

**Transportation Northwest (TransNow) Research Project Descriptions
Year 19: July 1, 2006-June 30, 2007**

Identifying Number	61-4186
Project Title	Improved Freight Modeling
Principle Investigator	Anne Goodchild,
Institution	University of Washington
PI's telephone number	Phone: (206) 543 3747 Fax: (206) 543 1543
PI's E-mail address	annegood@u.washington.edu
External Project Contact, address, telephone number	Barbara Ivanov Office of Freight Strategy and Policy WSDOT PO Box 47322 Olympia, WA 98504 Phone: 360.705.7931 Fax: (360) 705-6858 ivanovb@wsdot.wa.gov

ABSTRACT:

The proposed research will address an emerging need by local, state and regional transportation planners and policymakers to better understand the transportation characteristics, functions and dynamics of ocean port-to-handling facility and handling facility-to-final market freight movements. The research will also address a gap in the academic literature for freight transportation models that capture underlying economic forces. This research effort will focus on the development and refinement of a regional freight model of urban container movements from the port to a handling facility and beyond. Existing regional transportation planning models and analytical tools have evolved from passenger travel demand models that are ill-suited to fully capture the business decisions and economic influences driving urban freight flows and have been further constrained by access to appropriate freight data. This research activity proposes a modeling approach which will capture the fundamental economic choices individual shippers consider when trading-off the marginal benefits/costs associated with warehouse inventory management/control relative to transportation access and flow while incorporating the primary freight generation activity centers (warehouse/distribution centers) in the Puget Sound region. This work will identify, evaluate and incorporate data for the Puget Sound region recently available from a variety of existing sources. Some data collection may also be necessary.

The final product of this research study will be an improved tool to understand current and future freight movements through the Puget Sound region, and a methodology which will expand the current state of knowledge, and may be applied in other regions, both domestic and international. It will allow more in-depth and timely evaluation and analysis of different local/regional transportation policy initiatives such as the impact of migration of the main warehousing region, and development of inland inter-modal port facilities.

PROJECT OBJECTIVES

1. Bring together data from several sources regarding freight movements in Puget Sound, and exploit this data to develop a better understanding of existing freight flows in the region.
2. Highlight the weaknesses of current models being used for freight planning.

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3. Develop a model that incorporates the economic choices of shippers in estimating regional freight flows between primary freight generation activity centers.
4. Apply this model to the Puget Sound region validate against existing data, and estimate future regional freight flows.
5. Inform state and regional freight planning by using the model to address policy questions such as the expected volume growth in truck traffic between the Port of Seattle and the Green River Valley warehousing district, and the longevity of conditions driving movement of the warehousing district south.

TASK DESCRIPTIONS AND MILESTONES:

Task 1: Modeling Literature Review

- Assess state-of-the-art freight modeling efforts and techniques currently utilized. This will include developing an understanding of the modeling tools used in current/past studies by MPOs and other regional agencies and identifying what policy questions these models can address.
- Form advisory committee. The successful completion of this project involves a thorough understanding of existing tools, methods, and data requirements. We will identify an advisory committee to guide the research. The advisory committee will be asked to participate on an as needed basis. Several potential advisors have already provided significant input into the project.

Task 2: Data Review

- Carry-out a thorough scan of existing data sources. This will include scanning the literature as well as discussions with relevant parties at local transportation agencies, research entities, ports, and WSDOT. See Appendix 1 for preliminary list of potential data sources.
- Inventory of past and ongoing data collection efforts.
- Develop a method to judge the usability and quality of the existing data, and apply this method to the identified data sources. This will include defining qualitative and quantitative measures upon which data sources can be judged.
- Identify gaps in the existing data with respect to describing the current flow of containers between ocean ports, handling facilities, and beyond. If there are significant gaps in the data, plans will be developed for an efficient method by which to collect the data, considering how ongoing data collection can be exploited to support freight modeling efforts.
- Identify a small number of possible sites for future development of rehandling and warehousing facilities.

Task 3: Develop analytical model

Develop analytical model that captures the basic economic trade-offs of inventory cost and transportation cost. To do so it will be necessary to identify freight flows to be modeled. The level of detail necessary in the model depends on the desired outcomes and will be clarified through discussions with the advisory committee. Policy questions to be addressed may include the viability of landports, sensitivity of movements to land use and pricing changes. Flows identified for modeling may include direct rail, direct truck, transload-rail, and transload truck traffic flows. The demand for passenger travel will be an input to the model, obtained by the Puget Sound Regional Council transportation model.

Task 4: Application of the model to Puget Sound region.

Use the database developed in Task 2 as input into the model developed in Task3. Shippers will probably be categorized by value of goods moved, volume of imports/exports, or other relevant characteristics. These will be identified during the data scan and analysis phase. A validation exercise will be carried out.

Task 5: Dissemination of Results

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We will develop a final report for the project, as well as the four interim reports. We will publish the results in several scholarly journal articles, and present the results at academic conferences. As per requests from the advisory board or other audiences, we will be available to give additional presentations.

RELATIONSHIP TO OTHER PROJECTS:

This project does not build on other currently funded TransNow projects, but has identified an area that needs research attention. It is the beginning of a longer term research agenda for both PIs and we intend to extend the results to greater levels of detail, and a broader scope of cargo movements.

TECHNOLOGY TRANSFER ACTIVITIES:

1. We plan to work with local agencies to develop plans for workshops or presentations to disseminate our results. These groups (members of our advisory committee, e.g. PSRC, WSDOT, Port of Tacoma, Port of Seattle) will also be involved through-out the project so will already be aware of interim results.
2. We will publish at least 4 papers over the course of the 2 year project to disseminate the results to the academic community.
3. The results will also be incorporated into course curricula at the University of Washington and Washington State University.
4. The model and its results will also be incorporated into an Engineering Open House 2007 exhibit at the University of Washington to educate the broader Seattle community on goods movement.

POTENTIAL BENEFITS OF THE PROJECT:

Through this project we aim to provide a more useful tool for regional freight transportation planning for Puget Sound, Washington State, and other regions served by container ports. The results are directly relevant to the Port of Seattle, Port of Tacoma, Puget Sound Regional Council, Seattle Department of Transportation, Freight Mobility Strategic Investment Board and the Washington State Department of Transportation, in addition to more local agencies such as the Kent Valley Chamber of Commerce. In particular, we address the International Gateways traffic carried by Washington State, and part of the Washington State Transportation Plan. These agencies have been closely involved with the development of the proposal, and will continue to guide the development of the project through an external advisory committee. With this tool these agencies can better plan for, analyze, and set investment priorities. Outside of this region, the methods and understanding developed will translate to other regions, and can aid in setting national freight priorities. Through the course of the project we will create a database of relevant data for the Puget Sound Region. This alone could fill some gaps in the existing understanding of goods movement through the Puget Sound Region, for example, through development of a flow-map for containerized goods in the Puget Sound Region, so will be of value in researching other related questions. In addition to identifying the key drivers of distributional behavior (e.g. volume of import or export, value of import or export, or other operational characteristics) we will attempt to identify the drivers or inhibitors of freight activity, and understand their level of influence on freight volumes moved. This work will also fill a gap in the academic literature, providing a new paradigm for freight modeling that promises to spark interest and development of much needed tools.

**Transportation Northwest (TransNow) Research Project Descriptions
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Identifying Number	61-4230
Project Title	Wireless and Transit Tracking
Principle Investigator	Daniel J. Dailey
Institution	University of Washington
PI's telephone number	Phone: 206-543-2493 Fax: 206-616-1787
PI's E-mail address	dan@its.washington.edu
External Project Contact, address, telephone number	Nick Marquardt UW 401 S. Jackson Sound Transit Seattle, WA 98104 Phone: 206.689.4903 marquardt@soundtransit.org

ABSTRACT:

This proposal investigates the possibilities for transit management to take advantage of the ever increasing wireless/Wi-Fi infrastructure in urban areas.

The first area of interest involves the Wi-Fi on selected Sound Transit routes. At present the Metro AVL system is based upon dead reckoning using an odometry reading with digital maps and a set of signposts as reference points. At present when the vehicles take alternative routes, such as snow days, the tracking breaks down due to the vehicles not passing assigned signposts. However, with the installation of many Wi-Fi base stations throughout the metropolitan area the combination of Wi-Fi access on the vehicle and a mapping of Wi-Fi base stations can effectively provide a very high density of virtual signposts that will allow tracking even when the vehicles are off the standard route due to weather conditions, emergencies or driver error.

The second area is the soon to be GPS equipped Sound Transit busses operated by Pierce transit and Community transit. Soon to be installed passenger counting equipment has GPS capabilities included in the package. Under a previous project with Sound Transit we have demonstrated tracking prediction capabilities along the freeways; however, in the dense heart of the urban area the tracking and prediction capabilities degraded substantially due to the inability to reliably obtain satellite ranges. Using existing Wi-Fi sites as beacons would vastly improve the tracking in the urban area.

PROJECT OBJECTIVES

- To create a new positioning technology using existing Wi-Fi infrastructure.
- To demonstrate the utility of this positioning system for Transit tracking and information.
- To provide a system to augment GPS positioning in urban areas with satellite occlusion.
- To provide a DSRC-like positioning system that can be used by any vehicles in urban areas.

