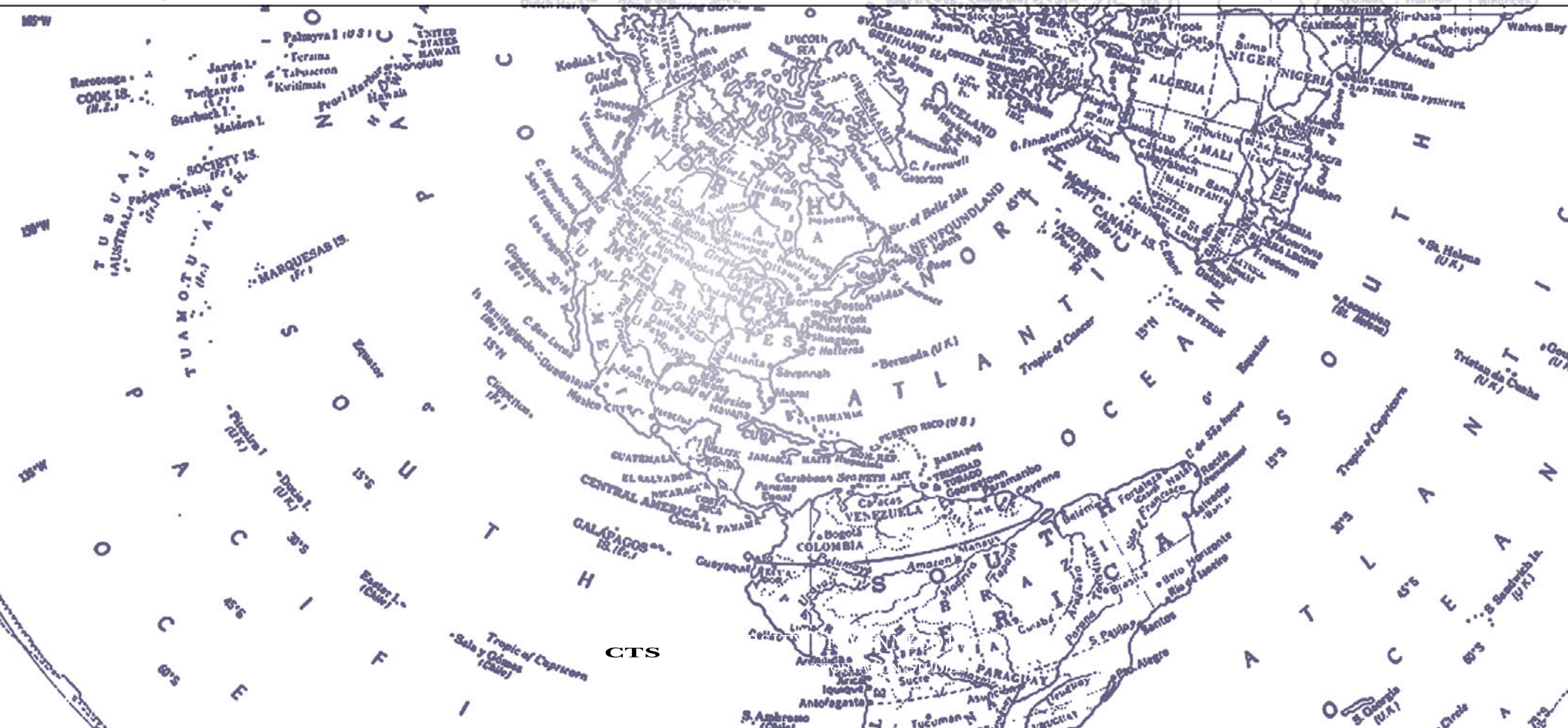




# INTELLIGENT TRANSPORTATION SYSTEMS INSTITUTE

2003-04  
ANNUAL  
REPORT



# INTELLIGENT TRANSPORTATION SYSTEMS INSTITUTE

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**A report of research,  
education, and technology  
transfer activities of the  
Intelligent Transportation  
Systems Institute at the  
University of Minnesota for  
fiscal year 2003–2004**

**INTELLIGENT TRANSPORTATION  
SYSTEMS INSTITUTE**

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Road fatalities are so common they are often relegated to the back pages of newspapers. Yet Minnesota’s upcoming Toward Zero Deaths conference will, for the moment, give this critical problem the attention it deserves. We need to re-examine our efforts in reducing the seemingly never-ending number of fatalities on our roads.

Although the vast majority of crashes occur in urban areas, more than two-thirds of fatal crashes occur in rural areas. And of fatal crashes in Minnesota, nearly 75 percent are either intersection crashes or lane-departure crashes. At the Institute, we have focused on these two problem areas for a number of years. Technologies that would enable the deployment of systems to mitigate the rural crash fatality problem have been developed; the costs, however, are considerable. The open question is how to best deploy these technologies to achieve the most benefit for the least cost.

The contrast between urban and rural fatalities in Minnesota is also reflected in crash statistics for other

states. When ranking all states by their rural fatality rate (Fig. 1), Minnesota is 36<sup>th</sup> in the country (for which the top rank is associated with the worst fatality rate). However, a rate of 1.8 fatalities per 100 million vehicle miles traveled (MVMT) is still unacceptable.

When one examines the causal factors associated with road fatalities (Fig. 2), it is clear why fatalities are more commonly associated with rural driving. Failure to keep in the proper lane, or running off the road altogether, is the most significant factor leading to rural road fatalities, while excessive speed is number two (by a factor of almost 2:1). Helping drivers stay in their lane by providing in-vehicle lane-departure warnings should be our number-one priority if we want to significantly reduce fatalities. This is an area where our research has led to a number of major new capabilities and in which we hope to continue leading the country.

Two population groups are most seriously affected—teenagers and older drivers. As shown in Figure 3, run-off-the-road crashes (and speeding) are

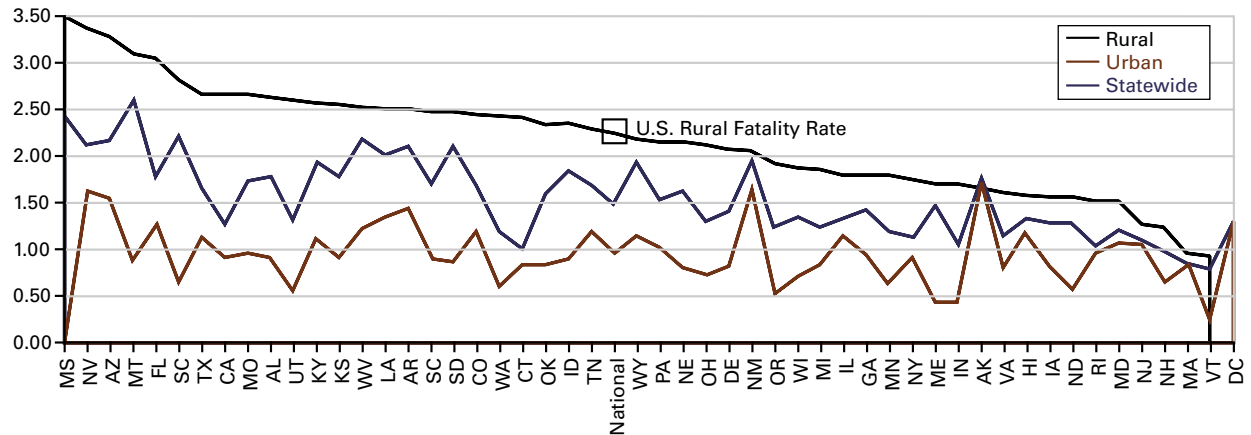


Figure 1. Urban and rural crash fatalities per 100 MVMT for the United States  
 Source: Fatality Analysis Reporting System, 2002 data

the predominant killer of younger drivers in Minnesota. This past year we seeded a program to develop new ways to reduce teenage fatalities. Crashes at intersections are the dominant type of fatal crashes among senior citizens. Our existing research program, with assistance from the Minnesota Department of Transportation and funding from a consortium of states and the Federal Highway Administration, is researching new ways to help drivers decide when it is safe to enter a rural unsignalized intersection.

There is a danger of becoming desensitized by the constant barrage of news of real people dying on our roads. We must find solutions—and we certainly hope to do our part at the ITS Institute. We are indeed gratified that our researchers are addressing the real problems that all of us face on our roads every day.

Whatever strides we do make are a testament to the help that we receive from others. We are thankful for the assistance of the members of our research selection and review panels and of our board for their selfless efforts. Furthermore, none of the progress that we have made to date would have occurred without the assistance, long hours, and diligent efforts of our staff. Their support is very much appreciated. And we cannot forget Mn/DOT, which

has made our partnership to explore and expand our transportation horizons so successful.

Finally, we thank the taxpayers and their legislative representatives who have entrusted us to help solve the really tough problems.



Max Donath

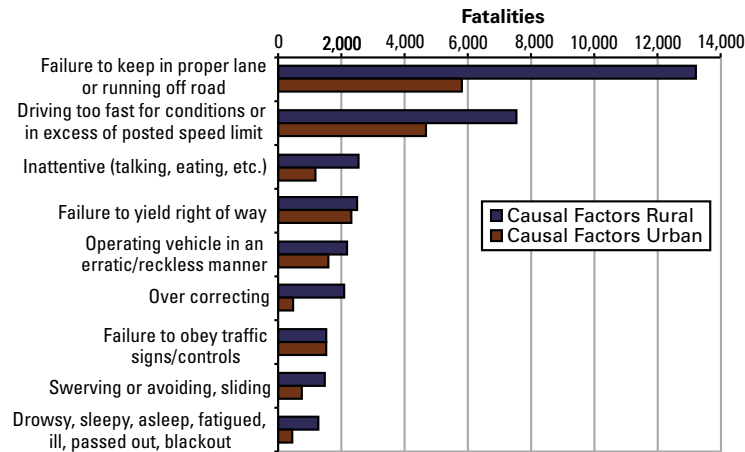


Figure 2. Causal factors associated with road fatalities: rural vs. urban (2002 FARS)

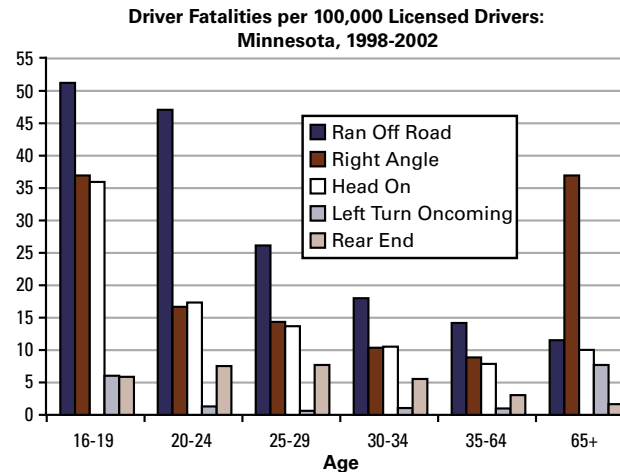


Figure 3. Driver fatalities per 100,000 licensed drivers in Minnesota (does not include vehicle occupants, which increases the numbers substantially)

Our focus is human-centered technology that enhances the safety and mobility of road- and transit-based transportation.

### MISSION STATEMENT

The Intelligent Transportation Systems Institute is a University Transportation Center (UTC) funded through the Transportation Equity Act for the 21st Century (TEA-21), the federal transportation bill passed in 1998. This funding continues the Institute's efforts initiated under TEA-21's predecessor, the Intermodal Surface Transportation Efficiency Act of 1991.

The Institute plans and conducts activities that further the mission of the United States Department of Transportation's UTC program: to advance U.S. technology and expertise in the many disciplines that make up transportation through education, research, and technology transfer activities at university-based centers of excellence.

Our focus is human-centered technology that enhances the safety and mobility of road- and transit-based transportation. To that end, we direct the collective energies of researchers from

multiple disciplines to advance the state of the art in the core ITS technologies of computing, sensing, communications, and control systems in order to surmount the significant transportation problems of the day.

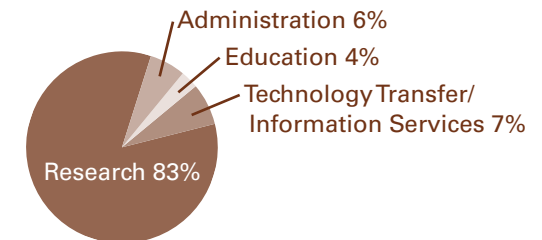
Based on our theme, we bring together engineers and cognitive psychologists from the University with our partners—the USDOT, the Minnesota DOT, other government agencies, and private industry—to ensure that Institute-developed technologies become tools that help us understand and overcome human limitations as they relate to transportation.

Additionally, we address issues related to transportation in a northern climate, investigate technologies for improving the safety of travel in rural environments, and consider social and economic policy issues related to the deployment of core ITS technologies.



### FINANCIAL REPORT

Expenditures for Year Five  
July 1, 2003–June 30, 2004



## MANAGEMENT STRUCTURE

The ITS Institute is located on the Twin Cities campus of the University of Minnesota and is housed within the Center for Transportation Studies (CTS). Much of the Institute's successful leadership in the development and application of intelligent transportation systems and technologies can be attributed to its state and national partnerships, including those with CTS, the Minnesota Department of Transportation, private industry, and county and city engineers.

The Institute director leads the Institute's operation, implements its strategic plan, and assumes overall responsibility for its success. In this role, he directs Institute programs, personnel, and funds.

The Institute's board guides and oversees the implementation of the Institute's work. The board works with the director to ensure that the USDOT's Research and Special Programs Administration requirements are met, approves annual plans and budgets, and meets at least twice yearly to provide direction to, and approval of, the Institute's activities.

Institute staff and University researchers, drawing from various areas of expertise, help create and disseminate knowledge related to intelligent transportation systems through research, education, and technology transfer activities. In addition, the leadership and staff of CTS provide connections and access to an extensive transportation research and education network. The Institute's affiliation with the Center allows it to work seamlessly with CTS staff and benefit from its diverse outreach, administration, and communications capabilities.

## ITS INSTITUTE BOARD MEMBERS Current members as of June 30, 2004



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Director, Center for Transportation Studies



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Executive Vice President,  
Dakota Area Resources and Transportation for Seniors



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**Toni Wilbur**  
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**Bob Winter**  
Director, District Operations Division,  
Minnesota Department of Transportation

### Board member whose term ended during the fiscal year:

**Dave Johnson**  
Manager, Research Services of the Office of Investment Management,  
Minnesota Department of Transportation



**Back row from left:** Michael McCarthy, Cadie Wright, Gina Baas, Laurie McGinnis, Amy Friebe, Cindy Holton, Peter Nelson, and Pamela Snopl. **Front row from left:** Max Donath, Chen-Fu Liao, Ted Morris, Linda Pelkofer, Arlene Mathison, and Dawn Spanhake. **Not pictured:** C.J. Loosbrock, Rick Odgers, and Jamie Yue.

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Nicholas Ward

### **Northland Advanced Transportation Systems Research Laboratories**

The NATSRL program director is Dr. James Riehl, dean of the College of Science and Engineering. Technical support is provided by Dr. Stanley Burns, professor and head, Department of Electrical and Computer Engineering (ECE); Dr. Donald Crouch, professor and head, Department of Computer Science; Dr. Taek Mu Kwon, professor, ECE; and Dr. David Wyrick, associate professor and head, Department of Mechanical and Industrial Engineering (MIE). Administrative oversight of the NATSRL program is managed by Carol Wolosz, with Jeanne Hartwick serving as the program accountant and David Keranen as the infrastructure engineer.

Faculty and research staff conducting ITS-related research for NATSRL include the following:

### **University of Minnesota Duluth, College of Science and Engineering**

James Riehl, Dean

**Electrical and Computer Engineering**  
Stanley Burns  
Ed Fleege  
Rocio Alba-Flores  
Mohammed Hasan  
Fernando Rios-Gutierrez  
Taek Kwon  
Marian Stachowicz  
Jiann-Shiou Yang

**Computer Science**  
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Donald Crouch  
Richard Maclin

**Industrial Engineering**  
Ryan Rosandich  
Martha Wilson  
David Wyrick

**Natural Resources Research Institute**  
Brian Brashaw  
Larry Zanko



## ITS INSTITUTE LABORATORIES AND FACILITIES

### ITS Laboratory

The Intelligent Transportation Systems Laboratory is a dedicated facility supporting ITS research and education. The lab's mission is to develop and provide state-of-the-art resources for researchers, students, and collaborators pursuing research in ITS.

Focused on supporting research in surveillance, monitoring, and management of traffic systems, the ITS Laboratory works in partnership with other University of Minnesota research facilities including the HumanFIRST Program and the Intelligent Vehicles Laboratory to enable a full spectrum of ITS research.

The lab's facilities are used by faculty and students in civil, mechanical, and electrical engineering, computer science, and affiliated disciplines. The lab's data-gathering capabilities and modeling expertise serve as the foundation for the development of interactive laboratory modules to support ITS-related courses at the University. The lab also hosts training and outreach events.

The ITS Laboratory has developed several generations of data-acquisition systems to meet the needs of researchers working on freeway traffic-flow issues. The most recent of these is the Beholder system, a fully independent network of video detectors providing space- and time-continuous coverage of the I-35W/I-94 commons freeway area in Minneapolis.

Beholder expands on the pioneering Autoscope system, originally developed at the University of Minnesota and now in commercial use. Beholder's portable monitoring stations are currently deployed on the roofs of several high-rise buildings overlooking the freeway, and transmit data back to the lab via a high-speed IEEE 802.16 wireless network.

Besides the data provided by the Beholder system, the lab is supplied with eight switchable compressed/streamed Internet video feeds by the Minnesota Department of Transportation (Mn/DOT). Researchers have the ability to switch between any of the approximately 300 Mn/DOT cameras monitoring the metropolitan freeway network.



Graduate student Vishnu Garg, research fellow John Hourdakis, and lab manager Ted Morris in the ITS Laboratory



Several traffic simulation packages are used in the ITS Laboratory, chiefly AIMSUN2 for microscopic flow simulation based on individual vehicles, and the KRONOS 9 package—developed at the ITS Institute—for macroscopic or platoon-based simulations. Other packages such as VisSim are used as needed.

Recent simulation and modeling projects at the ITS Laboratory have focused on improving the efficiency of metered access to urban freeway networks and on developing a dynamic, centrally regulated traffic signal preemption system for emergency vehicles.

Putting the researcher inside the simulation is the goal of the ITS Laboratory's Digital Immersive Environment, or DEN. Three large rear-projection screens surround the user; behind the scenes, a bank of six computers controls a visual environment developed using Open Scene Graph (OSG) and driven by data from an AIMSUN2 traffic simulator.

Each screen displays both left- and right-eye projections simultaneously, and polarized eyeglasses fuse the image channels to create a three-dimensional virtual world where the corners of the DEN melt away. Users can navigate and interact with the simulated world using a handheld wand; a high-accuracy tracking system constantly adjusts the perspective of the projected scene according to the position and orientation of the user's head.

The DEN can help investigators understand traffic flow within the context of urban design constraints, pedestrian uses, and other factors that have been impossible to visualize using conventional display technologies. It also complements the vehicle simulation capabilities of the HumanFIRST Program, including the ability to use the same virtual worlds in both environments.

### Human Factors Interdisciplinary Research in Simulation and Transportation

The Human Factors Interdisciplinary Research in Simulation and Transportation (HumanFIRST) Program's mission is to apply human factors research in order to understand driver behavior and support the design and evaluation of usable intelligent transportation systems. As implied by its name, the program's research strategy is based on a

### Finding solutions for limited bandwidth

The ITS Laboratory, with dedicated computer facilities and access to a wide range of traffic data feeds, offered professor Vladimir Cherkassky and graduate student Harry Rostovtsev an ideal research environment for their work on traffic video data transmission. The two researchers from the Department of Electrical Engineering and Computer Science received funding from Mn/DOT to implement a Quality of Service (QoS) system for limited-bandwidth IP networks carrying multiple video streams plus other low-priority data.

Video cameras to monitor traffic conditions are an increasingly important tool for metropolitan traffic managers. Often, multiple cameras are connected to a wireless IP network. As the number of cameras (and other data sources) grows, so do the demands placed on the network; network congestion leads to packet loss and poor performance.

Cherkassky and Rostovtsev constructed a dedicated IP network within the ITS Laboratory, including a mechanism that allowed them to constrict the network's bandwidth to simulate variable real-world conditions. The design of this network was determined after evaluation of Mn/DOT traffic data networks revealed that bottlenecks typically occur at wireless links to remote sites with multiple cameras and at junctions between networks of different types.

Using the open source ALTQ software package as a base, the researchers implemented a system of class-based traffic prioritization and bandwidth allocation—giving data streams different levels of network access and a portion of total network capacity. As data packets enter the network, they are first marked or “colored” to indicate what class they belong to; the packets then pass through a software filter that gives them access to the network according to their class.

Unlike many other QoS systems, this implementation allows dynamic reallocation of network capacity; for example, in the case of a crash, users can give higher priority and more bandwidth to cameras at the crash scene—even if this means “borrowing” bandwidth from other data streams.



driver-centered approach, considering the “human first” within the transportation system.

The HumanFIRST Program has a core staff of transportation research specialists made up of psychologists and engineers who provide a consistently available base of expertise. This core group is linked to a broad interdisciplinary network of experts in basic and applied sciences throughout the University to provide a flexible and comprehensive research capacity. This network is supported by affiliations with additional University research units, which allows the program to create responsive interdisciplinary teams to investigate a range of complex human factors research issues in transportation safety. The program also has close relationships with

the Minnesota Department of Transportation and the Department of Public Safety, as well as with traffic engineering consultants. These connections provide support for implementing research that will influence transportation policy in response to real-world problems both regionally and nationally. In addition, to ensure that research takes into account developments on the world stage, the program’s work is supported by international collaborations with experts in relevant disciplines.

Research in the HumanFIRST Program seeks to propose, design, and evaluate innovative methods to improve transportation safety based on a scientific understanding of driver performance and the psychological processes associated with traffic crashes. This research considers how a driver will accept and use a proposed system, while also considering the possibility of its producing undesirable driver responses and adaptation (e.g., distraction, complacency, fatigue, risk taking) that could undermine the system goal of improved safety.

Recent research topics include driver distraction from in-vehicle tasks and cell phones; rural and urban driver attitudes and crash risk; interventions for crash reduction at rural intersections; bus rapid transit using dedicated narrow shoulders; driver fatigue and methods for its detection; intelligent driver-support systems such as vision-enhancement, collision-avoidance, hazard-awareness, and lane-keeping systems for passenger and specialty-purpose vehicles; learned and inherited factors related to unsafe driving; alcohol impairment; attention-deficit/hyperactivity disorder and novice drivers; and in-vehicle use of Advanced Traveler Information Systems (ATIS).

The facility includes equipment for basic research on driver psychological functioning including a vision tester, DOT-certified alcohol Breathalyzer, mobile psychophysiology recording system, mobile eye-tracking system, video editing and behavior analysis suite, and a comprehensive psychometric test battery validated for traffic psychology.



