navigation," build upon previous research to improve the pedestrian interface at intersections.

The Second Generation Advanced Accessible Pedestrian System (AAPS II) was developed to offer additional capability and performance of the original AAPS system now being manufactured and distributed by Campbell Company of Boise, ID. The internet interface provides an efficient mechanism to customize the AAPS operations and allows traffic agency personnel enhanced capability for assessment of APS performance. The second generation hardware created a system where each pedestrian button can serve as an information center that can be used for non-contact pedestrian detection and tracking.

The second project on pedestrian guidance and navigation will use the AAPS in conjunction with a Smartphone and Bluetooth system to aid the visually impaired. The navigation device would alert pedestrians when they are about to stray into traffic, let them know how much further they have to reach the opposite curb, and possibly give them information about the geometry of the intersection. The use of Bluetooth instead of GPS would allow the setup to then be used for indoor navigation.

Contacts: Dr. Richard Wall, Email: **rwall@uidaho.edu**;
Dr. Denise Bauer Email: **dbauer@uidaho.edu**

Research Projects

The universities in the PacTrans consortium heavily invest in safety and environmental sustainability research to address transportation issues in the region and nationally. Our consortium has several sought-after data sources accumulated over many years of research that accounts for the users, vehicles, system network, roadway, and environment. Across the five universities, PacTrans has many researchers who are experts in all five of the Strategic Goals highlighted by the US DOT (safety, sustainability, state of good repair, livable communities, and economic competitiveness) whose expertise complements the PacTrans objectives of safety and sustainability.

The current PacTrans project portfolio is composed of projects of small, medium, and large scopes. The small projects are designed to help foster pilot research on new but promising concepts and ideas. The medium and large sized projects are designed to address research issues of regional importance and require two or more institutes to work together.

Research proposals are subject to a peer review process that is overseen by the PacTrans Board of Directors. The proposals are evaluated to determine technical merit, alignment with regional and national priorities, capabilities and resources of the research team, and project scope.

Upon completion of the research a draft technical report is submitted to PacTrans and is subject to a peer review prior to publication of the final report.

During its first year of operation, PacTrans funded a total of 22 research projects. All were new research.

PacTrans receives its funding from the USDOT via RITA to operate as the University Transportation Center (UTC) for Federal Region 10. Since UTC funds must be matched by non-federal sources on a 1:1 basis, all PacTrans research projects are required to provide match funds at least equal to the federal dollars allocated by PacTrans.

During its second year of operation, PacTrans funded a total of 32 research projects, of which 4 were continuing research projects started in the first year.

2012-2013 RESEARCH PROJECTS

Project Title	PI	Institution	Type
Characterization Of Frictional Int erference In Closely-Spaced Reinforcements In MSE Walls	**Armin W. Stuedlein**	OSU	SMALL
SSI-Bridge: Soil-Bridge Interaction During Long-Duration Earthquake Motions	**Ben Mason**	OSU	SMALL
PacTrans Education, Outreach and Administration Yr1	**Chris Bell**	OSU	Administration
Rendering Of Dense, Point Cloud Data In A High Fidelity Driving Simulator	**David Hurwitz**	OSU	SMALL
Educating Teenage Drivers In The Pacific Northwest Regarding The Dangers Of Distracted Driving (Phase I)	**David S. Hurwitz**	OSU	Multi-Outreach
Inspection, Assessment, Monitoring, and Renewal Strategies for Structures on Critical Lifeline Corridors – year 1 (2012-13)	**David Trejo**	OSU	Multi
The Use Of Synthetic Blended Fibers To Reduce Cracking Risk In High Performance Concrete	**Jason Ideker**	OSU	SMALL
Digital Dissemination Platform Of Transportation Engineering Education Materials	**Shane Brown**	OSU	Multi-Education
A Platform for Proactive Risk-Based Slope Asset Management– year 1 (2012-13)	**Andrew T. Metzger**	UAF	Multi
Estimating Future Flood Frequency and Magnitude in Basins Affected by Glacier Wastage – year 1 (2012-13)	**Anna Liljedahl**	UAF	SMALL
Phase II: Correlation Between Experimental And Finite Element Analysis Alaska Bridge 255- Chulitna River Bridge	**J. Leroy Hulsey**	UAF	SMALL
Investigation Of Anchor Nut Loosening In High-Mast Light Poles Using Field Monitoring And Finite Element Analysis	**Scott Hamel**	UAF	SMALL
PacTrans Education, Outreach and Administration	**William "Billy" Connor**	UAF	Administration
UI PacTrans Education, Outreach and Administration Budget (UI Project 2)	**Ahmed Abdel-Rahim**	UI	Administration
Performance Monitoring for Safe and Livable Communities: Fusing Data, to Improve Arterial Operations for All Users – year 1 (2012-13)	**Ahmed Abdel-Rahim -Michael Dixon (UI)**	UI	Multi UI LEAD
Production Of Renewable Diesel Fuel From Biologically Based Feedstocks	**Jon Van Gerpen**	UI	SMALL
Second Generation Accessible Pedestrian Systems	**Richard Wall**	UI	SMALL
Developing A Robust Survey Methodology For Collecting Information On The Port Truck Drayage Industry	**Anne Goodchild**	UW	SMALL
An Innovative Survey Design to Understand Sustainable Travel Behaviors – year 1 (2012-13)	**Cynthia Chen**	UW	Multi
Error Assessment For Emerging Traffic Data Collection Devices	**Edward McCormack**	UW	SMALL
Bicycle Route Choice: Gps Data Collection And Travel Model Development – Year 1 (2012-13)	**Qing Shen**	UW	SMALL
Assessment Of A New Screening Model For Use In Siting Near-Road NO2 Monitors	**Timothy Larson**	UW	SMALL
Laboratory Evaluation Of Recycled Concrete As Aggregate In New Concrete Pavements	**Haifang Wen**	WSU	SMALL
PacTrans Education, Outreach and Administration (Year 1 Project 1)	**Kenneth Casavant**	WSU	Administration
Developing a Performance Measurement Approach to Benefit/Cost Freight Project Prioritization – year 1 (2012-13)	**Kenneth Casavant**	WSU	Multi
Media Filter Drain: Modified Design Evaluation	**Liv Hasselbach**	WSU	SMALL

YEAR TWO RESEARCH PROJECTS

- **Project:** Behavior of Drilled Shafts with High-Strength Reinforcement and Casing
- **PI:** Armin W. Stuedlein (OSU)
- **Co-Investigators:** Pedro Arduino (UW)

Drilled shafts provide significant geotechnical resistance for support of highway bridges, and are used throughout the States of Oregon and Washington to meet their structural foundation requirements. Due to changes in construction methods and poor near-surface soils, the use of permanent steel casing for drilled shaft installation has increased. However, geotechnical design models for axial and lateral resistance of drilled shafts are largely based on soil-concrete interfaces, not soil-steel interfaces associated with large diameter steel casing. Owing to the increased understanding of our regional seismic hazards, the amount of steel reinforcement used in drilled shaft construction has increased over the past several decades, creating a new construction concern for engineers: the increased steel area results in a reduced clearance between adjacent reinforcement bars in the steel cage, such that concrete has an increased difficulty in penetrating the cage, increasing the likelihood for voids and defects within the shaft, which can lead to poor structural and geotechnical performance. The use of high-strength reinforcement steel can lead to increased clearance within the steel cage, mitigating concreting issues. The use of steel casing and the amount of steel area control the axial and lateral resistance of the shaft. However, depending on the method of construction, the steel casing may result in reduced axial load transfer to the surrounding soil. Thus existing analytical approaches need to be evaluated for modern construction methods, and new approaches developed if necessary to ensure desired performance criteria are met.

- **Project:** Performance-Measure Based Asset Management Tool for Rural Freight Mobility in the Pacific Northwest
- **PI:** Jeremy Sage (WSU)
- **Co-Investigators:** Ahmed Abdel-Rahim (UI), Kenneth Casavant (WSU)

Moving Ahead for Progress in the 21st Century (MAP-21) establishes national objectives to increase productivity and economic efficiency of the nation's freight infrastructure. The recent passage of MAP-21 has placed an emphasis on integrating asset and performance management tools to help transportation agencies better manage the critical transportation infrastructure. Infrastructure performance management expands the more traditional definition of Asset Management to include measurement and reporting of how those assets achieve their targeted operational objectives. While congestion and bottlenecks in urbanized areas readily, and deservedly, catch the attention of policy makers, many miles of multimodal transportation occur prior to freight trips arriving in (or accrue after leaving) urban areas. These miles and the ability to efficiently navigate them directly impact the productivity of the region's diverse transportation system. This project identifies and seeks to remedy performance measure gaps and freight mobility issues as they relate to identifying the appropriate infrastructure capacity to meet demand for both domestic and international economic competitiveness.