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TASK DESCRIPTIONS AND MILESTONES:

1. Obtain a mapping or map a set of Wi-Fi hotspots. hotspots.
2. Develop theory for combining Wi-Fi location data with GPS.
3. Obtain signal strength measures for various hotspots.
4. Implement algorithms for positioning in Matlab.
5. Use initial vehicle data to test and evaluate algorithms
6. Implement the algorithms in Java to deploy in the Tracker.
7. Evaluate WiFi position data for tracking and prediction.
8. Write Draft Report.
9. Write Final report based on draft report comments.

RELATIONSHIP TO OTHER PROJECTS:

This project extends the multi-agency, multi-county projects undertaken by the UW for Sound Transit. It takes advantage of the exiting algorithms and software that support the successful demonstration of using GPS for tracking and prediction shown at: <http://www.its.washington.edu/multi-modal/>.

TECHNOLOGY TRANSFER ACTIVITIES:

The project will be done in conjunction with Sound Transit so that the resulting software can be included in the system from the UW operated by Metro Transit.

The report on effectiveness will provide Sound Transit a basis for evaluating present and future positioning systems.

POTENTIAL BENEFITS OF THE PROJECT:

Sound Transit, Pierce Transit, and Community Transit are embarking on deploying automatic vehicle location systems that use GPS as one of the components. They all benefit from identifying methods to augment the GPS positions in urban canyons for fleet management. The traveling public benefits from improved traveler information. External agencies benefit from improved probe vehicle data for traveler information and traffic management.

**Transportation Northwest (TransNow) Research Project Descriptions
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Identifying Number	61-4431
Project Title	Developing an Area-Wide System for Coordinated Ramp Meter Control
Principle Investigator	Yinhai Wang
Institution	University of Washington
PI's telephone number	Phone: 206-616-2696 Fax: 206-543-5965
PI's E-mail address	yinhai@u.washington.edu
External Project Contact, address, telephone number	Ted Trepanier 310 Maple Park Avenue SE PO Box 47344 Olympia, WA 98504 Phone: (360) 705-7280 Fax: (360) 705-6826 trepant@wsdot.wa.gov

ABSTRACT:

From 1980 to 2003, yearly vehicle miles traveled increased by 89% from 1,527,295 million to 2,890,450 million, while road mileage increased only about 3% from 3,859,837 miles to 3,974,107 miles. The enlarging gap between travel demand and infrastructure supply has increased the level of congestion nationwide. Ramp metering has been broadly accepted and deployed as an effective countermeasure against both recurrent and non-recurrent congestions on freeways. However, current ramp metering algorithms tend to optimize only freeway travels using local detectors' inputs and overlook the negative impacts on local streets. This may generate two problems: 1) the optimal local settings may not result in a system-wide optimum in terms of traffic operations; and 2) the increased congestion on local streets due to ramp metering may counteract the gains in freeway operations. To solve these problems, we propose an area-wide ramp metering system to coordinate the previously isolated ramp meters for system-wide optimization. The Additive Increase and Multiplicative Decrease (AIMD) mechanism used for computer network congestion control is applied to calculate ramp metering rate. The effectiveness of this new ramp metering strategy will be evaluated using the VISSIM simulation tool.

PROJECT OBJECTIVES

The objective of this study is to develop an area-wide system for coordinated ramp-meter control using the AIMD mechanism. The VISSIM simulation tool will be used to evaluate the effectiveness of the proposed strategy. This AIMD-based strategy will be compared with the fuzzy logic and ALINEA algorithms.

TASK DESCRIPTIONS AND MILESTONES:

We will use the VISSIM simulation tool to implement the proposed strategy and evaluate its effectiveness. The objectives of this project will be fulfilled through the following five tasks:

- Research preparation and data collection;
- Ramp meter control strategy design;
- Simulation model development and calibration;
- System evaluation; and
- Documentation.

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Each of the above tasks may consist of several subtasks. A description of the tasks and subtasks is given below.

Task 1: Research preparation and data collection

- 1-1: Research team set up
- 1-2: Select two study sites, one with recurrent congestion and the other with frequent non-recurrent congestion;
- 1-3: Collect road geometry data and historical loop detector data; and
- 1-4: Collect incident data for the selected sites.

Task 2: Ramp meter control strategy design

- 2-1: Review the existing ramp meter control strategies;
- 2-2: Design the congestion detection algorithm;
- 2-3: Design the response group assembly algorithm; and
- 2-4: Design the ramp meter rate calculation equations.

Task 3: Simulation model development and calibration

- 3-1: Develop two VISSIM simulation models, one for each study site;
- 3-2: Calibrate the simulation models using the collected loop detector data;
- 3-3: Implement the designed ramp metering strategy;
- 3-4: Implement the fuzzy logic strategy; and
- 3-5: Implement the ALINEA strategy.

Task 4: System evaluation

- 4-1: Select measure of effectiveness for system evaluation;
- 4-2: Evaluate the effectiveness of the proposed strategy;
- 4-3: Evaluate the effectiveness of the fuzzy logic strategy;
- 4-4: Evaluate the effectiveness of the ALINEA strategy; and
- 4-5: Compare the three strategies and modify the system as needed.

Task 5: Documentation

- 5-1: Write the draft final report; and
- 5-2: Circulate the report for review, revise the report and close the project.

RELATIONSHIP TO OTHER PROJECTS:

This proposed project compensates two research projects currently conducted at the University of Washington: “Quantifying Incident-Induced Travel Delays on Freeways Using Traffic Sensor Data” and “WSDOT Incident Response Evaluation: Measurement of Recurring vs Non-recurring Congestion.” Data used by these two projects can be used for calibrating and testing the simulation models needed by this proposed project. Findings from this proposed research will also be helpful for the two ongoing projects to identify appropriate countermeasures against recurrent and non-recurrent congestion.

TECHNOLOGY TRANSFER ACTIVITIES:

The proposed AIMD-based area-wide ramp metering strategy will be compared with two important ramp metering strategies: fuzzy logic and ALINEA. If the proposed strategy outperforms the two popular algorithms, then the WSDOT and other transportation agencies may implement the proposed AIMD-based strategy in freeway on-ramp control. The VISSIM simulation model will be used for traffic control trainings and research.

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A final report detailing the achievements of the proposed project will be written and submitted to TransNow for review and distribution by June 2008. The results of this research project will also be documented in at least two papers, which will be submitted for publication in the *Transportation Research Record* or the *Transportation Research part B*.

POTENTIAL BENEFITS OF THE PROJECT:

Direct benefits from this proposed research project are as follows:

- An effective area-wide system for coordinated ramp meter control;
- VISSIM simulation models that implement fuzzy logic, ALINEA, and the proposed ramp metering strategies; and
- Comparison results among fuzzy logic, ALINEA, and the proposed AIMD-based strategies.

Freeway operation agencies and research institutes are recipients of these benefits.

**Transportation Northwest (TransNow) Research Project Descriptions
Year 19: July 1, 2006-June 30, 2007**

Identifying Number	61-4160
Project Title	Measuring Arterial Performance Using Vehicle Feet GPS Data and Traffic Sensor Data
Principle Investigator	Mark Hallenbeck
Institution	University of Washington
PI's telephone number	Phone: (206) 543-6261 Fax: (206) 685-0767
PI's E-mail address	tracmark@u.washington.edu
External Project Contact, address, telephone number	Mr. David Weld, Inrix 4055 Lake Washington Blvd NE Suite 200 Kirkland, WA 98033 Phone: (425) 284-3820 Fax: (425) 284-3879 david@inrix.com

ABSTRACT:

Arterial performance measurement has become increasingly important for traffic intensive urban areas. However, data on arterial operational performance are rarely available and practical measurement systems for arterials are yet to be developed. It is cost prohibitive to use traditional data collection technologies for collecting detailed operational performance information on arterials. A possible solution to this situation is the use of existing vehicle probe data from privately running vehicle tracking systems. The private sector is currently beginning to obtain and aggregate vehicle probe (GPS) data from multiple commercial vehicle fleets (taxiâ€™s, shuttle services, household service vans, etc.) in order to produce and distribute real-time traffic congestion information on arterials. This same data source provides (potentially) an ideal, low-cost, continuous data stream that can be used to measure arterial performance. Inrix Corporation is a leader in using fleet data for traffic congestion forecasts and has accumulated a large amount of fleet movement data. Inrix has agreed to supply several hundred thousand dollars worth of vehicle probe data to the University of Washington for traffic research and training. This project will fuse these privately collected data sources and traffic sensor data to develop a practical measurement system for arterial performance. The accuracy of this system will be tested using data from major arterials within the Seattle metropolitan region. If successful, the project outcome would be a demonstration of a cost effective system for monitoring congestion on all roads in almost all metropolitan regions in the country.

PROJECT OBJECTIVES

There are two primary objectives for this research;

- Testing of the accuracy of the Inrix dataset,
- Development of example arterial performance measures that can be computed using those data, should they prove reliable.

Should the research be successful, the result would be a demonstration of a cost effective system for monitoring congestion on all roads in almost all metropolitan regions in the country.

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TASK DESCRIPTIONS AND MILESTONES:

1. Obtain and format Inrix data
2. Collect ground truth data
3. Analyze accuracy and geographic coverage of Inrix data
4. Develop alternative arterial performance metrics
5. Compute performance metrics using Inrix data
6. Prepare reports and presentations on arterial performance using vehicle probe data

RELATIONSHIP TO OTHER PROJECTS:

This project continues the University of Washington's nation leading efforts in the development of roadway performance measures. It is an excellent corollary to the ongoing TRAC-UW research project, Arterial FLOW Methodology and takes advantage of the TransNow research previously completed by Dan Dailey on the use of transit vehicles as probes.