*Institute director Max Donath, research associate Mike Manser, HumanFIRST director Nic Ward, and research associate Mick Rakauskas, pictured with the program’s simulator, VESTR*

Much of the research of the HumanFIRST Program uses a state-of-the-art driving simulator (supplied by AutoSIM and OKTAL) engineered specifically for human factors research in surface transportation. This Virtual Environment for Surface Transportation Research (VESTR) is a versatile and realistic simulation environment linked to a full-cab SC2 vehicle donated by Saturn using software that can create virtual environments that precisely reproduce any geospecific location. This visual environment is generated with high-resolution images (2.5 arcmin per pixel) over a wide field of view (210-degree forward, 50-degree rear, 2 x 20-degree side mirror images). This immersive driving experience is enhanced by realistic motion generated by a three-axis motion base and both high- and low-frequency vibration units, including a surround-sound system. With multiple sound systems, configurable touch panel displays (including head-up displays), and haptic feedback through the seat and accelerator pedal, this simulator supports the investigation of a wide range of interface options for ITS development, design, and assessment. These features make VESTR one of the premier driving simulators in North America and Europe.

To support the validity of HumanFIRST research, the program has access to a variety of closed test tracks and road network field sites for on-road studies with instrumented vehicles.

### Gaining insight into driver distraction

Cell phones. Navigation systems. Hot coffee. Drivers face numerous, potentially hazardous distractions. Researchers with the Institute's HumanFIRST Program believe that tracking a driver's gaze will tell them more about how distraction might affect driving performance. However, since monitoring and quantifying everything a driver might look at is difficult, they're relying on help from two sophisticated eye-tracking systems.

The first, a video-based faceLAB system, has been used over the last year in the program's immersive driving simulator. From two cameras mounted on the dashboard, the system generates a digital map of a driver's face by looking for areas of high contrast. The system notes head position and movement to locate the eyes and can estimate the direction of a driver's gaze from his or her pupil orientation.

"On a superficial level, the eye tracker gives us the XY coordinates of the eyes—that's what it does in its most basic form," explains Michael Manser, a research associate with the HumanFIRST Program. But more important, he says, it can give researchers an indication of how vision and behavior are linked, and how a distraction can change cognitive processing stages.



*Data are collected by two cameras mounted on the dashboard (above), while research assistant Praveen Balachandran (left) monitors where the driver is looking.*

The researchers have integrated the simulator and the eye tracker so that the simulator can react in real time to what a driver does or where he or she looks. For example, if a driver's attention is diverted from the road, the simulator can trigger an event requiring more attentive driving.

Some of the ways the researchers have been distracting test subjects is by having them operate the CD player and temperature controls, answer questions, repeat words, and complete tasks on an LCD panel using a touchpad.

The HumanFIRST Program also recently acquired a head-mounted eye-tracking system by ISCAN that consists of a camera mounted on a visor worn by a test subject. Because the camera is located closer to a subject's eyes, the accuracy is much greater than with the dashboard-mounted system. Another advantage is that it's portable; the driver wears the camera, and the base computer can be placed in the back seat. HumanFIRST researchers have just begun using the new system in a test vehicle on a closed-road network.

Ultimately, Manser says, researchers want to learn from the eye trackers more about how drivers process information.

This knowledge could then be used to teach drivers how to better respond to various driving situations and possibly avoid a crash.

Down the road, the eye trackers will be put to use in HumanFIRST research on driver fatigue, impairment, mental workload, and other information-processing issues. In addition, researchers are planning to integrate the eye trackers with their digital databases to allow them to examine the design of road infrastructure (e.g., signs, traffic signals) by observing the effectiveness of visual sampling.

## Making rural intersections safer

Intersection decision support (IDS) represents an innovative new approach to preventing crashes at rural through-stop intersections, where secondary roads intersect high-speed rural expressways. Instead of regulatory signals, which disrupt mainline traffic flow and may lead to higher rear-end collision rates, IDS uses technologies developed in the Institute's intelligent vehicles research to give stopped drivers better information about vehicles approaching the intersection at high speed.

In the prototype system currently under development, a network of radar and lidar detectors deployed along a rural expressway tracks vehicles approaching a specific intersection. These speed and position data are communicated to a roadside central processing unit via a dedicated wireless network; the central unit computes the vehicles' trajectories and determines when gaps between approaching vehicles are

too small to allow safe crossing by a driver waiting on the secondary road.

Human factors research to develop an optimal infrastructure-based driver interface is a crucial component of this project. By using a wrap-around driving simulator, researchers can test multiple interface configurations in a safe yet realistic environment, under a wide range of virtual traffic and weather conditions.

The research team, led by Institute director Max Donath and IV Laboratory director Craig Shankwitz, hopes to develop a reliable, cost-effective system that can be widely deployed in rural areas. The ITS Institute has formed a partnership with state transportation agencies in eight states; participating agencies are sharing rural crash data for analysis and will have the opportunity to install a prototype system in their states to gather data and evaluate the technology under local conditions.

Data-gathering components of the IDS system have been installed at a rural test intersection, which was selected based on an analysis of crash information from around the state. Knowledge gained in this phase about traffic characteristics and driver behavior will be used to refine the system prior to testing the driver interface.



## Intelligent Vehicles Laboratory

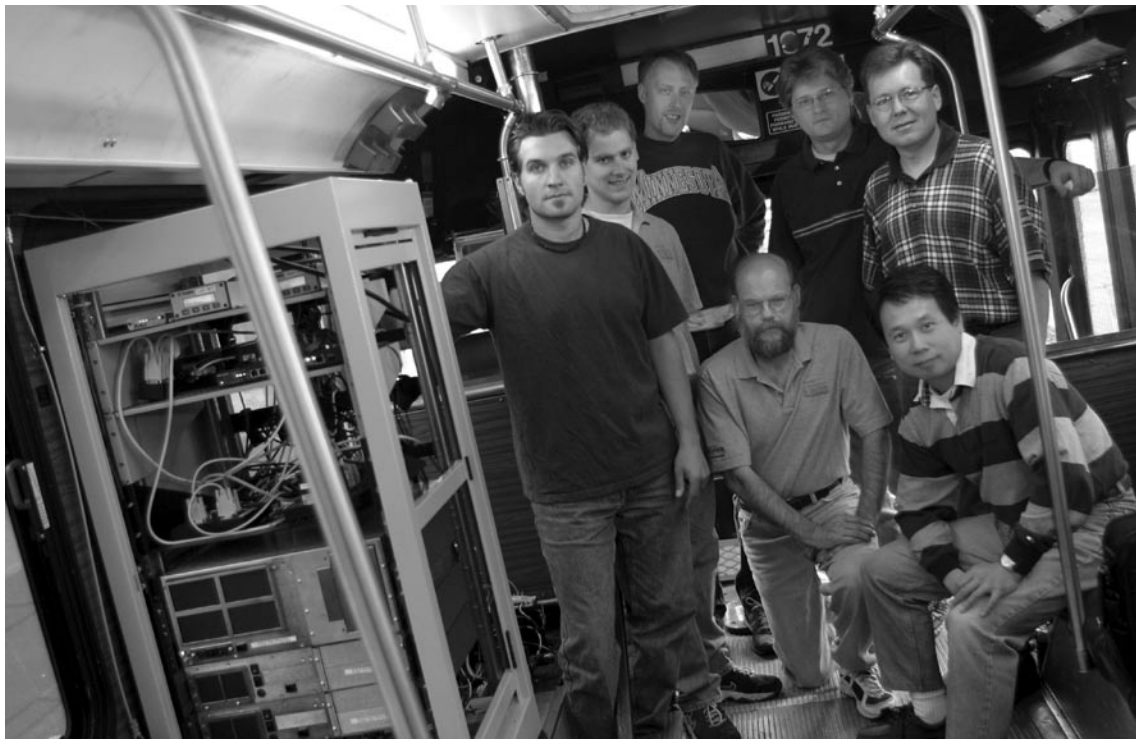
The Institute's Intelligent Vehicles Laboratory focuses on developing and testing innovative, human-centered technologies that improve the operational safety, mobility, and productivity of vehicles. These human-centered technologies integrate sensors, actuators, computer processors, and custom human interfaces to provide drivers with needed information under difficult driving conditions, including low visibility, severe weather, and narrow and congested roadways. Initially, these driver-assistive systems have been tested on specialty vehicles, including snowplows, patrol cars, ambulances, heavy vehicles, and transit vehicles. Ultimately, these systems will also be able to warn drivers and assist them with collision-avoidance and lane-keeping tasks on passenger vehicles.

The University of Minnesota is recognized as a leader in developing and testing driver-assistive systems and is one of a small number of universities nationwide conducting this work. The IV Laboratory's core staff is made up of engineering and computer science professionals who work closely with an interdisciplinary team of specialists, including cognitive psychologists specializing in human factors from the ITS Institute's HumanFIRST Program. The IV Laboratory staff has developed expertise in wireless communications, embedded computing, visibility measurement and quantification, geospatial databases, virtual environments, image processing, driver-assistive technologies, control systems, and sensors.

IV Laboratory research seeks to increase driver safety in difficult driving conditions through the use of vehicle-guidance and collision-avoidance technologies. Several vehicles serve as experimental testbeds, including

the SAFETRUCK (an International 9400 tractor-trailer), the SAFELOW (an International 2540 crew-cab snowplow), a state highway patrol car, and the TechnoBus (a Metro Transit bus). Using these vehicles, IV Laboratory researchers are developing, testing, and integrating advanced technologies including centimeter-level differential global positioning systems (DGPS); high-accuracy digital-mapping systems; range sensors, including radar and laser-based sensors; a windshield head-up display (HUD), a virtual mirror, and other graphical displays; haptic and tactile feedback; and intersection decision support systems to assist drivers at rural intersections.

The IV Laboratory's lane-assist technology is unique in that it uses DGPS and does not require hardware in the roadway surface.



IV Lab researchers aboard the TechnoBus include (clockwise from left): Alec Gorjestani, Walter Trach, program director Craig Shankwitz, Bryan Newstrom, Curt Olson, Pi-Ming Cheng, and Lee Alexander

The technology is transferable between various transportation modes and works in all low-visibility situations, including snow, fog, smoke, heavy rain, and darkness. In addition, these systems use human-centered technologies to enhance driving ability and reduce driver error due to distractions, fatigue, and other factors related to difficult driving situations.

Other current research topics include the design and testing of custom human interfaces, collision-avoidance sensors and algorithms, intersection-surveillance sensors, and wireless communication among vehicles and with the infrastructure.

The IV Laboratory's partnership with the Minnesota Department of Transportation provides access to roads and other infrastructure, including the Minnesota Road Research Project

(Mn/ROAD) test track, which consists of a freeway and a low-volume road pavement test track with 40 different road material test sections, 4,500 electronic sensors, a weigh-in-motion scale, a weather station, and DGPS correction signals. The IV Laboratory also has relationships with a number of other organizations and government agencies, including the U.S. Department of Transportation's Research and Special Programs Administration, Federal Highway Administration, and Federal Transit Administration; Twin Cities'

IV Laboratory research seeks to increase driver safety in difficult driving conditions through the use of vehicle-guidance and collision-avoidance technologies.

Metro Transit; Minnesota's Local Road Research Board; and various counties. These partnerships provide additional support for implementing research that will influence transportation safety in the United States and around the world.

### Northland Advanced Transportation Systems Research Laboratories

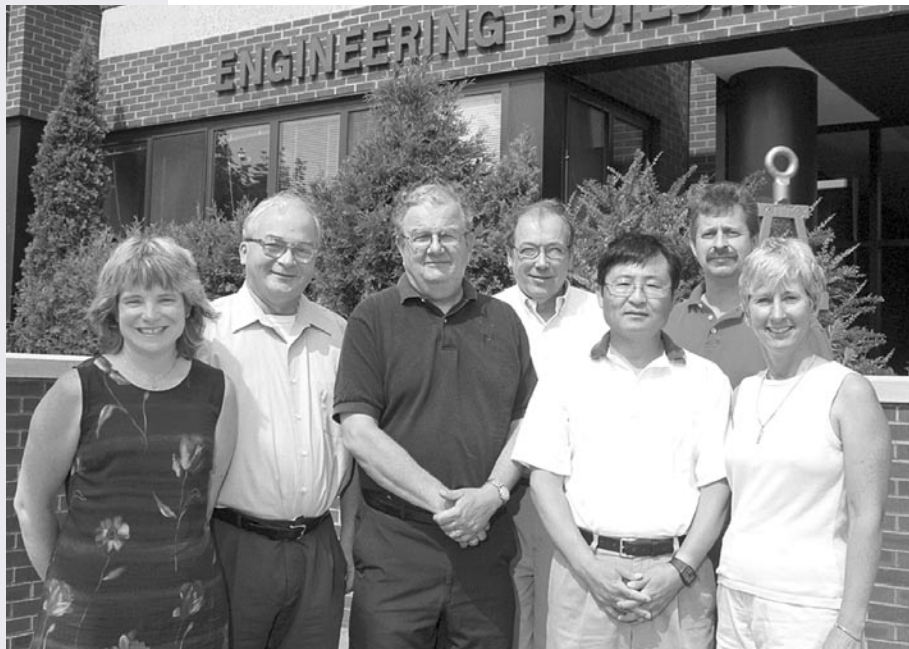
The mission of the Northland Advanced Transportation Systems Research Laboratories (NATSRL), located at the University of Minnesota Duluth, is to study comprehensive winter transportation systems and the transportation needs of cities in small urban areas. Research covers a wide range of topics, including optical and electronic traffic and road sensors, transportation data management, and the benchmarking of transportation infrastructure management practices. NATSRL is collaborating with the Minnesota Department

of Transportation, city and county engineers, and other agencies to address transportation-related needs, especially those specific to northern areas and climates.

NATSRL's current laboratories are the Advanced Sensor Research Laboratory, the Transportation Data Research Laboratory, and the Transportation Engineering Research Laboratory. The Advanced Sensor Research Laboratory goals include development and testing of advanced sensing technologies for pavement and road conditions (speed, weather impact, and traffic density); development of new techniques to detect incidents and abnormal traffic conditions; and real-world analysis and real-time measurements of road, weather, and traffic information. The Transportation Data Research Laboratory has developed a statewide traffic data archival and analysis system that is used by Mn/DOT for long-range planning and development of strategic traffic management plans, and continues research in the improvement of data integrity retrieved from the road sensors. The Transportation Engineering Research Laboratory is developing, in conjunction with Mn/DOT, an automated inventory management system for transportation infrastructure, as well as designing efficient management practices by benchmarking state DOT procedures, with a specific project in snowplow fleet management.

Other NATSRL research includes projects on developing and incorporating non-intrusive vibration testing techniques for inspecting timber, steel, and concrete bridges, and the student development of software tools to manage large volumes of transportation-related data.

In addition, NATSRL joins with Mn/DOT District 1 each year to hold a formal presentation of ongoing research efforts [see related article in the Technology Transfer section of this report].



*NATSRL staff, from left to right: Carol Wolosz, program director James Riehl, Stanley Burns, Donald Crouch, Taek Kwon, David Keranen, and Jeanne Hartwick*



## Getting more mileage from inductive loop detectors

Inductive loop detectors (ILDs) embedded in pavements are commonly used to measure traffic flow by registering each time a vehicle passes over them. But Professor Stan Burns of the Northland Advanced Transportation Systems Research Laboratories thinks that we could get much more information from the existing ILD network.

A typical ILD consists of a solenoid loop of wire buried about two inches below the surface of the pavement. When a vehicle passes through the detector's magnetic field, the vehicle's metal structure causes a disturbance in the electrical inductance of the loop. A

sensor attached to the loop registers an event each time the inductance change exceeds a threshold value.

An automobile's complicated arrangement of metal parts, however, produces a correspondingly complicated set of inductance changes as it passes over the detector, and the traditional method of recording only the threshold value discards potentially valuable information. Another side effect of the threshold-value system is that large vehicles—particularly commercial trucks—may be recorded as two separate vehicles rather than one large one.

An ILD system capable of capturing the “inductance signature” of different types of vehicles would reduce

counting errors due to inaccurate readings of large vehicles and could also enable traffic managers to calculate more accurate point-to-point travel times by tracking individual vehicles.

An experimental system developed by the NATSRL research team consists of three interdependent software modules: the Sampler module, which gathers data by controlling the sensing instruments and saves the inductance profiles for identification; the Viewer, which allows users to view one or more inductance profiles on a graph after user-selected signal processing algorithms have been applied; and the Identifier module, which classifies vehicles by comparing inductance curve data from the Sampler with inductance profiles stored in a database.

Burns and the NATSRL researchers have installed the experimental system at a Mn/DOT test station on Interstate 35 south of Duluth. At this stage, the system is able to distinguish between different vehicle types, although it still has trouble discriminating between cars with similar inductance signatures.

The test results illustrate the complicated nature of inductance-signature analysis. In addition to vehicles with similar construction, a detector system based on inductance curves must also contend with numerous environmental factors that affect each loop's three-dimensional magnetic field.

Work on ILDs is continuing at NATSRL, including three-dimensional modeling of the loop's magnetic field, exploration of “cross-talk” interference from adjacent loop detectors' fields, improved system accuracy, experimental verification, and the possibility of measuring vehicle speed using a single ILD.



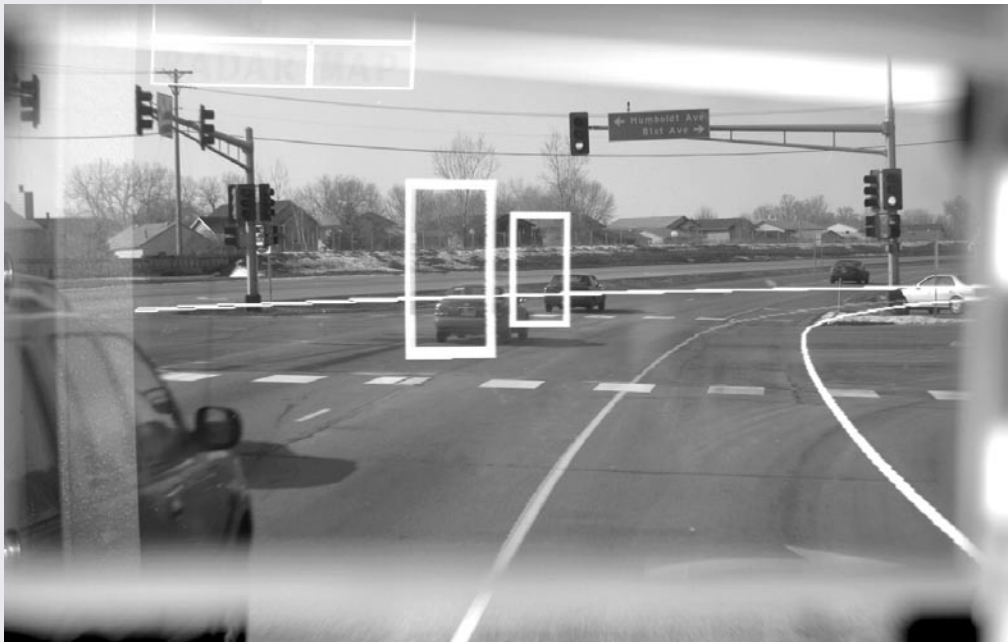
## RESEARCH

Institute research is centered on safety-critical technologies and systems for efficiently moving people and goods in the following areas:

- human performance and behavior
- technologies for modeling, managing, and operating transportation systems
- computing, sensing, communications, and control systems
- social and economic policy issues related to ITS technologies

The Institute’s research program joins technologists—for example, engineers and computer scientists—with those who study human behavior to ensure that new technologies adapt to human capabilities, rather than requiring people to adapt to technology.

The Institute’s geographic location gives it a unique advantage for developing research applicable to transportation in a northern climate and transportation in rural environments in addition to the metropolitan Twin Cities area.

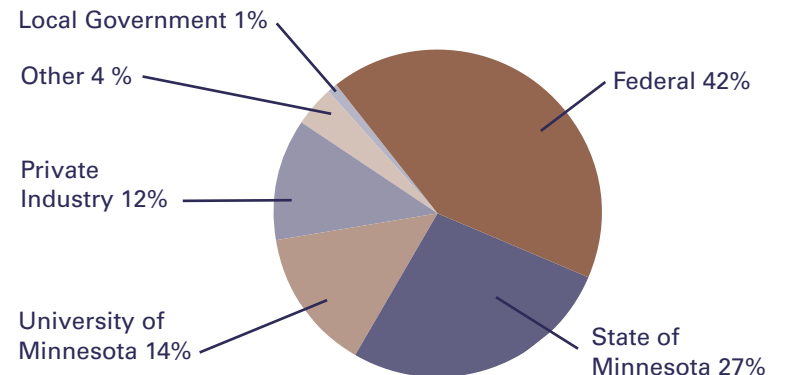


The ITS Institute research program includes research projects funded by various partners, including federal funds from TEA-21 legislation, the Federal Highway Administration, and the Federal Transit Administration. Other funding partners include the Minnesota Department of Transportation (Mn/DOT), the Minnesota Local Road Research Board, and Metro Transit, in addition to local governments, agencies, and private companies that contribute funding and in-kind match.

Activities undertaken by the Institute support all current ITS-related research projects, regardless of funding source; all current ITS-related projects are listed in this annual report. The research section comprises two parts. The first highlights in detail a selection of projects underway, while the second briefly describes other Institute projects either recently completed, in progress, or selected to begin this coming year.

## RESEARCH FUNDING SOURCES FOR ALL ITS-RELATED RESEARCH PROJECTS

The total funding for all ITS-related research projects was nearly \$6 million in FY04. Funding sources for projects receiving funding in FY04 are shown in the chart below.



## HUMAN PERFORMANCE AND BEHAVIOR

### Chromatic perception effects on collisions with snowplows

When it comes to clearing snow from roadways, poor-visibility conditions come with the territory. But in the process of clearing roads, snowplows can temporarily create even worse conditions for the drivers behind them. Under these “low-luminance contrast” conditions, drivers often can see the presence of a snowplow ahead, but are unable to tell how far away it is or even that they are approaching it. Some recent experiments also indicate that under low-luminance contrast conditions, people perceive themselves to be traveling significantly slower than they actually are. To compensate, they speed up. Together, these issues constitute some of the most hazardous conditions drivers in Minnesota commonly experience and are why snowplows are particularly vulnerable to rear-end collisions.

Through a series of simulated and real-world experiments, Professor Albert Yonas, with the Institute of Child Development, Lee Zimmerman, an adjunct professor in the Department of Electrical and Computer Engineering at Duluth, and a team of University researchers are testing how people perceive motion and space under low-luminance contrast conditions and how these relate to chromatic contrast conditions. Understanding whether these two phenomena are governed by the same neural mechanism could lead to a variety of solutions for reducing some of the hazards drivers face in poor-visibility conditions and possibly decrease the likelihood of rear-end collisions with snowplows.

“The safety of both motorists and plow operators is our main concern,” explains Sue Lodahl, a maintenance research and training engineer with the Minnesota Department of Transportation. “So we are extremely interested in this innovative look at how drivers perceive the speed of a snowplow and the speed at which they are approaching the truck in heavy snow and fog.”

