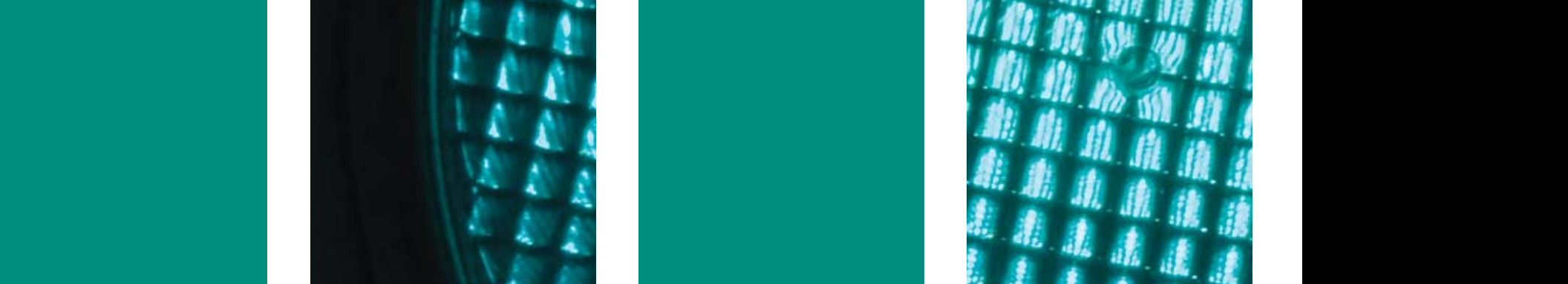


Human-centered technology to enhance safety and mobility

Annual Report 2007-2008



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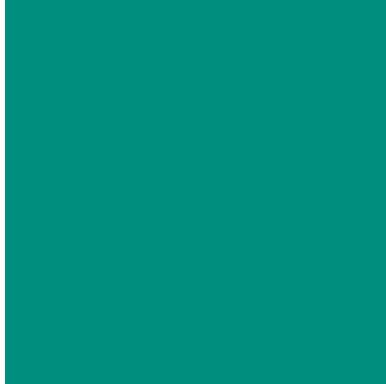
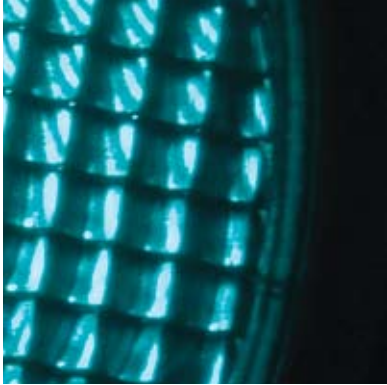
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CENTER FOR TRANSPORTATION STUDIES
UNIVERSITY OF MINNESOTA

Human-centered technology to enhance safety and mobility

A report of research, education, and technology transfer activities of the Intelligent Transportation Systems Institute at the University of Minnesota for fiscal year 2007–2008

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MESSAGE FROM THE DIRECTOR

Record gas prices grabbed headlines this spring and summer and were credited with pushing transit ridership to new highs in Minnesota and across the nation. As prices hovered around \$4 a gallon, transportation policy analysts—and drivers—had to come to grips with the potential for high fuel costs to reshape the United States' transportation landscape. Even with prices easing, it appears that higher fuel costs will induce permanent changes in transportation policy and travel behavior.

Other factors are also contributing to a surge in the popularity of transit. Growing public awareness of the environmental impact of greenhouse gas emissions from the transportation sector—highlighted in a recent University of Minnesota study commissioned by the state legislature—are causing many commuters to rethink their travel options. And frustration with high congestion levels may also be contributing to commuters choosing transit. The continued success of the Hiawatha light-rail line, which has so far recorded an increase of more than 15 percent in total ridership during 2008, is one more indicator that the public is ready to embrace new transportation options.

Today, the old paradigms of building more cars and paving more roads are proving inadequate for the challenges of transportation in the 21st century, and the public is looking for new options. The ITS Institute is working to provide these options through our research in the areas of intelligent vehicles, traffic management, and policy studies.

One example of these efforts is our participation in the U.S. Department of Transportation's Urban Partnerships Program, which enables metropolitan areas to partner with the federal government to implement cutting-edge technologies and management practices. This year, the ITS Institute, the Minnesota Department of Transportation, the Met Council, and other transportation stakeholders formed a partnership that was one of four metropolitan areas selected to participate in the program. This successful team effort is an example of the interdisciplinary collaboration that the ITS Institute and other University

Transportation Centers were created to achieve.

Under Minnesota’s Urban Partnership Agreement, a range of new measures aimed at reducing congestion and improving transportation efficiency will be put in place. Through our partnership with the Minnesota Valley Transit Authority, the ITS Institute will deploy advanced driver-assistive technologies on a fleet of 10 buses operating on highway shoulder lanes. These technologies, developed and refined by University of Minnesota researchers over several years, will enable bus drivers to operate safely and comfortably within the narrow shoulder lanes while avoiding the adjacent highway traffic.

Operating buses on bus-only shoulder lanes allows transit agencies to move commuters more efficiently, avoiding peak-period congestion. However, the inherent difficulty of driving a nine-foot-wide bus within the boundaries of a ten-foot-wide lane—especially in the inclement conditions of a Minnesota winter—has always tended to restrict shoulder lanes to optimal conditions. By integrating digital mapping, high-accuracy vehicle location, vehicle guidance, and driver display technologies, ITS Institute researchers have created a system that helps bus drivers guide their vehicles along their routes, watches out for other nearby vehicles, and uses feedback to warn the drivers if they begin to deviate from the lane. The result is a transit option that is both faster and safer.

Minnesota’s Urban Partnership Agreement represents an important affirmation of the need to seriously evaluate new transportation possibilities. In order to maintain our quality of life—as well as our national economic standing—we need to push the envelope and implement the new tools and technologies that will sustain our nation’s transportation systems.

However, even the combination of high fuel prices and new technologies will not make transit the preferred travel mode for urban and suburban residents. The current crop of hybrid and compact automobiles, like the Prius and the Mini Cooper, appeal to the image-conscious consumer’s sense of fashion as well as utility. In order to break travelers out of their automobile-centric mindset and achieve a significant mode shift to transit, we need to give riders transit options that are comfortable, attractive, and

convenient as well as safe and reliable. There is no reason that buses can’t offer all these options, and at significantly less cost than railed vehicles.

Beyond the vehicles themselves, enhancements to bus stops and stations could also help transform transit from a utilitarian to an attractive mode of travel. Improved and comfortable stations, better real-time information communicated by signage and text messaging to the enrolled traveler, and off-board fare collection that allows riders to board without waiting in line to pay are among the improvements that need to be deployed quickly.

Economic pressures, new technologies, and the willingness to take bold steps to make transit both more efficient and more attractive are the keys to building a new paradigm of personal transportation in our metropolitan areas. Through its research, education, and outreach activities, the ITS Institute is committed to helping make this new paradigm a reality—and to helping meet America’s future transportation needs through human-centered technologies.