The research team envisions arterial performance reports similar to the Freeway Network Usage and Performance report produced for WSDOT. The development of a successful arterial performance monitoring effort would also directly benefit the Puget Sound Regional Council's ongoing congestion management system efforts, as well as supplying calibration information to the Simulation Lab that has been proposed for funding by TransNow.

Lastly, the development of arterial performance measures would provide significant insight into the region's freight mobility discussion. One of the largest problems when dealing with freight mobility is the lack of information on delays trucks are experiencing on urban roadways. If this project is successful, information on freight delays and freight reliability on urban arterials would be available for that research.

TECHNOLOGY TRANSFER ACTIVITIES:

If this project can successfully illustrate how Inrix vehicle probe data can be converted into reliable arterial performance information, the results of this project could create entire new analysis possibilities for cities around the nation. Technology transfer of those results is imperative. Within Washington, this task is relatively easy. Because of the breadth and extent of the existing UW-WSDOT-PSRC collaboration in roadway and freight performance measures, the research team members are already actively collaborating with the WSDOT and PSRC staff that would use these data. The research team meets with these staff multiple times each month.

As part of both this project and as part of other on-going performance measurement activities with both WSDOT and PSRC, the research team will participate in numerous meetings with WSDOT and PSRC staff and make numerous presentations to professional societies (e.g., ITE, WTS, and ITS Washington) on the results of this project, demonstrating how those results can be used for key roadway performance measurement tasks.

In addition, the research team will write and submit papers (and make presentations at) both the Transportation Research Board meetings and the National Traffic Data Acquisition Conference (NATMEC) to publicize these findings and explain how they can be used to the advantage of state DOTs and other highway agencies and metropolitan planning organizations.

The research team will also meet all TransNow requirements, including producing the final report for this project and producing a one page implementation report prior to the end of this project in June 2007.

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POTENTIAL BENEFITS OF THE PROJECT:

As noted in the above sections, this project has the potential to dramatically change the availability of roadway performance data on arterials around the state, and potentially around the nation. If privately collected vehicle probe data can be provided cost effectively for all regional arterials and those data prove to be capable of providing reliable arterial performance information, then this project will demonstrate a paradigm shift has taken place in the types of analyses that can be cost effectively performed.

If the data to be supplied by Inrix prove to provide accurate and reliable arterial performance measures, a large number of highly beneficial analyses become possible for state DOTs, regional and local governments.

Depending on the nature of the Inrix results, these analyses could include:

- analyses of the effects of roadway congestion on the reliability of freight delivery and the costs of roadway congestion on freight operations,
- the routine analysis of the performance of arterial signal timing plans and the consequent need for retiming of those signals,
- the cost effective monitoring of the congestion relief effects of roadway improvement projects,
- the effects of construction traffic mitigation plans,
- the collection and use of actual arterial performance data in the planning and prioritization process associated with Transportation Improvement Plans

**Transportation Northwest (TransNow) Research Project Descriptions
Year 19: July 1, 2006-June 30, 2007**

Identifying Number	61-4027
Project Title	Accounting For Transit Infrastructure, Transit Operations and Pedestrian s In Concurrency
Principle Investigator	Mark Hallenbeck
Institution	University of Washington
PI's telephone number	Phone: (206) 543-6261 Fax: (206) 685-0767
PI's E-mail address	tracmark@u.washington.edu
External Project Contact, address, telephone number	King Cushman, PSRC 1011 Western Ave Suite 500 Seattle, WA 98104 Phone: (206) 464-6174 Fax: (206) 587-4825 KCushman@psrc.org

ABSTRACT:

Current Washington State Growth Management regulations state that jurisdictions in Growth Management counties must define a Concurrency process that ensures that adequate transportation facilities are present or will be present within three years before construction permits can be issued for new development. The current Concurrency regulations of most cities are based strictly on traffic congestion indices. Yet most city transportation plans assume that a growing segment of travel will occur via transit and pedestrian modes of travel. Research is required to determine practical ways of incorporating transit operations and pedestrian facilities into existing Concurrency systems in Washington jurisdictions. Having multi-modal concurrency systems in place will help reduce congestion in densely populated areas as vehicular trips will be substituted with transit and non-motorized options.

PROJECT OBJECTIVES

The primary objective of this project is to research more effective ways to integrate transit operations into the state's transportation concurrency practices. Transit operations work effectively only when the land uses they serve and the infrastructure on which the transit vehicles operate are designed to support them. Transportation concurrency is the part of the planning and permitting process that should ensure that cities which are counting on multi-modal solutions for mobility effectively include the facilities and services required by all modes of travel in their development plans, and then provide the funding for those services.

It is unclear (but a subject to be covered by this study) whether local jurisdictions that are permitting development should also control the funds required to provide the transit services, or at least contribute to the cost of providing transit services, that are which are needed by the developments they are permitting. Having effective multi-modal concurrency systems in place will help ensure mobility and reduce congestion in urban areas by making sure that transit and non-motorized travel options are in place when development occurs.

This project will determine how to refine Washington's existing concurrency practices to best achieve these results.

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TASK DESCRIPTIONS AND MILESTONES:

1. Update of existing literature review
2. Meetings with Consultation Group and Advisory Committee
3. Develop evaluation criteria
4. Develop evaluation methodology
5. Develop alternative concurrency approaches
6. Analyze alternative concurrency approaches
7. Produce recommendations
8. Write final report and make presentations

RELATIONSHIP TO OTHER PROJECTS:

This effort is a follow on to two previous studies of concurrency, the multi-phased PSRC study, Assessing the Effects of Transportation Concurrency, and the previous TRAC-UW effort, the Eastside Concurrency Study. This proposed TransNow project is a needed expansion of work funded by the legislature. The legislative effort is the source of the matching funds for the proposed TransNow project. (The Legislature passed Second Substitute House Bill 1565 in April of 2005. That bill includes the funding for the matching portion of this study.)

In addition to the work being done in Washington, several other States are continuing to look at ways to both perform some type of growth management, and at the same time, provide for the transportation systems required to both serve more dense urban development and shift the economic incentives that encourage sprawl. The state that has adopted an approach to transportation and growth management that is the most similar to Washington's is Florida. [9, 10] One of the main contributors to Florida's efforts in this area is Dr. Ruth Steiner of the University of Florida. Her work and ideas were used extensively in both the TRAC and PSRC studies referenced above. At the same time, TRAC staff have served on Dr. Steiner's advisory panels for Florida DOT sponsored projects.

TECHNOLOGY TRANSFER ACTIVITIES:

This project has two major implementation efforts. The primary implementation effort is a report to the Legislature that will be delivered in December 2006. The recommendations included in that report will be used in the legislative efforts to revise the existing growth management and concurrency statutes.

The second major implementation effort from this project stems from the ability to use funds from TransNow to extend the analysis of possible new concurrency procedures to multiple jurisdictions. (The legislative funding allows for only one example city. Funding from TransNow allows expansion of the case study effort to multiple cities.) With TransNow funding, the project team will be able to work directly with staff from those jurisdictions to understand how proposed procedures would effect delivery of transit services in those jurisdictions, as well as how the proposed revisions would benefit (and/or hinder) growth planned for those jurisdictions. These additional case studies should result in a far better examination of the pros/cons of the proposed procedures, as well as helping prepare these jurisdictions for changes in legislation that are likely to occur.

In addition to the report to the legislature, the project team will write and distribute city specific technical reports describing how revised concurrency might change under the recommended procedures. In addition, a one page summary of the project and its impacts on those example jurisdictions will be prepared.

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POTENTIAL BENEFITS OF THE PROJECT:

This project should result in both long and short term benefits.

The long term benefits should be more effectively coordinated land use and transportation plans and development permits that encourage the goals of the Growth Management Act.

The short term benefits of this project will be 1) a better informed legislature and legislative staff, as it begins deliberations on changes to the current Growth Management Act, and 2) more effective concurrency systems in participating cities (regardless of whether changes are made to the legal underpinnings of the GMA).

**Transportation Northwest (TransNow) Research Project Descriptions
Year 19: July 1, 2006-June 30, 2007**

Identifying Number	61-4028
Project Title	Traffic Simulation Lab
Principle Investigator	Mark Hallenbeck
Institution	University of Washington
PI's telephone number	Phone: (206) 543-6261 Fax: (206) 685-0767
PI's E-mail address	tracmark@u.washington.edu
External Project Contact, address, telephone number	Craig Stone WSDOT 401 Second Avenue S. Suite 200 Seattle, WA 98104 Phone: 206.464.1222 stonec@wsdot.wa.gov

ABSTRACT:

The growth in computer processing power has made traffic simulation a more cost effective and practical tool for a large number of traffic engineering operational analyses. However, insufficient support exists for both teaching traffic simulation at the universities and for applying and using these tools to meet WSDOT research needs. This project would create a traffic simulation facility at the University of Washington aimed at increasing access to traffic simulation software, data sets, and coursework to students throughout the Pacific Northwest. The center would also serve as a repository for calibrated data sets of WSDOT roadway networks that allow quick turnaround research analyses of WSDOT operational problems.