Using a simple computer driving simulator to replicate the effects of blowing snow and fog, Yonas and his team monitored test participants who were asked to decide whether a simulated truck approached or withdrew as the luminance contrast of the simulator display was varied. This experimental setup enabled the researchers to study snowplow designs and color characteristics that influence a driver’s detection of approach and impending collision. Through these efforts, the team found that lowering the luminance contrast between the image of a vehicle and the background greatly reduces one’s ability to perceive approach. They also discovered that flashing lights, such as those mounted on snowplows to attract attention, interfere with motion perception.

These findings will be incorporated into a second year of research in which the team will use more realistic driving-simulator methodology to develop new markings and lighting designs for snowplows. One new design approach may be to ensure that rear-facing lights and markings on snowplows create optimal luminance contrast while reducing the offending chromatic contrasts. A second possibility involves structuring rear-facing markings to help drivers better tell when they are approaching a snowplow. In the future, Yonas hopes to team up with Mn/DOT to further test the effectiveness of new markings and lighting designs on minimizing the effects of blowing snow on drivers’ ability to properly perceive both their speed when moving toward a snowplow and their distance from it.



*Albert Yonas guides research participant Hweon Seo as she judges whether a simulated snowplow on a computer display is approaching her.*



The overall findings of this work will likely result in improvements in driving safety through the careful choice of color warning markings, chromatically controlled lighting, and special fog tints on snowplows, as well as through better public education. “These improvements and changes would stand to significantly reduce the number of rear-end collisions with Mn/DOT plow trucks,” Lodahl says.

### **Ramp meter delays, freeway congestion, and driver acceptance**

In a number of cities across the nation, including Minneapolis and St. Paul, ramp meters have been installed at freeway entrance ramps in an attempt to reduce congestion and produce smooth traffic flow. However, there has been considerable controversy as to whether or not ramp meters reduce delay on the road system and concern



*Graduate research assistant Ben Chihak with researchers John Bloomfield and Kathleen Harder at Mn/DOT's Regional Transportation Management Center*

regarding how delay is distributed (e.g., some drivers must wait longer in order for other drivers to proceed more easily).

In their current study, human factors researchers Dr. Kathleen Harder and Dr. John Bloomfield, from the College of Architecture and Landscape Architecture, are working with Professor David Levinson, Civil Engineering, on a multidisciplinary investigation of the differences between perceived time and actual time spent waiting at ramp meters and in congested traffic.

This research attempts to quantify the value drivers associate with qualitatively different experiences of travel time when they encounter ramp meters. Drivers may feel that time passes more slowly when waiting at a ramp meter than when they are driving very slowly in stop-and-go traffic on the freeway. As a result, although the ramp metering system may actually reduce total travel time, it may not reduce drivers' perceived travel time.

For this study, the team employed two different types of experiments. One involved a variant of the often-used Computer-Aided Stated Preference (CASP) methodology in which a number of travel time distributions, each with a different ramp meter wait time and drive time, were presented to participants who then distributed their preferences among the alternatives. The second experiment used a novel methodology known as the Virtual Experience Stated Preference (VESP) method. It involved using a 210-degree forward-field-of-view immersive driving simulator to capture drivers' perceptions of the distributions of their travel time.

While CASP is the more frequently used methodology, with it participants are much further removed from driving experiences and are simply asked to state their preference. Conversely, the main benefits of the VESP method are that it more closely parallels a real driving experience, and it enables researchers to get participants' feedback immediately after they've driven a simulated route.

According to Harder and Bloomfield, a driving simulator has never been used to collect driver preference data for driving scenarios involving ramp meters. Ramp meter timing has been

investigated using traffic simulation models, but human preference models cannot be derived from these simulation models. Another feature of the study is that it allows the results obtained with the CASP and VESP methods to be compared. Though the team is continuing to analyze the information collected from these experiments, early results indicate that while in some cases the data obtained using the VESP and CASP methods are similar, in others they may be different. Harder and Bloomfield are still looking into these disparities to determine the significance.

The researchers also are working to determine the weight that drivers give to the qualitatively different travel times they experience—due to variations in the waiting time at ramp meters, the level of traffic congestion, and in the resultant freeway driving speeds. They will then use this information to develop models regarding the value of travel time that will enable Mn/DOT to better address driver perceptions of travel time as they manage the ramp metering system in the Minneapolis/St. Paul metro area.

## TECHNOLOGIES FOR MODELING, MANAGING, AND OPERATING TRANSPORTATION SYSTEMS

### Measuring the equity and efficiency of ramp metering

The Twin Cities' ramp metering system was originally designed to maximize traffic flow throughout the metro freeway network as a whole. Although the metering system has successfully increased the efficiency of freeway traffic flow, it also has been subject to increased political scrutiny due in part to perceptions of “inequity” in the system. The inequity emerges when drivers accessing area freeways at different times and at various entrance ramps experience different ramp waiting times; essentially, some drivers are delayed by the system in order to save travel time for others.

In order to scientifically study the issue, Assistant Professor David Levinson and research assistant Lei Zhang, of the

Department of Civil Engineering, led a research effort to identify and develop performance measures that evaluate both the efficiency and equity of ramp metering strategies to determine the system's overall effectiveness. Based on the findings of that study, Levinson and Zhang were then able to develop a freeway control strategy that considers both efficiency and equity.

The duo looked to various fields of study—including urban planning, geography, engineering, public policy, economics, and management—to collect a well-rounded set of perspectives on what “effectiveness” means. In the initial stage of this work, Levinson and Zhang defined and developed ramp meter performance measures over short-term and long-term scales. To provide a complete picture of ramp meter effectiveness, these performance measures were computed for ramps, freeway mainline segments, and origin-destination (O-D) pairs. The researchers then applied the newly developed performance measures to observed data collected for selected



David Levinson

This work shows that if people value their time differently, a ramp metering system that satisfies users must consider ramp delay in addition to freeway throughput.

highway segments by Mn/DOT's Regional Traffic Management Center before and during an experimental ramp meter shutoff period mandated by the state legislature.

Interestingly, until this study began, the traffic data collected before and after the ramp meter shutoff were not available to researchers. Special data collection efforts to obtain ramp queue lengths were undertaken by Mn/DOT to assist the University researchers. Additionally, through this work, a broader spectrum of performance measures was developed and applied to evaluate on-

ramp control strategies, giving decision makers a more complete view of system effectiveness than previously available. And, while traditional freeway control strategies try to minimize total delay in the system, which sometimes results in unequal distribution of delays among users, the new control objective developed

in this study considers both efficiency and equity in a systematic way. Specifically, efficiency-oriented ramp coordination, which prevents freeway traffic flow from breaking down, and equity-oriented coordination, which more evenly distributes delays among users, are distinguished and enforced under a common objective function rather than independently of each other.

The results of this work reveal that freeway mainline speeds and flows are consistently higher with ramp metering than without. Levinson and Zhang also found, however, that overall trip speeds, including those on both the freeway and the ramp, are not uniformly

higher with ramp metering than without. This suggests that long trips benefit from metering at the expense of short trips. Finally, this work also shows that if people value their time differently—for example, one minute waiting on a ramp versus one minute of free-flowing travel on the mainline—a ramp metering system that satisfies users must consider ramp delay in addition to freeway throughput. “The results show, analytically, that the most efficient control strategy is also the least equitable one,” Levinson added.

These conclusions have led to the development of a new family

of balanced efficiency and equity (BEE) freeway ramp control strategies based on “optimization theory.” Optimization theory recognizes that one minute of delay at entrance ramps is more onerous for drivers than one minute of free-flowing travel time on the freeway mainline.

With these new BEE

strategies in hand, decision makers are able to identify an optimal balance between efficiency and equity objectives when setting ramp meter times, which can be adjusted in response to public perception without any additional cost.

Mn/DOT has already applied some of the study findings, including limiting individual delay, to update its own control strategy. As the conflict between efficiency and equity goals in freeway on-ramp control heats up as congestion increases, freeway traffic engineers elsewhere may learn something from the empirical results that they can apply to their own control strategies.



## Accident prevention based on automatic detection of accident-prone traffic conditions

Some stretches of highway are more hazardous than others. In the Twin Cities metro area, one of the most crash-prone areas is the commons where interstate highways 94 and 35W come together. If traffic researchers could find out why crashes occur here, they might be able to help prevent them.

The ITS Lab's Beholder system is playing an integral role in helping two University researchers do just that. Professor Panos Michalopoulos and research fellow John Hourdakakis of the Civil Engineering Department are working to develop a crash avoidance/prevention system for crash-prone freeway locations. Their first step was to study the reasons for and mechanics of crashes by recording them and extracting raw traffic-detector measurements.

The Beholder system is providing the team with real-time video and traffic measurements, allowing them to observe and verify the incident represented in the recorded measurements. The advantage of using the Beholder system, Hourdakakis explains, "lies in the detail and resolution of the collected measurements. There is no other site in the world that [reliably and continuously] collects such information." For a stretch of highway that is more than a mile long, Beholder provides continuous individual vehicle speeds and headways around the clock. Having such detailed measurements for a specific location is essential for the success of the study, Hourdakakis adds.

So far, Michalopoulos and Hourdakakis have collected data on approximately 150 crashes and 300 near misses and have recorded and collected enough information to get an idea of the year-round traffic conditions in the area and the variety of crashes that occur there. What they have found so far is that crashes are not entirely random but rather depend on the traffic and geometric characteristics of each location. Specifically, the team has learned that crashes in this location are frequently related to two things: the congestion shockwaves that propagate backwards

from the merge area at the entrance ramp and further downstream, and the vast difference in driving speeds between the right and middle lanes, which makes changing lanes difficult and therefore dangerously distracting for drivers.

"We have identified most of the causes of crashes in this I-94 section and have analyzed the data and built models that so far look promising in detecting accident-prone conditions (APCs)," Hourdakakis explains. "We'll incorporate these models into algorithms that can automatically detect APCs and produce alarms when such conditions are present."

The current phase of research is reaching its conclusion, but the methods developed and lessons learned during the search for APCs on I-94 can be employed in research at other accident-prone locations. Along with the algorithms for APC detection,



Researchers John Hourdakakis, Vishnu Garg, Adinarayana Beegala, Panos Michalopoulos, and Wuping Xin. The rooftop cameras behind them are collecting data on the I-94 and 35W commons area just south of downtown Minneapolis.



John Hourdakakis and Panos Michalopoulos

Michalopoulos and Hourdakakis hope to produce such a methodology for tuning the system to another crash-prone site study and to produce specific models for the I-94 location.

The next phase, set to begin in November, involves implementing designs where different alternatives for traffic calming and/or raising driver attention will be evaluated and prepared for deployment.

## COMPUTING, SENSING, COMMUNICATIONS, AND CONTROL SYSTEMS

### Recognition of human activity in Metro Transit spaces

Since the events of September 11, the surveillance of public spaces has taken on greater importance and urgency. As video cameras are increasingly used at vulnerable areas—bridges, seaports, and potentially on airplanes—the volume of video data generated will be enormous. It simply won't be feasible for human operators to monitor and evaluate it all.

According to Professor Nikolaos Papanikolopoulos, of the University's Department of Computer Science and Engineering, autonomous vision-based systems are ideal for monitoring human activities in public places because they are more "attentive" than a human. A computer system could be used to first screen data, then highlight significant cases for human operators to evaluate.

Papanikolopoulos and research associate Osama Masoud developed a system to test the feasibility of this type of computerized monitoring. The project is aimed at helping Metro Transit, the Twin Cities transit

bus operator, recognize drug dealing and other suspicious activities at bus stops. Because drug dealing is characterized by individuals loitering for long periods at bus stops, it offered a good target behavior for the system.

Drawing on his and Masoud's earlier work on human detection and crowd monitoring, Papanikolopoulos, along with graduate students Guillaume Gasser and Nathaniel Bird, developed such a system. Across the street from a busy bus stop on the University of Minnesota campus, the researchers installed a video camera to watch people come and go at their test site.

The system uses standard equipment: an off-the-shelf video camera and a computer. The monitoring process itself is divided into three distinct phases: background subtraction, object tracking, and human recognition.



As individuals enter the bus stop scene, each is assigned a unique number and tracked.





*Osama Masoud and Nikos Papanikolopoulos*

Background subtraction involves separating the background scene supplied by the video feed from the foreground. By comparing each new frame in a video sequence to a background model of the scene (without activity), the system can detect moving objects. These objects are then separated from the background image and tracked. The researchers used a method based on an adaptive background modeling and subtraction technique known as nonparametric kernel density estimation, which allows for the detection of moving objects in outdoor environments with respect to changes in the background like changing illumination.

To enable the system to track objects in real time—here, people as they walk around a bus stop—the researchers developed algorithms to recognize pre-specified actions. As individuals enter the scene, the system assigns each a unique number and creates a database of these individuals. Because presence history information is generated for each target, the system can recognize individuals who leave and return.

For the human recognition component, the researchers chose a short-term biometric technique—clothing color. The system’s human recognition module segments the image of an individual into

three portions corresponding to the head, torso, and legs. Using the median color of these regions, two people can be quickly compared to see if they are the same person.

Results of the researchers’ test showed that the system could successfully track individuals in sparsely-populated outdoor scenes, with limited occlusion, in near real time. The system was also robust in handling image size changes due to differences in perspective as an individual walked across the scene, Papanikolopoulos says.

Expanding the system to recognize certain behaviors, such as leaving a package unattended, is a priority for future work. The Department of Homeland Security has recently funded the continuation of their research for the purpose of detecting security threats.

Defining what constitutes a threat, or threatening behavior, may be the toughest issue, Papanikolopoulos admits. “For me, this is one critical question that we need to answer. Can we learn what is suspicious activity?” he asks.

### **Designing efficient bandwidth and power modulations for better wireless transmissions**

In today’s media-rich world, more and more communication is done over wireless networks, and the demand for new mobile services seems unlimited as these systems now handle not only voice, but also video and image transmissions. Despite the increasing use of mobile multimedia communication, wireless systems still face two major problems: signal fading and limited bandwidth. Associate professor Mohamed-Slim Alouini and a team of researchers from the Electrical and Computer Engineering Department are embarking on research to help allay these particular challenges.

Unlike cable or fiber optic networks, for which the transmission length is fixed, the unknown transmission lengths of a wireless system create random signal behavior. This leads to lost signals, signal degradation, and overall unreliable performance.



*Graduate student Pavan Vitthaladevuni and Mohamed-Slim Alouini*

Alouini is working to develop spectrally efficient “hierarchical” transmission techniques whereby both voice and data are imbedded into a single signal.

Traditionally, one way to tackle this “fading phenomenon” problem was to use worst-case design methodology in which the channel is characterized and calibrated based on the worst possible transmission scenario. But while this approach may improve performance, it requires a lot of power, quickly drains the battery of a mobile device, and creates a significant amount of interference to other wireless applications.

Instead of using the worst-case approach, Alouini’s team is working to design adaptive communication techniques in which signal quality is estimated and tracked in real time. With adaptive modulation, when a signal fades, the power and rate are backed down and the data being transmitted are buffered until the signal improves; then, transmission resumes at higher rates when the channel quality improves. According to Alouini, this technique uses much less power and actually allows for faster average data transmission rates.

The researchers’ are also investigating the competition for bandwidth, or spectrum. Because the radio spectrum used in wireless communication is congested and in short supply, wireless applications, including intelligent transportation systems (ITS), must be able to transmit as much data as possible using as little bandwidth as possible. Alouini is working to develop spectrally efficient “hierarchical” transmission techniques whereby both voice and data are imbedded into a single signal.

After first creating simple, mathematically trackable models of a wireless system and of the fading phenomenon, the team developed unique performance analysis models that quantify channel imperfections using formulas. “We were the first to come up with a mathematical framework to evaluate the exact performance of several hierarchical transmission schemes over communication channels,” Alouini notes.

These newly developed modulation techniques were compared to traditional ones to determine what gains have been made using what scenarios. The team continues to study different types of

adaptive modem concepts that may be even more efficient, and they have collaborated with researchers at the University of British Columbia in Vancouver, Canada, to develop a multimedia modem that capitalizes on the concept of hierarchical constellations to transmit simultaneously voice and multiple classes of data over fading channels. Computer simulations show that this newly developed modem is more bandwidth-efficient than previously proposed modems for simultaneous voice and data transmission.

These research efforts will be instrumental in improving the reliability of wireless networks used in traffic management applications, and by other industries and individuals to extend battery time for mobile devices with less interference.

## **SOCIAL AND ECONOMIC POLICY ISSUES RELATED TO ITS TECHNOLOGIES**

### **Sustainable Technologies Applied Research Initiative: Spatial impacts**

Back in the 1980s at the dawn of the Internet age, futurists predicted that as telecommunications improved, people would stay home more. They could work, shop, and bank from home, and would save time and energy, reduce air pollution, even eliminate traffic. Though this hasn’t happened yet, it’s not for lack of technology. People could travel less—they just don’t.



*Kevin Krizek*

The relationship between information and communication technologies and household travel decisions is more complicated than futurists could have imagined. Unraveling that relationship to help transportation planners understand how urban areas may change as technology becomes pervasive is at the core of Kevin Krizek’s research.

As part of the Sustainable Technologies Applied Research (STAR) project, Krizek, an assistant professor at the Humphrey Institute, is in the middle of a six-year study of the impact of telecommunications on urban spatial structure and its subsequent impact on urban transportation demand and intelligent transportation systems. “We are looking at the degree to which information and technology affect personal travel habits,” he explained. “At one point, we thought that e-commerce could replace a lot of physical travel and therefore we’d eliminate our congestion woes. The emerging thought is that information technologies are not replacing household travel but are complementing it.”

Krizek is collecting and analyzing data on household travel decisions in three cities: Seattle, Pittsburgh, and the Kansas City metropolitan area. The urban areas differ from one another in degree of technology use and in congestion levels.

Examining such different cities, Krizek feels, will produce a clearer picture of how telecommunications will affect travel under a variety of circumstances.

The first step in this study was an extensive review of earlier studies into the influence of technology on household decisions. Earlier research found that many kinds of household activities could be replaced by telecommunications. Generally, researchers found that activities could be divided into subsistence activities

(such as commuting for work), maintenance (such as grocery shopping or banking), and leisure. For each of these activities, telecommunications could have a variety of effects: it could be a substitute for travel, such as working at home instead of commuting; it could modify travel in terms of time or location; and finally, telecommunications devices could generate travel that otherwise might not have occurred.

During the second phase of the research, Krizek conducted an extensive survey of several thousand households in the three study cities. The questionnaire asked residents about their use of technology for banking, shopping, and entertainment. It also asked about attitudes toward technology and various travel issues such as congestion and walking as a travel option.

Although he has not yet finished analyzing and interpreting the data, Krizek has already discovered some interesting results.

“There are a lot of things we have to figure out,” says Krizek. “One study found, for instance, that you can take a family out of the suburbs, but you can’t take the suburbs out of the family. That is, if a family moves from the suburbs into the city, they will take just as many trips using their car. The trips may be shorter, but the habit of driving is very hard to change.”

By understanding the demographics of those who use telecommunications and how, Krizek hopes to gain important



insight into transportation issues. The overall results of this work will help provide a stronger basis for formulating transportation policy now and in the future.

[This article has been adapted from material originally published by the Humphrey Institute of Public Affairs in *Places and Networks: New Hierarchies in Access and Activity*. See [www.hhh.umn.edu/centers/slp](http://www.hhh.umn.edu/centers/slp).]

### **Sustainable Technologies Applied Research Initiative: ITS and industry clusters**

Businesses worldwide are continually being reshaped by advances in ITS technologies. Yet despite the rapid development of these



*Lee Munnich*

technologies, ITS research generally focuses on the systems from the standpoint of the transportation agency or technology provider; the ways in which ITS affects transportation system users, especially businesses and industry, have gone largely unexplored.

To help fill that gap, Lee Munnich, senior fellow with the Hubert H. Humphrey Institute of Public Affairs, and research assistants Chandler Duncan and James Lehnhoff began a research effort to examine ITS technologies from the user's perspective. In this multi-year study, the researchers are working to learn more about the economic development aspects of transportation to find out how it can be used to improve a regional economy and to identify key policy actions or intermediaries that may better enable firms, communities, and regions to maximize the benefits of ITS technologies.

Because regional economies often are driven by the presence of industry clusters—that is, groups of companies making a similar product or components for that product that congregate naturally in

a specific region—the team chose two rural industry clusters located in northwestern Minnesota for which to analyze ITS use. Despite disadvantages that might have a negative economic impact—its distance from the Twin Cities (more than 300 miles) and lack of access to an interstate highway—the region enjoys a per capita income higher than that of other non-metro regions of the state, due in large part to the success of its industry clusters.

“Transportation is a huge issue for these industry clusters,” says Munnich. “They’re located in a very sparsely populated region. There are no interstate highways. The weather conditions can be horrible and have a severe effect on transportation. We’re trying to discover to what extent technology improvements affect the clusters and what improvements likely will be needed for the future.”

The two clusters involved in this particular study are those for recreational transportation equipment, which primarily involves the manufacture of snowmobiles and all-terrain vehicles, and wood products. To date, the researchers have conducted interviews and focus groups with industry representatives in order to learn how businesses within each cluster communicate with customers and suppliers, how they link suppliers and customers through transportation and communication networks, how they move goods, how the cost of transportation affects the firm's location, how their transportation needs have changed over time, and what changes they anticipate making in communication and transportation strategies in the future.

Although the study is ongoing, Munnich and his team have already uncovered some interesting differences between the two clusters. In the recreational equipment industry, for example, businesses are experiencing a rising demand for their products locally, nationally, and internationally. Many of these firms are already using technology to their advantage to handle product, inventory, and/or supply tracking and supply-chain management. For many firms in this cluster, technology also has enabled more cost-effective transportation options. The wood products cluster,

however, primarily serves only local and regional markets, and most firms in this industry have not widely implemented any supply, product, or inventory-management systems. Generally, these firms have smaller supply chains and are not as concerned with using ITS technologies for connectivity among companies. The bottom line so far is that the use of ITS technologies is “necessary but not sufficient” to business vitality in these clusters, Munnich says. This initial finding has opened up several other areas for further exploration and has led the researchers to ask sharper questions about these clusters regarding which technologies are used, how they are used, and what benefits they provide.

In the next phase of the study, researchers will take a broader look at the state as a whole in terms of what ITS is doing or

could be doing for industry in Minnesota. The study’s long-term objective is to determine specifically what technologies are needed and to identify any market barriers businesses face to using these technologies. The findings from this project will help transportation professionals make better decisions on how to use new technologies to strengthen industry clusters and enhance economic vitality in cluster areas.

In the next phase of the study, researchers will take a broader look at the state as a whole in terms of what ITS is doing or could be doing for industry in Minnesota.



## HUMAN PERFORMANCE AND BEHAVIOR

### John Bloomfield and Kathleen Harder, *College of Architecture and Landscape Architecture* **Fatigue Detection: Can Fatigue-Detection Devices Predict the Driving Performance of Sleep-Deprived Drivers?**

Status: **In progress**

This project is seeking to determine the relationship between sleep deprivation and driving performance and to determine whether impairments in driving performance caused by sleep deprivation can be predicted by fatigue-detection devices. If such impairments can be predicted, the researchers also hope to provide law enforcement with reliable benchmark data documenting the correlation between the devices and driving performance impairment.