As we look forward to these new opportunities, I would like to thank two members of the ITS Institute’s board whose terms ended during the past fiscal year: Rick Arnebeck, division director with the Minnesota Department of Transportation, and Don Theisen, Washington County Engineer. Their insights and dedication contributed to a great year for our Institute.

Finally, the last year saw the passing of two former board members. Toni Wilbur, a strong supporter of the Institute’s work, was technical director of traffic operations research and development at the Federal Highway Administration’s Turner Fairbanks Highway Research Center. Kathryn Swanson’s commitment to saving lives as Minnesota’s director of traffic safety was an inspiration to everyone who knew her in the transportation community. We will miss them.



Max Donath, Director
ITS Institute

“Our economic vitality and prosperity as a nation are increasingly becoming dependent on our willingness to embrace new transportation strategies.”

—Mary Peters, U.S. Secretary of Transportation

Overview

MISSION STATEMENT

The Intelligent Transportation Systems Institute is a national University Transportation Center (UTC) funded through the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), the federal surface transportation bill passed in 2005. This funding continues the Institute's efforts initiated under SAFETEA-LU's predecessors, the Transportation Equity Act for the 21st Century (TEA-21) and the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA).

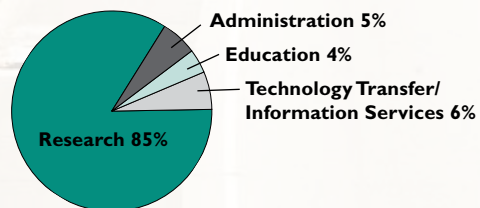
The ITS Institute plans and conducts activities that further the mission of the United States Department of Transportation's UTC program. That mission is to advance U.S. technology and expertise in the many disciplines that make up transportation through education, research, and technology transfer activities at university-based centers of excellence. To help us accomplish this, we direct the work of researchers from multiple disciplines to advance the state of the art in the core ITS technologies of computing, sensing, communications, and control systems to solve today's challenging transportation problems.

Our focus is on human-centered technology that enhances the safety and mobility of road- and transit-based transportation. To that end, we bring together technologists and those who study human behavior 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 optimize human capabilities as they relate to transportation.

Additionally, the Institute addresses issues related to transportation in a northern climate, investigates technologies for improving the safety of travel in rural environments, and considers social and economic policy issues related to the use of core ITS technologies.

Financial Report

Expenditures for Year Nine: July 1, 2007–June 30, 2008



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 results from 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 its 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 Innovative Technology 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 spread 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.

Board members whose terms ended during the fiscal year:

Rick Arnebeck Division Director, Minnesota Department of Transportation	Don Theisen County Engineer, Washington County
--	---

ITS Institute Board Members (as of June 30, 2008)



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(Chair)
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Transportation Studies



Anthony Kane
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Joe Peters
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Northland Advanced Transportation Systems Research Laboratories

The NATSRL program director is Eil Kwon. Support and guidance for NATSRL is provided by its advisory board and research advisory panel, whose members include the staff from partnership agencies, including Mn/DOT, St. Louis County, and the City of Duluth.

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

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Civil Engineering

Eil Kwon

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Labs and Facilities

HUMAN FACTORS INTERDISCIPLINARY RESEARCH IN SIMULATION AND TRANSPORTATION

The mission of the Human Factors Interdisciplinary Research in Simulation and Transportation (HumanFIRST) Program is to apply human factors principles 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 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 Departments of Transportation and Public Safety, private industry, traffic engineering consultants, and other related entities. 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
- intelligent driver-support systems such as vision-enhancement, collision-avoidance, hazard-awareness, and lane-keeping systems for passenger and specialty-purpose vehicles
- alcohol impairment including motorcycle safety
- intelligent driver-support systems for novice teen drivers
- in-vehicle use of advanced traveler information systems

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.

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 capable of creating virtual environments that precisely reproduce any geospecific location. In addition, specialized visual-effect software can produce realistic weather and lighting—including light and



HumanFIRST researchers, clockwise from left: Curt Olson, Michael Manser (standing), Janet Creaser, Peter Easterlund, and Mick Rakauskas

Keeping an eye on teenage drivers

The risk for motor vehicle crashes is extremely high among teen drivers—in fact, vehicle crashes are the leading cause of death for teens. In response, researchers from the University of Minnesota's HumanFIRST Program (led by research fellow Janet Creaser) and the University of Iowa are examining the use of an event-triggered video system that records and gives limited feedback about driving behaviors that may help motivate safer teen driving.

This study is using teens recruited from an urban high school in the Minneapolis-St. Paul area and complements a similar study conducted by the University of Iowa examining rural teen drivers. In the Twin Cities study, a DriveCam event recorder is mounted behind the rearview mirror in participants' vehicles. The camera continuously records video and audio data of the driver and the forward scene. The data are not saved, however, unless unsafe driving behaviors such as excessive acceleration, sudden braking, or erratic steering trigger the recorder, which then retains video and audio data 10 seconds before and 10 seconds after the trigger event. Recording these data makes it possible to see what

happened immediately before and after incidents.

The research study consists of three stages that together will help determine the system's efficacy. During the first stage, the cameras record events triggered by driving behaviors without letting the teens know they have triggered and recorded an event, thereby identifying drivers' normal behavior. In the second phase, when the recorder is triggered, a red light flashes to let drivers know the DriveCam has detected and recorded an event. At the end of each week, parents receive downloaded video recordings and a "driver report card" relative to their teen's driving performance that details such things as what behavior triggered the recording, the environmental conditions at the time, and whether the driver



was wearing a seat belt. Parents are asked to review this information with their teen in the hope that the teens will learn from both their good and bad behaviors. The drivers are evaluated during a third phase, with the camera recording events but once again without providing feedback to teens or videos to parents. The goal is to find out if drivers continue good behavior once the camera and parental feedback components are removed.

The research team's overall interest is to determine whether systems like the one studied have an effect on safety-related behaviors. The final analysis, set for completion in the fall of 2008, could help generate new means of driver education, decision-support systems, and licensing and training that may result in fewer crashes by teen drivers.

shadow that correspond with season and time of day—as well as vehicle headlights with nighttime glare and water reflections.

The visual environment is generated with high-resolution images (1.97 arcmin per pixel) over a wide field of view (210-degree forward, 50-degree rear, 2 by 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), haptic feedback through the seat and accelerator pedal, and a head-free eye-tracker that can detect in real time what a driver is looking at, 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.

Additionally, 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.

MINNESOTA TRAFFIC OBSERVATORY

The Minnesota Traffic Observatory (MTO), a joint effort of the ITS Institute and the Department of Civil Engineering, aids researchers' ability to study the complex dynamics of traffic flow throughout the Twin Cities region. The observatory combines real-time traffic data with state-of-the-art simulation systems, giving researchers and engineers the ability to analyze existing conditions and compare real-world observations with the results of simulated conditions.