PROJECT OBJECTIVES

There are four objectives for this proposal:

- 1) increase the availability of courses in the area of traffic flow simulation modeling, thus increasing the number of people trained in the use of simulation models and increasing the number of qualified staff available to both public agencies and the private sector
- 2) substantially increase traffic simulation modeling capabilities at the Department of Civil and Environmental Engineering at the University of Washington and make those capabilities accessible across the Pacific Northwest
- 3) decrease the time and cost required to apply simulation models for a wide range of traffic analyses within the state and region
- 4) perform specific simulation analyses for WSDOT, PSRC, and other agencies participating in the simulation lab

TASK DESCRIPTIONS AND MILESTONES:

- 5) Course Development
- 6) Course Instruction

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- 7) Advisory Board Meetings (once per quarter as a minimum)
- 8) Obtain Existing Data Sets
- 9) Code, Calibrate, and Maintain Simulation Datasets
- 10) Perform Selected Simulation Projects

RELATIONSHIP TO OTHER PROJECTS:

Simulation is a key aspect of a number of ongoing WSDOT and PSRC studies. A short list of the largest of these studies includes the following:

- the I-5 pavement rehabilitation project (which requires simulation testing of alternative construction traffic management plans)
- the I-405 corridor project
- the SR 520 bridge replacement and HOV lane design project
- the SR 99 Viaduct replacement project (which requires testing of alternative construction traffic management plans).

A variety of other research projects currently of interest to WSDOT and PSRC would benefit from access to simulation capabilities. Many of these studies are likely to be performed by University of Washington faculty, students, and staff if the capability of cost effectively doing those studies exists.

The University of Washington is actively performing a number of projects that directly apply to the use or enhancement of simulation models. The Principal Investigator (PI) and Co-PI for this study are leading many of these projects. One set of current projects is developing performance measurement systems that describe freeway and arterial performance and, especially, the reliability and variability of roadway performance. [See references 4 and 5 which are reports from these projects.] The limitation in this ongoing research is that these measures describe existing performance. They do not predict future performance levels that result from different traffic management plans. Predictions of roadway performance, especially the reliability of a given roadway's performance, require simulation models.

Considerable work needs to be done to connect the ongoing work on roadway performance to the models that are needed for predicting that performance. (Several ongoing UW research projects including Arterial FLOW Methodology, Northwest Region FLOW Analysis Support, and Incident Response Evaluation: Measurement of Recurring and Non-recurring Congestion - Phase 3 are examples of projects that both would contribute to the simulation center and could be greatly expanded through greater access to calibrated simulation networks.)

At the national level, the Future SHRP research program includes considerable funding for advances in simulation modeling. One of the key research topics for Future SHRP is to improve transportation agencies' ability to forecast the effects of different improvements on the reliability of roadway performance. [6] The creation of this center, the tools required to extract data from the current archives, and the ability to inexpensively extract existing roadway geometry from existing data structures (e.g., GIS files and digital images) should propel the Northwest into a leading role in the performance of that research.

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TECHNOLOGY TRANSFER ACTIVITIES:

Technology transfer will be an integral portion of this project. Technology transfer will occur both through the direct instruction of students and agency staff in the use and theory behind simulation software and through the application of the simulation software to projects specifically selected by involved agency staff.

In return for their basic support of the simulation lab, it is proposed that government transportation agencies be able to send staff to attend the simulation courses at no additional fee. (These students would not take the exams and would not be given university credit, but they would be expected to perform the homework and course projects and might be eligible for continuing education credits.) Subject to University of Washington approval, it is expected that between five and ten student slots would be available for qualified staff from agencies helping to fund the simulation center. In addition to training their own staff, the simulation lab will train students who will enter the transportation work force, where they will be able to directly apply their knowledge of simulation software.

In addition to training staff for both the public and private sectors, the simulation lab will be responsible for coding new roadway datasets, calibrating simulation networks, performing analyses at the request of the participating agencies, and providing all of those materials to those agencies. This will allow the simulation lab to:

- transfer simulation network data to agencies and firms that need those data
- answer policy questions for those agencies using the simulation lab capabilities
- improve the capabilities of the lab and consequently all other users of the selected simulation software.

As requested, a final report on the activities of the simulation lab (completed activities, plans for coming years) will be supplied to TransNow by the end of April 2007. Technical reports will be written and submitted to both TransNow and the sponsoring agencies as specifically requested analyses are completed. A one-page summary of the technology transfer and implementation activities for the simulation lab will be submitted by the end of June 2007.

POTENTIAL BENEFITS OF THE PROJECT:

The proposed project will provide multiple benefits to all participating parties. University students gain access to additional courses, as well as job skills that will greatly increase their marketability. The University will gain resources that will support the expansion of its teaching curriculum, as well as a program that facilitates nationally valued research by providing data, students, problem statements, and funding. State agencies will gain access to a significant increase in trained personnel, a decreased overall cost of applying simulation tools, improved simulation tool capabilities, and completed analyses of high priority projects. State agency staff will gain access to professional development training not otherwise available.

**Transportation Northwest (TransNow) Research Project Descriptions
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Identifying Number	61-4026
Project Title	De-Bonding Cracking in Hot Mix Asphalt Pavement
Principle Investigator	Steve Muench
Institution	University of Washington
PI's telephone number	Phone: 206-616-1259 Fax: 206-543-1543
PI's E-mail address	stmuench@u.washington.edu
External Project Contact, address, telephone number	Joe Mahoney, UW Mailbox 352700 University of Washington Seattle, WA 98195 Phone: 206-685-1760 Fax: 206-543-1543 jmahoney@u.washington.edu

ABSTRACT:

Recent evidence in Washington State, Hawaii and elsewhere indicates that a significant portion of cracking in thick hot mix asphalt (HMA) pavements is due to a previously uninvestigated phenomenon: bottom-up cracking of a de-bonded HMA surface layer. This cracking results when a surface HMA layer is not adequately bonded to underlying HMA layers (often through the inadequate or inappropriate use of tack coat) and behaves as an independent and extremely thin HMA layer. This de-bonding can shorten pavement life and cost agencies and taxpayers substantial money. Evidence from other pavement studies suggest de-bonding is much more prevalent and influential than previously thought. Potential benefits include: an understanding of this failure phenomenon, better specifications and practice for tack coat application to combat this failure, and ultimately better pavements with lower life-cycle costs.

This proposed study would be the first known investigation into the significance, prevalence and performance impact of what we are calling "de-bonding cracks". We propose to work with the Washington State Department of Transportation (WSDOT) to identify and perform statistical and forensic analyses on pavements thought to suffer from de-bonding cracks. This effort will establish the relative significance and prevalence of de-bonding cracking and form the basis for future, in-depth research.

PROJECT OBJECTIVES

This research will provide some of the first empirical evidence as to the existence, prevalence and impacts of de-bonding cracking. Specific objectives are:

1. Identify pavements in Washington and Hawaii that are likely to suffer from de-bonding cracking.
2. Determine whether or not de-bonding cracking can be identified with reasonable certainty based on WSPMS records or visual clues alone.
3. Determine the prevalence of de-bonding cracking in Washington and Hawaii.
4. Determine the relationship between poor tack coat application practice and de-bonding cracking.

TASK DESCRIPTIONS AND MILESTONES:

1. Data Mining

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2. Interviews
3. Field Investigation
4. Reporting
5. Technology Transfer

RELATIONSHIP TO OTHER PROJECTS:

This project builds on one ongoing WSDOT project and one previous project partially funded by TransNow:

- **WSDOT and Washington State University tack coat study (ongoing).** Investigated tack coat application rates, tack coat paving strategies and bond testing equipment. The final report is due in 2006. The proposed study would compliment this study by adding data of state-wide prevalence of de-bonding cracking issues, verifying issues with a second state's data and providing initial data concerning the effects on pavement performance.
- **WSDOT Pavement Guide Interactive (completed 2003, contained funding from TransNow).** Produced a multimedia CD-ROM containing a multitude of pavement-related information (example product at: <http://guides.ce.washington.edu/ptc>). The proposed study would add its data to this product in an effort to keep it up-to-date and actively use it as a technology transfer device.

TECHNOLOGY TRANSFER ACTIVITIES:

This research will result in an initial assessment of the existence, prevalence and impacts of de-bonding cracking in Washington and Hawaii. This assessment will be transmitted to interested parties (e.g., WSDOT, HDOT, City and County of Honolulu) via a standard report but it will also be developed as:

- **Tech Note.** Findings could be released in a WSDOT Materials Laboratory "Tech Note" (<http://www.wsdot.wa.gov/biz/mats/Pavement/TechNotes/technotes.htm>).
- **Interactive training.** A multimedia online training lesson will summarize results and provide initial training and information to study participants and the general public.
- **WSDOT Pavement Guide Interactive addition.** Multimedia training will also be included in the next regular update of the WSDOT *Pavement Guide Interactive*.

POTENTIAL BENEFITS OF THE PROJECT:

The potential benefits of this proposed investigation are:

- Immediate benefit (achieved upon completion of this proposed study)
 - Insight into the existence, prevalence and impacts of de-bonding cracking in Washington and Hawaii.
 - Direction for future studies
- Long-term benefits (potential benefits when combined with future studies)
 - Better specifications and practice for tack coat application to minimize de-bonding cracking.
 - Better pavements with lower life-cycle costs.