To carry out these objectives, driving performance data and various measures of impairment will be collected from a minimum of 20 subjects over a 20-hour period, during which time the subjects will be kept awake. Driving performance data will be collected while each subject drives in a driving simulator, and impairment will be assessed with various measurement instruments including EyeCheck™, the psychomotor vigilance test (PVT), and the digit symbol substitution test (DSST). If, when the resultant data are analyzed, reliable relationships between driving performance impairment and fatigue detection devices are found, they will be formulated in a way that aids their use by law enforcement officers.

To date, the simulator scenario development is nearing completion. The researchers are negotiating with the Minnesota Trucking Association in order to obtain participation of truck drivers in the study. The Human Subjects

Approval process is almost complete, and the researchers are working with the University's General Clinical Research Center so that when the driving simulation portion of the study is complete, the subjects will be escorted to the GCRC, where they will be monitored until they are able to leave.

**Project URL:** [www.its.umn.edu/research/projects/2002031.html](http://www.its.umn.edu/research/projects/2002031.html)

### Kathleen Harder, *College of Architecture and Landscape Architecture*

#### **The Effectiveness and Safety of Traffic- and Non-Traffic-Related Messages Presented on Changeable Message Signs**

Status: **Completed (in FY04)**

Changeable message signs (CMSs) were originally intended to warn motorists about traffic tie-ups and weather conditions. But today, the Minnesota Department of Transportation (Mn/DOT) is considering other possible uses, including the presentation of promotional, safety, law enforcement, and travel quality messages. As part of the nationwide program, CMSs are now



also used in the Amber Alert System to flash emergency alerts to motorists when a child is abducted.

All of these possible traffic-related and non-traffic-related uses of CMSs have provoked a number of issues about their effectiveness and the safety impacts they may have on traffic. This research attempted to answer several key questions, namely: Should messages be presented on CMSs only when they are necessary, or should there always be some message on them? Do the messages presented on CMSs cause slowdowns? Do the messages on CMSs actually work? And what is the impact of CMS messages on traffic flow?

Using a driving simulator, the researchers conducted two back-to-back experiments in which they examined how drivers responded to traffic-related and non-traffic-related messages. In one experiment, the team investigated the effectiveness of site-specific, time-critical messages; in the second, they focused on Amber Alert messages.

Based on their findings, the researchers came up with a series of recommendations they believe will help increase the effectiveness of CMS messages, including Amber Alerts. These include making the public more aware of the Amber Alert system and changing the Amber Alert messages themselves. Since the experiments show that it is particularly difficult for drivers to remember the license plate number flashed on a CMS, the Amber Alert messages should, instead, tell drivers to tune into an appropriate radio station, whose call sign will be easier to remember. The radio station should then frequently repeat the full Amber Alert message, including the license plate number, which will greatly increase the likelihood that a driver encountering the vehicle mentioned will recognize it.

**Project URL:** [www.its.umn.edu/research/projects/2003038.html](http://www.its.umn.edu/research/projects/2003038.html)

### **Reducing Crashes at Controlled Rural Intersections**

Status: **Completed (in FY04)**

Right-angle crashes are a problem at rural through-stop intersections, accounting for 71 percent of the fatal crashes in Minnesota in 1998, 1999, and the first half of 2000. Using a driving simulator, the researchers investigated the effect of several interventions (e.g., innovative signage, improved sight lines for drivers) intended to increase the saliency of a problem intersection in Goodhue, Minn. One group of 24 participants drove with the intersection modeled as it is now, while a second group of 25 drove with the interventions implemented at the intersection. On the minor road, the effect of the interventions was to make the participants stop closer to the stop signs and begin to reduce speed further from the intersection. On the major road, their effect was to make participants reduce speed substantially on approaching the intersection.

The implications of these findings are: 1) by stopping closer to the stop signs, drivers should have a better view of the major road and be better able to judge gaps in the traffic on it; 2) by beginning to slow down further from the intersection, drivers will stop in a more controlled fashion and be less likely to inadvertently run the stop sign; and 3)



if a vehicle pulled into the intersection from the minor road, necessitating an emergency braking maneuver by the vehicle on the major road, the speed reductions would produce even greater reductions in the stopping distances if the proposed mitigation methods were implemented. Right-angle crashes would be less likely to occur, and if they could not be avoided, their severity would be reduced.

**Project URL:** [www.its.umn.edu/research/projects/2001008.html](http://www.its.umn.edu/research/projects/2001008.html)

### **User-Centered Auditory Warning Signals in Snowplows**

Status: **Completed (FY04)**

Because the snowplow operator's tasks are predominately visual, warnings presented visually may interfere with critical tasks. Auditory warnings could reduce visual load if they are meaningful, effectively signal danger, and are not annoying.

The researchers conducted a driving simulation experiment using a 210-degree forward field-of-view driving simulator and a field test to investigate using auditory icons as side and forward collision-avoidance warnings. Participants in the experiment drove on simulated snow-covered roads in 105-meter (344-foot) visibility conditions.

Analysis of data from 28 participants showed the side collision-avoidance warnings were equally effective; lane-change response times were approximately 1.1 seconds for both a single- and double-beep car horn warning (although participants said that the double-beep warning sounded more urgent). Analysis of the forward collision-avoidance warning data, obtained from 32 participants, showed that the mean response time with a warning consisting of two bursts of screeching-tire sounds was significantly faster than with a



single-screech warning—with both warnings significantly faster than the mean time obtained when no warning was given. The poorest collision outcomes occurred with no warning; outcomes were better with the single-screech warning, and better still with the double-screech warning. In the field test, six of seven snowplow operators preferred the double-beep side-collision warning. As a result, the researchers recommend that an auditory icon sounding like the double-beep of a car horn be used as a side collision-avoidance warning, and an auditory icon sounding like two successive bursts of screeching tires be used as a forward collision-avoidance warning.

**Project URL:** [www.its.umn.edu/research/projects/2000038.html](http://www.its.umn.edu/research/projects/2000038.html)

**Guidelines for Using Rumble Strips**  
Status: **In progress**

This project is in response to a request by the Minnesota Local Road Research Board for research that focuses on the effect of in-lane rumble strips on stopping behavior at problem intersections. The few existing case studies reveal that the data are not definitive in terms of whether or not rumble strips have a noticeable effect on stopping behavior at rural stop-controlled intersections; however, these studies were not well-controlled (e.g.,

the age, quality, and maintenance of the rumble strips in the case studies were not controlled for), so questions remain regarding the utility of rumble strips.

County engineers frequently find themselves in litigious situations because of the public’s perception that rumble strips are highly effective devices at problem rural controlled intersections. On the other hand, rumble strips can become a liability because once in place, they are often not properly maintained. This research is attempting to conduct a well-controlled empirical study that will establish guidelines for where to use and not use rumble strips in order to move toward standardization. Such guidelines would be helpful to county engineers, giving them more knowledge regarding whether or not in-lane rumble strips should be a tool they apply to problem intersections.

**Project URL:** [www.its.umn.edu/research/projects/2003032.html](http://www.its.umn.edu/research/projects/2003032.html)

**Investigating the Effects of Rumble Strips on the Stopping Performance of Sleep-Deprived Drivers**

Status: **In progress**

This is the second in a set of three studies on the effects of rumble strips on stopping performance. The first study was conducted with attentive drivers in a driving simulator and revealed that the presence of rumble strips has no effect on the point at which a driver begins to slow down or on the distance away from the intersection at which he or she actually stops. Findings indicate that the presence of rumble strips only affects the point at which they begin to brake.

The current project is investigating the effect of in-lane rumble strips on the stopping performance of sleep-deprived drivers. The study is being conducted with the new advanced driving simulator in the HumanFIRST Program at the

University of Minnesota, piggybacking on a larger study examining the effects of sleep deprivation on driving performance.

**Project URL:** [www.its.umn.edu/research/projects/2003001.html](http://www.its.umn.edu/research/projects/2003001.html)

**Psychological and Roadway Correlates of Aggressive Driving (Phase II)**

Status: **In progress**

This project is an interdisciplinary effort to understand the extent to which pre-existing cognitions, emotions, roadway conditions, and attitudes toward driving contribute to aggressive driving. In Phase I of this project (already completed), a survey analysis revealed self-reported factors that can prompt aggressive driving behavior. In Phase II, researchers are examining these factors in a simulated driving environment of the Institute’s HumanFIRST Program. Previous studies on aggressive driving have failed to address the factors that can precipitate aggressive driving as comprehensively as proposed in this study. Results from Phase I and Phase II of this research will yield a rich resource of information for educational outreach throughout Minnesota and beyond, with the goal of reducing incidents of aggressive driving.

**Project URL:** [www.its.umn.edu/research/projects/2002034.html](http://www.its.umn.edu/research/projects/2002034.html)

**Tom Smith, School of Kinesiology**  
**Reducing Risk Taking at Passive Railroad Crossings with Active Warnings**

Status: **In progress**

A disproportionate number of vehicle-train crashes in Minnesota occur at passively signed highway-rail intersections (HRIs). The high percentage of (mostly rural) passively signed HRIs is attributable to the high cost of conventional active warning technology. This study evaluates driver interaction



with a low-cost active warning system being considered by Mn/DOT for potential installation at passive HRIs. The objective is to ascertain if, relative to HRIs with passive signage, drivers interact more cautiously with HRIs equipped with active warning system technology.

The study was conducted using a simulated driving environment consisting of various HRI scenarios and 25 subjects (15 females, 10 males).

Major results show that the presence or absence of a train, fog, or signage significantly affects dependent variables for all measurement intervals; the incidents of vehicles beating a train or hitting a train are higher with passive advance warning signs, relative to active warning signs; with a train present and clear visibility, for all measurement intervals, active advance warning signs are associated with lower mean vehicle speeds, compared to mean speeds observed with passive advance warning signs; active advance and crossing warning signs were perceived by respondents as more usable and more perspicuous than passive advance and crossing warning signs; and finally, flashing words (e.g., a variable message sign) are perceived by respondents as more perspicuous than flashing lights on an active advance HRI warning sign.

These results support the conclusion that installation of low-cost active warning systems at passive railroad

crossings, with both advance and HRI active warnings, will benefit driving safety.

**Project URL:** [www.its.umn.edu/research/projects/2000041.html](http://www.its.umn.edu/research/projects/2000041.html)

**Mike Wade, School of Kinesiology**  
**Accident Analysis for Low-Volume Roads**

Status: **In progress**

This study is analyzing existing crash data reported in three categories of crashes—fatality, personal injury, or property damage—that occur in selected counties in Minnesota on county and township roads. The project will select an outstate county (Martin County) and determine not only the frequency and location of crashes on the county and township roads in that county, but also record the nature of the signage and other characteristics of the cluster of crashes, such as weather, time of year, time of day, and other factors that may be unique to intersections where significantly more crashes occur than by chance.

This database and the proposed analysis should provide useful information for county engineers to better determine the impact of signage



and seasonal variation along with other aspects—all of which affect the decisions they make for collision-prone intersections.

**Project URL:** [www.its.umn.edu/research/projects/2002008.html](http://www.its.umn.edu/research/projects/2002008.html)

**Deer Avoidance Research: Use of Motion Detector Flashing Light**  
Status: **In progress**

This project is evaluating the potential impact of a new technology—motion detection information relative to the presence of deer in and around major highways—on driver behavior. Experiments will be performed that will record driver behavior as a function of the new deer motion detection system. Deer presence will be displayed as a warning light, which will flash in the area adjacent to the detection of the deer. Variables of interest will include the location and nature of the illuminated signal; the rate at which the warning light flashes; rural versus urban drivers; age of the operators (less than 40 years of age, older than 60 years of age), and possible gender effects. The variables will be generated in consultation with a Mn/DOT technical panel, and the research will be carried out at the University of Minnesota using a driving simulator.

**Project URL:** [www.its.umn.edu/research/projects/2002023.html](http://www.its.umn.edu/research/projects/2002023.html)



**Nicholas Ward, Department of Mechanical Engineering**  
**Design and Safety Implications for ATIS Use with Cell Phones**

Status: **In progress**

There is considerable debate (without sufficient research) about cell phones as a risk factor in traffic crashes and their relative risk compared to other existing secondary tasks drivers may perform in the vehicle. Now that many states are intending to introduce traveler information systems that may be accessed with cell phones while driving, there is an even greater need for relevant research to determine the risk of this secondary task. A risk can be assumed for any task that demands driver attention and distracts the driver from the primary driving task. Thus, the key question is not if cell phone use imposes a risk, but rather, if the amount of risk is unacceptable. An acceptable risk threshold can be assessed in relative terms by comparing cell phone use to other common risk factors. First, there is a range of common in-vehicle tasks that are routinely engaged in by the driving population. The risk imposed by this common task set may be considered a baseline that is based on the notion of consensual risk. Second, demonstrable limits have been set for other impairment factors such as alcohol (BAC 0.10). The risk imposed by these legislated limits can also be considered as a baseline that is based on the notion of sanctioned risk. This project will assess the “relative” risk of cellular phone use on driving impairment and driver mental effort compared with commonly accepted in-vehicle tasks as well as BAC 0.08.

**Project URL:** [www.its.umn.edu/research/projects/2003040.html](http://www.its.umn.edu/research/projects/2003040.html)



**Driving Performance During 511 Information Retrieval and Cell Phone Conversation Tasks, Combined Under Varying Levels of Traffic Density**  
Project Status: **In progress**

Currently, Minnesota has a 511 service that may be accessed by users while driving. There is considerable debate about cell phones as a risk factor in traffic crashes. Mn/DOT-funded research begun in 2003 will assess the “relative” risk of cell phone use to other common risk factors, including existing in-vehicle tasks and alcohol. As a logical and necessary extension of this research, this new project will assess cell phone use for 511 applications compared with other cell phone (conversation) interactions. These data will be used to evaluate the usability of 511 in traffic and to give design recommendations.

**Project URL:** [www.its.umn.edu/research/projects/2004036.html](http://www.its.umn.edu/research/projects/2004036.html)

**Human-Centered Interventions Toward Zero Deaths in Rural Minnesota: Psychological Factors, Driver Risk Taking, and Acceptable Interventions**

Status: **Newly funded**

Motor vehicle crashes predominate as the cause of mortality in rural areas. Persons involved in a rural crash are three times more likely to die than persons involved in an urban crash. Since most rural crashes involve rural drivers, research must consider the pertinent human factors by examining the relationship between

the personalities and attitudes of rural drivers toward safety and the higher rural crash rate, as well as driving style, relative to the urban context. This project will attempt to support the development of a human-centered intervention to reduce the carnage from the high rural crash rate in Minnesota by investigating these psychological and social factors that may predispose rural drivers to drive less safely.

**Project URL:** [www.its.umn.edu/research/projects/P2005024.html](http://www.its.umn.edu/research/projects/P2005024.html)

**Albert Yonas, Institute of Child Development**  
**Improving the Ability of Drivers to Avoid Collision with Snowplows in Fog and Snow**

Status: **Newly funded**

The researchers have created a laboratory test bed for investigating the effects of blowing snow, fog (luminance contrast), flashing warning lights, and color on the ability of drivers to perceive that they are approaching or withdrawing from a simulated vehicle. In doing so, they have found that lowering the luminance contrast between the image of a vehicle and the background significantly reduces the ability to perceive approach. In a

low-contrast, equiluminant situation, the researchers required twice as much retinal motion as normal to begin to sense approach. Flashing lights, such as those mounted on snowplows to attract attention, also interfere with motion perception. Consequently, the researchers plan to completely characterize the chromatic contrast effect of blowing snow and fog on the color space by making systematic physical measurements on a selected number of carefully chosen color surfaces. In addition, they will use their computer-controlled laboratory task, and well-understood psychophysical methods, to investigate the impact of vehicle color and lighting enhancements. For example, they will investigate the effects of the number, location, color, and flashing of warning lights on the ability to perceive that a driver is approaching a vehicle. Results will enable them to make recommendations to increase the safety of Minnesota drivers.

**Project URL:** [www.its.umn.edu/research/projects/P2005068.html](http://www.its.umn.edu/research/projects/P2005068.html)





## COMPUTING, SENSING, COMMUNICATIONS, AND CONTROL SYSTEMS

**Vladimir Cherkassky, Department of Electrical and Computer Engineering**  
**Quality of Service Implementation for Transmission of Video Data (Phase II)**  
 Status: **In progress**

This project is investigating the practical transmission of multiple video streams over limited-bandwidth communication channels. This includes transmission over limited-bandwidth wireless channels, as well as transmission over fixed-link channels where the bandwidth requirements exceed available link capacity.

Previous research (Phase I) focused on the technical issues important for quality of service (QoS), such as video compression (using off-the-shelf commercial hardware/software) and



prioritization of video data in packet-switching (IP) networks. These issues have been addressed using the prototype system developed and installed at the ITS Lab at the University of Minnesota. Phase I research helped to understand and quantify the trade-offs between the amount of compression, quality of video, available network bandwidth, and varying network traffic loads. Phase II research is concerned with practical design choices for implementing QoS under “typical” network configurations used at Mn/DOT. This includes implementing the QoS prioritization software in the prototype system at the ITS Lab; analyzing existing network configurations and application settings that require QoS implementation; and simulating these network configurations in the prototype system in order to evaluate practical effectiveness of the QoS approach for different application settings.

In Phase II, potential bottlenecks that might disrupt data flow when Mn/DOT networks are congested were identified. Also, a prototype system for studying the effects of QoS, configured to provide video streams from a set of video servers, has been set up in the ITS Lab. An open source QoS software has been configured as part of the prototype system to provide QoS to the video streams. In the future, different real-time scenarios will be simulated in the prototype system and the behavior of the QoS software under these settings will be extensively studied.

**Project URL:** [www.its.umn.edu/research/projects/2003010.html](http://www.its.umn.edu/research/projects/2003010.html)

**Max Donath and Pi-Ming Cheng, Department of Mechanical Engineering, and Shashi Shekhar, Department of Computer Science and Engineering**

**A New Approach to Assessing Road User Charges: Evaluation of Core Technologies**

Status: **Completed (in FY04)**

The main goal of this research was to develop the system requirements for the GPS and the digital map components that make up the core of an in-vehicle road user charging system. The focus was to evaluate both GPS and digital maps in the most difficult of environments—where roads of different jurisdictions and possibly different fee structures are located in close proximity to each other (a highway and a frontage road, for instance). In order for the system to be effective, it must be able to place the vehicle on the correct road.

GPS receivers that are commonly used by automotive navigation systems do not have sufficient accuracy for road user charging applications. However, the GPS-determined positions can be corrected, and thus made more accurate, using publicly and privately available wireless signals, namely, using differential GPS (DGPS). This experimental study based on road testing found that only certain DGPS receivers are capable of achieving the needed accuracy.

Extensive testing of existing digital maps found that they are also not accurate enough to be used for road user charging. There are, however, new, more accurate digital maps (not yet publicly available) that are already being used for vehicle safety applications. By combining DGPS and such high-accuracy digital maps, the ability to design a road user charging system with high geographical resolution can become a reality.

**Project URL:** [www.its.umn.edu/research/projects/1999002.html](http://www.its.umn.edu/research/projects/1999002.html)

**Max Donath and Craig Shankwitz, Department of Mechanical Engineering**  
**Driver-Assistive Systems for Snowplows**

Status: **Completed (in FY04)**

Operating a snowplow is a difficult and dangerous task. The snowplow driver faces challenging environmental problems including icy roads, blowing and drifting snow, and impaired vision due to the blowing snow, darkness, etc. In addition to these problems, snowplow drivers experience stress due to long hours of operation and the tasks required to successfully clear streets and highways. This project led to the development of a snowplow equipped with the hardware and software necessary to provide an effective driver’s assistance package.

**Project URL:** [www.its.umn.edu/research/projects/2000042.html](http://www.its.umn.edu/research/projects/2000042.html)

**USDOT Intelligent Vehicle Initiative (IVI) Specialty Field Operational Test**  
 Status: **Completed (in FY04)**

The University of Minnesota has been a partner in the USDOT-sponsored Specialty Vehicles Field Operational Test (FOT). The project team is made up of Mn/DOT, the University of Minnesota, and 3M, which provided a magnetic-based lateral-guidance system. The



purpose of the FOT was to integrate vehicle-guidance and collision-avoidance technologies into a comprehensive driver-assistive system used to improve driver vision under conditions of low visibility.

The FOT was originally proposed and executed as a three-year, multi-phased program. Year One prepared the infrastructure on Highway 7, designed vehicle systems and interfaces to support the operational test, and performed initial integration work for the Human-Machine Interface (HMI). Infrastructure that was installed included three DGPS receivers and broadcast stations and six visibility sensor stations located at periodic intervals along Highway 7. The focus of Year Two was to verify and document the performance of the infrastructure designed and installed in Year One, install, test, and debug vehicle systems, and perform validation exercises on the results of the HMI work. For both the infrastructure and HMI, changes and modifications to the respective systems were made to improve on-road performance. Once vehicle systems were verified, operator training was performed, and data collection and analysis methods and procedures were put in place to facilitate an independent evaluation of the work performed for this contract.

The aim of Year Three was to actually perform the FOT and provide data and results to the independent government evaluator. Due to an unusually mild winter and the resulting inability to collect a great deal of data, the program was extended to include a fourth year. The fourth year (2002–2003) had a winter as mild as the previous winter. As a result, a closed test-track evaluation was performed rather than an operational test. A report documenting the results and conclusions will be published. For the fourth year, there was no independent government evaluator; rather, all

evaluation efforts were undertaken by the University, with support and feedback provided by Mn/DOT.

**Project URL:** [www.its.umn.edu/research/projects/2000037.html](http://www.its.umn.edu/research/projects/2000037.html)

#### **Toward a Multi-State Consensus on Rural Intersection Decision Support** Status: **In progress**

The National Safety Council estimates that 32 percent of all rural crashes occur at intersections. Although the average crash occurring at an intersection is not as severe as one occurring on the open road, 16 percent of all fatalities on rural highways are intersection-related.

Minnesota is partnered with California, Virginia, and the FHWA in a pooled-fund consortium (the Infrastructure Consortium) dedicated to improving intersection safety. Each member of the consortium is tasked with addressing an aspect of intersection safety; the Minnesota team's objective is to develop a better understanding of the causes of crashes at rural intersections and then develop a toolbox of effective strategies to mitigate the high crash rate.

Rural Intersection Decision Support (IDS) focuses on enhancing a driver's ability to successfully negotiate rural through-stop intersections. The system uses sensing and communication technology to determine the safe gaps and then communicate this information to the stopped driver so that he or she can make an informed decision about crossing the intersection or entering the traffic stream



of a major road. The goal of the research is to reduce crashes and fatalities at such intersections without having to introduce traffic signals, which on high-speed rural roads often lead to an increase in rear-end crashes.