- **Project:** A Platform for Proactive Risk-based Slope Asset Management Phase II
- **PI:** Keith Cunningham (UAF)
- **Co-Investigators:** Michael J. Olsen (OSU), Joseph Wartman (UW)

Unstable slopes, including coherent landslides, rock falls, and debris flows, present significant risk to safety and regional commerce. This risk is a long-term concern that highway managers contend with on an on-going basis. The widespread spatial and temporal distribution of these landslides poses a number of challenges when deciding when, where, and how to allocate funds for mitigation efforts to maintain these assets. This challenge is compounded by the high level of effort currently required to survey, inspect and sample slopes for the purpose of condition assessment as part of an asset management program. Slope assessment has traditionally been costly and laborious, limiting it to a few sites. However, routine assessment is altogether necessary due to the potential consequences of a failure. Current best-practices for management do not necessarily facilitate proactive slope management – identifying and remediating hazardous conditions before a failure occurs. Current inventory systems are time consuming to complete (years) and generally only provide basic information after a collapse has occurred and likely caused damage. As such, they do not provide an understanding of how risk varies with time and location. However, a proactive, near-automated approach for the identification of possibly unstable locations prior to catastrophic failure offers the potential to significantly enhance public safety and reduce overall operation and repair costs. Advanced technologies such as Mobile Laser scanning (MLS) show great promise in quickly and frequently assessing large sections of highway. Time-series datasets from the MLS system enable remote assessment of slope stability with a higher level of confidence than current probabilistic studies based on inventories due to a significantly higher spatial and temporal resolution achievable with MLS. The scope of the current PACTRANS-funded project Phase I, entitled "A Platform for Proactive Risk-based Slope Assessment" includes the development of qualitative relative risk model for slope stability assessment using terrain models created from MLS data. In the second phase of the work, we will focus on quantitative time-series analysis using MLS data and integrating this information into the model developed in the first phase of research and into an agency's transportation asset/ performance management program.

- **Project:** High Performance Bridge Systems for Lifeline Corridors in the Pacific Northwest
- **PI:** Marc Eberhard (UW)
- **Co-Investigators:** Andre Barbosa (OSU), Dawn Lehman (UW), Charles Roeder (UW), John Stanton (UW), David Trejo (OSU)

Reinforced concrete bridges in seismic regions have changed little since the mid-1970s, when ductile details were first introduced. Nearly all bents (intermediate supports) are constructed of cast-in-place reinforced concrete and conventional reinforcing steel. Such bridges have served the Pacific Northwest (PNW) well in the past, but to meet current performance expectations, new structural systems are needed to improve: seismic resilience, speed of construction, durability, and life-cycle costs. Improving seismic performance increases the safety of the travelling public, both by reducing the possibility of collapse and also, by allowing emergency vehicles to use the structure immediately following an earthquake. Reducing the onsite construction time further improves safety by reducing the amount of time that workers will be exposed to traffic hazards. It is not enough to develop new systems. Once these new systems have been developed, it will be necessary from bridge engineers to have sufficient information to be able to select the appropriate one for a particular application.

- **Project:** Data Collection and Spatial Interpolation of Bicycle and Pedestrian Data
- **PI:** Michael Lowry (UI)
- **Co-Investigators:** Yinhai Wang (UW), Mike Dixon (UI), Ahmed-Abdel Rahim (UI), Mark Hallenbeck (UW)

It is very difficult to measure safety without knowing how many people use a facility. For this reason, millions of dollars and decades of research have sought to estimate and forecast travel demand, such as through the ubiquitous 4-step model. Unfortunately, existing methods are lousy for estimating pedestrian and bicycle volumes. In fact, most agencies forego expensive, data-intensive models and instead resort to simply using expert judgment when estimating pedestrian and bicycle volumes. Cities and state DOTs struggle to collect and utilize pedestrian and bicycle data in an effective and meaningful way.

This project will create new planning tools to estimate and forecast pedestrian and bicycle volumes. Local agencies and state DOTs can use the tools to help improve safety, prioritize capital improvement projects, and create transportation plans that improve overall quality of life by enhancing these modes.

- **Project:** Educating Teenage Drivers in the Pacific Northwest Regarding the Dangers of Distracted Driving Phase II
- **PI:** David S. Hurwitz (OSU)
- **Co-Investigators:** Linda Boyle (UW), Ahmed Abdel-Rahim (UI), Ghulam Bham (UAF), William Cofer (WSU)

Driver distraction can be defined as the diversion of driver attention away from the driving task, and it can result from factors both within and outside of the vehicle (Sheridan, 2004). It can include anything that distracts a driver from the primary task of driving and has been categorized as follows: visual (e.g. reading a map), auditory (e.g., listening to a conversation), biomechanical (e.g., tuning a radio), and cognitive (e.g. 'being lost in thought,' and 'looking but not seeing') (Ranney et al., 2000). Most distractions are actually a combination of these, thus it may be more useful to categorize distractions according to the task that drivers are engaged in while driving (rather than the combination of the forms of distractions). For example, cell phones are associated with cognitive, auditory, biomechanical, and potentially, visual distractions. Both the attentional demands placed on the driver by a secondary task and the driver's willingness to engage in that task contributes to the potential for driver distraction and thus increases the likelihood of crashes (Donmez et al., 2006). A distracted driver may also make riskier decisions. As observed by Cooper et al. (2003), distracted drivers made left hand turns with smaller gap acceptance than drivers who were not distracted. As teenage drivers gain moderate levels of experience, they also tend to have greater crash risks related to driver distraction when compared to drivers in other age groups (Lam, 2002). One proposed explanation for this is that younger drivers appear more willing to accept new technologies and devices than other drivers. As younger drivers become confident in their driving abilities, they tend to overestimate their ability to multitask with these devices while driving (Sarkar and Andreas, 2004). Poysti et al. (2005) also found that young drivers, from 18-to 24 years old, were more likely to use their cell phones while driving than middle aged drivers. The goal of the study is to examine driver distraction among teenagers including what tasks they consider to be distracting as compared to their level of engagement in these same distracting tasks. This study differs from other studies in that a follow-up period will be used to identify differences in response based on feedback and education on distraction.

- **Project:** Refinement and Dissemination of a Digital Platform for Sharing Transportation Education Materials
- **PIs:** Kevin Chang (UI) and Ahmed Abdel-Rahim (UI)
- **Co-Investigators:** Shane Brown (OSU), David Hurwitz (OSU), Bill Cofer (WSU), Robert Perkins (UAF), Linda Boyle (UW)

National interest abounds in improving engineering education stemming from concerns over the role of the US as a national economic leader (NRC 1999; NRC 1999), low performance on concept inventories (Hestenes, Wells et al. 1992; Olds, Streveler et al. 2004; Gray, Costanzo et al. 2005; Allen 2006), and a sense that we can improve the state-of-the-practice. These concerns have led to the development of an abundance of materials and methods that have been shown to be an effective means of improving student learning and other important educational outcomes. While progress has been made improving courses and curriculum, it is greatly hindered by inefficiencies associated with duplicating development efforts. For example, there are approximately 200 introduction to transportation engineering courses taught annually in the US and little evidence to suggest that teaching materials (other than textbooks) are being shared between the instructors of these courses. The National Science Foundation (NSF) spends millions of dollars annually through the Transforming Undergraduate Education (TUES) (NSF 2012) in the STEM program on the development and testing of teaching methods and materials. Conversations with NSF program managers indicate that they are disappointed with the rate of return on this investment, and would like to see much less development and much more sharing and dissemination of best practices. New NSF programs are emerging specifically on utilizing best practices and understanding the adoption process.

- **Project:** Smartphone-Based System for Automated Detection of Walking
- **PI:** Philip Hurvitz (UW)

Walking is the most effective mode of travel to access transit: transit hubs with higher residential and employment densities have higher ridership levels because they serve areas where a large population is within a short walk of transit service. Walking has additional benefits: it is well-known as a low impact mode of travel for short trips to and from, as well as within, commercial areas; and it is the most popular form of physical activity. However, current data on walking are notoriously poor. Travel surveys and diaries underestimate walking activity and lack information on walking paths taken, thereby undermining transportation policies that can encourage sustainable travel. Objective data on how often, how long and where people walk are essential to support environmentally friendly and safe transportation systems.

- **Project:** Field Validation of Recycled Concrete Fines Usage
- **PI:** Donald Janssen (UW)

A system for quantifying waste fines in a ready-mix concrete plant's waste-water recirculation system will be designed, fabricated, and installed at the Stoneway Readymix Concrete Plant (in the Seattle area). Concrete mixtures produced at this plant will then be evaluated to document the effects of the waste fines optimization procedures.

- **Project:** Testing of Cavity Attenuation Phase Shift Technology For Siting Near-Road NO2 Monitors
- **PI:** Tim Larson (UW)

Recent research has identified the public health importance of air pollution exposures near busy roadways. As a result, the Environmental Protection Agency (EPA) significantly revised its Nitric oxide (NO2) air quality standard in 2010. The current regulatory focus has shifted from assessment of longer-term (annual average) NO2 concentrations measured at locations away from busy roads to shorter-term (1-hour average) concentrations measured at locations near busy roads. Even though EPA has developed extensive guidelines for siting traditional air quality monitors that are located relatively far from roads, their siting guidance for near-road NO2 monitors is not yet officially established. Therefore this project proposes to test a more direct approach to siting near-road NO2 sampling locations using a state-of-the-art NO2 monitor that is no more expensive than traditional EPA chemiluminesce-base monitors, is much more readily deployed on a mobile platform, and can ultimately be used as the regulatory monitor at the official sampling location.