Rather than showing one or two locations, the observatory offers a view of large systems where many different parts interact. Video feeds flow into the observatory from an extensive network of traffic cameras. The observatory is connected by fiber-optic lines to the Minnesota Department of Transportation's traffic operations center, allowing it to capture live feeds from up to 16 of the more than 300 cameras the agency uses to monitor the metropolitan freeway system. In addition, the observatory operates a dedicated system of cameras overlooking the I-94/35W Commons interchange in Minneapolis—turning one of the most accident-prone intersection areas in the state into a real-world laboratory for the study of traffic flows and vehicle crashes.

The availability of a wealth of high-quality video data is ideal for the use of machine-vision systems to

monitor and categorize vehicle movements. Computer image-processing algorithms developed by University of Minnesota researchers enable the observatory to track and analyze complex traffic patterns at intersections, on freeway interchanges, and in other areas that are difficult to study using other data sources.

Another key component of the MTO is a virtual traffic control center and simulation lab. Interfacing traffic signal control hardware with realistic traffic network models creates a powerful tool for examining system performance under a variety of conditions.

Given the complexity of the traffic issues that the observatory is designed to study, robust visualization tools are critical. In addition to a large projection wall, two innovative pieces of equipment provide researchers with powerful interactive visualization capabilities.

The GIS/MAP table combines the large horizontal working surface of a traditional drafting table with the interactive capabilities of geographic information systems technology. Two ceiling-mounted digital projectors create a seamless image covering the entire conference-table-sized surface, which can be manipulated using a tabletop pointing device to pan and zoom in on specific areas. In contrast to traditional ways of viewing digital maps and models on a desktop monitor, the table allows users to comfortably survey



the entirety of a large traffic system and quickly focus in on areas of interest. [See related sidebar on how planners are using the table and collaborating with the MTO.]

The Digital Environment, or DEN, takes a different approach—putting viewers in the center of the action via three-dimensional immersive graphics. Three sides of the cubical structure are formed by large rear-projection

screens presenting polarized images from two slightly different sources; a user wearing specially designed glasses sees a different image with each eye, producing a realistic sense of three-dimensional space. A tracking system mounted in the DEN's ceiling monitors the position of the user's head and adjusts each projector to provide an accurate perspective.

Visualizing better planning processes

Project planning by state, county, and city agencies requires a great deal of involvement from various government agencies and the general public to achieve the best project outcomes. Scarce resources among agencies and busy lifestyles among the public at large, however, often create significant barriers to participation. Researchers from the University of Minnesota's Hubert H. Humphrey Institute of Public Affairs and civil engineering department are working together to find out how technology could be used to minimize these barriers and lead to better stakeholder participation in various planning processes. The research team includes John Hourdos, a civil engineering researcher and director of the Minnesota Traffic Observatory (MTO), Carissa Schively Slotterback, assistant professor in the Humphrey Institute's Urban and Regional Planning Program, and several graduate students.

Although research is being conducted by others regarding specific technologies, this study provides the next step of determining how to tailor technology to the unique characteristics of different types of planning and participatory efforts. The MTO's GIS/Map table was influential in getting this project started as team members began to think about how the table might be used to enhance participation efforts. They expanded their thinking to other types of technologies that might be used in participation. The team is now gathering information about typical participation processes in which planners, engineers, and other practitioners are involved—including open house meetings, public hearings, and technical, advisory, or steering committee meetings. The research team is hoping to understand the typical characteristics of these processes (meeting types) in terms of who participates, when they occur in the planning process, what their purpose is, and what their outcomes are. Once they understand

the characteristics, they can better identify ways to tailor various technologies to improve participation efforts. Customizing technology to these unique characteristics would enable planning and transportation professionals to create more realistic pictures of projects throughout the planning and development processes, giving stakeholders more influence over and satisfaction with the completed project.

Through a series of focus group discussions with practitioners that included representatives from the Minnesota Department of Transportation (Mn/DOT) and other state, regional, and local agencies, the research team is examining the agencies' current participatory processes and their perspectives on applying technology in these settings. Based on the information gathered, the team will identify the strengths and weaknesses of various types of technological enhancements that could be incorporated within these existing processes. One avenue being explored is that of developing ways to distribute project information other than at public meetings. For example, this might be a Web site with interactive features that allows individuals to study the pros and cons of different project scenarios, offer comments, and take part in the planning process entirely online.

The final analysis from this work will produce important feedback about ways to integrate technology into planning and participatory processes and further insight about the importance of tailoring technology to various settings. As a follow-up to this study, the team hopes to develop a Web site on which technology-related information would be posted and organized to help practitioners make decisions about the technology options available for their particular situation.



Ted Morris, John Hourdos, and Chen-Fu Liao at the MTO's map table

INTELLIGENT VEHICLES LABORATORY

The Institute's Intelligent Vehicles (IV) Laboratory develops and tests innovative, human-centered technologies that improve the operational safety, mobility, and productivity of the transportation network in general, and highway vehicles in particular. These human-centered technologies integrate sensors, actuators, computer processors, and custom human interfaces to provide drivers with needed information under difficult driving conditions such as low visibility, severe weather, and narrow and congested roadways.

Although the IV Lab is focused primarily on vehicles, it also considers the roadway, supporting infrastructure, and electronic wireless communication as part of the transportation network and uses all of these elements in generating solutions to today's transportation problems.

Driver-assistive systems developed by the IV Lab have been tested on specialty vehicles including snowplows, patrol cars, ambulances, heavy vehicles, and transit vehicles. Ultimately, these systems will also

be used on passenger vehicles, providing drivers with warnings and assistance with collision-avoidance and lane-keeping tasks. Numerous vehicles utilizing IV Lab driver-assist technologies have been deployed in both Minnesota and Alaska.

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 consists of engineering 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 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

Intersection system to help drivers gauge the gap

The Intelligent Vehicles Laboratory continued to work on improving rural intersection safety in fiscal year 2007 as a member of the federally supported Cooperative Intersection Collision Avoidance System—Stop Sign Assist (CICAS—SSA) research coalition.

The IV Lab's efforts to develop collision-prevention technologies for rural deployment began with the Intersection Decision Support (IDS) research program. In that effort, the lab developed a system of sensors and computer processing algorithms that tracks vehicles approaching an intersection on a high-speed rural highway, processes the data to measure gaps in traffic, and displays a warning to drivers waiting on a minor road if the gap in highway traffic is too small to permit safe crossing or entry onto the highway.

Following the testing of a prototype IDS data-gathering system at a rural intersection in southern Minnesota, as well as the successful deployment of a portable data-

gathering system in several partner states, the IV Lab (led by Craig Shankwitz) and the HumanFIRST Program (led by Michael Manser) were selected by the Federal Highway Administration (FHWA) to participate in CICAS. Minnesota's research, with major funding and support from the FHWA and Mn/DOT, focuses on developing infrastructure-based systems for rural deployment.