**Project URL:** [www.its.umn.edu/research/projects/2001048.html](http://www.its.umn.edu/research/projects/2001048.html)

#### **William Durfee, Department of Mechanical Engineering** **Optimal Secondary Controls Using a Configurable Haptic Interface** Status: **In progress**

Secondary controls are proliferating in automobiles as more and more electronic features are added for communication and navigation. The use of configurable, adaptable control knobs with haptic (touch) and aural feedback properties optimized to the driver and to the task may enable safe operation of a variety of secondary control functions with minimum distraction to the driver. In this project, the researchers are developing and testing new technology for configurable, manual controls with computer-controlled haptic and aural feedback properties. Controls will be tested in tabletop and driving-simulation experiments with human subjects to determine if optimal control properties can indeed benefit drivers. A future goal is to adapt this technology to drivers with motor, sensory, or cognitive disabilities.

**Project URL:** [www.its.umn.edu/research/projects/2003034.html](http://www.its.umn.edu/research/projects/2003034.html)



#### **Ravi Janardan, Department of Computer Science and Engineering** **Real-Time Collision Warning and Avoidance at Intersections** Status: **In progress**

Collisions between vehicles at urban and rural intersections account for nearly one-third of all reported crashes in the United States. This has led to considerable interest at the federal level in developing an intelligent, low-cost system that can detect and prevent potential collisions in real time.

This project is motivated by the need for methods that address problems raised by the Intelligent Vehicle Initiative Federal Infrastructure Consortium. The researchers are developing a system that uses video cameras to continuously gather traffic data (e.g., vehicle speeds, positions, trajectories, vehicle sizes) at intersections and then applies efficient algorithmic techniques to detect potential collisions and near misses in real time. The goal is to establish the feasibility of this approach using both computer simulations and field tests at actual intersections.

The current status of the project includes the development of a comprehensive video processing module for video acquisition and frame-by-frame analysis and tracking of vehicles, as well as the design and implementation of a variety of collision detection algorithms.

**Project URL:** [www.its.umn.edu/research/projects/2002025.html](http://www.its.umn.edu/research/projects/2002025.html)

#### **Taek Mu Kwon, Department of Electrical and Computer Engineering (Duluth)** **An Automatic Visibility Measurement System Based on Video Cameras (Phase II)**

Status: **In progress**

Poor-visibility conditions often lead to large-scale chain vehicle crashes that take lives and damage property. Such visibility-related crashes might be prevented if motorists were warned ahead of time to reduce speed and drive cautiously before entering a poor-visibility zone.

The challenge is to accurately measure visibility in real time in order to determine the optimal speed limit and then notify drivers in real time. The objective of this research was to advance visibility measurement technologies that process images captured through video cameras.

There are two fundamental problems in converting atmospheric parameters into visibility, which is the case in most of today's visibility meters. The first is that visibility is a complex multivariable function of many atmospheric parameters so that measurements of one or two parameters, as is currently done for most visibility meters, cannot accurately estimate the true human-perceived visibility. On the other hand, any attempt to measure every possible atmospheric parameter is simply too complex and costly. The second source of difficulty results from an attempt to express the spatially variant nature of atmospheric visibility using a single representative value: distance. This works only if the atmosphere is uniform, which it rarely is.

A solution offered by this research is to measure visibility using visual properties of video images (perceived information) instead of indirectly measuring physical properties of

atmosphere and then converting them into visibility. The spatial variance problem in visibility was solved by introducing a new concept of relative measurement of visual information referred to as the Relative Visibility (RV).

The research also extended the first phase of the video-based visibility study in which fixed multiple targets were used. The main finding was that the accuracy of visibility measurements increases as more targets in varying distances are used. For night visibility, measurements of air-opacity using a reflective near infrared (NIR) source from a specific type of surface property provided the most accurate representation.

**Project URL:** [www.its.umn.edu/research/projects/2000024.html](http://www.its.umn.edu/research/projects/2000024.html)

#### **Section Travel-Time Measurement Using Inductance Signatures of Loop Detectors**

Status: **In progress**

On Twin Cities metro freeways, loop detector stations have been installed at a half-mile spacing, forming sections. Each section thus comprises two sets of detector stations: one at the section entrance (upstream) and the other at the section exit (downstream). This research is studying a new way of measuring the average section travel time by tracing inductance signatures of the vehicles from two points, the section entrance and exit. This involves extracting the features of the inductance signatures generated by each vehicle passing through the upstream station and then re-identifying them at the downstream station by matching the features on both ends. For signal processing of vehicle inductance, several blind de-convolution approaches will be studied to develop an algorithm that leads to more clear discrimination of the inductance signatures. Another important issue in the feature-extraction

process is normalization of the signatures such that each signature found is independent of the speed of the vehicles. An adaptive optimization approach will be developed for this normalization process. During the vehicle identification process, the features will be time-stamped with the arrival time and will be used to compute the travel time. Section travel-time has a significant advantage over other travel-time measurement approaches because once the travel time of all sections is known, travel time from any point to any other point can be computed by simply adding the section travel times along the route. Since this new section travel-time measurement works in real time, if a network-wide system is installed, it would provide real-time route travel time.

**Project URL:** [www.its.umn.edu/research/projects/2003027.html](http://www.its.umn.edu/research/projects/2003027.html)

**TMC Traffic Data Automation for Mn/DOT’s Traffic Monitoring Program**

Status: **In progress**

The Minnesota Department of Transportation (Mn/DOT) has been responsible for collecting, analyzing, and publishing traffic count data from the various roadway systems throughout the state. The traffic reporting system mainly developed by the Traffic Forecasting and Analysis Section (TFAS) of Mn/DOT has been used in several federal programs, for internal Mn/DOT applications, and by many private-sector firms. This project is continuing the TFAS automation efforts by computerized integration of the current manual effort to import, filter, and analyze the TMC portion of traffic data contributed to Mn/DOT’s Traffic Monitoring System. The resulting system will allow users to specify the conditions for acceptance tests required by TFAS for both continuous and short-duration count volume data. Once the

filtering procedures and parameters are set by an operator, the raw data can be automatically processed by the system without human intervention.

**Project URL:** [www.its.umn.edu/research/projects/2001033.html](http://www.its.umn.edu/research/projects/2001033.html)

**Nikolaos Papanikolopoulos, Department of Computer Science and Engineering Development of a Tracking-Based Monitoring and Data-Collection System**

Status: **In progress**

This project is working toward the development and deployment of a flexible, portable, and reliable intersection-monitoring and data-collection system. The proposed system will be based on vehicle-tracking methodologies implemented on a single or multiple camera(s). Researchers will compute a variety of traffic and behavior data such as turning vehicle counts, vehicle trajectories, vehicle classes, delays, lane changes, gap acceptance behavior by turning vehicles, speed variations, safety-related data, and other



types of intersection data as needed by traffic engineers. The proposed system could be used for accessing the effectiveness of existing signal timing plans and operational methods and the level of intersection safety. The researchers’ approach will include the development of a user-friendly interface and will chiefly employ existing camera hardware. The researchers also envision the proposed system to be used as the main tool for before/after study of the effectiveness of intersection and local area improvement treatments.

**Project URL:** [www.its.umn.edu/research/projects/2003042.html](http://www.its.umn.edu/research/projects/2003042.html)

**Finding What the Driver Does**

Status: **Newly funded**

This project will work toward the development of a system for monitoring driver activities. In general, drivers try to keep vehicle control and evaluate the environment around them. When drivers become fatigued or distracted, their behavior presents abnormal changes. Researchers will use an entropy-based encoding of a behavioral activity in order to evaluate and quantify the divergence from a safety norm. To facilitate this type of encoding, behavioral activities will be clustered, classified, and characterized using the latest computer vision techniques. Several experiments to verify the efficacy of the approach will be conducted.

A potential benefit of the proposed work is a decrease in the number of vehicle crash-related deaths, in accordance with the Toward Zero Deaths initiative.

**Project URL:** [www.its.umn.edu/research/projects/P2004010.html](http://www.its.umn.edu/research/projects/P2004010.html)

**Preventing Attacks to Critical Transportation Infrastructure**

Status: **Newly funded**

Preventing attacks to transportation infrastructure is a major concern for the Department of Homeland Security. Bridges, tunnels, seaport structures, airports, and rail and bus stations are vulnerable to attacks. Vehicular and pedestrian traffic is abundant at most of these sites. Recognizing events that may precede attacks is complex, since several of them blend in easily with the normal traffic activity at a particular site. This project will investigate using infrared sensors and cameras in the visible range in order to classify certain events as the pre-steps of an attack on critical transportation infrastructure. One example is a car stalled/stopped at a bridge.

Currently, several states and federal agencies use human patrols to monitor events around a bridge. This project seeks the development of an automated system that notifies human operators about incidents in the general vicinity of critical infrastructure sites.

**Project URL:** [www.its.umn.edu/research/projects/2004047.html](http://www.its.umn.edu/research/projects/2004047.html)



**Rajesh Rajamani and Lee Alexander, Department of Mechanical Engineering**

**Lateral Stability of a Narrow Commuter Vehicle**

Status: **In progress**

In an effort to explore technological solutions for increasing the carrying capacity of urban highways, this research is developing a prototype of a one- or two-passenger narrow vehicle, the width of which (about one meter or 3.3 feet) would allow two vehicles to drive side by side down a standard 12-foot-wide (3.7-meter-wide) traffic lane, thereby substantially increasing the number of vehicles per hour the lane can handle.

A major obstacle the researchers are working to overcome is that a narrow vehicle is unstable when turning at highway speeds unless it has the ability to tilt from side to side like a motorcycle to maintain its center of balance.

The team began the project by evaluating various types of suspension geometry and considered power sources for both the vehicle and the control system. After a suitable geometry and power source were chosen, researchers designed the rear-wheel-drive vehicle, which has two wheels in the front and one in back, then built a working prototype of the vehicle.

With the physical model constructed, the team conducted a set of experiments that progressed from dry to slippery pavement and from simple to more complex maneuvers. Researchers used remote control to guide the vehicle around their testing grounds. The experiments yielded promising results and demonstrated that by using the automatic control system, the vehicle was able to tilt and balance itself while executing complex turns.

Next, the researchers will work toward building a safer, second-generation



vehicle capable of higher speeds and of actually carrying a passenger. Future work will also include the study of human-machine interfaces, including drivability and comfort, and collision avoidance for such a machine. The results of this work are meant to stimulate the development of future transportation technologies that reduce congestion on freeways in Minnesota and across the country.

**Project URL:** [www.its.umn.edu/research/projects/2001030.html](http://www.its.umn.edu/research/projects/2001030.html)

**Rajesh Rajamani, Department of Mechanical Engineering**  
**GPS-Based Real-Time Identification of Tire-Road Friction Coefficient**

Status: **In progress**

This project is developing a new GPS-based friction identification system for winter maintenance vehicles that will measure the road friction coefficient at the tires and make this real-time information available to the maintenance vehicle operator. This would enable the operator to adjust the amount and kind of deicing material to be applied to the roadway.

In work completed so far, a vehicle-based system for friction measurement has been developed and evaluated on a winter maintenance vehicle, the SAFEPLow. The vehicle-based system utilizes real-time measurements of the longitudinal and lateral motion of the vehicle together with a knowledge of vehicle dynamics in order to calculate

the value of the friction coefficient at the tires.

The advantage of the system developed in this project is that it is applicable during both vehicle acceleration and braking and works reliably for a wide range of slip ratios, including high-slip conditions. The system can be used on front/rear-wheel-drive as well as all-wheel-drive vehicles. Experimental results show that the system performs reliably and quickly in estimating friction coefficient on different road surfaces during various vehicle maneuvers.

As part of the project, a wheel-based friction measurement system is also being developed. This system uses a redundant wheel on the vehicle similar to that used by commercial friction measurement systems such as the Norsemeter. Unlike the Norsemeter, however, the advantage of the system being developed is that it requires no forced skidding of the external wheel and is likely to be a more reliable system due to the presence of very few moving parts. The wheel-based system is currently being evaluated on the SAFEPLow.

Besides winter maintenance, real-time identification of the friction coefficient should also be valuable for other vehicle systems, including ABS, skid control, collision avoidance, and adaptive cruise control systems.

**Project URL:** [www.its.umn.edu/research/projects/2002026.html](http://www.its.umn.edu/research/projects/2002026.html)

**Automated Winter Road Maintenance Using Road Surface Condition Measurements**

Status: **Newly funded**

This project aims to develop an automated sander control system for a snowplow using the friction coefficient of the road surface and pavement temperature as key measurements for feedback.



The project consists of two major technical activities: 1) Improvement of an existing tire-road friction measurement system on the SAFEPLow by using additional piezo sensors mounted on the insides of the tires of the snowplow. These additional sensors will help improve the accuracy and reliability of the friction measurement system; and 2) Automation of the snowplow sander using real-time measurements from the friction measurement system and a pavement temperature measurement sensor, and experimental evaluation of the performance of the automated system on the SAFEPLow.

The project should lead to the development of valuable winter maintenance technology in which knowledge of pavement conditions is used to keep roads in good condition. The technology will help reduce material costs, help better utilize maintenance crews, and lead to safer roads in winter.

**Project URL:** [www.its.umn.edu/research/projects/P2005035.html](http://www.its.umn.edu/research/projects/P2005035.html)

**Craig Shankwitz, Department of Mechanical Engineering**  
**Advanced BRT: Innovative Technologies for Dedicated Roadways**  
 Status: **In progress**

In the United States, a number of transit agencies are either operating Bus Rapid Transit (BRT) systems or are in the process of initiating this service. For example, Twin Cities Metro Transit operates a BRT system using a network

of 200 miles of road shoulders to allow bus passage during periods of high traffic congestion. Lane Transit in Eugene, Oregon, and the Cleveland Regional Transit Authority are considering a BRT system, both of which are likely to use lane-assist technology on dedicated, narrow lanes.

The present Intelligent Vehicles Lab (IV Lab) lane-assist system is based on precise vehicle-positioning technology and a high-accuracy digital road map. This system requires a reasonably clear view of the sky overhead in order to receive GPS satellite information. Without a clear view of the sky, GPS information is unavailable, disabling the lane-assist system. Urban canyons, roads with tall trees located close to the roadway, bridges, and underpasses all represent areas where the GPS receiver cannot receive satellite signals, and therefore cannot operate.

This project proposes augmenting the present IV Lab lane-assist system with ranging and positioning technology that will allow it to operate in the difficult environmental conditions listed above. Alternative ranging and positioning sensors will be analyzed, modeled, and eventually incorporated into the IV Lab lane-assist system. Successful augmentation will result in a system that meets the operational and robustness needs of transit agencies as well as the cost-effectiveness and reliability needs of the bus manufacturer and its OEM supplier.

As a means to this end, the IV Lab intends to work with transit agencies and bus manufacturer(s) to deploy an augmented DGPS digital map lane-assist system for a BRT narrow-lane application in the United States.

**Project URL:** [www.its.umn.edu/research/projects/2002041.html](http://www.its.umn.edu/research/projects/2002041.html)

**Bus Rapid Transit Technologies: Assisting Drivers Operating Buses on Road Shoulders**

Status: **In progress**

Metro Transit (the Twin Cities transit system) and the Minnesota Department of Transportation cooperatively operate a BRT-like capability throughout the Twin Cities metro area in which buses operate in high-occupancy vehicle (HOV) lanes and on specially designated road shoulders, albeit at speeds significantly lower than limits posted for the adjacent highway. However, operating transit buses that are typically 9 feet across from mirror to mirror on shoulders that are usually no more than 10 feet wide presents serious challenges. For one thing, these narrow lanes require that bus drivers maintain a lateral error of less than one-half foot to avoid collisions. This is difficult under the best of conditions and becomes impossible in bad weather, low visibility, and high traffic congestion. In response, this research is developing driver-assistive technologies to solve these challenges.

Researchers are adapting lane-keeping and forward collision-avoidance technologies originally developed for snowplows. Significant enhancements to the snowplow-based system have been made to specifically address issues involved with guiding a wide bus on a narrow lane. One such enhancement is the provision of torque feedback through the steering wheel to help a driver maintain the proper position in the narrow shoulder. A second enhancement is the incorporation of side and rear sensors used for collision avoidance.

To aid system development and facilitate testing, the team has outfitted an experimental vehicle—a Metro Transit bus—with a system that provides haptic feedback to the driver. The TechnoBus is fitted with a steering actuator, which



provides torque feedback to a driver. This feedback system uses a differential global positioning system (DGPS) and an inertial sensor to determine bus position and orientation. The position of the bus as determined by the DGPS system is compared to the location of the shoulder as provided by a digital lane-level geospatial database, or digital map. Using the error between where the bus is and where it should be, a corrective torque proportional to that error is applied to the steering wheel. When the bus is on a trajectory to leave the lane, the system also vibrates the driver's seat on the side to which the bus is departing, providing a second feedback path to the driver.

Researchers are also studying related human factors issues and have already conducted a pilot study in which 12 drivers were trained and tested under three conditions during rush-hour traffic: normal traffic lane without lane-assist technology; shoulder use without lane-assist technology; and shoulder use with lane-assist technology. Preliminary results suggest that the system may be a valuable aid to support bus driving on dedicated shoulders for BRT applications and also indicate that drivers themselves like the system.

The overall findings of this research were used to identify system requirements and recommend next steps. Since no market-ready, turnkey lane-assist systems are currently available, the next step for the research team is to field-test a system that integrates GPS, magnetic guidance, vision, and other

available technologies and then test a robust, fail-safe system.

**Project URL:** [www.its.umn.edu/research/projects/2001046.html](http://www.its.umn.edu/research/projects/2001046.html)

**Driver-Assistive Systems for Rural Applications: A Path to Deployment**  
 Status: **In progress**

This project has two components. The first is to develop and implement an automated means to collect geospatial data and process it in order to create a geospatial database suitable for use in driver-assistive systems. The approach used for this research will be to equip a vehicle with DGPS; sensing, digital cameras, and image capture hardware; image processing software; and data-acquisition equipment that will facilitate the real-time determination of the global position of a paint stripe as a vehicle travels on a lane. Given this sensory and data-acquisition system, the location of all paint markings on the roadway can be accurately determined and used as the basis of a multipurpose high-accuracy geospatial database or digital "map."

A complement to the image-processing task will be to use paint-stripping machines to collect geospatial data. The image-based system will be modified so that the global location of the paint nozzle can be determined from a sensor suite and a DGPS receiver located on the paint-stripping machine.

Converting the collected raw data into geospatial information becomes the next task. From that data, smoothing, feature extraction, and formatting software will



be developed that will allow for the automated creation of the digital map.

The second component is to form partnerships with county engineers who are responsible for snow removal in difficult environmental and visibility conditions. Two counties have elected to work with the IV Lab to test these systems. Polk County will be testing the driver-assistive system using a DGPS system that uses GPS corrections provided by a geosynchronous communications satellite. This system forgoes the need to provide a local, ground-based GPS base station and the wireless communication equipment needed to get the correction to the roving vehicle, thereby offering sufficient performance at a much lower cost. However, satellite-based correction systems are slower to recover if corrections or satellite information are lost. Testing will explore the tradeoffs between conventional and satellite-based correction systems.

In St. Louis County, a conventional real-time kinematic (RTK) system will be used for GPS corrections. However, the topology in St. Louis County is quite hilly and so will provide an opportunity to determine first-hand the robustness of conventional RTK systems in a difficult environment.

The Polk County plow has been equipped with the necessary technology, but because of a lack of snow during the winter of 2002–2003, no operational testing was undertaken. St. Louis County took delivery of the plow, but lack of snow in St. Louis County also delayed testing. The project received a no-cost extension until June 2004, with the hope that heavy snows in 2003–2004 would allow for thorough operational testing.

**Project URL:** [www.its.umn.edu/research/projects/2002009.html](http://www.its.umn.edu/research/projects/2002009.html)

**Gang Plowing Using DGPS**

Status: **In progress**

Gang plowing is one method used by Mn/DOT to increase the productivity of snowplow operations. However, these gains in productivity often come at the expense of increased driver stress. These higher stress levels are the result of the low visibility caused by the snow clouds created by the lead snowplow and by anxious drivers trying to pass between the slower moving plows.

To improve the gang-plowing process, researchers are working on an enhancement to an existing driver-assistive system. The proposed system would combine tactile steering feedback with throttle and brake actuators to help the driver of the following vehicle maintain the proper following distance and lane position behind the lead vehicle. The enhanced driver-assistive package would provide for improved safety on two fronts. First, driver stress and therefore driver fatigue will be reduced; alert drivers are in better control of their vehicles. Second, the driver-assistive system will allow a "tighter" formation for the plows, reducing the opportunity for a rogue motorist to try to squeeze in between the ganged snowplows. A side-scanning laser sensor and a "virtual mirror" will also be used to detect the rogue motorist trying to violate the gang formation.

This work builds on the driver-assistive work done under the Specialty Vehicle pooled-fund project. The pooled-fund work will bring the development of gang-plowing technology to the point where experiments will have been performed at Mn/ROAD to verify the concept. This approach to gang plowing will be demonstrated on an actual road, Minnesota Trunk Highway 101 between Rogers and Elk River, Minn.

**Project URL:** [www.its.umn.edu/research/projects/2002038.html](http://www.its.umn.edu/research/projects/2002038.html)

**Infrared Sensors for Driver-Assistive Systems for Specialty Vehicles, Including Snowplows**

Status: **In progress**

The University of Minnesota driver-assistive system has been proven in tests with snowplows on Highway 101 between Elk River and Rogers, with snowplows in field tests at the Rosemount Research Station, and on patrol cars during high-speed tests at Brainerd International Raceway. The system has worked well, allowing drivers to drive normally under low- (including zero) visibility conditions.

This research is investigating the applicability of infrared (IR) sensors for use as a stand-alone for general snowplow operations and as an integrated sensor for the driver-assistive system. Based on deployment timelines and budgets, IR systems may be deployed prior to the deployment of comprehensive driver-assistive systems. It is critical to ensure that these IR systems work well alone and that they can be integrated into driver-assistive systems as they are deployed in the future.

**Project URL:** [www.its.umn.edu/research/projects/P2003020.html](http://www.its.umn.edu/research/projects/P2003020.html)



### Multi-Use, High-Accuracy, High-Density Geospatial Database

Status: **Newly funded**

High-accuracy (2–8 cm) DGPS and high-accuracy (5–20 cm) geospatial databases are the primary components of the IV Lab driver-assistive systems. In addition to vehicle-based systems, the IV Lab geospatial database has been used in other applications—for instance, for a new intersection decision support (IDS) project in which radar sensors are used to determine the state of an intersection as a first step in warning drivers when it is unsafe to enter an unsignalized intersection. For this application, the geospatial database is used to improve the ability of the radar system to determine whether a target represents a legitimate threat at the intersection.

The IV Lab geospatial database was designed and optimized for vehicle applications, and as such it provides real-time access to an extremely accurate, dense geospatial data. Because of this optimization, however, its functionality in other applications is somewhat limited. As new applications arise (e.g., the need to integrate high-accuracy geospatial data into a driving simulator), a more “global” approach to the geospatial database is required. This project proposes a redesign of the geospatial database and database manager and the development of a new front end to serve a wide application base.