- **Project:** Identifying and Analyzing the Relative Advantages and Disadvantages of Public-Private Partnerships and Traditional Delivery for Roadway Projects
- **PI:** Jan Whittington (UW)

With the recent adoption of Moving Ahead for Progress in the 21st Century (MAP-21), the U.S. Congress sent out a clarion call to the transport community that all roads should lead to private sector financing of our infrastructure. Congress increased the key transport lending tool, the TIFIA program, almost ten-fold to $1 billion in the second year of the authorization bill to spur private participation. The Wall Street Journal further laid out to the financial sector and its readership, "Private investment in America's transportation systems through public private partnerships (PPPs) has the potential to expand, revitalize and rationalize our infrastructure. With the right policies, that can happen. Motorists, truckers, shippers and private investors all stand to benefit." This project aims to assess the advantages and disadvantages of Public-Private Partnerships (P3) in comparison to traditional forms of project delivery and financing (DBB). The project targets research to the State of California and the Pacific Northwest States of Region 10, including Oregon, Washington, Idaho, and Alaska, making use of results from existing completed cases of side-by-side projects delivered traditionally and delivered through partnership agreements.

- **Project:** Changing Retail Business Models and the Impact on CO2 Emissions from Transport: E-commerce Deliveries in Urban and Rural Areas
- **PI:** Anne Goodchild (UW)

E-commerce currently represents approximately 8% of total shopping, up from 6% only 5 years ago with a compound annual growth rate of approximately 9% (Mulpuru et al. 2008, 2013). Online shopping is growing at a faster rate than traditional retailing, and presents a new model for freight transportation. By eliminating stores, e-commerce results in a more streamlined supply chain, often ending in residential rather than commercial locations. In addition, e-commerce often bypasses commercial locations, relying instead on more distribution and warehousing facilities. This project will build on previous work, which examined the carbon dioxide (CO2) impacts of grocery delivery in the city of Seattle and will examine the CO2 and criteria pollutant implications for serving e-commerce customers in rural areas. The earlier work garnered broad attention as it found significant reductions in CO2 emissions were possible when delivery services replaced personal travel, offering a sustainability advantage with online shopping. The largest reductions were observed when delivery services served geographically clustered customers. The work proposed here will look at a variety of previously unexamined customer densities, road connectivity, and depot proximities to better understand the environmental impacts of e-commerce over a broader set of land use patterns, including both rural and urban development. This will allow us to understand how the earlier findings apply more universally.

- **Project:** Encouraging Young Civil Engineers: Support for the UAF College of Engineering and Mines Steel Bridge Team Competition Steel Bridge
- **PI:** Leory Hulsey (UAF)

The University of Alaska, Fairbanks (UAF) has a long and successful history competing in the American Society of Civil Engineers (ASCE) Steel Bridge Competition. In this competition, university students design and construct a small steel bridge that meets criteria established by the competition committee. Students learn to apply the knowledge learned in the classroom to an actual design project which they then construct. Not only do students learn application of structural design, but they learn constructability issues, scheduling, estimating and costing principles, and personnel management. Many of these students work for the Alaska Department of Transportation and Public Facilities (ADOT&PF) after graduation. Dr. Leroy Hulsey is the team faculty adviser. Funds will provide materials for the competition.

- **Project:** Roundabout Design Training for Alaska's Engineers
- **PI:** Nathan Belz (UAF)

Roundabout are an emerging type of intersection design, are a relatively new addition to the transportation system in the United States. As a result, guidelines for roundabout design and construction are very broad and leave much room for subjectivity. This can result in roundabout designs with performance and safety well below the level that was anticipated. Peer review of roundabout designs is one way of controlling this. As the peer review of designs becomes more popular, it is apparent that there is a need to develop a proper procedure for and identification of critical elements that should be checked during this review process. Without such standards, the effectiveness of these reviews may be compromised. Further, the application and design of roundabouts is still evolving. As such, it is critically important that planners and engineers are kept up-to-date with the "state-of-the-art" and "best practices" for roundabout design so that these intersections will positively contribute to the transportation system.

- **Project:** Improving Performance, Knowledge, and Methods to Provide Quality Service and Products
- **PI:** Billy Conner (UAF)

The "Strategic Plan" of the Alaska Department of Transportation & Public Facilities (DOT&PF) establishes "Excellence" as one of the department's core values, and defines it as "Personal and department commitment to continually improve individual, team, and organizational knowledge, performance, and methods to provide quality service and products". The extent to which this core value is exercised in practice is a function of the interpretation of this definition and inherent commitment, which are reflected in organizational culture. Unfortunately, a unifying organizational "culture of excellence" and the associated prioritized sense of what needs improvement within the DOT&PF has not fully evolved. Consequently, those that seek to promote "excellence" often face multiple questions and points of resistance, such as: (1) Priorities that conflict with improvement opportunities; (2) Low awareness of technologies, solutions, research, and best practices; (3) Poorly planned, prioritized, and targeted deployment efforts; (4) Lack of resources available for deploying improvements – including funding and training; and (5) Policies, procedures, and/or practices that are inconsistent with promoting excellence, deploying innovation, and continuous improvement.

- **Project:** Evaluate Presawn Transverse Thermal Cracks for Asphalt Concrete Pavement
- **PI:** Jenny Liu (UAF)

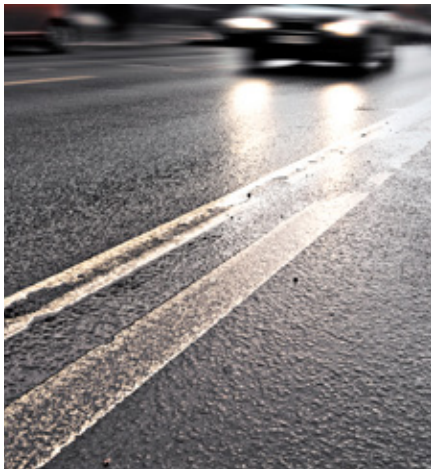
Many states are faced with the challenges of aging and degrading roadway pavements, and low temperature cracking is one of the most prevalent pavement distresses found in Alaska and in cold areas of other northern states. This requires significant repair efforts to maintain an acceptable pavement condition. The low temperature cracks are extensive enough that a significant portion of the Department of Transportation (DOT) Maintenance and Operations budget is allocated to sealing and the associated work required to repair low temperature cracking. Until new technology may someday eliminate cracking, significant funds will continue to be spent on crack sealing and repair. Innovative and cost-effective approaches and techniques to preserve and maintain existing highway systems (other than "worst first") are needed. Presawing of thermal cracks has provided promising results in controlling pavement degradation usually associated with natural thermal cracking, according to the field observation from a few asphalt concrete (AC) pavement projects in Alaska. However, a systematic approach has not been developed to implement optimum application of this technique in AC pavements, especially when the thermal cracking actually involves both the AC layer as well as the underlying aggregate.

- **Project:** The Value of Depressed Medians on Divided Highways in Alaska
- **PI:** Guhlam Bham (UAF)

The population of Alaska especially the city of Anchorage is steadily increasing. As a result, traffic volumes are higher and demands to add lanes to existing highways is increasing in order to relieve congestion. In Alaska, an expressway or freeway is a high-speed (U 50 mph), multilane, divided highway with partial access control. These divided highways typically utilize wide medians. These medians are considered an option to be replace with narrow medians in order to provide additional through lanes to cater to the needs of higher traffic volume and keep traffic congestion to a minimum. During the Alaska winter where snow accumulates in medians from October to April, drivers can lose control of their vehicles in slippery road conditions; however, these wide medians with heavy snow serve as a refuge to absorb the impact of a crash. The damage to a vehicle and its occupants can be minimal as a result. If the existing wide medians are used to construct additional lanes, these wide medians will no longer be available to act as safety cushions. On the contrary, a narrow median will mainly act as a barrier to separate vehicles traveling in the opposite direction. Without a depressed median (a vee ditch), single vehicle run-off-road crashes could evolve into multi-vehicle crashes among vehicles traveling in the same direction. These depressed wide medians also act as snow storage areas, allowing snow to be plowed on both sides of the road. Eliminating these medians will reduce the available snow storage space and require plowing all of the snow to the right and increase the snow load to one side of the road. A study is proposed that will examine the operational and safety benefits of 1) keep existing wide medians, and 2) replace existing medians with a) concrete barriers, b) high tensioned cable barriers, and c) another feasible alternative. Modern protective devices, such as cable barriers, offer protection with a lower risk of vehicle damage and personal injury than do traditional concrete barriers and guardrails. The study will evaluate the benefits of travel way that is safer to use. Further, the study will examine the benefits of higher traffic volume with minimal congestion to the cost of construction of additional lanes and property damage to vehicles as a result of collision with different types of barriers.