Over the past year, IV Lab staff worked to refine the alert and warning-timing algorithms using models of driver gap acceptance behavior. This research is linked to the development of effective infrastructure-mounted animated graphic displays, currently under way in collaboration with human factors researchers from the HumanFIRST Program.

Other work during the past year focused on the sensor suite required to perform vehicle tracking. To reduce the cost and complexity of the system under development, the researchers explored alternative sensor types and reduced



sensor sets for both the minor road and major highway system components. Alternative sensors included standard inductive loop vehicle detectors and a type of small "microloop" detector.

in difficult driving conditions through the use of vehicle-guidance and collision-avoidance technologies. Several vehicles serve as experimental testbeds: the SAFETRUCK (an International 9400 tractor-trailer), the SAFEFLOW (an International 2540 crew-cab snowplow), a state highway patrol car, and a Minnesota Valley Transit Authority (MVTA) 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; and haptic and tactile feedback.

The IV Laboratory's lane-assist technology is unique in that it uses DGPS and does not require hardware in the roadway surface. 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 difficult driving conditions are encountered by drivers on a daily basis. For example, the vast majority of vehicle crashes occurring at rural, unsignalized intersections are the result of drivers incorrectly gauging the size of a gap between oncoming vehicles—not running stop signs. The IV Lab has developed a sophisticated rural intersection data-collection system used to study how drivers waiting at a low-volume minor road enter or cross a high-speed, high-volume expressway. This test intersection is located in Minnesota at the junction of U.S. 52 and Goodhue County Road 9 approximately eight miles south of Cannon Falls, Minnesota. The data collected at the intersection are being used to model driver behavior to determine where the gap-acceptance decision process fails and leads to a crash, and to then design countermeasures to reduce the number of these crashes.

Because safety systems can produce improvements only if they are deployed, the IV Lab works with a variety of states to collect data and evaluate system performance. For instance, three vehicles (and a fourth planned) with driver-assist technology have been deployed in Alaska, where high snowfall rates and dry, blowing snow routinely cause whiteout conditions and zero visibility. By March 2008, the Minnesota Mobile Intersection Surveillance System (MMISS) will have collected driver behavior at rural expressway through-stop intersections in Wisconsin, Iowa, Michigan, North Carolina, Georgia, New Hampshire, Nevada, and California. Data collection throughout the United States will ensure a nationally deployable intersection safety system designed to save lives among rural drivers.

Additional research topics include the design and



From left, back row: IV Lab researchers Alec Gorjestani, Eddie Arpin, Bryan Newstrom; front row: Mike Abegg of the MVTA, Pi-Ming Cheng, and Arvind Menon

testing of custom human interfaces, collision-avoidance sensors and algorithms, 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 (MnROAD) 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—among them, the U.S. Department of Transportation's Research and Innovative Technology Administration, Federal Highway Administration, and Federal Transit Administration; Twin Cities' Metro Transit; the Minnesota Valley Transit Authority; 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.

Virtual snow for safer winter driving

At first glance, a snowplow might seem hard to miss. But winter weather conditions can interfere with human visual perception in ways that make it difficult to judge the position and speed of even a big, bright orange plow, resulting in dangerous collisions. To help prevent these errors, researchers at the University of Minnesota Duluth are developing new tools to study the effects of winter conditions on human vision.

One of the main sources of difficulty for drivers in conditions of blowing snow, according to assistant professor of computer science Peter Willemsen, is a condition known as equiluminance in which the apparent brightness of an object is nearly the same as that of the surrounding scene. Equiluminance can be produced by particulates, such as snow, suspended in the air; it is particularly problematic at dawn and dusk, when low light levels make accurate distance perception even more difficult.

To learn more about the visibility problem, Willemsen and his research team are moving from the real world to a virtual environment where visibility conditions can be fully controlled. But doing simulator research has its own problems—such as how to mimic the visibility-reducing effects of snow. So the researchers are developing new computer graphics techniques that will produce more realistic snow effects.

In the first phase of their study, the researchers developed a snow rendering system that uses a model of millions of individual particles to compute how light is scattered and absorbed as it passes through a snow cloud. The team is currently working on integrating this snow rendering capability into a driving simulation

system in order to carry out a series of experiments with different lighting configurations mounted on the plow. They hope to find a better way to light up snowplows to make it easier for other drivers to determine a plow's speed and distance.

When the simulation system is complete, the researchers say,

it may find a place in training programs for snowplow drivers, who work regularly in conditions of low visibility. Beyond helping drivers avoid collisions with snowplows, this research has the potential to improve scientists' understanding of human visual perception in low-light or equiluminant conditions.



Pete Willemsen (front center) with students Michele Olsen, Daniel Schobert, and Siddharth Deokar

NORTHLAND ADVANCED TRANSPORTATION SYSTEMS RESEARCH LABORATORIES

The Northland Advanced Transportation Systems Research Laboratories (NATSRL), founded in 2000, is an advanced research program located at the University of Minnesota Duluth. Its mission is to develop innovative ITS technologies that can make surface transportation systems in northern areas safe, efficient, reliable, and environmentally sound.

Since its inception, NATSRL has been strongly supported by its key stakeholders, including the Minnesota Department of Transportation, St. Louis County, and the City of Duluth.

Current research focus areas in NATSRL include advanced traffic/pavement sensor technologies; vehicle/driver safety technologies; transportation data archival and analysis methods; renewable power for ITS operations in rural areas; and traffic safety and operational strategies for rural and urban areas.

Specific NATSRL research projects currently ongoing in these focus areas include a wireless detection network to measure spatial traffic data; a video-based vehicle tracking system with a customized processor for efficient real-time traffic detection; an early detection and warning system for driver drowsiness; a realistic snow-rendering simulation system to assess the effects of alternative snowplow truck color and lighting options on the perception of following drivers; a carbon nanotube-based integrated pavement sensor for traffic detection; an advance warning system to prevent snowplow box collisions; and development of a freeway travel time database and Mn/DOT weigh-in-motion data archive design.

In addition, NATSRL partners with Mn/DOT District 1 each year to provide a research workshop, where on-going research efforts are presented to local practitioners.



Research is investigating how to make snowplows more visible in blowing snow.

Research

ITS 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 drivers to adapt to technology.

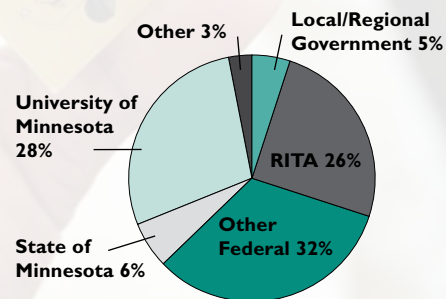
The Institute's geographic location gives it a unique advantage for developing research applicable to transportation in a northern climate and transportation in rural environments in addition to the metropolitan Twin Cities area. The ITS Institute research program includes research projects funded by various partners, including federal funds from SAFETEA-LU legislation, the Federal Highway Administration, the Federal Transit Administration, the National Highway Traffic Safety Administration, the National Park Service, and the Department of Homeland Security. Other funding partners include the Minnesota Department of Transportation (Mn/DOT), Minnesota Local Road Research Board, Metropolitan Council, Hennepin County, Metro Transit, and the Minnesota Valley Transit Authority in addition to local governments, agencies, and private companies that contribute funding and in-kind match.