**Project URL:** [www.its.umn.edu/research/projects/P2005043.html](http://www.its.umn.edu/research/projects/P2005043.html)

### Shashi Shekhar, *Department of Computer Science and Engineering*

#### Evacuation Route-Schedule Planning for Disasters Damaging Automatic Traffic Control Systems

Status: **In progress**

Evacuation route-schedule planning identifies paths to move populations out to safe areas in the event of catastrophes, natural disasters, and terrorist attacks. Current approaches are based on assignment-simulation tools (e.g., DYNASMART). However, the quality of solutions from these tools depends on the logical configuration of the transportation network. Currently, engineering judgment is used to select logical network configuration. This project is working to develop algorithms and software tools to determine effective logical network configuration given physical transportation network and evacuation traffic demand. Developing efficient and effective algorithms for logical network design is a challenging research problem due to the exponential combinatorial search space of possible solutions. The new algorithms will also be integrated with assignment simulation tools such as DYNASMART. Researchers will also evaluate the new algorithms under certain given scenarios. This research will provide new tools to help Mn/DOT find optimal logical network configurations to supply to assignment simulation models toward effective evacuation route-schedule planning.

**Project URL:** [www.its.umn.edu/research/projects/2004051.html](http://www.its.umn.edu/research/projects/2004051.html)

### Jiann-Shiou Yang, *Department of Electrical and Computer Engineering (Duluth)*

#### Traffic Flow Modeling Simulation and Signal Timing Plans Evaluation of the Miller Hill Corridor

Status: **Completed (in FY04)**

This research presents a study of the traffic flow modeling, simulation, and signal timing plans evaluation of the Miller Hill corridor. The corridor on Highway 194 between Arlington Avenue and Haines Road is recognized as one of the most heavily traveled and congested roadways in the Duluth area. The ability to better understand traffic in that area will provide for better traffic management and better traveler information.

The traffic data along the corridor was collected over a 10-month period using a non-intrusive side-fire mounted RTMS traffic detector. A modified Papageorgiou’s macroscopic model was then developed to model the traffic flow on the corridor. Using the data collected, the model parameters were identified by solving a least-squares optimization problem. From the dynamic model developed, a traffic flow simulation system was then further developed and implemented to perform the real-time traffic simulation along the corridor during the afternoon rush hours.

Finally, based on the traffic flow modeling and simulation results, the traffic signal timing optimization along the corridor was conducted. The ultimate goal of this research is to provide a better signal-timing plan to improve the efficiency of traffic movement in that area.

**Project URL:** [www.its.umn.edu/research/projects/2001043.html](http://www.its.umn.edu/research/projects/2001043.html)

### A Nonlinear-State Space Approach to Arterial Travel Time Prediction

Status: **Newly funded**

Travel time information is a good operational measure of the effectiveness of transportation systems and can be used to detect incidents and quantify congestion. Travel time prediction refers to predicting and calculating travel time before a vehicle has traversed the arterial/freeway or route of interest. The ability to accurately predict freeway and arterial travel times in transportation networks is a critical component for many ITS applications (e.g., advanced traffic management systems, in-vehicle route guidance systems).

This project will focus on arterial travel time prediction by developing a recursive, nonlinear-state space model to predict short-term travel time on arterials. Prediction of travel time is potentially more challenging for arterials than for freeways because vehicles traveling on arterials are not only subject to queuing delay but also to traffic signal delay. Kalman filtering/time series analysis techniques will be incorporated with the prediction model due to their ability to update travel time information continuously to reflect the traffic fluctuation in real time. Unlike many off-line algorithms that use only historical data for prediction, both real-time and historical data will be used in the process of travel time prediction. Real-time data will be collected using the Global Positioning Systems (GPS) probe vehicle technique. In addition, information on traffic conditions on upstream and downstream links via video detectors will be used to improve the quality and robustness of the data.

The model will be implemented and field-tested on Minnesota State Highway 194 between Mesaba Avenue and Haines Road, one of the most heavily traveled and congested roadways in the Duluth area. The result is expected to provide a valuable tool for monitoring and gauging the traffic system performance and service quality of the arterials in the area of interest.

**Project URL:** [www.its.umn.edu/research/projects/P2005034.html](http://www.its.umn.edu/research/projects/P2005034.html)

## TECHNOLOGIES FOR MODELING, MANAGING, AND OPERATING TRANSPORTATION SYSTEMS

**Gary Davis, Department of Civil Engineering**

### A Case-Controlled Study of Driving Speed and Crash Risk

Status: **In progress**

In crash reconstruction, individual vehicle crashes are treated as essentially deterministic events, although incomplete information can leave one uncertain about how exactly a crash happened. In statistical studies, on the other hand, crashes are treated as individually random, although the parameters governing their probability distributions may be modeled deterministically. Selection of one or the other of these approaches affects how data are interpreted. In this research, a simple deterministic model of a vehicle/pedestrian encounter is used to illustrate how naïvely applying statistical methods to aggregated data could lead to an ecological fallacy and to Simpson’s paradox. This research suggests that these problems occur because the statistical regularities observed in crash data have no independent status but are simply the result of aggregating particular types and frequencies of mechanisms.

**Project URL:** [www.its.umn.edu/research/projects/2001032.html](http://www.its.umn.edu/research/projects/2001032.html)



### Identification and Simulation of Common Freeway Accident Mechanisms

Status: **In progress**

Determining whether or not an event caused a vehicle crash often involves determining the truth of a counterfactual conditional, for which “what happened” is compared to “what would have happened” had the alleged cause been absent. Previous research by others has developed a rigorous method for posing and answering causal questions—an approach that is especially well suited to the reconstruction and analysis of crashes.

In this project, researchers applied these methods to freeway rear-end collisions. Starting with video recordings of crashes, trajectory information on a platoon of vehicles involved in a crash was extracted from the video record. These trajectories were used to estimate each driver’s initial speed, following distance, reaction time, and braking rate. Using a model of rear-end crashes, it was then possible to simulate what would have happened had, other things equal, certain driver reactions been other than they were. In each of three crashes the researchers found evidence that: 1) short following headways by the colliding drivers were probably causal factors for the collisions; 2) for each collision, at least one driver ahead of the colliding vehicles probably had a reaction time that was longer than his or her following headway; and 3) had this driver’s reaction time been equal to his or her following headway, the rear-end collision probably would not have happened.

**Project URL:** [www.its.umn.edu/research/projects/2003007.html](http://www.its.umn.edu/research/projects/2003007.html)



### Identification of Causal Factors and Potential Countermeasures for Fatal and Severe Rural Crashes

Status: **In progress**

Developing effective strategies for achieving a zero-fatality goal requires understanding the exact causes of traffic crashes. This project will address this issue by first conducting a detailed reconstruction and causal analysis of a core sample of fatal Minnesota crashes, and second by conducting an expert assessment of the presence of specified causal factors, and susceptibility to countermeasures, for a larger sample of fatal and/or severe rural crashes.

**Project URL:** [www.its.umn.edu/research/projects/2003014.html](http://www.its.umn.edu/research/projects/2003014.html)

### Bus Signal Priority Based on GPS and Wireless Communications

Status: **Newly funded**

With the recent installation of GPS systems, Metro Transit is monitoring bus locations and schedules in order to provide more reliable transit services. Many applications are enabled by such vehicle-location systems. Using this type of information and other on-board systems, transit vehicles could potentially be used as probes for determining traffic speeds and travel times along freeways and major arterials.

Transit Signal Priority (TSP) for transit

has been proposed as an efficient way to improve transit travel and operation. Bus signal priority has been implemented in several U.S. cities to provide more reliable travel and improve customer ride quality. Current signal priority strategies mostly utilize sensors to detect buses at a fixed or at a preset distance away from the intersection. Signal priority is usually granted after a reprogrammed time offset after detection. This study will take advantage of the GPS system on the buses and knowledge about bus stop locations to develop a signal priority strategy that could consider the bus’s timeliness with respect to its schedule, number of passengers, location, and speed.

**Project URL:** [www.its.umn.edu/research/projects/P2005030.html](http://www.its.umn.edu/research/projects/P2005030.html)

### Cross-Median Crashes

Status: **Newly funded**

A cross-median crash occurs when a vehicle leaves its current path of travel, completely crosses the median dividing the highway’s directional lanes, and collides with a vehicle traveling in the opposite direction. AASHTO’s *Roadside Design Guide* suggests two countermeasures for preventing cross-median crashes: 1) the use of medians wide enough to provide adequate “clear zones” where a driver can stop or regain control of a vehicle before crossing into the opposing traffic stream, and 2) for areas where medians are less than 10 meters wide and annual daily traffic is greater than 20,000 vehicles/day, installation of median barriers.

As with any safety countermeasure, installation should begin with those locations showing the greatest expected benefits. This project will first review the state of the art in median crash protection through a literature review and a survey of current practices. This will be followed

by statistical modeling of the frequency of median-crossing crashes in Minnesota, with the objective of identifying those locations where countermeasure installation is most likely to pay off.

**Project URL:** [www.its.umn.edu/research/projects/P2005019.html](http://www.its.umn.edu/research/projects/P2005019.html)

### Eil Kwon, formerly with the ITS Institute

#### Development of Dynamic Route Clearance Strategies for Emergency Vehicle Operations (Phase I)

Status: **Completed (in FY04)**

Eliminating red lights along the route of an emergency vehicle can give emergency response teams a critical speed boost. Not only is the emergency vehicle able to proceed without slowing or stopping at intersections, but traffic on crossing streets is prevented from entering the route, so traffic volume is effectively reduced around the emergency vehicle.

Traffic Signal Preemption systems consist of some form of vehicle-mounted signal emitter combined with sensors mounted on or near traffic signals. When triggered by an emergency vehicle’s transmitter, these sensors activate a control mechanism that alters the traffic signals’ timing cycle. The result is that traffic signals change to green more quickly when a transmitter-equipped vehicle is approaching and stay green until the vehicle has cleared the intersection.



Intersection-based signal preemption with local detection, however, has several limitations: a vehicle-mounted signal transmitter must have a clear “line of sight” to the traffic signal in order to trigger the preemption routine, and it is possible to needlessly preempt intersection signals that are not on the emergency route if they happen to be located in the line of sight.

Dynamic route clearance goes beyond intersection-based signal preemption by managing the entire route that the vehicle takes from dispatch to emergency scene. In a dynamic system, a network-monitoring module continually gathers traffic information and passes these data to a route selection subsystem, which then calculates an optimal route based on current conditions.

Mathematically determining the best (i.e., lowest travel time) route is an example of the “single-source shortest path” problem; to solve it, the route selection module employs the well-known Dijkstra’s algorithm. In this case, the network-monitoring module first computes travel time between points considering current traffic conditions, and the algorithm computes the “shortest” route in terms of time rather than space. As soon as the emergency vehicle clears an intersection, the system initiates a signal-timing recovery procedure to return the signal to its original pattern.

To evaluate the route-based dynamic preemption system, Kwon and his team used VisSim™ microscopic traffic simulation software interfaced to an external virtual control center module. A virtual intersection controller module was also developed to emulate different types of signal preemption strategies including the existing method with local detection.

The streets around the University of Minnesota’s Minneapolis campus were selected as the sample network for

this evaluation. Simulation of multiple distinct routes revealed that route-based dynamic signal preemption produced superior results on relatively long and complicated routes when compared to the existing intersection-based preemption method. Network-wide traffic performance was also evaluated from the point at which the emergency vehicle was introduced into the simulation until the end of the simulation period 30 minutes later. Total vehicle-hours of travel and delay per vehicle data show comparable or better results under the dynamic preemption method when compared to intersection-by-intersection signal preemption, even while the emergency vehicle itself realizes a significant travel-time reduction.

**Project URL:** [www.its.umn.edu/research/projects/2002033.html](http://www.its.umn.edu/research/projects/2002033.html)

#### **Dynamic Estimation of Freeway Weaving Capacity for Traffic Management and Operations (Phase II)**

Status: **Completed (in FY04)**

Understanding the behavior of weaving flows and estimating the effects of time-variant traffic conditions on the capacity of weaving areas is critical for developing effective operational and design strategies for freeway systems that can maximize existing capacity for a given freeway system. The previous phase of this research identified and classified the major weaving areas in the Twin Cities metro freeway network. Further, the traffic behavior and the factors affecting capacity in a type A ramp-weave section—the most common type of weaving area in the Twin Cities metro freeway system—were analyzed and an online model was developed to estimate the time-variant capacity of type A ramp-weave sections.

This research expanded on the

previous work by addressing the traffic behavior and capacity issues at multiple weaving areas, where more than two weaving sections are sequentially located. In particular, the flow process at multiple weaving sections, including lane-changing locations and behavioral patterns and the factors affecting flow breakdowns and capacity changes, was analyzed using field data collected from the selected weaving areas. Finally, the functional relationship between capacity changes and weaving patterns was identified and modeled.

**Project URL:** [www.its.umn.edu/research/projects/2001022.html](http://www.its.umn.edu/research/projects/2001022.html)

#### **David Levinson, Department of Civil Engineering and Kathleen Harder, College of Architecture and Landscape Architecture Ramp Meter Delays, Freeway Congestion, and Driver Acceptance**

Status: **In progress**

Minnesota’s pre-shutdown ramp metering algorithms tried to maximize throughput, implicitly minimizing total delay. If time at the ramp is not weighted the same as time in motion by users, this time-minimizing strategy may not maximize utility for travelers. This research attempts to quantify the value individuals associate with qualitatively different experiences of travel time: waiting at a



ramp meter or freeway-to-freeway ramp meter versus traveling at varying freeway speeds requiring shifts in acceleration and deceleration. This information will enable the researchers to better time ramp meters in a way that responds to individual perceptions.

**Project URL:** [www.its.umn.edu/research/projects/2002018.html](http://www.its.umn.edu/research/projects/2002018.html)

#### **David Levinson, Department of Civil Engineering Improving the Estimation of Travel Demand for Traffic Simulation**

Status: **In progress**

Many current traffic management schemes are tested and implemented using traffic simulation. An Origin-Destination (OD) matrix is an ideal input for such simulations. The underlying travel demand pattern produces observed link counts, and these counts could be used to reconstruct the OD matrix. This research developed an offline approach for estimating a static OD matrix over the peak period for freeway sections using these counts.

Almost all existing offline methods use linear models to approximate the relationship between the on-ramp and off-ramp counts. Previous work indicates that the use of a traffic flow model embedded in a search routine performs better than these linear models. In this research, that approach is enhanced using a microscopic traffic simulator, AIMSUN, and a gradient-based optimization routine, MINOS, interfaced to estimate an OD matrix. The problem is highly non-linear and non-smooth, and the optimization routine finds multiple local minima but cannot guarantee a global minima. However, with a number of starting “seed” matrices, an OD matrix with a good fit in terms of reproducing traffic counts can be estimated. The dominance of the mainline counts in the

OD estimation and an identifiability issue is indicated from the experiments. The quality of the estimates improves as the specification error, introduced due to the discrepancy between AIMSUN and the real-world process that generates the on-ramp and off-ramp counts, decreases.

**Project URL:** [www.its.umn.edu/research/projects/2001034.html](http://www.its.umn.edu/research/projects/2001034.html)

#### **The Value of Traveler Information for Motorists**

Status: **In progress**

A major strategy of federal ITS initiatives and state departments of transportation is to provide traveler information to motorists. This is relatively uncontroversial, but its effectiveness is unknown.

Traveler information can save travelers time if they choose alternative routes based on the information they receive. However, there are other benefits to drivers. For example, simply knowing of a delay of a certain duration will reduce driver uncertainty. The economic value of information that reduces driver uncertainty is one of several variables the researchers aim to measure in this research. They will assess user preferences for trips as a function of the presence and accuracy of information, travel time, number of stops, stopped delay, specific route, time of day, traffic conditions, individual and vehicle characteristics, and weather. In this way, the researchers can specify and estimate a more sophisticated route choice model accounting for those characteristics.

To date, most route choice models embedded in transportation planning models simply assume that travelers choose the shortest (time) route. This research will ascertain the extent of this misspecification.

**Project URL:** [www.its.umn.edu/research/projects/2004021.html](http://www.its.umn.edu/research/projects/2004021.html)



**Panos Michalopoulos,**  
*Department of Civil Engineering*  
**Development of a Portable Wireless Measurement and Observation Station**  
 Status: **In progress**

In spite of progress made in ITS technology over the past decade, road instrumentation for data collection purposes continues to be somewhat inadequate. Furthermore, the majority of data-collection devices depend on outdated technologies to take very limited measurements, such as volume and occupancy. This was recently experienced in a study for evaluating ramp metering in which even actual ramp demands had to be measured manually. Because of the extent of the roadway system, however, it is impossible to deploy sufficient instrumentation for all planning, traffic, and research needs. For this reason, there is a need for developing and testing an easily deployable, low-cost data collection and surveillance station that can be used for measuring detailed traffic data such as individual speeds, density, and other factors.

This project continues the work of John Hourdakos and Ted Morris in the ITS Laboratory, in which a prototype of such a station was developed, and tests it. Such an easily deployable, low-cost data collection and surveillance station could be used for planning and traffic management as well as for research purposes, such as simulation,



modeling, and control. This “total” station capitalizes on recent advances in machine vision traffic sensors, digital video compression and transmission, and wireless communication networks. In essence, it is the first step toward the development of a highway laboratory for traffic studies and research.

**Project URL:** [www.its.umn.edu/research/projects/2002030.html](http://www.its.umn.edu/research/projects/2002030.html)

**Evaluation and Improvement of the Stratified Ramp Metering Algorithm Through Microscopic Simulation**  
 Status: **In progress**

This research is in response to a request for low-cost innovative solutions for evaluating and improving the current and future ramp-metering strategies in the Twin Cities. This is a continuation of a recently concluded project in which the previous Mn/DOT ramp control algorithm was successfully evaluated for two Twin Cities freeways. In this previous project, it was demonstrated that evaluation results through simulation are similar if not superior in content and accuracy to the ones reached by before-and-after studies.

This project goes beyond evaluation and seeks to find a methodology for optimizing the new ramp-metering algorithm quickly and efficiently prior to field deployment. In the first year, the new stratified metering algorithm will be evaluated and compared with the old algorithm, a simple control plan (i.e., fixed-time metering), as well as with a no-control case. Detailed statistics will evaluate all aspects of the new algorithm’s operation including queue formation and bottleneck operation, as well as long and short trip travel times. In addition, a sensitivity analysis will be conducted in order to understand the behavior of the new control algorithm with respect to changes in traffic

demand, occurrence of traffic incidents, detector malfunctions, inclement weather conditions, and changes in the algorithm’s own parameters. If successful, further plans include expansion of the sensitivity analysis to include the impacts of traveler information on the control strategy. Based on the knowledge acquired through the sensitivity analysis, fine-tuning of the algorithm parameters will take place through both manual search and optimization methods. Finally, researchers will explore improvements to the algorithm structure in order to better take into account queue and other traffic pattern measurements.

**Project URL:** [www.its.umn.edu/research/projects/2004050.html](http://www.its.umn.edu/research/projects/2004050.html)

**Streamlining of the Traffic Modeling Process for Implementation in the Twin Cities Freeway Network**  
 Status: **In progress**

This research will attempt to streamline the traffic modeling process for practical implementation and to substantially improve Mn/DOT engineers’ productivity in view of the new federal requirements for roadway improvements, design, and planning. Streamlining will also improve decision making and allow more widespread use of simulation internally for design, planning, operations, maintenance, and construction.

The key element in improving traffic operations and infrastructure is the ability to assess the effectiveness of various alternatives prior to implementation. Simulation methods have long been recognized as the most effective tool for such analysis, and various simulators have been developed by different agencies for analyzing freeway and/or arterial networks.

Although a great deal of effort has gone toward making simulation suitable

for practical applications, engineers still regard it as a complex tool. In the previous phase of the proposed project, a number of rudimentary and crude tools for accelerating the simulation process were developed for improving the research team’s effectiveness and productivity to meet tight deadlines. Subsequently, the technology was transferred to Mn/DOT through a series of training courses and continued technical assistance. During this collaboration, it became evident that in order for simulation to be effectively employed by Mn/DOT, more substantial automation and streamlining of the simulation process are needed for non-research-oriented engineers. As a result, the continuation phase aims to further improve the earlier simulation tools and methodologies and, in cooperation with Mn/DOT’s modeling group, streamline the process to specifically address the needs and issues raised by practicing engineers within Mn/DOT and the research team. Special effort will be made to ensure that the methodologies developed are general—i.e., not tied to a particular simulation package.

**Project URL:** [www.its.umn.edu/research/projects/2004049.html](http://www.its.umn.edu/research/projects/2004049.html)

**Development of Real-Time Traffic Adaptive Accident-Reduction Measures for the I-94/35W Commons Section**  
 Status: **Newly funded**

According to Mn/DOT statistics, the westbound section of I-94 at the 94/35W commons south of downtown Minneapolis is the location of more crashes than any other location in the Twin Cities. In an ongoing project related to crash prevention and the detection of crash-prone conditions, this location was heavily instrumented, and data were collected and analyzed. Between



September 2002 and October 2003 more than 150 crashes occurred on this stretch of highway (95 of them captured on video), ranging from simple rear-end collisions to multi-vehicle crashes with injuries. In addition, 215 near misses have also been recorded at the same location. These data show that crashes occur under certain traffic conditions that can be detected prior to a crash occurring.

This project will capitalize on the results by using techniques for early detection of crash-prone conditions to develop a traffic calming/driver warning system for reducing crashes. The system will be specifically tuned for maximum effectiveness on the aforementioned I-94 section. The goal of this first phase will be to design, evaluate, refine, and finalize such a system. In the next phase, researchers will estimate cost and time requirements and recommend necessary steps for field deployment and evaluation.  
**Project URL:** [www.its.umn.edu/research/projects/P2005071.html](http://www.its.umn.edu/research/projects/P2005071.html)

**Employment of Traffic Management Laboratory for the Evaluation and Improvement of Stratified Metering Algorithm: Phase III**  
 Status: **Newly funded**

This project is in response to a Mn/DOT request for a robust and computationally

feasible solution for enhancing and improving its new stratified ramp control strategy. The research is a continuation of the ongoing project related to testing and evaluating the effectiveness of this strategy through rigorous microscopic simulation. As suggested from a one-year field operation and a recently concluded preliminary assessment, this strategy is generally effective in achieving a balance between freeway performance and ramp delays. However, the strategy can be further improved to address some inherent limitations and enhance its performance.

This research will enhance the strategy by providing more reliable ramp demand prediction, improving the trade-offs between freeway performance and ramp delays, and developing a more accurate and computationally feasible on-line ramp-queue size estimator. In addition, a methodology for determining location-dependent bottleneck capacity will be established to make the strategy more adaptive to freeway geometric characteristics. All the enhancements and improvements to the stratified ramp control strategy will be computationally feasible, and their effectiveness will be assessed by comparison with the current prototype version using microscopic simulation. Finally, the sensitivity analysis of the stratified ramp control strategy commenced in the current phase will be continued to cover adverse weather conditions based on the measurements being collected.