- **Project:** Evaluate H2RI Wicking Fabric for Pavement Applications
- **PIs:** Bill Conner and Xiong Zhang (UAF)

H2Ri wicking fabric is a new geotextile manufactured by TenCate Geosynthetics. It contains both a high modulus polypropylene yarn for reinforcement and a nylon wicking yarn which can absorb and transport water for drainage under unsaturated conditions. Therefore, H2Ri is a dual functional geosynthetic product, which can serve as reinforcement and provide drainage. When properly designed, it has the potential to dehydrate the subgrade and base course and consequently improve the performance of pavements. This potential has been qualitatively confirmed by a laboratory research performed at the University of Alaska Fairbanks and a small test section constructed on the Dalton Highway at mile 110, AKA "Beaver Slide" in Alaska. However, there is no method available to quantify and incorporate the benefits of H2Ri into a pavement design. There are several key questions remain unanswered such as: How far does the H2Ri wicking fabric can transport water? How much is the water transport rate? What is the range of the water removal in the vertical direction? This proposed research is trying to answer these questions so that the benefit of the H2Ri wicking fabric can be incorporated in to design.



- **Project:** Assessment of Lube Oil Management and Self-Cleaning Oil Filter Feasibility in WSF(WA State Ferries)Vessels
- **PI:** Liv Haselbach (WSU)

Lube oil management aboard vessels is a critical component of maintaining the life of a vessel engine. Lube oil and the associated filters are expensive as is the maintenance and associated downtime. Disposal of filters as a hazardous waste and handling of lube oil presents an environmental risk and additional costs. Preventive and predictive management of lube oil can reduce lube oil maintenance costs and environmental risk, making the operation of Washington State Ferries (WSF) vessels more sustainable and cost effective. To gain these benefits WSF needs to consider both the economic and the environmental impacts of the self-cleaning oil filters alternative. This research proposal is part of a larger, stepwise effort which asks the following questions: (1) Can self-cleaning oil filters be retrofitted on WSF vessels providing the same level or better of contaminant removal as paper filters? (2) Is the use of self-cleaning oil filters a cost effective solution that reduces environmental risks? (3) Will self-cleaning filters save money by extending maintenance change out lube oil periods and reducing environmental disposal costs and risks? (4) Can improved monitoring and analysis of lube oil lengthen the time period between lube oil changes while maintaining the life of the engine?

- **Project:** NDE System for Determining Wood Guardrail Post Integrity
- **PI:** Donald A. Bender (WSU)

Wood guardrail posts degrade over time due to decay, insects and weathering, and the Washington State Department of Transportation (WSDOT) needs an inspection system to determine the condition of posts along our highways to effectively prioritize future investments in guardrail upgrades. There are approximately 1.5 to 2 million guardrail posts on the state highway system. Post inspection methods at WSDOT have never been uniformly defined, and the inspection opportunities have normally been associated with pavement preservation projects. Combined with a parallel WSDOT study, the goal is to develop a reliable, cost-effective nondestructive evaluation (NDE) procedure for inspecting wood guardrail posts. The proposed stress wave NDE system will address deficiencies in current equipment with regard to ease of use and worker safety; efficient ways to acquire/store/transmit data; along with heuristics to interpret data and guide decision-making on guardrail maintenance and replacement. Specific objectives are to: (1) Work with an industrial partner on a new prototype stress wave instrument with features to consistently initiate stress waves; inspect posts below grade; store stress wave transit times, global positioning system (GPS) coordinates and time; and transmit data to a cloud server. (2) Characterize the prediction accuracy and reliability of the proposed NDE system. (3) Work with WSDOT representatives to integrate NDE data collected in the field into their geographic information system (GIS) system to help guide maintenance decisions with other GIS layers of information. (4) Conduct field trials and time-motion studies to obtain worker feedback with regard to training, ease of use, safety implications and feedback for improving the system.

- **Project:** Development of a Durable Asphalt Mix for Eastern Washington and Mountain Passes
- **PI:** Haifang Wen (WSU)

The pavements in the State of Washington witnessed great differences in performance, depending on the climatic zones. The climate west of the Cascade (referred to as West) is generally mild with wet winters. The climate in east of the Cascade (referred to as East) is drier with more extreme temperatures which often drop below freezing during winter. Studded tires are widely used in this area during winter time, creating additional damage (rutting and abrasion) to the hot mix asphalt (HMA) pavements. The climate within Cascade Range (referred to as mountain passes) is mild in summer but much severe in winter with frequent snow and freezing conditions. The average lives of pavements within West (16.7 years) are significantly longer than those in East (10.9 years) or Mountain pass (as low as 5 years). In addition, there seems to have more catastrophic failures of pavements in Mountain Pass, such as SR 12 (Weston et al.).

- **Project:** Enhancing the Resilience of Idaho's Transportation Network to Natural Hazards and Climate Change
- **PI:** Tim Frazier (UI)

The goals of this research are to determine both the process (i.e., methodology) and the technology (i.e., models) through which the vulnerability science community may provide value on critical and pervasive hazard risk-related issues to state and regional decision makers in Idaho for the purpose of transportation infrastructure resilience enhancement. To achieve the research goals, this study will conduct a probabilistic risk and vulnerability assessment of the state's transportation network to current and future hazards with a special focus on increased flooding and landslide hazards associated with climate variability and change. Upon completion of the vulnerability assessment, mitigation and adaptation strategies will be developed in collaboration with the Idaho Department of Transportation (IDOT) and the Idaho Bureau of Homeland Security (IBHS) for the purpose of reducing negative impacts associated with current and future geophysical phenomenon. The research will have three phases: 1) Conduct a hazards and climate change vulnerability assessment to determine current and future threats to the state's transportation network; 2) Conduct a needs assessment with IDOT and IBHS to determine short and long-term mitigation and adaptation opportunities and constraints; 3) Presentation of results. By the end of the proposal year, the researcher will have developed a methodology and research results that will determine the vulnerability of the state of Idaho's transportation network to current geophysical hazards and future hazards associated with climate change impacts. Overall, the proposed research is expected to produce the following outcomes: (1) Geographic information system (GIS) modeling to determine the vulnerability of the state's transportation network geophysical hazards. (2) A framework for determining opportunities and constraints for transportation mitigation strategies. (3) A short and long range plan for the implementation of mitigation and adaptation strategies to enhance the resilience of Idaho's transportation network. (4) Process evaluation by research stakeholders.

- **Project:** Modeling Passing Behavior on Two-Lane Rural Highways: Evaluating Crash Risk under Different Geometric Condition
- **PI:** Michael Dixon (UI)

Passing maneuvers on rural two-lane highways are a complex task with a significant effect on safety, capacity, and service quality. This maneuver, which involves driving in the lane of the opposing traffic, is associated with simultaneously increasing crash risk and increasing the driver's speed. Understanding drivers' passing behavior and their decision-making on two-lane rural highways can significantly contribute to accurately predicting risk and service quality. Only limited research has been conducted to capture and document drivers' perception of when they need to pass and passing decision-making. This is partly because it is difficult to collect detailed

data on driver perceptions and passing behavior in the real-world environment. Furthermore, field studies offer little control over the intervening variables, and usually no information on the drivers being observed. Evidence showing the effects of this limited research lies in recent work assessing passing sight distance (PSD) standards for two-lane highways in two preeminent manuals. One is the American Association of State Highway and Transportation Officials (AASHTO) Green Book, which states minimum PSD and the other is the Manual on Uniform Traffic Control Devices (MUTCD). Marking of passing and no-passing zones is based on PSD criteria presented in the MUTCD. The National Highway Cooperative Highway Research Program (NCHRP) Report 605 presented recommendations regarding current procedures and guidelines used to estimate minimum PSD requirements for highway design and pavement marking. The report concluded that the MUTCD PSD criteria for marking passing and no-passing zones should also be used for PSD design. It also concluded that although the longer AASHTO PSD criteria might provide improved traffic operational efficiency, the AASHTO PSD are so long they are often impractical. As a result of the report recommendations, the PSD values in the 2011 AASHTO green book were modified and brought closer to the MUTCD PSD values. The field data used to validate different PSD models in NCHRP 605 was based on video data collection. Videos were used to study distance traveled by the passing vehicle in the opposing lane, the speed differential between the passed and passing vehicles, and the deceleration rate used by the passing vehicle when the passing maneuver was aborted. No relationship was established between driver perception of quality of service, passing behavior, and the present highway conditions. Finally, the only tool available for estimating two-lane highway performance resides in the Highway Capacity Manual (HCM). This tool is not based on any relationship between observed user perception, documented driver passing behavior, and two lane highway conditions. As a result, the Transportation Research Board's Committee on Highway Capacity & Quality of Service identified researching two-lane highway traffic operations as a high priority research subject, as did the American AASHTO.

- **Project:** A Framework for Improved Safety and Accessibility through Pedestrian Guidance and Navigation
- **PI:** Denise Bauer (UI)

With the changes in America's demographics comes a need to provide improved accommodation of individuals with reduced capabilities. To date, our research has focused upon assistive pedestrian signal technologies for pedestrians with impaired vision. Such individuals must learn to cross complex intersections safely using a range of sensory inputs, including auditory cues from traffic surge and beaconing systems. Unfortunately, reduced vehicle noise, particularly for hybrid or electric vehicles, combined with increases in background sound levels, reduces the effectiveness of this approach. Furthermore, once the signal changes and the pedestrian starts to cross, there is very little communication with the pedestrian other than the possibility of active beaconing. The traffic controller has no way of knowing how far pedestrians have progressed and whether they are still in the crosswalk. This project is proposing the integration of commercial technologies commonly found in smartphones and other mobile electronics into a framework that will provide for pedestrian tracking and navigation. Such capability would allow the pedestrian signal device to take corrective action, such as providing navigational corrections or extending the walk signal (in extreme circumstances). With a "technology-neutral" framework (using a device other than a smartphone), this pedestrian support can be expanded to other avenues, such as railway crossings, bus terminals, and airports.