Activities undertaken by the Institute support all 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 under way, 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 ITS-related research projects was approximately \$7.7 million in FY08. Sources for projects receiving funding in FY08 are shown in the chart to the right.

During this period, 50 faculty and research staff and 65 students were involved in ITS-related research.



MOTORCYCLE RIDING IMPAIRMENT AT DIFFERENT BAC LEVELS

HumanFIRST Program research fellows Janet Creaser and Mick Rakauskas, former HumanFIRST director Nic Ward, consultant Erwin Boer, and Intelligent Vehicle Lab (IV Lab) director Craig Shankwitz collaborated to study the effects of alcohol on motorcyclists, taking advantage of the programs' access to unique research facilities and expertise in monitoring driver performance.

Motorcycles and scooters are more popular than ever—even in Minnesota, where frigid winters limit riders to a few months a year. But statistics from the National Highway Traffic Safety Administration (NHTSA) show that while motorcycles account for only three percent of motor vehicle registrations, they make up 11 percent of total motor vehicle fatalities. Crash reporting data reveal that alcohol is more likely to be a factor in motorcycle crash fatalities than in fatalities involving automobiles (one in three fatal crashes for motorcycles versus one in four automobile crashes). And, alarmingly, statistics from the Centers for Disease Control indicate that the number of fatalities due to motorcycle crashes each year in the United States is currently rising, reversing a nearly two-decade downward trend.

With these statistics in mind, and given the unique demands of motorcycle operation, safety experts are asking whether the restrictions on blood-alcohol content that govern automobile drivers are appropriate for motorcyclists.

With funding from NHTSA, the study aimed to fill a gap in research on the effects of alcohol consumption on motorcycle operation. While a large body of research has been devoted to detailed analysis of how alcohol interferes with automobile operation, relatively little effort has been made to study the effects of alcohol on the different skills required to operate a motorcycle.

This discrepancy is due in large part to the technical difficulty of research on motorcycle rider impairment. Advanced driving simulators for motorcycles are virtually unknown, and in-vehicle testing is largely impossible due to the hazards of impaired motorcycle operation

and strict laws prohibiting motor vehicle operation while intoxicated.

To overcome these obstacles, the IV Lab researchers first created a motorcycle that could be operated safely by a study subject while under the influence of alcohol. They modified a common motorcycle by adding two outriggers that engage if the bike tips during a test ride. (The outriggers prevent the bike from landing completely on its side or on the rider.)

The motorcycle was then equipped with an onboard suite of sensors also designed by research engineers from the IV Lab. The Motorcycle Data Acquisition System, or MoDAQ, monitors both the participant and the various control surfaces of the motorcycle. In addition, a set of inertial measurement units were deployed on the motorcycle's frame and the rider's helmet to measure acceleration and rotational rate.

Even with added safety features, operating the motorcycle with alcohol-impaired research subjects would



For their experiments, researchers added two outriggers that engage if the motorcycle tips during a test ride.

still have been prohibited by Minnesota law, which applies to private driving courses and tracks as well as to public roads. Fortunately, one driving course in Minnesota is specifically exempt from the state law: the Minnesota Highway Safety and Research Center in St. Cloud. The facility is one of several closed courses used in HumanFIRST research.

The research team recruited 24 male study participants who had a minimum of five years of motorcycling experience and drank alcohol at least once a week but with no history of alcohol dependence. After training designed to familiarize the riders with the research motorcycle, the riders participated in three day-long test sessions during which they either drank alcohol to reach a blood-alcohol concentration of .02, .05, or .08 g/dL (the legal limit in Minnesota) or were given a placebo (alcohol applied to the rim of a glass containing a non-alcoholic beverage).

After consuming the alcoholic beverage or the placebo,

the participants rode through a test course developed in collaboration with motorcycle instructors Bill Shaffer and Jed Duncan from the Minnesota Motorcycle Safety Center. The course included a variety of tasks, ranging from routine riding situations to emergency maneuvers. Data from both baseline (non-alcohol) rides and rides after consuming alcohol were gathered for each participant, enabling the researchers to compare the effects of different amounts of alcohol consumption.

Analysis of data from these tests revealed that some impairment was evident in motorcycle riders at the 0.05 blood-alcohol level, below the 0.08 level that constitutes intoxication in the eyes of the law. And while self-reports by the test subjects indicated that many riders may realize when alcohol is affecting their riding performance, the researchers caution that the evidence does not mean that self-regulation is sufficient to mitigate the increased crash risk due to riding after drinking.

INFLUENCE OF A HAPTIC DRIVER SUPPORT SYSTEM ON INFORMATIONAL PROCESSING, ATTENTIONAL RESOURCE MANAGEMENT, AND DRIVING PERFORMANCE

Only a few decades ago, catastrophic failure of critical components was a common cause of automobile crashes. Since then, improvements in automotive engineering have greatly reduced the number of crashes caused by mechanical failure while driving. So why are so many people still losing their lives every year in automobile crashes? One explanation for this apparent paradox is that while engineers have been very successful in making vehicles safer, drivers remain largely unchanged. Today, driver error may play as significant a role as mechanical failures in crashes. In addition, the myriad electronic controls and options in current vehicles, not to mention cellular phones and other personal communication devices, mean that the potential impediments to good driving performance may be increasing.

All drivers, no matter how experienced, are subject to natural limits of human behavior, cognition, and

perception. But just as technology can help overcome physical limitations, it can also help address the perceptual and cognitive biases that often lead to less-than-optimal driving performance.

The potential solution, says Michael Manser, director of the HumanFIRST Program, is using technologies that support—rather than impede—good driving practices. For the past four years, he has been one of the primary researchers in a collaborative effort with Nissan Motor Company of Japan aimed at evaluating a new driver-assistive system.

The Nissan system uses a haptic (touch-based) feedback mechanism attached to the accelerator pedal to provide variable resistance depending on how close a driver's vehicle is to a lead vehicle. Forward-looking range sensors are able to sense changes in distance much more accurately and quickly than the human eye and relay these changes instantly, even if the driver's attention is elsewhere.

Although humans are endowed with highly evolved senses of hearing and touch, we rely almost exclusively on vision when we get behind the wheel. In this context, says Manser, haptic feedback systems are interesting because they exploit a relatively underused information channel that may not compete with the many visual cues that drivers already have to process.