**Project URL:** [www.its.umn.edu/research/projects/P2005070.html](http://www.its.umn.edu/research/projects/P2005070.html)

## SOCIAL AND ECONOMIC POLICY ISSUES RELATED TO ITS TECHNOLOGIES

**Frank Douma, Humphrey Institute of Public Affairs**

**Telecommunications and Sustainable Transportation**

Status: **Completed (in FY04)**

The Minnesota Department of Transportation (Mn/DOT) has taken a leading role in developing ITS technologies aimed at improving the state's transportation system and has committed to making that system safer as well as more multimodal. Telecommunications technologies, both wireless and wireline, are key components to a number of ITS applications and technology bundles. In particular, global positioning systems (GPS) and telework have the potential to significantly impact transportation operations and travel behavior.

This project attempted to assess these potential impacts by investigating the changes in travel behavior resulting from use of broadband telecommunications at the household level, as well as opportunities for improving operations by applying wireless telecommunications technologies to suburban transit and to rural emergency services.

The first task examined travel behavior and telework changes that may arise from installation of high-speed telecommunications technology directly to homes. To perform this assessment, time-use diaries developed in a previous project were modified for use and administered in both urban and suburban residential settings. Results were compared with travel data from other parts of the Twin Cities metro area to determine if travel behavior benefits could be gained.

The second task assessed operational benefits that might be gained by

deploying GPS-based ITS applications in suburban areas among populations that do not have cars available as a primary mode of transportation. Focus groups of community members, users, and providers were used to determine preferences and political barriers, and data from an operational deployment was used to assess effectiveness.

The third task built upon information gained from focus groups held in Rochester and Virginia, Minnesota, in August 2001. Using this information as a starting point, researchers examined the institutional and technical network requirements to deliver wireless services that enhance transportation safety.

The fourth task involved a series of educational and outreach activities related to work in the preceding three tasks, such as work reviews, seminars, and presentations at University and community forums, led by Humphrey Institute faculty.

**Project URL:** [www.its.umn.edu/research/projects/2002016.html](http://www.its.umn.edu/research/projects/2002016.html)

**Kevin Krizek, Humphrey Institute of Public Affairs**

**Understanding the Potential Market of Metro Transit's Ridership and Services**

Status: **In progress**

This research aims to better understand the potential market of transit riders in the Twin Cities metropolitan area, riders' preferences for travel, and how transit and transit services could be adapted to better meet rider needs. The primary source of information includes Metro Transit surveys of non-riders and current riders in concert with existing Metro Commuter Services data from the Metropolitan Council on carpooling and vanpooling preferences.

These data sources represent extremely rich surveys that could shed light on basic travel preferences that transit could better serve. The focus is to examine more closely the attitudes, preferences, and needs of both current and potential riders. The range of improvements possibly includes using technology to better track ridership behavior, modifying a frequent rider program, adjusting routes and times, and understanding and delineating different market segments of travelers. The analysis and findings of the research will be pursued jointly with staff from Metro Transit and the Met Council to enhance their utility to each agency. The study will also provide recommendations on more specific data that could be collected to provide baseline information to help monitor existing and future programs and traveler information.

**Project URL:** [www.its.umn.edu/research/projects/P2004035.html](http://www.its.umn.edu/research/projects/P2004035.html)

**Lee Munnich, Humphrey Institute of Public Affairs**  
**Sustainable Technologies Applied Research Initiative FY03**

Status: **Completed (in FY04)**

The Sustainable Technologies Applied Research Initiative (STAR) project is investigating the intersection of various networks—including ITS-infused transportation networks—and how they interact with physical places, as well as the changes that are occurring among and between networks and the dimensions (e.g., access, activity) that concern the STAR researchers. As of July 2003, research activities in the five topic/task areas have included the following:

### Spatial Impacts (Task 1)

Researchers have completed the first phase of a study of the spatial location of information workers in four metropolitan areas—Atlanta, Denver, Phoenix, and

Minneapolis-St. Paul. Working with 1990 data from the Census Transportation Planning Package (CTPP), the study found that the workplace locations of information workers were more spatially concentrated than other workers in all four metropolitan areas. Generally, their workplace locations tended to be focused on traditional central business districts and university centers, with mixed results in “edge city” centers. The residential locations of information workers were also more concentrated in three of the four areas, but the difference tended to be less significant. Preliminary analysis of commuting effort indicates that information workers tend to spend more time commuting than other workers. The study will ultimately include an analysis of the 1990 CTPP data with that of the 2000 CTPP.

Researchers have completed revisions to the case study of the use of telecommunications in the food processing industry reported on previously, with no new findings. Researchers began the study of the diffusion processes and network externalities of telecommunications innovations and continued the study of industry clusters and product life-cycle influences on activity location.

**Modeling of Wireless Rural EMS Performance (Task 2): Tom Horan**  
Researchers completed the ontology



development of version 1 of the emergency management systems (EMS) ontology, using Protégé software. This effort was summarized in a research-in-progress paper submitted to the Association for Information Systems Americas Conference. Researchers planned and conducted a second case study, which included interviews with Mn/DOT experts, State Patrol members, and Public Service Answering Points (PSAP) representatives.

#### **Industry Clusters (Task 3)**

Researchers conducted personal interviews in northern Minnesota with companies in the recreational transportation equipment and wood products industry clusters. These companies provided key information regarding the use and needs of ITS technologies as well as how these technologies affect supply and production relationships within the clusters.

#### **Networks and Productivity (Task 4)**

Researchers worked on enhancing the new node/link model by adding an equilibrium assignment and congestion effects. Researchers have also developed some qualitative evidence on network expansion decisions.

#### **Roundtable Discussion (Task 5)**

Researchers have begun planning to invite past and current SLPP graduate research assistants for a day of discussion around the topic of the “new transportation professional” and training needs as they relate to ITS. STAR researchers will also take an active role in organizing and participating in professional workshops and conferences related to the research themes noted above.

**Project URL:** [www.its.umn.edu/research/projects/2003012.html](http://www.its.umn.edu/research/projects/2003012.html)

#### **Sustainable Technologies Applied Research Initiative FY04**

##### **Status: In progress**

The STAR project is investigating the intersection of various networks—including ITS-infused transportation networks—and how they interact with physical places, as well as the changes that are occurring among and between networks and the dimensions (e.g., access, activity) that concern the STAR researchers. Year three activities have led to the following focus areas for Year Four.

#### **Spatial Impacts (Task 1)**

Researchers will complete their report on the General Mills case study; complete Labor Demand Modeling; Location Patterns of Information Workers; develop and test their externalities/diffusion model; continue development of the location demand model; and launch, collect, analyze, and report on a study of how different elements of information and communication technology affect household travel behavior.

#### **Modeling of Wireless Rural EMS Performance (Task 2)**

Researchers will use the knowledge acquisition system to model and assess emergency management systems (EMS) performance. Once the model has been specified, a companion performance specification simulation will be conducted. Researchers will also explore the implications of this approach for the broader assessment of ITS systems.



#### **Industry Clusters (Task 3)**

The researchers will use existing quantitative techniques to identify and compare new industry data with past industry data to understand how Minnesota industry clusters have changed, and how those changes may have affected ITS use. They will also analyze the data for changes in cluster size and distribution over time and conduct roundtable discussions to enhance the quantitative information.

#### **Networks and Productivity (Task 4)**

Researchers will study and optimize existing codes, formulate the new-node/link model, code the new model, run the model on a sample network and debug codes, integrate the model with the link expansion model, collect Twin Cities network data, and calibrate the integrated model for the Twin Cities.

#### **Roundtable Discussion: May 2004 (Task 5)**

The researchers will develop a white paper on applications of technology-related impacts (and data) for local and rural planners as well as transportation managers. They will also organize roundtable discussions, conference presentations, and invited speakers and conduct outreach to local and national decision makers and educators.

**Project URL:** [www.its.umn.edu/research/projects/2004099.html](http://www.its.umn.edu/research/projects/2004099.html)

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Vithaladevuni, P., and Alouini, M.S. (2003). An upper bound on the VER of block coded hierarchical constellations. *Proceedings of the PACRIM 2003 Conference*.

Vithaladevuni, P., and Alouini, M.S. (2003). A tight upper bound on the BER of linear systematic block codes. *IEEE Communication Letters*, vol. 8, no. 5.

Wahlstrom, E., Masoud, O., and Papanikolopoulos, N. (2003). Vision-based methods for driver monitoring. *Proceedings of the IEEE Sixth International Conference on Intelligent Transportation Systems*.

Wahlstrom, E., Masoud, O., and Papanikolopoulos, N. (2003). Vision-based methods for driver monitoring. *Proceedings of the International Thermal Spray Conference and Exposition*.

Wang, J., and Rajamani, R. (2004). The impact of ACC systems on highway safety and traffic flow. *Journal of Automobile Engineering, Proceedings of the Institution of Mechanical Engineers, Part D*, vol. 218: 211–230.

Ward, N. J., Gorgestani, A., Shankwitz, C., and Donath, M. (in press). A preliminary demonstration study of the usability of a vision enhancement system for state patrol vehicles. *ITS Journal*.

Ward, N., Manser, M., de Waard, D., Kuge, N., and Boer, E. (2003). Quantifying car following performance as a metric for primary and secondary (distraction) task load: part A, modification of task parameters. *Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting*.



Ward, N.J., Shankwitz, C., Gorgestani, A., Donath, M., de Waard, D., and Boer, E. (in press). Bus rapid transit and bus driver stress. *Ergonomics*.

#### Craig Shankwitz

Xiao, H., Ambadipudi,

S., and Michalopoulos, P. (2004). Evaluation of freeway improvements through state of the practice simulators. *Proceedings of the ITS America 2004 Annual Meeting*.

Xin, W., Michalopoulos, P., Hourdakakis, J., and Lau, D. (2004). Minnesota's new ramp control strategy: design overview and preliminary assessment. *Transportation Research Record: Journal of the Transportation Research Board*.

Yang, J.S. (2004). Special events traffic signal timing control via a SPSA optimization algorithm—a case study. *Proceedings of the 83rd Annual Meeting of the Transportation Research Board*.



#### Jiann-Shiou Yang and Rocio Alba-Flores

Yang, J.S. (in press). Traffic flow model validation and simulation. *Journal of the Franklin Institute*.

Yang, J.S. (2004). Traffic flow model validation and simulation: an experimental study. *Proceedings of the 2004 IEEE International Symposium on Intelligent Control*.

Yang, J.S. (2004). Traffic signal timing control for small-scale road network. *Proceedings of the IASTED International Conference on Control and Applications*.

Yang, J.S. (in press). Traffic timing control via a neural network-based simultaneous perturbation stochastic approximation approach. *International Journal of Control and Intelligent Systems*.

Yang, J.S. (in press). Traffic timing control via a neural network-based simultaneous perturbation stochastic approximation approach. *Proceedings of the 2004 IEEE International Symposium on Intelligent Control*.

Zanko, L., and Hopstock, D. (2003). Minnesota taconite as microwave-absorbing road aggregate material for deicing and pothole patching applications. *Proceedings of NATSRL Research Day, Mn/DOT District 1*.

Zhang, L., and Levinson, D. (in press). An agent-based approach to travel demand modeling. *Transportation Research Record: Journal of the Transportation Research Board*.

## SELECTED PRESENTATIONS

Alouini, M.S. (2004, May). Adaptive multimedia transmission over wireless links. CTS 15th Annual Transportation Research Conference, St. Paul, Minnesota.

Alouini, M.S. (2003, November). Bandwidth and power efficient modulations for multimedia transmission over wireless links. ITS Institute Advanced Transportation Technologies Seminar Series, University of Minnesota, Minneapolis.

Arumugan, H., Veeraraghavan, H., Atev, S., Masoud, O., Janardan, R., and Papanikolopoulos, N. (2003, December). Real-time collision warning and avoidance at intersections. Project Panel, Minneapolis.

Bloomfield, J.R. (2003, September). Predicting waiting times for appropriate gaps in traffic on divided highways. Vision In Vehicles X, Granada, Spain.



#### Kathleen Harder

Bloomfield, J.R., Harder, K.A., and Chihak, B.J. (2003, September). Stopping behavior. Vision In Vehicles X, Granada, Spain.

Davis, G., and Pei, J. (2004, January). Applying Bayesian methods to the

clinical investigation of speed as a cause of road accidents. 83rd Annual Meeting of the Transportation Research Board, Washington, D.C.

Davis, G. (2003, June). Bayesian networks and traffic accident reconstruction. Ninth International Conference on Artificial Intelligence and Law, Edinburgh, United Kingdom.

Davis, G. (2003, September). Causal determination in road accidents: an application of the Halpern/Pearl notion of actual cause. Second Workshop on the Investigation and Reporting of Incidents and Accidents, Williamsburg, Virginia.

Davis, G. (2003, June). Eliminative induction, Bayesian inference and road accidents. Second Joseph Bell Centre Workshop on the Evaluation of Evidence, Edinburgh, United Kingdom.

Davis, G., and Swenson, T. (2004, January). A field study of gap acceptance by left-turning drivers. 83rd Annual Meeting of the Transportation Research Board, Washington, D.C.

Davis, G. (2004, January). What do we really want to know and how can we find this out? 83rd Annual Meeting of the Transportation Research Board, Washington, D.C.

Digham, F.F., and Alouini, M.S. (2004, June). Selective diversity with discrete power loading over Rayleigh fading channels. IEEE International Conference on Communications, Paris, France.

Donath, M. (2004, June). Emerging technologies. Mn/DOT Metro District Management Team Meeting, St. Paul, Minnesota.

Donath, M. (2004, February). Transportation technologies. Senate Transportation Committee, St. Paul, Minnesota.

Douma, F. (2004, May). Evaluation of GPS technology as used in services-on-demand public transit. CTS 15th Annual Transportation Research Conference, St. Paul, Minnesota.

Douma, F. (2004, May). Information & communication technology (ICT) and travel in the Twin Cities metropolitan area. CTS 15th Annual Transportation Research Conference, St. Paul, Minnesota.

Douma, F., and Hedblom, M. (2004, April). ITS opportunities resulting from developments in home broadband telecommunications. ITS America 2004 Annual Meeting, San Antonio.

Douma, F., and Krizek, K. (2004, May). ITS opportunities resulting from developments in home broadband telecommunications. CTS 15th Annual Transportation Research Conference, St. Paul, Minnesota.

Douma, F., and Duncan, C. (2004, May). Transportation alternatives for diverse populations. CTS 15th Annual Transportation Research Conference, St. Paul, Minnesota.

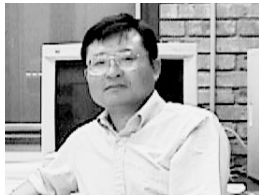
Douma, F., Wells, K., Horan, T., and Krizek, K. (2004, January). ICT and travel in the Twin Cities metropolitan area. 83rd Annual Meeting of the Transportation Research Board, Washington, D.C.

Harder, K.A. (2003, December). The effectiveness and safety of traffic and non-traffic-related messages presented on changeable message signs (CMS). ITS Institute Advanced Transportation Technologies Seminar Series, University of Minnesota, Minneapolis.

Harder, K.A. (2004, March). The effectiveness and safety of traffic and non-traffic-related messages presented on changeable message signs (CMS). ITS Minnesota Annual Meeting, Minneapolis.

Harder, K.A. (2004, March). Psychological and roadway correlates of aggressive driving. Lifesavers 2004, San Diego.

Hossain, M.J., Alouini, M.S., and Bhargava, V. (2004, June). Hierarchical constellation for multi-resolution data. IEEE International Conference on Communications, Paris, France.



Kwon, T. (2004, March). Rural ground transportation: what are the issues? James L. Oberstar Forum on Transportation Technology and Policy, Duluth, Minnesota.

**Taek Kwon**

Levinson, D. (2003, November). The rise and fall of roads. 50th North American Regional Science Council Annual Meeting, Philadelphia.

Levinson, D. (2003, November). The rise and fall of roads. American Conference on Information Systems, Tampa, Florida.

Levinson, D., Harder, K.A., Bloomfield, J.R., and Winiarczyk, K. (2003, August). Weighting waiting: evaluating the perception of in-vehicle travel time under moving and stopped conditions. 2003 International Association for Travel Behaviour Research, Lucerne, Switzerland.

Munnich, L. (2003, September). Intelligent transportation systems and industry clusters. ITS Institute Advanced Transportation Technologies Seminar Series, University of Minnesota, Minneapolis.

Shankwitz, C. (2003, September). Intelligent vehicle lab technology. AASHTO Annual Meeting, Minneapolis.

Vitthaladevuni, P.K., and Alouini, M.S. (2004, March). Exact VER computation for cross QAM constellations. Conference on Information Sciences and Systems, Princeton, New Jersey.

Yerra, B., and Levinson, D. (2004, February). The emergence of hierarchy in transportation networks: how networks grow. Western Regional Science Association Conference, Rico Rico, Arizona.



**Lei Zhang and David Levinson**

Zhang, L., and Levinson, D. (2004, January). An agent-based travel demand model. 83rd Annual Meeting of the Transportation Research Board, Washington, D.C.

Zhang, L., and Levinson, D. (2004, February). An agent-based travel demand model. 46th Western Regional Science Association Annual Meeting, Maui, Hawaii.

Zhang, L., and Levinson, D. (2004, March). A model of the rise and fall of roads. MIT Engineering Systems Symposium, Cambridge, Massachusetts.

## EDUCATION

The Institute's activities in education encompass a multidisciplinary program of coursework and experiential learning that reinforces the Institute's theme. The educational program includes the disciplines of computer science and engineering, electrical and computer engineering, civil engineering, mechanical engineering, human factors, public policy, and others.

By sponsoring and supporting varied educational initiatives for students, the Institute is generating interest in its core ITS science and technologies. These initiatives include developing new curriculum and courses, involving undergraduate and graduate students in research projects, sponsoring students to attend national conferences, presenting awards that recognize outstanding students, and offering research assistantships to help attract more students to the study of transportation. This section of the annual report highlights some of our efforts in the area of education.



*Kathleen Harder discussed the use of changeable message signs at an Institute-sponsored seminar.*

### Transportation seminars showcase ITS research

During the 2003–2004 academic year, the Institute continued its multidisciplinary seminar series at the University. These Advanced Transportation Technologies Seminars included presentations by local and national researchers addressing diverse areas of ITS research, such as traffic management and modeling, human factors, sensing, intelligent vehicles, and social and economic policy issues as they relate to road- and transit-based transportation.

The seminars provide a way for students to learn about ITS

technologies in areas outside their current field of study, for researchers to learn about other projects in progress, and for practitioners to learn about the technologies of the future.

The seminar series is available as a one-credit graduate-level course, or attendees can earn one professional development hour for each seminar. The series is also a required course in the Graduate Certificate Program in Transportation Studies at the University of Minnesota. Seminars are videotaped and available for loan by request; one presentation was also Web-streamed on the Internet.

The past year's presentations were:

- "Evaluating GPS for Assessing Road User Charges." Pi-Ming Cheng, Mechanical Engineering
- "ITS and Industry Clusters." Lee Munnich, Humphrey Institute of Public Affairs
- "The Origins, Status, and Future of GPS." Bradford Parkinson, Professor Emeritus, Department of Aeronautics and Astronautics, Stanford University
- "Inductive Loop Detector Signal Analysis." Stan Burns, UMD Electrical and Computer Engineering
- "Integrated Multi-Sensor Navigation Systems." Demoz Gebre-Egziabher, Aerospace Engineering and Mechanics
- "Adaptive Modulation for Bandwidth- and Power-Efficient Transmission Over Wireless Links." Mohamed-Slim Alouini, Electrical Engineering and Computer Science
- "The Effectiveness and Safety of Traffic- and Non-Traffic-Related Messages Presented on Changeable Message Signs." Kathleen Harder, College of Architecture and Landscape Architecture

### Career Expo reaches new heights

This past March, the Institute partnered once again with CTS, the Minnesota Local Road Research Board, the Minnesota Local Technical Assistance Program, and the Women's Transportation Seminar to hold the annual Transportation Career Expo on the





*Students and prospective employers met during the annual Career Expo.*

campus of the University of Minnesota.

Although the 100-plus students gathered came from a variety of departments and disciplines, they arrived with the same goal in mind: finding a job. The Transportation Career Expo gave students an opportunity to ask questions, receive seasoned advice, obtain feedback on their resumes, and network with employers. In its eighth year, this expo was the most successful to date, with 12 schools represented from three states, 22 exhibiting employers, and more students in more majors than ever before.

The event offered a general session on career preparation and four concurrent sessions on specific areas of transportation: engineering/technical careers, transportation planning and policy careers, transportation logistics careers, and careers in intelligent transportation systems. Students also met and networked with representatives from companies involved in the transportation field during the final part of the event.

## **Sanderson receives Student of the Year award**

Katherine (Kate) Sanderson, a graduate student enrolled in the University of Minnesota's Civil Engineering Ph.D. program, received the ITS Institute's 2003 Outstanding Student of the Year Award.

Sanderson has served the University and the transportation community in several ways, including as a teaching assistant in several transportation and traffic engineering courses. Dr. Gary Davis, a professor in the Civil Engineering Department who has worked closely with Sanderson, describes her as a "can-do" person and a natural leader. Sanderson has demonstrated leadership abilities as vice-president of the North Central Section of the Institute of Transportation Engineers student chapter, as president of the Minnesota chapter of Women's Transportation Seminar, and by spearheading efforts to create the Interdisciplinary Transportation Student Organization (ITSO), now a valued networking group for students interested in transportation.

Sanderson has also been involved in a variety of research efforts at the University. Her thesis research attracted attention for her findings on the extent of highway expansion needed to accommodate future travel demand and was featured on local television news and in a newspaper editorial.

Sanderson received the award in January at the Transportation Research Board 83rd Annual Meeting in Washington, D.C. "I am honored that the ITS Institute, an organization with such a range of activities and talent, gave me the opportunity to travel to Washington, D.C., and enabled me to attend the TRB conference," she says. "The conference is a huge event on the transportation calendar, and a great place to meet people with similar interests and learn from the technical sessions and posters."

Sanderson is currently working as a transportation engineer at URS Consultants in Minneapolis. Previously, she received her bachelor of engineering from the University of Sydney, Australia, and her master's of science at the University of Minnesota.



*ITS Institute director Max Donath, Kate Sanderson, and Gary Davis at the Student of the Year reception in Washington, D.C.*

## Institute sponsorships help students attend national conferences

The Institute grants travel awards to students so they can attend various conferences and report on their research to a larger audience, attend research sessions, and help staff the Institute display. This past year, the Institute sponsored 22 students to attend the national meeting of the Transportation Research Board (TRB) in January and ITS America in April.

Students attending TRB were Steven Altstad, Nicholas Andrisevic, Adinarayana Beegala, Wei Chen, Chandler Duncan, Vishnu Garg, Olivier Hoffmann, Xue Li, Yi Li, Ning Li, Justin Ocel, Jonathan Osmond, Jianping Pei, Shipeng Sun, Qiang Wang, Wuping Xin, Lei Zhang, and Ewa Zofka. Students who attended ITS America were Adinarayana Beegala, Pete Bernardy, Deodatta Bhoite, Wenling Chen, Lei Zhang, and Xi Zou.