- **Project:** Geospatial Analysis of Bicycle Network "Level of Stress", Bicycle Crashes and the Geo-coded Pavement Conditions for Risk Factors Identification
- **PI:** Haizhong Wang (OSU)

Safety remains a problem on U.S. roadways, with more than 32,000 fatalities, 2.2 million injuries and 6 million crashes each year. Less than two percent of motor vehicle crashes deaths are bicyclists. The loss of 677 lives in bicycle/motor vehicle crashes in the U.S. in 2011, although lower than the 830 fatalities in 1995, is still on the rise just a few years ago. Cities and counties in the United States have made small progress promoting bicycling by developing painted bike lanes, separate bicycle-only highways, bike share programs and incentives for businesses that encourage employees to bike to work. Recent research proposes evaluating urban bicycle treatments of this kind by how to reduce bicycle crashes and the stress-level for cyclists on road networks (Mekuria, Furth and Nixon 2012). This report proposes a four-step classification system for streets, roads, highways and bike paths based on research into consumer categories of bicycle users. The system ranges from stress "level one" streets where vehicles travel under 30 miles an hour and provide for good vehicle visibility such that small children can safely bike on them, to stress "level four" streets with 40 plus mile per hour vehicle traffic only traversed by professional cyclists. This proposed study merges existing research on spatial pattern of bicycle crashes and pavement conditions with recently proposed criteria for evaluating bicycle network "level of stress" connectivity and how it is connected to the casual patterns of bicycle crashes. This research combines demand based household travel data from the 2011 Oregon Household Activities Survey (OHAS) and Oregon crash database with supply based geographic information system (GIS) analysis of the City of Corvallis, Oregon's bicycle infrastructure network to evaluate the impact of bicycle infrastructure investment on household behavior, and the statewide crash database. Multiple measures of connectivity to bicycle networks are evaluated, including level of service directly around households, number of destinations for given trip purposes within specified ranges of the households, and the number of bicycle lane miles connected to the household through low-stress networks. The research team will utilize demographic information from the OHAS dataset to minimize issues of self-selection into specific, bicycle friendly units by individuals of certain ages and family structures and GIS-based Oregon statewide crash database.

- **Project:** Assessing the Capacity of the Pacific Northwest as an Intermodal Freight Transportation Hub
- **PI:** Hectro Vergara (OSU)

The economic health of the Pacific Northwest greatly depends on domestic and international trade markets and the efficient performance of freight transportation systems and their interconnections across the region. Very important industries in the region such as manufacturing, agriculture, retail and construction are heavily dependent on freight transportation. In the state of Oregon only, $16 million worth of cargo was moved on roads each hour of every day during 2008. Intermodal transportation refers to the use of two or more transportation modes to move goods from origin to destination to take advantage of economies of scale (for example, containers that are moved from a ship to a truck or to a train). Besides the economic benefits of intermodal transportation, overall sustainability is also improved as linkages between different transportation modes allow better utilization of transportation assets and a reduction of greenhouse gas emissions as goods are transported more efficiently. The Pacific Northwest has a geographical advantage as compared to other regions on the West Coast of the United States and Canada as it can easily connect Eastern markets in Asia with consumers in the Midwest region of the United States. However, although some previous studies have analyzed the potential of the intermodal infrastructure and operations in some of the states in the region, it remains unclear how the Pacific Northwest as a whole is currently positioned to serve as a major hub for intermodal freight transportation and what are the major areas for improvement in order to increase the overall economic and environmental sustainability of freight transportation. This will benefit policy makers and major stakeholders throughout the region as they plan future projects needed to expand the infrastructure and technological and operational capacity of the Pacific Northwest as a major intermodal freight transportation hub within the United States.

- **Project:** SSI Bridge 2: Evaluation of Soil Structure Interaction Effects on PNW Bridges
- **PI:** Ben Mason (OSU)
- **Co Investigator:** Andre Barbosa (OSU)

The Pacific Northwest (PNW) is prone to large subduction zone earthquakes as well as smaller, shallow, crustal earthquakes. The effects of these types of earthquakes on PNW bridges is not well understood – especially the effects of the large magnitude, long-duration subduction earthquake motions. In this project, we will solve the following problem: How will typical bridges in the PNW respond during impending earthquake events? The term "typical bridges" here is meant to imply the majority of the bridge stock in the PNW that has not been subjected to rigorous seismic analysis and design. Typical bridges are extremely important, because they account for the majority of the PNW's bridge stock, and they are critical for the lifeline routes after the impending earthquake occurs. In summary, this work will eventually lead to guidance for designing and retrofitting typical bridges in the PNW, and this guidance will be critical for ensuring that our transportation corridors remain functional after the impending event. This, in turn, will improve the safety of the PNW's typical bridge stock as well as the overall community livability and economic viability of the PNW following the impending earthquake. PacTrans also funded the first year of this work. In this first year, the project has developed a comprehensive soil-bridge model, which was designed to represent a typical PNW bridge. The project performed analysis of the bridge using a suite of 14 earthquake motions. Seven of the motions were recorded during shallow, crustal earthquakes, and the other seven motions were recorded during the recent subduction zone earthquakes in Chile and Japan. The analysis is showing key differences between the soil-bridge response during the subduction zone earthquakes versus the shallow, crustal earthquakes. In particular, the demands on the soil-bridge system are higher during the subduction zone event. We currently have an MS student finishing a thesis on this project and we are planning on writing a journal paper based on these results.

- **Project:** Investigating the Feasibility of Using QR (Quick Response) Codes for Construction Document Control in Highway Construction
- **PI:** Hyun Woo Lee (OSU)

The success of construction operations depends on the effective management of a variety of construction documents such as drawings and specifications. Despite this importance, the construction industry still lags behind other industries in its use of information technology (IT) and mobile devices in document controls. Thus, hard copy documentation still prevails as the primary method of document management within the industry. In particular, the unique nature of highway construction adds more challenges to the document control of departments of Transportation (DOTs) due to geographically dispersed operations and prolonged nighttime operations.The challenges make it difficult to carry around hard copies of specifications and drawings, and make it even more difficult to verify whether or not the construction documents in hand are up-to-date. Experience tells that any failure to timely access correct documents during a project can result in delays and incorrect decisions (Finch et al. 1996).

Provided that the method of document transfer dictates the ease and effectiveness of sharing information among project members, Bowden et al. (2006) suggested that the use of mobile IT in document management can reduce time and cost of construction, defects, and accidents. In particular, embedding QR codes in drawings can offer an enhanced level of control over information flow and transfer by effectively linking paper documents to electronic documents, and accordingly provide the beneficial characteristics, including: fast and remote access; quick links to related materials; dynamic updating; and easy version verification. Therefore, embedding QR codes in highway construction documents can support DOTs and the industry by maximizing the efficiency of their document control practices, and, as a result, can improve the overall performance of public infrastructure projects.

- **Project:** Development of Improved Corrosion Inspection Procedures for Reinforced Concrete Bridges
- **PI:** O. Burkan Isgor (OSU)

First-level inspection procedures (e.g. visual inspection, chain drag or hammer sound tests) to detect corrosion-related issues in reinforced concrete bridges work only after significant damage to the structure has already occurred in the form of excessive cracking and/or delamination. Early detection and accurate monitoring of corrosion activity require more detailed inspections, which may include half-cell potential mapping and/or taking cores for laboratory analyses for mechanical properties and chloride profiling. Half-cell potential mapping of reinforced concrete bridges is a standardized method that indicates the probability of corrosion across the inspected areas. Half-cell potential results, however, do not provide any information about the rate of corrosion. It has also been shown that half-cell potential readings can be misleading, particularly in the case of localized corrosion, for which corrosion rates can be significantly high while measured half-cell potentials on concrete surface may indicate low probability of corrosion . As a result, corrosion monitoring that only relies on half-cell potential mapping can lead to misleading interpretations about the corrosion state of reinforced concrete bridges. Without the kinetic data, it is generally difficult to detect issues in early stages and to plan and prioritize mitigation and repair actions accurately. For a more robust assessment, additional data that would reflect the kinetics of the corrosion process are needed to supplement the half-cell potential mapping results. Unfortunately existing corrosion rate measurement techniques for concrete structures are inaccurate, unreliable and slow. Chloride profiling results alone cannot be used to assess corrosion rates within a bridge because they only provide information about when the steel may lose its passivity.

- **Project:** Evaluation of Existing and Alternative Information Signs in Oregon
- **PI:** David Hurwitz (OSU)
- **Co-Investigator:** Michael Olsen (OSU)

Roadway signs are a key component to promote safe and efficient transportation systems by providing simple messages to road users. One common sign type, the symbol sign, uses a recognized and widely understood symbol to efficiently convey information rather than words, numbers, or other means of communication. The "Information" sign is often used to indicate locations where motorists can obtain information about local roads, tourist attractions, and community services. The symbol currently specified in the Manual of Urban Traffic Control Devices (MUTCD) for the Information sign is "INFO" in white text on a blue background (2009). However, the symbol "i" (lower case letter i) is commonly used in many other instances related to the transportation network (e.g., Google Maps) and is also used widely in Europe and other countries for roadway networks. As a result, concerns have been raised that road users, particularly international visitors, may not readily comprehend the current information sign as indicating a place to get information (Katz et. al. 2008).