Manser first set out to determine whether drivers could effectively process information presented to them through this novel non-visual channel. The HumanFIRST Program's immersive driving simulator provided an ideal environment for initial testing, allowing the research team to monitor driver reactions and control the parameters of driving situations in which the haptic feedback system would be activated.

Reaction-time data from initial tests revealed that drivers responded to the sudden slowdown by a lead vehicle by moving their feet off the accelerator pedal more quickly when using the haptic feedback system, and that this benefit was present in both high-complexity and low-complexity secondary task scenarios.

A second finding highlights some of the hidden complexity of driver response. The data reveal that the initial reaction times of drivers using the haptic feedback system are better (i.e., lower), but that drivers then take slightly longer to transition from the accelerator pedal to the brake pedal. Manser believes this slight delay may result from drivers performing a visual double-check on the lead vehicle to make sure it is actually slowing. This extended transition time is more than offset by the reduced reaction time, making total response time significantly better with haptic feedback than without.

These results substantiate the hypothesis that the use of a haptic

feedback system can result in a significant improvement in driver performance, and that this is the result of the system freeing cognitive resources that are then directed to the primary task of driving. However, an unintended consequence is that drivers could use the cognitive resources it frees up to perform other secondary tasks.

The HumanFIRST researchers devised a second test to investigate this possibility. Like the first test, it involved performing a secondary task while following a lead vehicle, but this time the task required drivers to interact with a touch-screen display rather than adjusting a stereo system. This task was designed to be more demanding perceptually, cognitively, and physically in order to approximate the normal demands of an in-vehicle secondary task (e.g., using a cellular phone) of real-world situations.

The researchers found that using the haptic feedback system improved vehicle controllability (the primary task), and also improved drivers' performance on the secondary task. These findings suggest that drivers are taking advantage of the newly freed resources from the haptic system to improve driving performance and to improve secondary task productivity. HumanFIRST has received follow-on funding from Nissan to continue researching the implications of the haptic pedal system.



Experiments studied how drivers used the accelerator and brake pedals in response to haptic feedback.



Lee Alexander, Krishna Vijayaraghavan, and Rajesh Rajamani demonstrate the battery-less traffic sensor.

NEW BATTERY-LESS WIRELESS TRAFFIC SENSORS AS A REPLACEMENT FOR LOOP DETECTORS

The ability to measure traffic flow rate is crucial to traffic monitoring and control. Ramp meters, which control the number of cars entering the freeway, are set according to current traffic conditions. So are variable messaging signs, which alert drivers to conditions on the road ahead. Accurate traffic flow measurements are also essential to Minnesota's 511 traveler information service.

One way of measuring traffic flow is by using loop detectors. These widely used devices consist of a large electrically powered wire coil embedded in the roadway. Each passing car triggers a change in the magnetic field of the wire, which is recorded by the detector.

Due to their accuracy, loop detectors have proven popular in the United States and Europe. But now Professor Rajesh Rajamani, research fellow Lee Alexander, and graduate Ph.D. student Krishna Vijayaraghavan, all with the Department of Mechanical Engineering, are developing a new battery-less, wireless traffic sensor that may offer even greater benefits.

Like the loop detector, the new sensor accurately measures traffic volume and vehicle speed, but it also provides new data such as vehicle length and the number of axles. In addition, it costs less than a loop detector, is easier to install, and is more environmentally friendly because it uses no energy.

The sensor consists of two components: a piezoelectric beam embedded in the road and a data processing unit located within a few hundred feet of the road. Cars passing over the beam cause it to vibrate. The vibration creates electric energy that is used to send information to the data processing unit.

Every time a vehicle passes over the beam, the sensor captures and stores energy. The harvested energy is more than enough to power the device and keep it running. Unlike a loop detector, which must be attached to an external power source, the beam is self-powering.

More than 6,000 loop detectors are currently in use in the Twin Cities metro area—one in every lane of every

mile of every major highway. Each loop detector must be continually powered, even at times when there is little traffic on the road. Because the new sensors do not depend on an external power source, their use would cut energy consumption.

Researchers estimate that the wireless sensors would cost less than \$100 each, compared to more than \$700 in hardware costs for a typical loop detector. The wireless sensors are easier to install because there's no need to connect the beam to a power supply or to other signal lines. The beam is also smaller than the loop, which means that highway crews would need to drill only a small slot in the roadway instead of laying the wire needed for the loop. As a result, there would be no need to close lanes and stop traffic for long periods of time during installation of the beam.

To design the sensor, the team developed several computer models and simulations. Using the data from these studies, the researchers built the prototype. They tested the device by placing it under a wooden ramp in a University parking lot and driving over it. Further testing was done in a vacant lot where the team placed the device in a hole and covered it with mud and gravel.

The researchers are now developing a smaller version of the piezoelectric beam. They are also working on an enhanced sensor that will measure vehicle weight in addition to length and number of axles. Future testing will compare the new sensor to existing sensors in terms of longevity and accuracy.

Ultimately, the team hopes to develop and evaluate a sensor network that can be used for short-term applications such as turn analysis at rural intersections. Rajamani estimates that the battery-less, wireless sensor will be ready for highway use in two to three years.

ANALYSIS OF UNINHABITED AERIAL VEHICLES: ITS CONCEPT OF OPERATIONS

Unlike metropolitan highways, rural roads lack sensors—usually cameras or loop detectors—to collect traffic data such as average speeds, car counts, and queue lengths. For this reason, engineers have been evaluating the use of miniature airplanes, known as remotely operated vehicles (ROVs) or uninhabited aerial vehicles (UAVs), to help collect some of this data.

Besides playing a useful role in rural areas and other locations where traffic sensors are rare, the vehicles could also be used to inspect roads, bridges, and other infrastructure. In emergencies, they could help with disaster management by transmitting pictures or serving as temporary cell phone towers.

In fact, says Demoz Gebre-Egziabher, assistant professor of aerospace engineering and mechanics, ROVs and UAVs were used in the recovery effort after Hurricane Katrina to look for signs of life in empty buildings and inspect damaged structures before rescuers were allowed to enter. In general, however, the use of ROVs and UAVs is currently banned by the Federal Aviation Administration (FAA). Research is permitted only in very restricted environments and under tightly controlled conditions. Regulators want to be sure that the vehicles will not crash into buildings or other planes and that they will not break up and fall into crowds or onto busy highways. In other words, just like large aircraft, ROVs and UAVs will need to meet safety criteria before they are allowed to fly.

As a first step toward creating safety criteria, Gebre-Egziabher and his research team (students Troy Wigton and Zhiqiang Xing, research scientist Greg Nelson, and research engineer Curt Olson) are identifying hazards associated with ROVs and UAVs and quantifying the likelihood of their occurrence.