**Transportation Northwest (TransNow) Research Project Descriptions
Year 19: July 1, 2006-June 30, 2007**

Identifying Number	268794
Project Title	Incorporation of Forward-Directivity into Seismic Hazard Analysis
Principle Investigator	Adrian Rodriguez-Marek
Institution	Washington State University
PI's telephone number	Phone: 509 335 7088 Fax: 509 335 7632
PI's E-mail address	adrian@wsu.edu
External Project Contact, address, telephone number	Kim Willoughby 310 Maple Park Ave SE PO Box 47372 Olympia, WA 98504 Phone: 360 705 7978 Fax: 360 705 7978 WillouK@wsdot.wa.gov

ABSTRACT:

Recent earthquakes have shown that pulse-type earthquake ground motions that result from forward-directivity effects can result in significant damage to structures. These observations have recently been corroborated by experimental evidence and analytical research. Forward-directivity (FD) effects at a site occur when fault rupture propagates towards a given site and the directions of rupture and slip coincide. While FD effects are confined to within 20 miles of a fault, many urban centers in the U.S. are built on top of faults; hence FD can have significant impact on the vulnerability of transportation infrastructure. Various bridges in the cities of Seattle and Tacoma, as well as other sites in Washington State, are vulnerable to damage due to FD effects. Current research at WSU has identified some of these bridges and preliminary results have shown that FD motions can control design loads in these bridges.

In a typical design project, seismic demand is characterized by the Equal Hazard Spectrum (EHS) and is determined using Probabilistic Seismic Hazard Assessment (PSHA). Due to the inherent complexity of PSHA, the interactive web features made available by the USGS are often used to determine the EHS. However, FD effects are not necessarily accounted for in the USGS analysis and this becomes a problem when a fault that potentially can generate FD ground motions controls a significant portion of the hazard at a site. Moreover, it is often necessary to obtain full time histories for design or for analysis of geotechnical problems. When the potential for FD exists, there are no guidelines as to how these ground motions should be selected.

The approach taken by designers is to obtain a design spectrum using probabilistic analyses and then modify this spectrum to account for FD using coefficients obtained from deterministic analyses. The problem with this methodology is that there are no guidelines as to how to couple deterministic and probabilistic analyses and to determine design time-histories. The goal of the proposed research is to provide a methodology for incorporating FD effects into PSHA and provide guidelines for the selection of FD time histories for design. The proposed methodology will lead to a more rigorous treatment of FD motions in PSHA, and thus to a better evaluation of seismic hazard for sites affected by FD.

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PROJECT OBJECTIVES

The overall goal of this research project is to develop a methodology for the inclusion of the effects of near-fault forward-directivity into the determination of seismic demand for a structure or a geotechnical system. The focus of the study will be the potential for near-fault effects associated with the Seattle and Tacoma faults in Washington State, and how these near-fault effects can affect the transportation infrastructure in the state.

Specific objectives of the research include:

- Establish an Equal Hazard Spectra for design (e.g. a 2500 year return period EHS) using PSHA and incorporating forward directivity effects in the Seattle Fault.
- Establish a Hazard Curve for a selected Damage Measure for the EHS of the Seattle Fault.
- Determine a Hazard Curve for the selected Damage Measure using repeated generation of earthquake scenarios in the Seattle Fault, both using a time domain methodology and a spectral domain methodology.
- Compare the Hazard Curves obtained using both methodologies with that obtained using the EHS.

TASK DESCRIPTIONS AND MILESTONES:

The proposed project is divided in two parts, the first of which will be performed during the first year of the project, and the second which will be proposed for a second year of funding pending the appropriate re-authorization. Tasks for both years are included in this proposal, although further discussion of the tasks for the second year is left for a follow-up proposal to be submitted next year. Research in year one is restricted to study the effect of FDGMs to simple structural and geotechnical systems (e.g. nonlinear SDOF systems and MDOF systems, and similarly simplified geotechnical structures). Research in the second year will be targeted to more specific structural or geotechnical systems (e.g., a problem of immediate relevance to the WSDOT). A research task within year one will be targeted to the selection of these systems.

YEAR ONE

Task 1. Selection of appropriate Damage Measures. This task implies the selection of a structural and geotechnical system that will be tested for its response to NFGMs. For example, in response spectra-based design, the systems in question are multiple linear SDOF systems with varying periods. The initial target is to select two simplified systems from which *Damage Measures* will be computed. One of these systems will be a simple geotechnical system (e.g., a soil column where the damage measure will be peak strains). The other system will be a nonlinear MDOF system. Along with the *DM*, a numerical methodology for their computation will be selected.

Task 2. Characterization of the seismicity of the Seattle and Tacoma Faults. This task will be achieved through an extensive review of the pertinent literature.

Task 3. Perform Probabilistic Seismic Hazard Analyzed of sites located near the Seattle and Tacoma Faults. PSHA analyses will be performed using the open source program OpenSHA (<http://www.opensha.org>). Analyzes will incorporate forward directivity effects following the approach of Abrahamson (2002). An equal hazard spectra (EHS) with a return period of 2500 years will be obtained. The choice of return period is to render this EHS compatible with code design.

Task 4. Generate earthquake scenarios and ground motions. These scenarios are compatible with the PSHA performed in Task 3. For each scenario, ground motions compatible with that scenario will be selected using both the spectral approach of Somerville (2003) and spectral matching techniques (e.g. Abrahamson 2000). Ground motions will also be selected using the time-domain approach of Bray and Rodriguez-Marek (2004).

Task 5. Compute DM for all earthquake scenarios. Numerical analyses will be conducted to compute the damage measures for both the equal hazard spectra in Task 3 and the multiple scenarios in Task 4. A

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hazard curve will be constructed for the DM both for the equal hazard spectra, following the methodology of PBD, and for the multiple scenarios in Task 4 using a Monte Carlo approach.

Task 6. Draw conclusions. The results of Task 6 will be analyzed to draw conclusions regarding the relative benefits of the *spectral approach* (Task 4), the *time domain* approach (Task 4), and an approach using exclusively the equal hazard spectra (Task 3).

Task 7. Report writing and technology transfer. The PI will work directly with the state DOT (WSDOT) to ensure that methodologies developed within this research are taken into consideration for design and retrofit of transportation facilities in Washington State. Moreover, the PI will seek to present the research to the professional community through seminars and publications.

Task 8. Selection of a structural or geotechnical system for Year Two. This task will be performed by seeking collaboration from the WSDOT. The preparation of year two proposal will be a component of Task 8.

YEAR TWO. The proposal for year two will be based on the conclusions from the research in Year One. The research will follow the same methodology but with the damage measure selected as the performance of a critical transportation facility in Washington State. The tasks outlined below are only preliminary, details will be provided as the results of Year One research are obtained.

Task 9. Development of numerical model for the selected Damage Measures.

Task 10. Computation of Damage Measures for selected systems.

RELATIONSHIP TO OTHER PROJECTS:

The proposed project is closely related to a FHWA funded project in which the PI is a participant. The FHWA project was targeted at the response of two bridges in Washington State to FDGMs. Preliminary results of the project indicated that design forces in these bridges could be controlled by the demand imposed by FDGMs. In this case, however, FDGMs were not selected in a manner compatible with PSHA. The research opened up questions as to whether the conclusions made for the two target bridges are applicable in general to other structural systems, and the more important questions of how to incorporate forward directivity effects into PSHA.

Certain deliverables from the FHWA project will feed directly into the proposed research. Namely, a comprehensive database of recorded FDGMs has been compiled as part of the FHWA project. Moreover, guidelines for determining nonlinear spectra for FDGMs were also developed as part of that research.

TECHNOLOGY TRANSFER ACTIVITIES:

- The initial output of this research will be a report detailing the methodology developed for the inclusion of FD effects in hazard analyses. This report will be publicly available through a PDF file in the internet on the TransNow home page.
- The PI will work directly with the state DOT (WSDOT) to ensure that methodologies developed within this research are taken into consideration for design and retrofit of transportation facilities in Washington State. The PI will also seek to disseminate this research to appropriate port and municipal authorities in Seattle. The external contact person for this research is Kim Willoughby:

Kim Willoughby, P.E.
Research Manager - Construction, Materials, Bridges and Structures, and Maintenance
Washington State Department of Transportation
310 Maple Park Avenue SE
PO Box 47372

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Olympia, WA 98504-7372
Phone (360) 705-7978

- The PI will seek to present the research to the professional community through seminars. Specifically, presentations to the Seattle ASCE chapter will be arranged.
- The PI has an extensive record of scholarly publications. Papers and presentations at regional and national transportation conferences will be made (e.g. TRB, AASHTO conferences), and scholarly publications in Journals are expected after the completion of Year Two of this research.

POTENTIAL BENEFITS OF THE PROJECT:

This research will have direct benefits to society by providing adequate methods of risk analysis that will allow for better resource allocation and life protection. Near-fault ground motions, and in particular FDGMs, pose a significant risk to long period structures, and consequently bridges in particular, in large urban centers in the United States. Since cities such as Los Angeles, San Francisco, and Seattle, as well as population centers near the New Madrid seismic zone, are underlain by faults capable of producing significant ground motions enhanced by forward-directivity effects, the result of this research will directly benefit these communities.