- **Project:** Improving Sustainability of Urban Streets via Rain Gardens – How Effective Are These Practices in the Pacific Northwest?
- **PI:** Meghna Babbar-Sebens and Arturo Leon (OSU)

Stormwater managers and engineers are required to evaluate the effectiveness of any best management practice (BMP) that is implemented by a city on its roadways. While artificial drainage systems are easier to evaluate, natural drainage systems are more challenging because of the variability in the design of the system itself. Better monitoring and evaluation methods are needed to evaluate the performance of such systems in the Pacific Northwest climate, since they are also sensitive to the runoff flows they receive and to the climate in the region they are installed. The Northwest Environmental Defense Center (NEDC) and the Oregon Department of Transportation (ODOT) are currently expending approximately $2.1 million in funds per year (from FY 2011- FY 2014) for stormwater retrofit programs not associated with highways within the Willamette River watershed. The City of Corvallis is one of the cities that is recipient of this funding and is also working on a city-wide design of a system of raingardens. One of the settlement agreement criteria between NEDC and ODOT include monitoring of BMP effectiveness. Most literature available on rain garden monitoring and assessing effectiveness do not explain how the design parameters of the rain gardens interact with the wet-dry climate found in the Pacific Northwest. Hence, investigations are needed to assess the long term effectiveness of rain gardens for stormwater drainage, assess effect of rainfall intensities and duration on individual rain garden design and on a system of rain gardens, assess effectiveness of these systems when they are placed on primary, secondary, and tertiary roadways, and develop engineering standards for stormwater retrofits that use such systems. Such investigations are also needed to demonstrate the impact and success of capital investment made by these Pacific Northwest agencies for improving stormwater collection systems.

Education

Transportation education and workforce development are high priorities for the PacTrans institutions as key components of the mission and plans for the consortium. Our five universities educate the majority of transportation professionals working in Region 10 and have won awards for innovative and effective engineering education efforts. PacTrans' activities in education and workforce development emphasize cultivating future leaders and professionals through education on the systems approach to safe and sustainable transportation solutions.

PacTrans provides educational and workforce development activities in several different areas centered on four themes: enhancing student learning through an adoptable curriculum, increasing student experiences with real-world transportation issues, increasing the recruitment of students through expanded university outreach programs, and improving regional collaboration in education and workforce development.

Each year PacTrans provides scholarships, fellowships, assistantships, and internships to students at the PacTrans universities. As part of our mission to bring talented professionals into the transportation field, PacTrans provides funding to students seeking transportation-related degrees. Students and faculty in the PacTrans universities are directly involved in transportation research and education, and have developed strong relationships with state transportation departments and other regional organizations.

Region 10 Student Conference

Transportation students in Region 10 gather every year at the Region 10 Student Conference. PacTrans and the UW Student Chapter of the Institute of Transportation Engineers (ITE) jointly sponsored the Region 10 Student Conference on October 19, 2013 at the University of Washington. In existence for over a decade, this tradition serves as an excellent venue for students to share research and develop professional connections.

University of Idaho student snowmobile team demonstrates a low-pollution snowmobile.

Annual Transportation Research Board (TRB) Meeting

The Annual TRB Meeting attracts approximately 11,000 transportation professionals from around the world. The meeting, held every January in Washington, D.C., represents one of the most important and widely attended venues for transportation researchers and practitioners to exchange research information and share technology transfer stories.

The meeting covers all transportation modes, with more than 3,000 program presentations and a variety of sessions addressing topics of interest to all attendees—policy makers, administrators, practitioners, researchers, and representatives of government, industry, and academic institutions.

Every year, PacTrans honors the center's Student of the Year by sponsoring full travel costs and awarding $1,000. The Student of the Year is nominated by transportation faculty for excellence in academic achievement and overall contribution to the transportation community. The Student of the Year is officially recognized by CUTC at the awards banquet held in conjunction with the TRB meeting.

PacTrans reimburses a portion of conference travel expenses for students who are the primary presenter/author of a paper accepted for presentation at the meeting. At the 93rd Annual Meeting (January 12 – 16, 2014), more than 30 research papers were presented by PacTrans graduate students as primary authors.

Outreach Activities to New Entrants into Transportation

All five consortium members sponsor educational and recruitment activities for high school students, under-represented minority and women students, military veterans, and K-12 student populations to encourage their interest in transportation science and technology.

TRANSLINK'S JEFF BUSBY TALKS AT TRANSPORTATION GRADUATE SEMINAR

Jeff Busby, Senior Manager, Project Development at TransLink in Vancouver, BC, spoke with University of Washington transportation graduate students on May 2, 2014. He discussed how areas in Metro Vancouver are using transit stations to stimulate better development and the relationship between development and transportation infrastructure. Metro Vancouver is projected to grow by 50% over the next 30 years, meaning that there will be a 50% increase in the number of trips taken. TransLink hopes the increase in trips will be entirely on transit, and are working toward making development in Metro Vancouver as transit-friendly as possible.

WOMEN'S TRANSPORTATION SEMINAR (WTS) GALA

The 2014 Women's Transportation Seminar (WTS) Gala was held on March 27 at the Westin Hotel in Seattle. Mary E. Anderson, master's student in Sustainable Transportation at the University of Washington student, received the Helene M. Overly Graduate Memorial Scholarship. Amy Riley, also of the University of Washington, received the Sharon D. Banks Memorial Undergraduate Scholarship.

OSU PARTICIPATES IN WTS CONFERENCE

PacTrans was visible at the WTS Conference this year participating as one of its many sponsors. Two of our Oregon State University graduate students, Allie Peters and Jennifer Warner, represented PacTrans at the Women's Transportation Seminar (WTS) Annual Conference held in Portland, Oregon May 14-16. At this international event, Allie and Jennifer represented PacTrans at the information booth, where they explained the goals of the consortium and highlighted research being conducted. They also attended technical sessions and workshops on topics such as "Women in Transportation Construction," "The Evolution of the Parking Lot," and "Communicating Technical Topics to Non-Technical Audiences."

PACTRANS OSU RESEARCHERS AWARDED DDETFP FELLOWSHIPS

Oregon State University School of Civil and Construction Engineering graduate students Dylan Anderson and Rachel Vogt have been awarded 2014 Dwight David Eisenhower Transportation Fellowships. The highly competitive national awards are given as part of the Dwight David Eisenhower Transportation Fellowship Program (DDETFP), established in 1991 to attract qualified students to the fields of transportation education and research, and advance transportation workforce development.

Advised by OSU associate professor Katharine Hunter-Zaworski, Anderson is developing a manual to improve safety at rail public transportation platforms. The research, conducted under the Transit Cooperative Research Program (TCRP), will assist transit agencies to prevent and minimize public rail transit safety incidents.

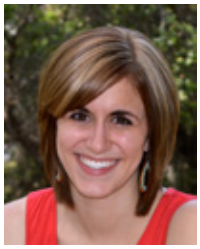
Vogt, who is advised by OSU assistant professor Haizhong Wang, is working with the Oregon Department of Transportation to understand and address questions related to decreasing fuel tax combined with increasing infrastructure costs. As Oregon continues to explore a Road User Charge (RUC), her research will focus on how various rate structures and implementation strategies may impact different socio-economic groups and regions of the state.

CONGRATULATIONS TO OUR 2014 GRADUATES

L-R: Jonathan Corey, Ph.D., Erika Wygonik, Ph.D., Zun Wang, Ph.D., Menglin Wang, Ph.D.

PACTRANS FABULOUS FOUR: 2014 FELLOWS

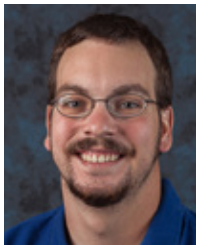
As part of PacTrans' mission to bring talented professionals into the transportation field, PacTrans provides funding to students seeking transportation-related degrees each year.



Arianna Allahyar

As a Seattle native, Arianna Allahyar is excited to be back in the Pacific Northwest after graduating June 2013 with a bachelor's degree in Urban and Regional Planning from California State Polytechnic University, Pomona. In her time as an undergrad, Arianna worked with the City of Los Angeles Planning Department for two years, and as a multimodal transit intern with the Riverside County Transportation Commission. In addition, she has gained significant experience working for Parsons Brinckerhoff as a transportation planner. Since joining the firm, Allahyar has provided technical support for a variety of transit planning efforts in the Puget Sound region.

Allahyar has experience in geographic information systems (GIS) analysis, traffic operations analysis, travel demand modeling, and policy analysis and is thrilled to be continuing her graduate studies in transportation engineering at the University of Washington. She strives to continuously evolve as an expert in the transportation realm and connect with professionals across the industry. She looks forward to making a positive impact on multi-modal transportation systems throughout her career.



Joseph Flood

Joe Flood received bachelor's degrees in mathematics/statistics and brain and behavioral sciences from Purdue University in West Lafayette, Indiana in 2013. He has worked as a summer assistant for the Hendricks County Engineering Office in Danville, Indiana, where he performed a county-wide inventory of road signs, photographing signs and entering their condition into a database. After completing his MSCE, he plans to work as a traffic engineer or transportation planner and pursue his PhD.