“Attending the TRB meeting was very useful for my research, career, and job hunting,” says student Vishnu Garg, who is planning a career as a transportation engineer. Expressing appreciation for the opportunity to travel to TRB, Garg says he learned a good deal from the sessions and from networking, “which is very important for one’s career,” he says.

## Institute offers summer education events for high school students

In July, the ITS Institute partnered for the fourth year with the Fond du Lac Tribal and Community College to host the National Summer Transportation Institute, a program that emphasizes outreach to students from Minnesota’s Native American communities.

The Summer Transportation Institute brought 15 students from several high schools in the Duluth area to the Twin Cities to learn about ITS-related research and technologies. The day



Students Lei Zhang, Deodatta Bhoite, and Adinarayana Beegala help staff the ITS Institute display, part of the Minnesota Guidestar exhibit, at ITS America’s annual meeting.



ITS Lab manager Ted Morris, center, gives a tour to high school students attending a University summer science and engineering program.

included a presentation on the topic of ITS, discussion with Institute staff about careers in transportation, and tours of the Minnesota Department of Transportation’s Regional Transportation Management Center and TAXI2000, a personal rapid transport development company.

The Institute also hosted 20 students from the University of Minnesota’s Summer Explorations in Science, Engineering, and Mathematics (SESEM) Program. The group was introduced to the topic of ITS and given a tour of the ITS Laboratory, where they learned about the lab’s facilities and current research at the Institute, including computer simulations and traffic control strategies.

By introducing high school students to advanced transportation research projects funded by the UTC program, the Institute hopes to encourage students to choose transportation- and technology-related educational fields when they enter college.

## Development continues on Web modules for students

Mark Tollefson, a local high school science teacher and the K-12 coordinator for the ITS Institute, continues to develop curriculum materials on ITS topics. Previously, he had developed a ramp metering Web module that gave high school students the opportunity to investigate ramp metering and its impact on travel. A CD-ROM containing the module and a poster explaining ITS were distributed to 160 high schools throughout Minnesota.

A Web module on Global Positioning Systems (GPS) has been completed and will also be distributed to area schools in the fall of 2004. Along with listing various Web sites about GPS, the curriculum includes quizzes that check students' learning progress. Tollefson is currently working on a new module on the topic of human factors.

Reaching students early with fun, hands-on activities is one way the Institute hopes to interest them in a career in transportation.

The ramp meter module can be accessed at [www.its.umn.edu/education/rampmodule/index.html](http://www.its.umn.edu/education/rampmodule/index.html), and the GPS module at [www.its.umn.edu/education/gps/INDEX.HTML](http://www.its.umn.edu/education/gps/INDEX.HTML).

## Interactive simulations enhance ITS education and outreach

ITS Laboratory senior systems engineer Chen-Fu Liao continues to work on tools that will give researchers, students, and eventually the public access to advanced computer-generated traffic simulation systems.

In addition to previous work creating simulation-based modules for courses, Liao developed a Web-based 2-D traffic simulation module for a transportation engineering course for use during fall semester of 2003. The module focuses on intersection timing analysis and optimization with different traffic demands and control strategies.

Liao is also working on an ambitious project to develop a virtual reality traffic simulation environment for use over the Web. The new module will be targeted at undergraduate and high school students, traffic engineers, and distance-learning students at the University.

In the future, Liao plans to continue supporting simulation modules used in various engineering courses and to develop new lab modules focused on different ITS technologies, such as advanced traffic signal controllers and Global Positioning Systems.

## Doctoral student awarded dissertation fellowship

A graduate student advised by Institute researcher Mohamed-Slim Alouini received a Doctoral Dissertation Fellowship (DDF) for the 2003–2004 academic year. Pavan Kumar Vitthaladevuni, a doctoral candidate in the Department of Electrical Engineering, assisted professor Alouini on the Institute-funded project, “Bandwidth and Power-Efficient Modulations for Multimedia Transmission Over Wireless Links.”

The purpose of the DDF program is to give outstanding final-year Ph.D. candidates who are making timely progress toward the degree an opportunity to complete the dissertation within the upcoming academic year by devoting full-time effort to the research and writing of the dissertation.

Vitthaladevuni says he was glad to have received the prestigious fellowship. “I was sure it would make my job search easier after graduation, and it did.” The fellowship allowed him to spend his last year at the University concentrating on the final problem he was solving and on writing his dissertation, titled, “Generalized Hierarchical Constellations: Design, Performance and Applications.” Vitthaladevuni has recently accepted a job with Texas Instruments to work with wireless local-area network design and implementation.



*Pavan Kumar Vitthaladevuni and Mohamed-Slim Alouini*

## TECHNOLOGY TRANSFER

The Institute could not accomplish its goals without the transfer of its expertise and research results to local, national, and international audiences for use in real-world applications. Technology transfer also communicates to the world who we are, raising the profile of the Institute and its research, and serves to educate students, policymakers, and the general public about ITS issues and solutions.

Our efforts in this area are far-ranging in order to reach a broad and diverse audience of researchers, students, practitioners, policymakers, and others among the general public. Over the past year, we have provided tours and demonstrations of our research and facilities, sponsored seminars, published



*Top: The head-up display  
Right: Near Thompson Pass*



printed pieces, and maintained and updated our Web site. But perhaps the most direct method of transferring technology has been to send graduating students out into the workforce.

This section of the annual report highlights some of our technology transfer activities over the past year.

### Institute technology heads north to Alaska

In 2003, the ITS Institute reached beyond the borders of Minnesota to share its expertise and technology with the Alaska Department of Transportation and Public Facilities. Researchers from the Institute's Intelligent Vehicles Laboratory (IV Lab) received funding from the Alaska DOT to supervise the installation of driver-assistive systems on two Alaskan vehicles—a snowplow and a snow-blower truck. The systems were developed by IV Lab researchers with funding, in part, from the ITS Institute.

Alaskan transportation officials contacted the Institute regarding the suite of driver-assistive technologies integrated into the SAFEFLOW advanced snowplow. They hoped that Minnesota's technologies would be able to help snowplow operators working in Thompson Pass, east of Valdez. This important transportation link is subject to heavy snowfalls that necessitate frequent snow removal operations under difficult conditions.

A number of vehicle-guidance and collision-avoidance technologies are integrated on the SAFEFLOW in order to address the difficult and dangerous driving conditions, such as near-zero visibility, that operators of specialty vehicles frequently face. These technologies include a head-up display (HUD), which allows drivers to "see" road markings via images projected onto a combiner mounted close to the windshield, and a driver's seat that provides tactile warnings in the event of lane departure. [More information on the SAFEFLOW can be

found on the Intelligent Vehicles Initiative’s field test Web page at [www.its.umn.edu/research/ivifieldtest/.](http://www.its.umn.edu/research/ivifieldtest/)]

Bryan Newstrom, a researcher with the IV Lab, spent three weeks installing and testing the system in Alaska during the winter of 2003–04. During his time there, he trained various Alaska DOT drivers to use the system. “They really liked it and thought it could be useful,” Newstrom said. Considering the similar cold-climate issues facing transportation system managers in Minnesota and Alaska, it seems likely that Institute research will continue to attract attention from other northern areas.

**UMD’s transportation program holds second annual research event**

The Northland Advanced Transportation Systems Research Laboratories (NATSRL) held its second annual Research Day on November 13 at Mn/DOT District 1 Headquarters in Duluth. A large crowd of faculty, students, transportation engineers, and others attended the daylong event.

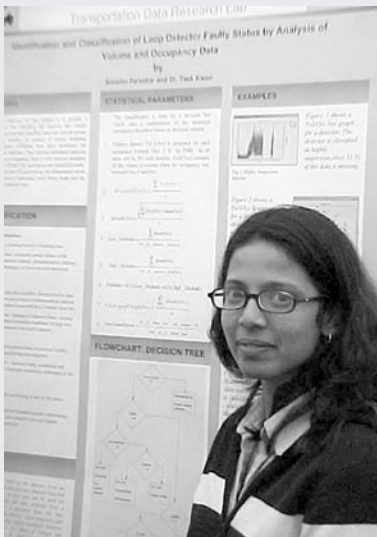


*UMD researchers and students showcase their work at NATSRL’s annual Research Day.*

Twelve project teams presented detailed updates on their research efforts as part of the research poster format added this year. Many of these presentations were given by students, who also answered questions on their specific roles in the projects along with the status of their findings.

Principal investigators gave a brief update on their research in the formal presentation sessions. Highlights included comments from Dr. Martha Wilson, UMD’s Mechanical and Industrial Engineering Department, on her snowplow modeling project. Dr. Taek Kwon, Electrical and Computer Engineering, gave a synopsis of his work in archiving data from Mn/DOT’s road sensors and in developing programs to efficiently access and share the data. Brian Brashaw, a timber and forestry specialist from UMD’s Natural Resources Research Institute, showed a video on the implementation of his research on non-intrusive means of performing inspections on timber bridges.

New research areas under NATSRL were addressed in the afternoon session. Drs. Mohammed Hasan and Fernando Rios-Gutierrez, Electrical and Computer Engineering, discussed their analysis of a sensor in surveying and detecting pavement conditions when ice or snow is present, and Dr. Ryan Rosandich, Mechanical and Industrial Engineering, gave a brief report on his initial work in developing a model to evaluate and quantify the risk in transportation construction project schedules. In addition, Roberta Dwyer, Mn/DOT District 1 engineering project manager, presented an update on Mn/DOT’s research agenda, tying the efforts in progress under NATSRL to current needs and applications within Minnesota’s state transportation program.



*UMD student Anushri Parsekar presents a research poster.*



*AASHTO conference attendees view intersection decision support technologies.*

### **Institute featured as Minnesota hosts AASHTO conference**

Several ITS Institute research facilities were offered as tour options for attendees of the American Association of State Highway and Transportation Officials (AASHTO) national meeting, held last September in Minneapolis. Conference attendees included state DOT, Federal Highway Administration, and industry representatives from across the country and abroad.

AASHTO conference participants also got a close-up look at some of the research underway at the University. About 20 people rode the TechnoBus—a specially equipped Metro Transit bus implementing advanced navigational and driver-assistive technologies—along the University’s transitway. The bus operated in tandem with SAFEPLow, another of the instrumented testbeds used by the Institute’s Intelligent Vehicles Laboratory, to demonstrate the use of the technology for gang-plowing operations. The TechnoBus riders could see the plow’s operation via live video wirelessly transmitted from the plow.

Other participants viewed an intersection on the transitway equipped with intersection decision support (IDS) technologies. The ITS Institute is part of a three-member national consortium that is creating deployable IDS systems to address specific intersection crash scenarios.

### **IV Lab technology evaluated for use in mining**

In many open-pit mines throughout the world, productivity is often hampered by the presence of heavy fog or dust. Because of the large size of pit-

mine machinery and the possibility of a machine falling off the edge into the pit, mine operations must shut down when visibility is poor. As a result, some mines operate at only 40 percent efficiency.

One manufacturer of heavy mine equipment has recently acquired the IV Lab’s head-up display (HUD) as a way to address low productivity. Due to the precision involved with mine operations, many mines operate high-accuracy (dual frequency, carrier phase) DGPS systems. This positioning capability, combined with high-accuracy geometric models of the open-pit mine, are used in conjunction with the IV Lab HUD to provide equipment drivers with a virtual display of the mine while driving in low visibility.

The manufacturer is currently undergoing simulator and in-vehicle tests to evaluate the feasibility of the system for this application. If initial trials are successful, the system will be tested and evaluated in a mine production setting.



*The HUD, shown here on a vehicle at dusk, can help drivers “see” the roadway when low-visibility might otherwise obscure it.*

The Institute's IV Lab initially developed and tested the HUD in conjunction with other driver-assistive technologies to help snowplow drivers safely navigate and clear roads in "white-out" conditions caused by blowing snow.

### Institute researcher involved in congressional discussion of homeland security

Professor Shashi Shekhar of the Department of Computer Science and Engineering was invited to present his recent work on evacuation planning at a congressional breakfast on homeland security held February 5 in Washington, D.C.



*Shashi Shekhar*

Among those in the audience were members of Congress and their staff as well as representatives from a number of federal agencies, including the National Geospatial Intelligence Agency, the National Security Agency, the U.S. Geological Survey, the Department of Homeland Security, the National Science Foundation, and the USDOT.

Shekhar provided an overview of evacuation planning, which identifies paths and schedules to move at-risk populations out of the city to safe areas in the event of terrorist attacks, catastrophes, or natural disasters. Its goal is to identify near-optimal evacuation routes and schedules to minimize evacuation time despite limited transportation network capacity and the possibly large at-risk population.

Finding the optimal solution is computationally exorbitant due to the large size and limited capacities of the transportation networks, Shekhar says. His research proposes novel geospatial algorithms to determine viable evacuation plans. Evaluation of his team's methods for evacuation planning for a disaster at the Monticello nuclear power plant near the Twin Cities indicated that

the new methods lowered evacuation time relative to existing plans by providing higher capacities near the destination and by choosing shorter routes.

### Visiting researchers help foster strategic partnerships

Over the last year, the Institute continued to work with visiting researchers and instructors. Dr. Thomas Horan, an associate professor at Claremont Graduate University and visiting scholar at the Humphrey Institute of Public Affairs, is part of the Sustainable Technologies Applied Research (STAR) Initiative. Horan is doing research on wireless emergency management systems and telecommunication network planning and access in a rural context.

The Advanced Transportation Technologies Seminar Series provided an opportunity to host Dr. Bradford Parkinson, Professor Emeritus with the Department of Aeronautics and Astronautics, Stanford University, who presented, "The Origins, Status, and Future of GPS."

The Institute also hosted two researchers from the international arena. Dr. Jeroen Keppens, research fellow from the Centre for Intelligent Systems and their Applications and the Joseph Bell Centre for Forensic Statistics and Legal Reasoning in Edinburgh, United Kingdom, presented a seminar on "Automating Abductive Reasoning for Diagnosis." Professor Yoram Zvirin, faculty of



*Bradford Parkinson of Stanford University discussed GPS at an Institute-sponsored seminar.*

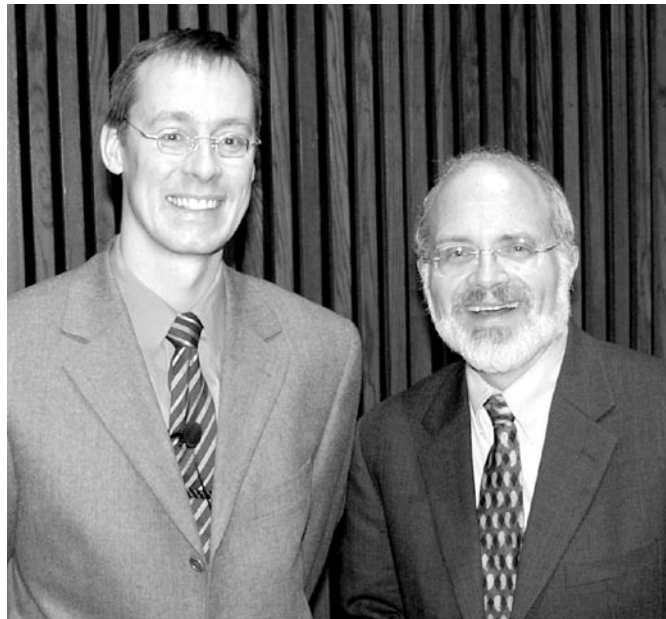
From pioneering automotive crash tests to “smart” driver-assistive systems, vehicle safety research has a long history and a bright future at the University of Minnesota.

Mechanical Engineering, Technion, I.I.T., and director of the Israel National Museum of Science, Planning, and Technology in Haifa, Israel, presented a seminar titled, “New Transportation Systems Based on Cybernetic Vehicles.”

Other visiting researchers include Nobuyuki Kuge and Tomohiro Yamamura of Nissan and Erwin Boer of the University of California, who are working with the Institute’s HumanFIRST Program.

### Speakers address vehicle safety initiatives at annual event

In March, Institute director Max Donath addressed attendees of the third annual ME (Mechanical Engineering) Day. From pioneering automotive crash tests to “smart” driver-assistive systems, vehicle safety research has a long history and a bright future at the University of Minnesota, he said. Donath, who



*Claus Ehlers of DaimlerChrysler AG and Institute director Max Donath at ME Day*

played a leading role in organizing this year’s events, also noted that the development of new safety systems is an integral part of the ITS Institute’s mission, which focuses on using “human-centered technology” to enhance safety and mobility.

The event featured a lecture by Dr. Claus Ehlers of DaimlerChrysler AG, where he is senior manager of System Safety and Assisting Systems. Ehlers oversees a diverse research and development program that includes collision-avoidance, crash-mitigation, and driver-support technologies.

The lecture was followed by a reception and dinner during which Donath narrated a presentation on the groundbreaking work of James “Crash” Ryan, a member of the Mechanical Engineering faculty and an early leader in safety engineering for passenger cars.

### Institute research cited in national, local media

Because such a vast audience can be reached by local and national media—be it print, radio, or television—coverage is a way to raise awareness about the Institute’s work and the value of research, as well as to give research results to those who can use that information.

The Institute has had a successful year of gaining media attention. The Institute’s research on intelligent decision support (IDS) systems was mentioned in a March 2 article in the *Wall Street Journal*. The article highlighted the use of intelligent transportation systems, in vehicles and as part of the infrastructure, for improving safety. The Institute’s IDS project seeks to reduce crashes at unsignalized rural intersections where traffic on low-volume rural collector roads enters a highway carrying high-speed traffic.

Local television news, as well as the Minneapolis *Star Tribune*, covered a seminar given by Institute researchers Gary Davis and Kate Sanderson, Civil Engineering, on their latest research on metro-area congestion (“Building Our Way out of Congestion?” Oct. 8, 2003).





Rajesh Rajamani

Professor Rajesh Rajamani, Mechanical Engineering, was interviewed in October regarding his adaptive cruise control research for a segment on tailgating that ran on the local FOX news affiliate.

The September 15, 2003, issue of *Inside ITS* featured an announcement of the Institute's grant from the USDOT and a brief interview with Institute director Max Donath about current research projects. Donath was

also interviewed by Minnesota Public Radio regarding work on bus rapid transit.

Finally, research associate Kathleen Harder, who focuses on driver behavior research, was interviewed in August for a local NBC news affiliate story on aggressive driving. In addition, her simulations study related to changeable message signs and the AMBER alert system was profiled in a transportation column in the *Star Tribune* in September.

### Web, publications promote Institute work

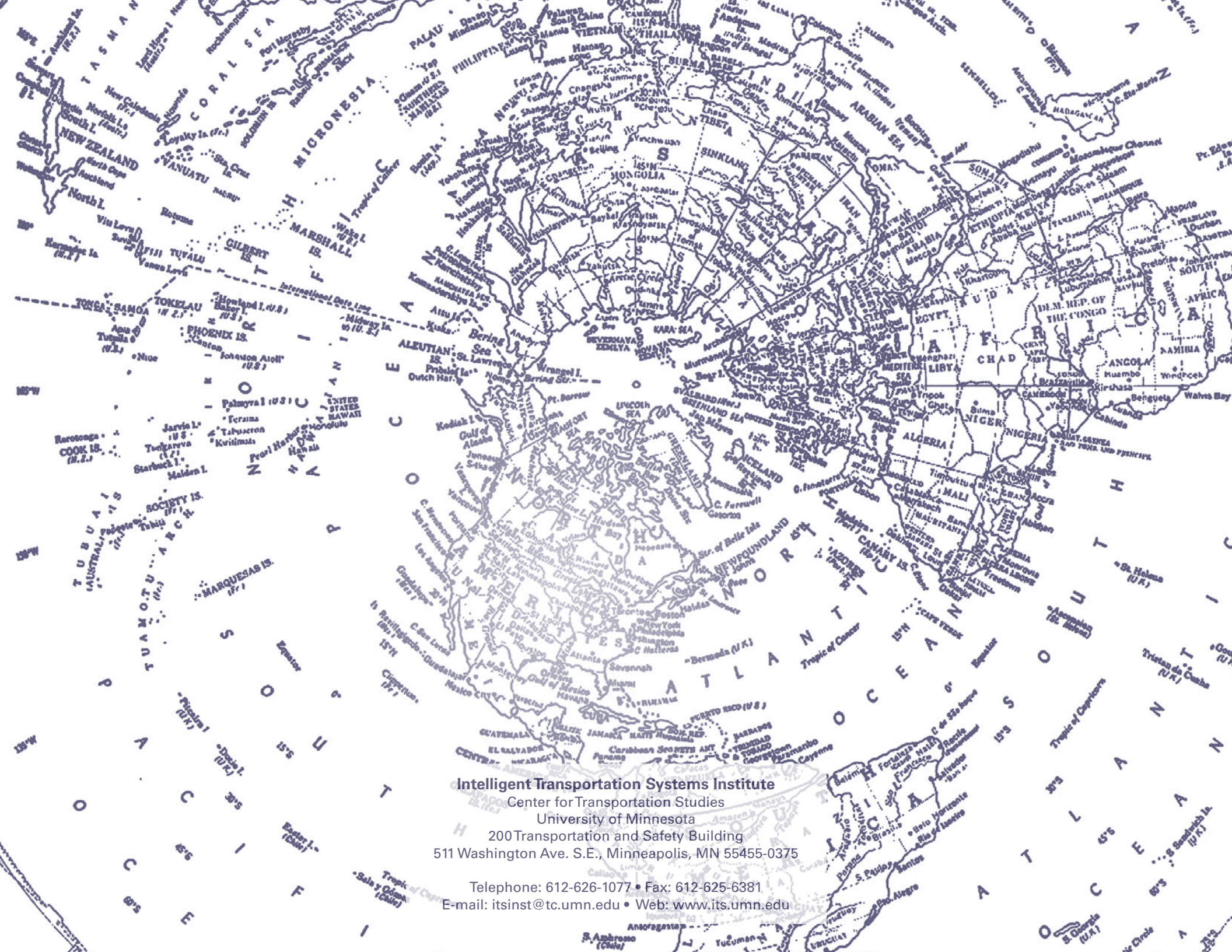
Improvements continued to be made to the Institute Web site over the past year. A new section was added to the research area to highlight projects in several significant areas, including ramp metering, rural intersection safety, simulation and modeling of traffic systems, and others. These topic areas are more specific than the core science and technology areas and are aimed at researchers, professionals, and graduate students with specific implementations in mind.

Web pages focusing on the Institute's current work in intersection decision support (IDS) were created to promote this new project. Additional Institute-related news articles were added

to the site, as well as coverage of the fall semester Advanced Transportation Technologies Seminar Series.

Circulation of the ITS Institute's *Sensor* newsletter remained strong, at around 2,200—indicating continued interest in ITS research activities among academic and professional audiences. Other publications included a four-color brochure promoting the work and resources of the ITS Institute, a semiannual and annual report, and research reports.

All communications materials can be found on the ITS Institute's Web site: [www.its.umn.edu](http://www.its.umn.edu).



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