This research will benefit structural and geotechnical engineers by providing a methodology to include Forward Directivity effects in determining the seismic hazard in structures and geotechnical systems. Both the State DOT and the professional community that deals with the determination of seismic hazard for design in Seattle will be directly benefited.

**Transportation Northwest (TransNow) Research Project Descriptions
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Identifying Number	TBD
Project Title	MANAGING PEDESTRIAN AND BICYCLIST SAFETY II
Principle Investigator	Anne Vernez Moudon
Institution	University of Washington
PI's telephone number	Phone: 206-685-4057 Fax: 206-685-9597
PI's E-mail address	moudon@u.washington.edu
External Project Contact, address, telephone number	Paula Reeves WSDOT Highways and Local Programs Olympia, WA Phone: 360-705-7258

ABSTRACT:

The safety of non-motorized transportation systems is essential to the public acceptance and overall success of Washington State and local jurisdictions efforts to reduce congestion. The State and the jurisdictions goals to increase non-SOV travel options and the use of transit, need to be combined with those to insure the safety of these alternatives.

This project is the continuation of current work developing and using a database of 13,914 individual pedestrian and bike collisions. This database is the first in the nation to have geocoded individual collisions in Geographic Information Systems (GIS) for the entire State (1999-2004). Having the precise location of a large number of collisions over a period of several years promises that significant progress can be made in explaining factors associated with collisions and in identifying underlying causes. The new Washington State collision database is particularly momentous that the State also has some of the most advanced data on road characteristics and land uses associated with trip origins and destinations. These latter data are accessible in GIS for all populated areas of the State and available at the finest resolution.

In the proposed project, current research on road design and land use correlates of collision frequency and severity will be augmented by :

1. Analyses of pedestrian motor vehicle collisions on city streets;
2. Analyses of bicycle motor vehicle collisions on SR and on city streets;
3. Longitudinal analyses of the collision data to identify potential causes of collisions;
4. Scenario planning examinations of safety-dependent locations, such as (a) freight routes, (b) transit hubs, (c) areas that are experiencing major development and growth, (d) areas subject to substantial infrastructure investments, and (e) areas with different levels of transportation efficiency (measured as travel options available beyond SOV travel, and derived from the Transportation Efficient Land Use Mapping Index TELUMI).

PROJECT OBJECTIVES

This project's principal goal is to analyze pedestrian/bicyclist motor vehicle collisions (P/BMVC) and to examine the significance and strength of their association with road characteristics, vehicular traffic conditions (cars, trucks, and buses), and land use features along roadways. Models will measure the odds of

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future P/BMVC to occur, based on specific environmental conditions. Model results identifying factors associated with high risk of P/BMVC will serve the purpose of targeting future pedestrian and bicyclist safety improvement programs, and of developing road and land use treatments and countermeasures

The proposed project will augment on-going research on the road design and land use correlates of the frequency and severity of pedestrian motor vehicle collisions on State Routes. The following are specific goals of the project:

1. Analyses of pedestrian motor vehicle collisions on city streets;
2. Analyses of bicycle motor vehicle collisions on SR and on city streets;
3. Longitudinal analyses of the collision data to identify potential causes of collisions;
4. Scenario planning examinations of “safety-dependent” locations, such as (a) freight routes, (b) transit hubs, (c) areas that are experiencing major development and growth, (d) areas subject to substantial infrastructure investments, and (e) areas with different levels of transportation efficiency (measured as travel options available beyond SOV travel, [Moudon, Kavage et al in press, Moudon, Sohn et al. 2005])

TASK DESCRIPTIONS AND MILESTONES:

1. <u>Hotspots analyses of pedestrian collisions on state routes and city streets.</u> This task will include the testing of different approaches to hotspot identification and their application
2. <u>Multivariate analyses of pedestrian collisions on city streets.</u> Includes data development; test sampling approaches; GIS data capture; perform appropriate analyses of data distribution, coding, correlations, analyses of variance, etc., in preparation for modeling, as well as model estimation and interpretation of results
3. <u>Hotspots analyses of bicyclist collisions on state routes and city streets.</u> Includes testing of different approaches to hotspot identification and their application
4. <u>Multivariate analyses of bicyclist collisions on state routes and city streets.</u> Include data development; test sampling approaches; GIS data capture; perform appropriate analyses of data distribution, coding, correlations, analyses of variance, etc., in preparation for modeling, as well as model estimation and interpretation of results
5. <u>Longitudinal analyses.</u> Investigates the extent to which collisions are recurrent or not in given locations over the 6 years that data are available. Both hotspot and multivariate analyses will be performed.
6. <u>Scenario planning.</u> Carrying out hotspot and multivariate analyses of pedestrian and bicyclist collisions on the following transportation facilities and areas: (1) Freight routes—based on WSDOT road classification; (2) Transit hubs—based on the existing and planned infrastructure of regional and local transit systems; (3) Growth areas—based on regional and local indicator of residential or employment growth; (4) Facilities and areas where recent infrastructure investments have been made; (5) Areas with different levels of transportation efficiency—based on GIS maps of transportation efficiency, derived from the Transportation Efficient Land Use Mapping Index—TELUMI, which measure land use that support travel options beyond SOV travel.
7. <u>Final Report.</u> Draft to be submitted to TransNow, WSDOT and TRAC for review at least two months before the scheduled end of the project. Final Report to incorporate responses to the reviewers’ comments.

RELATIONSHIP TO OTHER PROJECTS:

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This work continues previous Washington State DOT projects on Pedestrian Safety and Transit Corridors (Hess, Moudon et al. 2003) and Pedestrian Safety Treatment and Countermeasures (Nee and Hallenbeck 2003). It complements an on-going project with WSDOT on Managing Pedestrian Safety (in progress).

We will continue to use two types of data: the pedestrian and bicyclist collision data (1999-2004) assembled by WSDOT for the entire road system of Washington State (State, county, and city roads and streets); and the state-of-the-art parcel-level GIS land use data available for all urbanized areas of the State of Washington (University of Washington, WAGDA).

The Washington Traffic Safety Commission (WTSC) has a long standing record of supporting the safety of non-motorized travel in the areas of enforcement and facility design (Washington Traffic Safety Commission 2006).

Over the last decade, the Principal Investigator has worked with WSDOT, regional, and local agencies to improve pedestrian safety (Hess, Moudon et al. 2001; Hess 1999; Koepsell, McCloskey et al. 2002; Moudon, Hess et al. 2002; Moudon, Hess et al. 1997). She has recently completed a 4-year project for the Centers for Disease Control and Prevention, which produced instruments to score neighborhood walkability (Moudon and Lee 2003, Moudon, Lee et al 2006). This latter research also produced models estimating associations between bicycling travel and land use (Moudon, Lee et al. 2005)

TECHNOLOGY TRANSFER ACTIVITIES:

A final report will be submitted to TransNow, TRAC, WSDOT, and WTSC. In addition, papers will be prepared for and presented at the Transportation Research Board and the Association of Collegiate Schools of Planning. We expect to produce at least two papers to be published in Transportation Research Record and in Transportation Research. We will also prepare project findings summaries for TransNow and TRAC publications.

POTENTIAL BENEFITS OF THE PROJECT:

In the medium and long ranges, we expect to provide evidence for increasing public and institutional awareness of pedestrian and bicyclist safety needs, with the effect of increasing the scope and effectiveness of safety enhancement projects directed at pedestrians and bicyclists. The project will guide the forging of more effective collaborative ties between transit agencies and WSDOT, to ensure the safety of the bus riding public, as well as to direct the implementation of traffic control measures and road designs that decrease the risk of P/BMVC. Being able to identify the locational and land use characteristics associated with P/BMVCs will enable WSDOT, policy makers, local jurisdictions, and transit agencies to effectively target pedestrian safety programs in areas where safety and improvement investments can yield the highest return.

**Transportation Northwest (TransNow) Research Project Descriptions
Year 19: July 1, 2006-June 30, 2007**

Identifying Number	61-4330
Project Title	Occlusion Robust Vehicle Tracking Using Motion-based Features
Principle Investigator	Yinhai Wang
Institution	University of Washington
PI's telephone number	Phone: (206) 616-2696 Fax: (206) 524-6016
PI's E-mail address	yinhai@u.washington.edu
External Project Contact, address, telephone number	Ted Trepanier 310 Maple Park Avenue SE PO Box 47344 Olympia, WA 98504 Phone: (360) 705-7280 Fax: (360) 705-6826 trepant@u.washington.edu

ABSTRACT:

It is of fundamental importance to track vehicles for traffic data collection and operations. For example, if a vehicle can be tracked at intersections, its control delay can be accurately measured. However, most traffic detectors are point sensors and do not have the tracking capability. GPS-equipped vehicles can be tracked, but there are only very few of such vehicles on roadways. The widely deployed surveillance video cameras enable a means to track vehicles on major arterials. Most video-based vehicle tracking algorithms, however, are based static features extracted from edge detection and background subtraction. These algorithms do not perform well when vehicles are occluded or when camera vibrates. Considering that both vehicle occlusion and camera shaking are common phenomenon on current roadways, a more robust video image processing algorithm for vehicle tracking is desired.

In this study, an occlusion robust vehicle tracking algorithm using motion-based features are proposed. In the proposed algorithm, the Kanade-Lucas-Tomasi (KLT) feature tracking algorithm is employed for motion feature extraction. An improved K-means algorithm is applied to classify feature points into groups. Each feature group corresponds to one vehicle. Bayesian Information Criterion (BIC) is used as the selection criteria for choosing the optimal number of clusters.