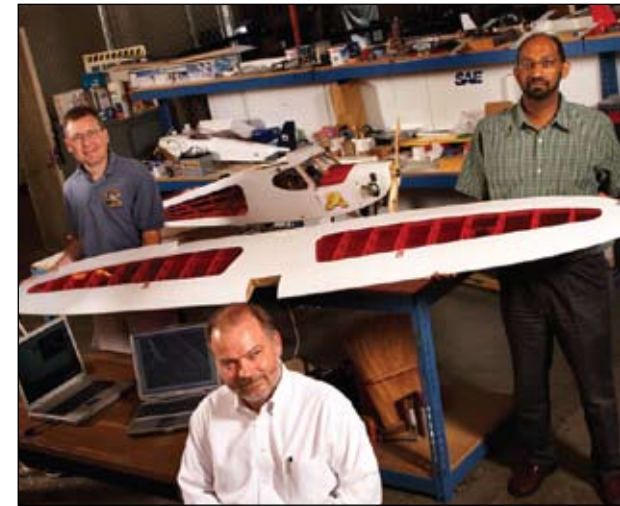
The first stage in this research involves determining the reliability of the computer systems in the vehicle. The researchers want to find out, for example, whether the Global Positioning System (GPS) provides sufficiently reliable information all the time.

But GPS is just one of many different systems in the vehicle. So during the second stage of their research, Gebre-Egziabher and his colleagues will determine the reliability of the mathematical methods used to combine information from multiple systems. This task resembles the navigational challenge faced by bats, Gebre-Egziabher explains. In the dark, bats rely on their natural sonar to avoid flying into a wall. In the light, they rely on their vision. When placed in a well-lighted room with a large window, bats will sometimes fly into or hit the window because they ignore their sonar and trust their vision.

To avoid a fate similar to the bat's and assure safe operation of the vehicle, the mathematical methods must determine when each system should be trusted and when it should be ignored. The researchers are focusing on a particular set of data used in these mathematical methods: the location and orientation of the vehicle—that is, where the vehicle is and which way it is pointed.

FAA safety standards are expressed in terms of mathematical odds, such as a one in a million chance of malfunctioning. Because safety standards for ROVs and UAVs have not yet been determined, Gebre-Egziabher and his colleagues are considering various odds. For example, if the standard is one in a million, developers would use a given method. For a standard of one in 100,000, the equations used in the mathematical methods might be slightly different.

The ultimate goal of the researchers is to create a methodology that federal and state agencies can use to develop safety standards for ROVs and UAVs. Such a methodology will also allow designers to develop hardware specifications that include operational requirements such as system reliability, required accuracy of location, and velocity estimation. In addition, operational procedure designers could use the methodology to determine the required qualifications for operators of remotely controlled planes.



Curt Olson, Greg Nelson, and Demoz Gebre-Egziabher with their remotely operated aerial vehicle

TRANSPORTABLE, LOW-COST TRAFFIC DATA COLLECTION AND WIRELESS SURVEILLANCE DEVICE FOR RAPID DEPLOYMENT FOR INTERSECTIONS AND ARTERIALS



The transportable data collection device, deployed next to a traffic signal

Many commuters spend at least part of their daily round trip on arterial streets as they drive to or from the freeway. And some don't use the freeway at all because their entire commute takes place on city streets.

Well-timed traffic signals on busy arterials can minimize stops and delays, which improves overall traffic coordination and reduces congestion. Fewer stops and delays also reduce energy consumption and pollution levels since drivers spend less time in intersections with car motors idling and emitting exhaust.

To time signals correctly, traffic engineers need to determine detailed traffic flow characteristics (vehicle counts and type, turnings, and queue size). But this is not easy to do because, despite recent advances in technology, most traffic engineering studies of intersections and arterial streets are done manually. In other words, someone must sit on the side of the road and count cars as they pass by.

Such studies are notoriously inaccurate. They also provide no visual record of traffic characteristics for verification, analysis, or research that could lead to improved safety and control practices. This means that traffic engineers must rely on the *Highway Capacity Manual*, which is generally inadequate for the advanced applications dictated by current ITS requirements.

Manual studies are costly, time-consuming, and logistically difficult. As a result, these studies are performed only when absolutely necessary—because of reconstruction, congestion, unusually high crash rates, excessive public complaints, or emergency situations.

But this may soon change. University of Minnesota researchers are working on a stand-alone data-collection and video-surveillance system that is inexpensive and nonintrusive. A rapidly deployable and easy-to-use device is being developed by civil engineering professor Panos Michalopoulos, Minnesota Traffic Observatory manager Ted Morris, and civil engineering graduate student Jory Schwach.

Their goal is to create a device that will automatically measure traffic volumes, turning movements, speeds, and other characteristics of traffic operations at intersections and urban arterials. It will also provide a video record, which will allow surveillance and visual verification of traffic data.

To develop the required specifications for the apparatus, Michalopoulos, Morris, and Schwach consulted with a panel of researchers, engineers, and practitioners in the field of traffic data collection. The team determined that the device should:

- Be constructed from off-the-shelf components for less than \$5,000;
- Include both video detection and recording capabilities;
- Include a video camera on a self-raising mast at least 30 feet high;
- Require no more than 15 minutes to set up and take down;
- Be portable enough for one person to set up;
- Be weatherproof; and
- Have the ability to record for long periods without its battery needing to be recharged.

In addition, wireless camera control and data acquisition are under development and will be added to the current prototype.

To test the apparatus, researchers are deploying it at five intersections in the Twin Cities metropolitan area. The intersections were chosen because they represent the five most common designs used in American cities. During each deployment, the system will record week-day morning, mid-day, and evening peak-hour travel times over the course of one week—producing about 40 hours of video. Once the test is complete, the research team will manually verify all the automatically extracted traffic data against the video record.

The apparatus will also be deployed in the middle of the block preceding the intersection to measure vehicle speeds and volumes immediately upstream of the intersection site.

In the future, multiple systems could be deployed simultaneously to collect data along critical corridors. Researchers also hope to further develop the apparatus so that it will one day have the capability of automatically extracting left and right turns within a given intersection.

The new device promises to provide traffic engineers with more detailed data and a greater ability to verify its accuracy. This will allow engineers to create better strategies for arterial operations and to improve inner-corridor traffic management.



Jory Schwach, Panos Michalopoulos, and Ted Morris

ACCESS TO DESTINATIONS: ESTIMATION OF ARTERIAL TRAVEL TIME

Access—or how long it takes people to reach necessary or desirable destinations such as jobs, stores, or movie theaters—is one of the most important concepts in transportation planning, but to determine accessibility, planners need accurate estimates of travel time. Freeway travel time is easily estimated due to the presence of loop detectors—electrically powered wire coils embedded in roadway that measure traffic flow. Yet not all travel takes place on the freeway. Every automobile trip includes at least some time spent on arterial streets, and some trips take place entirely on arterials. But since detectors are not built into arterials, travel time on these streets is more difficult to measure. For this reason, planners must rely on mathematical models or equations.