He is interested in psychological factors of transportation, including transportation neuroeconomics and social factors influencing driving and travel behavior. Flood remembers that one of his favorite activities as a child was drawing road maps! Needless to say, he is thrilled to study transportation at the University of Washington. He is assisting in the UW PacTrans office where he's inspired by the people he works with on the cutting edge of transportation research and education, a group he hopes to join in the near future.

Darwin Li

When Darwin Li first came to attend the University of Washington as an undergraduate, he knew immediately he would be majoring in civil engineering. He always found it fascinating that billions of people on this earth are able to coexist and travel to follow their dreams — safely, efficiently and cost-effectively. His curiosity led him to specialize in transportation engineering.

As a senior in the Undergraduate Civil Engineering Program, Li interned for the Seattle Department of Transportation, performing a variety of tasks such as ITS, surveying, data management and collision analysis. After working at SDOT for an additional year after graduation, he decided to pursue a Master's in Transportation Engineering at the University of Washington.

Li is excited to be moving forward with an internship at the Kirkland-based consulting firm, Transpo Group. After earning his master's degree he hopes to put his skills, experience, and passion to good use in the field of Transportation Engineering.

Luka Ukrainczyk

Luka Ukrainczyk has been working as an intern at the Toll Division of the Washington DOT, where he performed studies on income generation by the SR 520 bridge and a lifespan analysis of GoodToGo tags. He received his undergraduate degree from the University of California, Davis. He has worked in the Community Development Department at the City of Woodland, and was an Undergraduate Research Fellow at the UC Institute of Transportation Studies.

His master's research focuses on modeling factors that influence demand for the SR 167 HOT lanes. He hopes his work will expand the use of demand pricing and encourage participation in alternative travel modes in the greater Seattle area.

Outreach

PacTrans implements outreach programs each year with the goal of fostering collaboration with the public at both the regional and national levels. Our outreach activities vary a great deal and, whenever possible, involve our students. Whether it is meeting with young visitors from a local elementary school to discuss all that is possible in the field of transportation engineering, or giving presentations on the dangers of distracted driving at local high schools, our outreach activities are designed to engage and inspire.

PACTRANS HELPS FUND ASRA STUDENT CHALLENGE

Seven Alaska high school students enrolled in The Alaska Summer Research Academy (ASRA) Civil Engineering module, cosponsored by AKDOT&PF Research, Development & T2 and the Alaska University Transportation Center, and rose to the challenge: to design and build a full-scale, multi-use trail bridge able to accommodate the width and load of a utility task vehicle (UTV), commonly referred to as a side-by-side ATV.

The ASR module focused on civil and transportation issues showing how engineering principles are used to solve problems. Students applied basic design principles of statics and structural analysis to complete their final bridge project.

As part of the challenge, two teams first competed to develop the best design. In phase two, the teams came together to share their work and selected a design for the final collaborative bridge project. Construction was completed after just three days, and the bridge supported the ATV with a weight and payload of 1,400 pounds.

Above: Keith Whitaker leads the group in a load testing exercise using a PASCO bridge set with load cells. Below: Students worked hard to meet their assembly deadline

PACTRANS JOINS UW PAWS-ON SCIENCE AT THE PACIFIC SCIENCE CENTER

PacTrans was among more than 30 University of Washington research groups who participated in the annual Paws-On Science weekend April 4-6, 2014 at the Pacific Science Center in Seattle, WA. The exhibit, titled "Red Light Green Light," was co-sponsored by PacTrans and the STAR Lab, a University of Washington transportation research lab led by Dr. Yinhai Wang.

Several PacTrans STAR Lab researchers volunteered to speak with families and school groups about safe and sustainable transportation research in the region. Interactive pedestrian detection and the Drive Net transportation data analysis, visualization, and mapping platform were among the highlights of the exhibit. This event was a great opportunity to engage the next generation of engineers and scientists in research and development at the UW through hands-on activities and demonstrations.

The Paws-On Science weekend was very well attended, with over 11,000 adults and children participating.

PACTRANS STAR LAB PARTICIPATES AT UW ENGINEERING DISCOVERY DAYS

PacTrans joined the celebration at UW Engineering Discovery Days. Engineers and scientists from across campus displayed their most engaging research and projects April 25-26, 2014. Nearly 9,000 students, parents, and faculty attended the two-day event, which was free and open to the public. PacTrans STAR Lab and other labs presented their research to people of all ages.

Highlights included a PacTrans research project which displayed an earthquake table used by structural engineers to test how structures will withstand earthquakes. This type of testing is crucial to discover how a structure, such as a bridge, would perform during a major natural disaster.

The STAR Lab also demonstrated video-based pedestrian detection systems, controllers used for traffic signals. Students had fun while learning about transportation with "Traffic Hero," a game similar to "Guitar Hero." Players scored points by successfully using a detection system to locate cars.

PEER EXCHANGE VISIT BRINGS TENNESSEE DOT TO THE PACTRANS STAR LAB

On July 23, 2014 officials from the Tennessee Department of Transportation (TDOT) visited the Smart Transportation Applications and Research (STAR) Lab to learn about its research and technologies regarding transportation data collection, management, and analytics tools. As part of a larger exchange event between Washington State Department of Transportation (WSDOT) and TDOT, Dr. Yinhai Wang, STAR Lab director, introduced the TDOT visitors to the lab's facilities and recent research focuses, including data quality control, mobile device based data collection and knowledge discovery, and DRIVE Net.

A test drive through DRIVE Net (Digital Roadway Interactive Visualization and Evaluation Network) revealed a robust capability to access and analyze datasets from WSDOT, including traffic detector data, incident data, INRIX data, and weather data. The network has the potential to answer important transportation questions, including how many congestion spots exist in a certain area, when they occur, and the ability to determine congestion patterns from the data.

The TDOT traveled to a number of Washington agencies, programs, facilities and partners in the exchange visit, and the stop at STAR Lab raised a great deal of interest in the lab's work. "Very impressive," said one TDOT representative. "I'm very happy to see your operations.

AutomotiveUI 2014 in Seattle

AutomotiveUI, the International Conference on Automotive User Interfaces and Interactive Vehicular Applications, was held in Seattle from September 17 – September 19, 2014. As the premier forum for UI research in the automotive domain, AutomotiveUI brings researchers and practitioners interested in both the technical and the human aspects of in-vehicle user interfaces and applications. PacTrans was one of several sponsors supporting the conference.

SCANDINAVIAN EXCHANGE AND TRANSPORTATION COLLABORATIONS

Norway, due to its location on the northern edge of Europe, has unique transportation challenges. This country, which is roughly the same size and population as Washington State, has rugged terrain and severe winter weather. In spite of these challenges, Norway's transportation system is notably safe (half as many fatalities per year as in Washington State), environmentally efficient with a high level of non-motorized transportation and transit usage, and still functions effectively during long periods of darkness and heavy snow fall.

The UW's Department of Civil and Environmental Engineering (CEE) has increasingly strong ties with Norway's two main transportation institutions: the Norwegian University of Science and Technology (NTNU) in Trondheim, which is Norway's national engineering and technical university, and the Norwegian Public Roads Administration (NPRA). This linkage provides an opportunity for CEE personnel to learn about the Norwegian's technology-based approach to improving freight and person mobility. Conversely, Norway, as a small country, often reaches outside its border for transportation expertise and both NTNU and the NPRA actively support connections with Washington State.

These connections include 30 years of exchanging transportation graduate students in both directions under the Valle Scandinavian exchange program. This year one UW student (Jerome Drescher) is headed to NTNU and one NTNU student (Kine Nilssen) will be coming to CEE. A former Valley scholar and a recent CEE transportation PhD graduate, Kelly Pitera, is now a professor at NTNU. There also have been a number of exchange visits by staff from CEE, NTNU, and the NPRA.

PacTrans researcher and CEE Research Assistant Professor Edward McCormack recently returned after a year as Chief Engineer at the NPRA where he supported a new Traffic Engineering Research Centre (TERC) at NTNU. His research included work on truck performance measures for Norway's transportation network and testing transportation applications of unmanned aircraft.

This international relationship should continue to grow. Professor McCormack will have an affiliate positon with NTNU and will be funded to support the NPRA's research program. One goal of this funding includes setting up a joint ITS laboratory between the UW's STAR lab and FERC. It is also anticipated that the funding from Norwegian projects will be proposed as a match for PacTrans supported research.

CHAIRMAN OF ISRAEL ASSOCIATION FOR INTELLIGENT TRANSPORT SYSTEMS VISITS PACTRANS AND THE UW STAR LAB

During a recent visit to Seattle, Ur Omry, chair of the Israel Association for Intelligent Transport Systems, visited the UW campus and met with PacTrans director Dr. Yinhai Wang and assistant director Meghan MacKrell. ITS Israel is a nonprofit organization with a goal to improve road safety, road efficiency, and the environment. Established in 2008 by a group of volunteers, its members include highway management organizations, road and traffic engineers, automotive systems companies, municipalities, and academic institutions. ITS operates in concert with the Israeli DOT, Israel National Road Safety Authority, the Standards Institution of Israel, other major key players, and with ITS stakeholders worldwide.