The proposed algorithm is functional on highways under even light changing conditions because most feature points tracked will not be affected by luminance change. It is also robust to camera vibrations due to relaxed requirements of the stable background.

PROJECT OBJECTIVES

The objectives of this study are:

- To explore the feasibility of collecting traffic data through vehicle tracking using surveillance video camera images;
- To develop an effective approach for vehicle tracking under conditions with severe traffic occlusion problems; and
- To build up a computer system that implements the proposed tracking algorithm and automates the vehicle tracking process.

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TASK DESCRIPTIONS AND MILESTONES:

The proposed approach for vehicle tracking consists of three major functional modules. The real traffic data from congested highways will be used to examine the robustness of the approach when dealing with vehicle occlusion problems. A computer system will be developed using the Microsoft C#.Net technology.

The objectives of this project will be fulfilled through the following seven tasks:

- Research preparation and studies of related algorithms;
- Video data input module design and implementation;
- Motion features extraction and tracking module design and implementation based on KLT algorithm;
- Feature clustering algorithm development and implementation;
- Vehicle identification module design and implementation;
- System evaluation; and
- Documentation

Each of the above tasks may consist of several subtasks. A description of the tasks and subtasks is given Below:

Task 1: Research preparation and data collection

- 1-1: Research team set up
- 1-2: Select two study sites, one with little camera vibration problems and the other with severe camera shaking problems. Both sites are subject to traffic congestion at peak hours;
- 1-3: Collect video data under several typical conditions, such as free flow and congestion at both study sites; and
- 1-4: Collect regular traffic measurements, such as speed and truck percentage, at the selected sites for analysis.

Task 2: Video data input module design and implementation

- 2-1: Configure the hardware for the video input model
- 2-2: Design the related image digitization algorithm; and
- 2-3: Implement video data input module using the Microsoft DirectX technology.

Task 3: Motion features extraction and tracking module design and implementation based on the KLT algorithm

- 3-1: Review the existing KLT feature tracking algorithm;
- 3-2: Modify the KLT algorithm to address the particular properties of vehicle tracking;
- 3-3: Implement the modified tracking algorithm; and
- 3-4: Build up a standard module interface for the feature clustering module;

Task 4: Feature clustering algorithm development and implementation

- 4-1: Review and study the clustering algorithm;
- 4-2: Modify the general K-means clustering algorithm for particular application of feature tracking;
- 4-3: Design the optimal strategy for self-acting selection of cluster numbers using the Bayesian Information Criterion measure;
- 4-4: Implement the feature clustering module; and
- 4-5: Build up a standard module interface for the vehicle identification module.

Task 5: Vehicle identification module design and implementation

- 5-1: Robust identification algorithm design based on feature groups; and
- 5-2: Implement vehicle identification and tracking strategy;

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Task 6: System evaluation

- 6-1: Select measure of effectiveness for system evaluation;
- 6-2: Evaluate the effectiveness of each functional module;
- 6-3: Evaluate the effectiveness of the whole system; and
- 6-4: Modify the system as needed.

Task 7: Documentation

- 7-1: Write the draft final report; and
- 7-2: Circulate the report for review, revise the report and close the project.

RELATIONSHIP TO OTHER PROJECTS:

This proposed project compensates and extends three research projects currently conducted at the University of Washington: “Development of Video-based Vehicle Detection and Classification System,” “Research on Pedestrian Identification and Tracking Using Mean Shift Approach ,” and “A Statewide Operations Data Archive.” The first two projects provides a deep insight to vehicle occlusion problems and leads to a better understanding of feature based tracking methods. Some of standard functional modules, such as the live video feed module, developed by those two projects can be used for this proposed projects. This proposed project provides a new source of data for traffic operations in Washington State and enhance the third project listed above.

TECHNOLOGY TRANSFER ACTIVITIES:

The proposed motion feature based tracking approach will be applied to highways for data collection. If the proposed approach can identify and track vehicles accurately under severe congestion, then the WSDOT and other transportation agencies may be interested to incorporate the proposed system to their data collection systems. Vehicle tracking results will be posted online to demonstration the effectiveness of the proposed algorithm. Findings of this research will also be presented at the annual meeting of Transportation Research Board (TRB).

A final report detailing the achievements of the proposed project will be written and submitted to TransNow for review and distribution by June 2008. The results of this research project will also be documented in at least two papers, which will be submitted for publication in the *IEEE Transactions on ITS* or *Computer-Aided Civil and Infrastructure Engineering*.

POTENTIAL BENEFITS OF THE PROJECT:

Direct benefits from this proposed research project are as follows:

- an occlusion robust approach for vehicle tracking;
- a computer system that tracks vehicles in real-time using surveillance video camera images;
- a better understanding of possible applications of video image processing for traffic data collection;
- a basic platform for further advanced traffic measurements, such as incident detection, traffic control delay estimation at intersections

**Transportation Northwest (TransNow) Research Project Descriptions
Year 19: July 1, 2006-June 30, 2007**

Identifying Number	61-2394 (year 2)
Project Title	Cost-Effective Safety Improvements for Two-Lane Rural Roads
Principle Investigator	Yinhai Wang
Institution	University of Washington
PI's telephone number	206-616-2696
PI's E-mail address	Yinhai@u.washington.edu
External Project Contact, address, telephone number	Dave Olsen WSDOT PO Box 47329 Olympia, WA 98504-7329

ABSTRACT:

Accidents on Washington State roadways cost about \$5.6 billion dollars in 2002, or \$930 per person in Washington State. About 56 percent of fatal and disabling accidents occurred on two-lane rural roads each year, although these roads account for only less than a quarter of the total yearly miles traveled in Washington. The fatal and disabling injury collision risk on two-lane rural roads is 2.4 times as high as that on urban roads. Cost effective safety improvements for two-lane rural roads are urgently needed.

This study aims at identifying accident causal factors on two-lane rural roads and making quantitative evaluations on possible countermeasures. There are three major steps in this study: 1) Roadway geometry data, accident data, traffic volumes, and control devices will be plotted in a GIS system for intuitive comparison and hazardous location identification; 2) Accident-prone locations will be selected for further study to identify major causal factors to traffic accidents; and 3) An econometric model will be developed to quantify the impact of each causal factor on accident risk and identify the cost-effectiveness safety improvement plans. Findings from this study may help decision makers to understand the collision causations better and select more effective countermeasures against two-lane rural roadway accidents.

PROJECT OBJECTIVES

The objective of this study is to better understand rural roadway accident causes in Washington State and to help find cost-effective solutions for reducing the frequency and severity of crashes on rural two-lane roadways.

TASK DESCRIPTIONS AND MILESTONES:

Project Start and End Dates	September 1, 2005 - August 31, 2007
Current year budget	\$30,000
For two-year project, total budget and start and end dates	\$45,000
Modal orientation of the project	Highway
Student involvement (thesis, assistantships, paid employment)	Guohui Zhang (PhD), Patikhom Cheevarunothai (PhD) – RAs

Transportation Northwest (TransNow) Research Project Descriptions
Year 19: July 1, 2006-June 30, 2007

RELATIONSHIP TO OTHER PROJECTS:

This proposed project will conduct follow-up research from two previous research projects entitled “Modeling Vehicle-to-Vehicle Accident Risks at Signalized Intersections” and “A Numerical Examination of Freeway Rear-End Accidents Considering the Mechanism of Accident Occurrence,” respectively. The modeling approach used in those two projects can be applied to this study. Our experiences and findings from these two projects will make the proposed project start at a higher level.

TECHNOLOGY TRANSFER ACTIVITIES:

The rural two-lane road accident database developed for this study can also be used for future safety studies at WSDOT. Results from the statistical analyses will help WSDOT to better understand rural two-lane roadway safety issues and identify locations with higher accident risks. The accident risk models developed for quantifying the relationships between major accident types and causal factors can also be used for evaluating the effectiveness of safety improvement plans on rural two-lane roadways.

A final report detailing the achievements of the proposed project will be written and submitted to TransNow and to the WSDOT for review and distribution. The results of this research project will also be documented in at least two papers, which will be submitted for publication in the *Transportation Research Record* or the *Accident Analysis and Prevention*.

POTENTIAL BENEFITS OF THE PROJECT:

Direct benefits from this proposed research project are as follows:

- Better understanding of accidents occurring on rural two-lane roads in Washington;
- Accident risk models that can be used to evaluate the potential effectiveness of countermeasures against accidents on rural two-lane roadways; and
- Identified accident-prone locations and possible countermeasures to support optimized funding allocations for rural two-lane roadways.

**Transportation Northwest (TransNow) Research Project Descriptions
Year 19: July 1, 2006-June 30, 2007**

Identifying Number	61-2393 (year 2)
Project Title	Estimation of Incident-Induced Travel Delays on Freeways
Principle Investigator	Yinhai Wang
Institution	University of Washington
PI's telephone number	206-616-2696
PI's E-mail address	Yinhai@u.washington.edu
External Project Contact, address, telephone number	Pete Briglia 1107 NE 45 th St, Suite 535 University of Washington Seattle, WA 98195 206-543-3331

ABSTRACT:

The Greater Seattle area has consistently been ranked as one of the most congested areas in the U.S. Traffic congestion on Seattle's major roadway network costs each commuter an average of \$759 annually in wasted time and fuel. The increased travel cost has seriously degraded the economic competition capability of business entities in King County.