UW-TONGJI DUAL MASTER DEGREE PROGRAM REACHES FINAL STAGES

A new UW-Tongji Dual Master Degree (DMD) program in transportation is in the final stage of being realized. Every year, this program will enroll five students who have been admitted to the graduate transportation program at Tongji University, a top-ranked university in civil engineering and transportation in Shanghai, China.

These five students will spend the first year in Tongji, the second year at UW, and the third and final year back in Tongji. At the end of the three-year program, after completing all required courses and research at both institutions, the students will receive two graduate degrees: a Master of Engineering from Tongji University and a Master of Science in Civil Engineering from UW. Students are responsible for their own costs at the UW and are also eligible for the Teaching and Research Assistantships offered at UW.

This DMD is the result of many discussions and visits held between the two universities and marks a significant milestone toward many fruitful research and education collaborations in the years to come.

Technology Transfer

PacTrans is committed to a program of technology transfer directed toward researchers, transportation professionals, public policy makers, and the general public. As such, technology transfer is integrated in all research projects from beginning to end. At the proposal stage of research, PIs submit an implementation plan describing their intentions for disseminating the results of their research. A representative from transportation agencies or private industry participates in the monitoring panel for each multi-institutional project to ensure the potential practical value and facilitate the possible technology transfer activities of the research products. The PacTrans Region 10 Transportation Conference scheduled on October 17, 2014, offers a great platform for people from the practice side to talk to the researchers for technology transfer opportunities. Additionally, through peer-reviewed journals, conference proceedings, other scientific arenas, and through social media, PacTrans researchers share the results of their PacTrans-funded research projects and seek for partners for technology transfer. PacTrans newsletters and annual reports also serve as vehicles for outreach and technology transfer. People can access publications through the PacTrans website (www.pactrans.org) or via e-mail. To take advantage of receiving publications via e-mail, contact pactrans@uw.edu.

PACTRANS STAR LAB

A strong ITS research program and its corresponding supporting laboratory are indispensable resources for high-quality training of ITS professionals and for solving traffic problems in the Puget Sound region. Following Dr. Yinhai Wang's proposal in June 2003, the Department of Civil & Environmental Engineering in the University of Washington College of Engineering and PacTrans' predecessor, Transportation Northwest (TransNow), USDOT University Center for Federal Region 10, decided to establish a laboratory for Smart Transportation Applications and Research (STAR) to enhance the strength of ITS research and education at the University of Washington. Major objectives of the STAR Lab are: support advanced ITS research, cultivate ITS professionals, explore effective solutions to transportation problems, provide hands-on training instruments and software applications for students in ITS classes, and construct a bridge between the UW and agencies of transportation practice.

The STAR Lab is located at More Hall 101 on the UW Seattle campus. Over the past ten years, the STAR Lab has gained broad support from both transportation agencies and private industry, and developed numerous practical tools and technologies in traffic sensing, sensor data analysis, traffic simulation, and other areas. For example, the Washington State Department of Transportation (WSDOT) has decided to make the STAR Lab a remote training center and provides live traffic data and traffic operation software for research and training activities. Leading companies in the ITS field also provided great support to the STAR Lab. The recently received patent (U.S. Patent No. US 8,358,808 B2 Spatiotemporal System for Video-based Vehicle Detection) significantly improves video-based vehicle counts under challenging light and environmental conditions. For further information about the STAR Lab, please contact Dr. Yinhai Wang:

TEL: **206-616-2696**
FAX: **206-543-5965**
EMAIL: **yinhai@uw.edu**

WEBSITE: **www.pactrans.org**
TWITTER ACCOUNT: **@PacTransUTC**

NEWSLETTERS

The PacTrans Newsletter features highlights of research, student achievements, events, and news pertaining to the Pacific Northwest Transportation Consortium and its partners. The newsletter is published quarterly and is posted to the PacTrans website and distributed to the newsletter list.

Funding and Expenditures

FINANCIAL PARTNERSHIPS

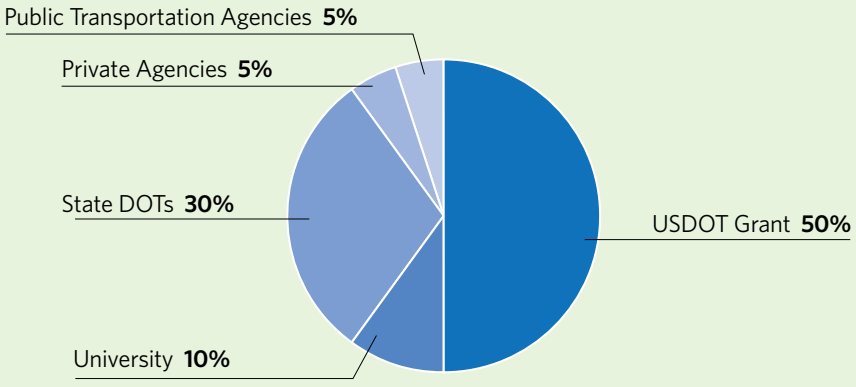
PacTrans continues to serve as the USDOT Region 10 University Transportation Center with $6.9 million funding from the USDOT and an equal amount of match funds from local partners. The $13.8 million funds have been applied or scheduled to apply to research, education, workforce development, outreach, and technology transfer efforts in Region 10. Specifically, PacTrans research focuses on developing data-driven safe and sustainable solutions for the diverse transportation needs of the Pacific Northwest.

An extensive collaboration network has been established during the past years. Example partners who collaborated with PacTrans include the following companies, public agencies, and professional societies:

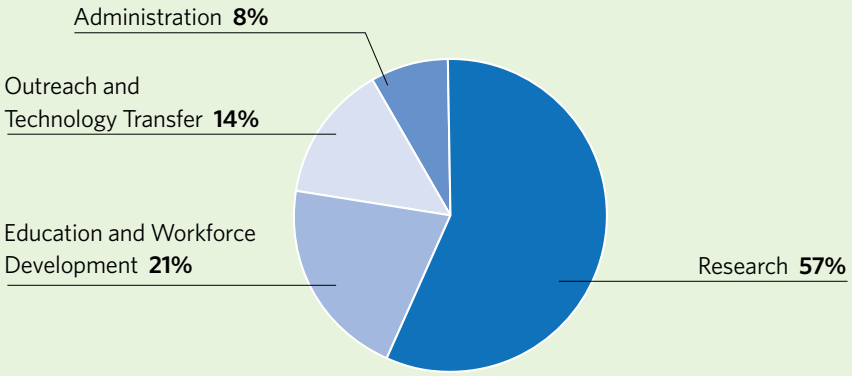
- Alaska Department of Transportation and Public Facilities
- CH2MHILL
- City of Bellevue
- City of Lynnwood
- City of Portland
- City of Seattle
- Idaho Transportation Department
- National Cooperative Highway Research Program
- Oregon Department of Transportation
- Oregon State University
- Parsons Brinckerhoff
- Toyota Motors
- Port of Seattle
- Port of Portland
- Puget Sound Regional Council (PSRC)
- Transpo Group
- University of Alaska, Fairbanks
- University of Idaho
- University of Washington
- Washington State Department of Transportation
- Washington State Transportation Improvement Board
- Washington State University
- Washington Traffic Safety Commission
- Western Systems
- Intel
- Microsoft

Funding Sources

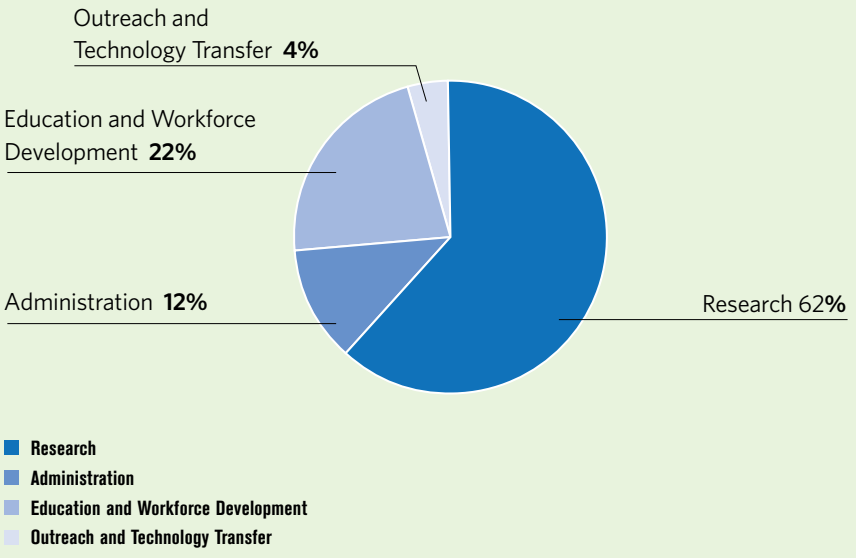
[$6.9 million USDOT funds + $6.9 million match funds]



2013-2014 Expenditures



Cumulative Expenditures 2012-2014



www.pactrans.org

University of Washington
112 More Hall
Box 352700
Seattle, WA 98195-2700

e: pactrans@uw.edu

@PacTransUTC