In order to solve the congestion problems, a better understanding of congestion causes and impacts is essential. On freeways, it is generally believed that more than 50% of congestion is the result of incidents. Particular attention should be paid to travel delays caused by non-recurrent congestion due to the fact that non-recurrent congestion may be effectively alleviated by cost-effective solutions through traffic management, control, and incident response. In this study, a queuing diagram-based algorithm will be developed for calculating the total travel delays caused by incidents using historical loop detector data and incident data. A computer system implementing this algorithm will also be built to automate the process. This proposed algorithm does not require choosing the reference speeds or other ambiguous thresholds for delay calculation. Therefore, it is easy to understand and implement. The accuracy of the proposed algorithm can be tested using the VISSIM simulation tool.

PROJECT OBJECTIVES

The objective of this study is to develop an algorithm for quantifying incident-induced travel delay on freeways using archived loop detector data and incident log data. The algorithm will be automated in a computer program to facilitate the application.

TASK DESCRIPTIONS AND MILESTONES:

Project Start and End Dates	September 1, 2005 - August 31, 2007
Current year budget	\$45,000
For two-year project, total budget and start and end dates	\$90,000
Modal orientation of the project	Highway
Student involvement (thesis, assistantships, paid employment)	Ryan Avery (PhD), Jianyang Zheng (PhD) - RAs

Transportation Northwest (TransNow) Research Project Descriptions

Year 19: July 1, 2006-June 30, 2007

RELATIONSHIP TO OTHER PROJECTS:

This proposed project takes advantage of several funded projects recently conducted by the research team at the University of Washington, including “Measurement of Recurring Versus Non-Recurring Congestion,” “Identification of Congestion Causes,” “ITS Backbone Infrastructure,” and “Improving Dual-Loop Truck (and Speed) Data: Quick Detection of Malfunctioning Loops and Calculation of Required Adjustments.” Findings of these projects and the established databases through previous studies can be directly applied to this research.

TECHNOLOGY TRANSFER ACTIVITIES:

The estimated travel delays caused by incidents of different types are important inputs for the WSDOT to allocate the limited funding resource against incident-induced congestions on freeways. These results also provide a better understanding on the portion of delay caused by recurrent congestion or non-recurrent congestions at a specific roadway section and, therefore, help to price congestion properly. The queuing diagram-based algorithm developed in this study will be implemented in a computer program to facilitate the application.

A final report detailing the achievements of the proposed project will be written and submitted to TransNow and to the WSDOT for review and distribution. The results of this research project will also be documented in at least one paper for possible publication in *Transportation Research Record* or the *ASCE Journal of Transportation Engineering*.

POTENTIAL BENEFITS OF THE PROJECT:

Direct benefits from this proposed research project are as follows:

- A better understanding of incident delays that helps to choose incident response strategies and congestion countermeasures;
- A queuing diagram-based algorithm and its computer implementation for incident delay estimation on freeways; and
- A study database with incident and traffic data for further studies on freeway incidents.

**Transportation Northwest (TransNow) Research Project Descriptions
Year 19: July 1, 2006-June 30, 2007**

Identifying Number	61-2307 (year 2)
Project Title	Optimization-based Methods for Image Registration
Principle Investigator	George Turkiyyah
Institution	University of Washington
PI's telephone number	206-543-8741
PI's E-mail address	george@ce.washington.edu
External Project Contact, address, telephone number	Sivaneswaran Nadarajah WSDOT PO Box 47365 Olympia, WA 98504-7365 360-709-5475

ABSTRACT:

Image registration is one of today's challenging problems in image interpretation. Image registration is the problem of aligning points and features in one image/view to corresponding points and features in another image/view of the same or another object, or a template object. It involves deforming an image/template to best fit another one. Image registration is essential whenever images obtained at different times, devices, lighting conditions, perspectives, etc, need to be compared and integrated in some fashion. In most problems, especially-planted markers to help with the registration do not exist. Image data and perhaps some a-priori information about the content of the images is the only information available.

One motivating problem is the automatic evaluation of distress on roads. WA State, as many other states, scans the complete highway system every year using cameras mounted on a special van that travels the state highways. The images, while covering every inch of road, are naturally never taken at the exact same locations nor with the same lighting conditions, etc. So the comparison of images to assess the increase in cracking and distress between scans is not possible without registration. Currently human operators have to look painstakingly at the massive amounts of image data to make these assessments. This is time-consuming, expensive, error-prone and perhaps not the most effective way to collect useful information for the data. Automated methods for registration and comparison can assist engineers in condition evaluation, or at least in prioritizing the areas that seem to be showing most increase in distress.

The image registration problem may be formulated as a large scale optimization problem where the objective is to minimize a distance metric between the two images. The unknown of the problem is a discretization of a non-rigid displacement field that distorts one image into another. The formulation is generally ill-posed and needs to be regularized, and constraints from a-priori problem information may be included. Techniques from finite element methods in elasticity may be used in the discretization and the resulting problem consists a large scale nonlinear algebraic optimization problem. Multigrid methods can significantly speed up the computations necessary for solving these problems. Despite the challenging nature of this problem, significant algorithmic progress has been made on it recently. Most of the advances have been fueled by medical image registration problems, and made practical and affordable by the massive amount of computational power now available in most offices/departments.

While our motivating problem is the condition evaluation of pavements, the numerical methods proposed will find broad application in the analysis of traffic video data and similar problems.

Transportation Northwest (TransNow) Research Project Descriptions Year 19: July 1, 2006-June 30, 2007

PROJECT OBJECTIVES

The goal of this project is to develop and implement methods for comparing digital image data of transportation facilities to assess change in their condition over time. The main challenge in this problem is the ability to register image sequences, taken at different times, perhaps with different cameras, and in different environmental conditions. Registration is a nonlinear transformation that produces correspondence between image features to allow their metrics to be directly compared. Our demonstration application is the monitoring of distress evolution in concrete pavements.

TASK DESCRIPTIONS AND MILESTONES:

Project Start and End Dates	September 1, 2005 – August 31, 2007
Current year budget	\$45,000
For two-year project, total budget and start and end dates	\$90,000
Modal orientation of the project	Highway
Student involvement (thesis, assistantships, paid employment)	None listed

RELATIONSHIP TO OTHER PROJECTS:

The proposed project builds on several previous and ongoing projects in the area of digital image collection, archiving and interpretation:

- The WSDOT web-based Pavement management System. Over the last year, we have developed a web-based version of the WSDOT PMS system. In this version, we have incorporated access to multi terabyte-sized data sets that represent video images of the interstate system in the State of Washington. The data is collected by a van driving the interstate system annually (rightmost lane). We have made that data accessible through a map-based web interface allowing users to “drive” a road segment and examine its conditions.
- We have recently started a project funded by NSF to look at extracting strain field data from x-ray tomography images of structural concrete specimens underloading. We seek to get a sequence of images taken at different load levels, and develop methods to be able to identify the damage and its evolution at increasing load levels. The proposed project directly complements and contributes to these two efforts. The WSDOT video database of the interstate highway system represents a wealth of data that can be used to help maintain the highway system in very efficient manner. Computer tools that can help in the interpretation of that data are important in this task, because a strictly manual effort for the interpretation of the whole data set is prohibitively expensive. The second project listed above shares some common methodology with the proposed project and the methods and algorithms developed there will form some of the building blocks that we propose to use for this project. We also believe that video data collection is becoming more prevalent as the cost involved in high quality image acquisition and storage drops. The methods we propose to develop are likely to find application in many other transportation areas where there is a need for interpreting temporal image sequences.

TECHNOLOGY TRANSFER ACTIVITIES:

The implementation plan involves testing the proposed methods on the WSDOT video database of concrete pavements. The database currently contains detailed 03 and 04 data and in the next couple of months will have 05 data. 06 data will also be available during the course of this study. This set of data provides a sufficiently long duration and some sections of the interstate system may show detectable deterioration that requires WSDOT engineers to look at in further detail. The implementation will be done in two phases. The first phase implementation, which will be in Year 2 of the project, will allow a user through a web-based map interface to select a section of highway in a given year, and obtain the raw and the registered images for that same section of road from prior or subsequent years. The visual interface will show users (who at

Transportation Northwest (TransNow) Research Project Descriptions
Year 19: July 1, 2006-June 30, 2007

this stage will likely be WSDOT engineers and managers) how the system is matching the images from road sections in different years, and will allow them to give us some feedback on the reliability of the system in various conditions. In the final phase, towards the end of the project, the system will quantify the change in conditions (increased areas of cracked regions, increased length or width of linear cracks, etc.) and show this information to the user through the web-based map interface. Although the final road condition evaluation and assessment will naturally be made by WSDOT engineers and managers, the implementation of an image registration system will allow them to focus their efforts on the regions that are of most interest (essentially using the results of the system as a “first cut”).

POTENTIAL BENEFITS OF THE PROJECT:

The direct project benefit will come from the specific focus application. The implemented methods will allow personnel in Transportation agencies to better interpret the wealth of road condition video data that they collect. More broadly, in many areas of condition assessment, tracking performance, etc. the need to register image sequences is a critical task. The development of successful methods and implementations of these ideas in concrete pavement condition monitoring could open the doors for other application areas.