Although mathematical models work well for estimating freeway travel time, they are not always accurate for arterial travel time. That's because traffic flow on arterials is controlled by traffic signals. As a result, accurate estimation needs to take into account factors such as the timing of the red and green lights, how long lights stay

green, and what proportion of vehicles pass through the intersection on a green light without stopping.

In a recent study, a component of the larger Access to Destinations Study, civil engineering professor Gary Davis and graduate student Hui Xiong compared travel-time predictions generated by five commonly used models to actual travel-time measurements made in the field.

(Access to Destinations is an interdisciplinary research and outreach effort coordinated by the Center for Transportation Studies. The first research component, Understanding Travel Dimensions and Reliability, focuses on improving the understanding of travel within urban transportation systems.)

The goal of Davis and Xiong was to determine which mathematical models produce the most accurate predictions of arterial travel time. Commonly used models can be divided into two kinds: those that include the effect of traffic signal timing and those that don't. Davis and Xiong wanted to determine whether a model that didn't take into account signal timing could produce a reasonably



Gary Davis

accurate forecast of travel time on arterial streets.

To find out, the researchers randomly sampled traffic flow on 50 arterial streets throughout the Twin Cities metro area. To measure actual travel time on a street segment between signals, two observers—one at either end of the segment—entered into a laptop computer the last three license numbers of as many passing cars as possible. The time each car arrived at a signal was also recorded. The license numbers and times were later matched to determine travel time between signals.

Davis and Xiong then compared the travel times recorded in the field with the estimated times generated by five commonly used mathematical models. To do this, they gathered information needed for each model, such as the length of each link and timing of signals. And they determined traffic volume by videotaping and

counting passing cars on each segment. This information was plugged into each model.

The researchers found that the two models that allowed for the inclusion of signal-timing information produced the most accurate results. The more precise the signal-timing information, the more accurate the prediction. But even when less precise “default” information about signal timing was included in the model, the estimated travel time was still acceptably accurate.

One mathematical model in particular—known as the Skabardonis-Dowling model—produced the best results, using both precise and default information. Davis and Xiong recommend that this model be used in the next phase of the Access to Destinations Study when researchers will analyze changes in travel time and accessibility and begin considering possible future policies.

SCHOOL TRAVEL AND THE IMPLICATIONS FOR ADVANCES IN TRANSPORTATION-RELATED TECHNOLOGY

School choice was created as an alternative to forced desegregation. It has proven popular with parents, allowed urban districts to retain white middle-class students, and is encouraged by the “No Child Left Behind” Act of 2001. But it has also had unexpected implications for transportation.

These days, it’s not uncommon for five students who live on the same city block to be bused or driven to five different schools in five different areas of town even though they all live within walking distance of the same neighborhood school.

Elizabeth Wilson became interested in the implications of school choice one morning as she biked near her home in St. Paul’s St. Anthony Park neighborhood. She found herself riding behind five school buses, choking on exhaust fumes, and wondering about the impact of busing on the environment, energy use, and transportation.

Wilson, an assistant professor at the Hubert H. Humphrey Institute of Public Affairs, decided to take a

closer look at school travel. The initial analysis was very simple: Wilson, Kevin Krizek, former researcher at the Humphrey Institute, and graduate student Ryan Wilson compared the PTA list from the neighborhood school attended by Wilson’s daughter with the list from a citywide school attended by the child of a friend.

They geocoded the addresses and, using national data, categorized each student as “walk” or “not walk.” For students in the “not walk” category, she created two scenarios: In the first, students took the bus. In the second, they were driven to school.

The researchers determined that compared with the neighborhood school, the citywide school had 6 times fewer walkers. Students traveled 4.5 times as many miles, and this travel created between 3 and 4.5 times the amount of criteria pollutants and greenhouse gases.

In the scenario with bus service, emissions were reduced and the number of miles traveled decreased by 30

or 40 percent compared to the scenario in which students were driven to school. No bus service reduced the cost to the school system. But in all scenarios, the neighborhood school came out ahead.

In the next phase of the study, Wilson, Krizek, and Julian Marshall, assistant professor of civil engineering, surveyed parents of grade school children in St. Paul and Roseville. The survey included questions about modes of travel, concerns about travel, and demographic information.

Survey results confirmed the initial analysis: distance from school affects the choice of travel mode. Results also showed that local data are useful. This includes information about actual rates of walking, busing, and driving, as well as the use of different modes of travel to and from school.

The most surprising finding was that white and non-white parents had different attitudes toward school travel. Non-white parents, for example, had more concerns about safety, including children's safety while waiting at the bus stop and walking home. They were less concerned about long bus rides, however. Researchers learned from school personnel that this was because many non-white parents used bus service as proxy childcare.

These concerns are extremely important in districts such as St. Paul, where the majority of students are non-white. In addition, transportation planners must think about school concerns, including cost, safety, and convenience.

The implications of school choice should also be considered when assessing programs such as Safe Routes to School. Such programs may not be effective if a high percentage of neighborhood children attend magnet or charter schools in other neighborhoods.

Ryan Wilson has continued this examination of school travel issues. He created two statistical models of travel behavior, using the data set created by Marshall, Krizek, and Elizabeth Wilson, along with a full sample of all elementary-age students in the St. Paul School District. Using these models, he analyzed and quantified the transportation effects of various education policies, such as no school



choice and school choice on a lesser geographic scale.

Among his findings: total walking and school bus travel is slightly greater from-school than to-school. Magnet schools draw from broader geographic regions than neighborhood schools and students are less likely to walk, not because of parents' attitudes toward travel, but simply because they live too far away. School district transportation costs are also greater for magnet schools because more magnet students ride the bus.

This research provides planners with a framework for examining different school choice or transportation policies and evaluating their impact on the school district budget, school choice opportunities, and active transportation.

"School choice matters," Wilson says. "The barriers to the deployment of new transportation technology are real and important. We hope that our work will provide the context needed by researchers who are investigating emerging technologies."

TECHPLAN—ITS AND PRIVACY: DEVELOPING NEW RULES FOR VIRTUAL ROADS

ITS technologies can give planners and engineers new tools that produce a safer and more efficient transportation system. However, because many of these technologies track and record the movements of individual citizens, scholars and legal advocates have begun to raise privacy concerns. Under the auspices of the TechPlan Program, a research program at the Humphrey Institute of Public Affairs funded by the ITS Institute, a team is investigating the implications of privacy law related to emerging ITS technologies. Thus far, State and Local Policy Program assistant director Frank Douma, along with research assistants Steve Frooman and Jordan Deckenbach, has found that while privacy protections for citizens on the open road

are quite sparse, the rapid development of these technologies may require a reconsideration of parts of the legal framework for privacy in America.

The United States does not currently have a comprehensive legal framework for privacy but instead relies on a nebulous web of state and federal constitutional provisions and statutes. The major issue in examining ITS is whether the ability of surveillance technologies to track and record where a specific vehicle has been, as well as predict where it may go, begins to impinge upon some of these protections.

Most broadly, the United States Supreme Court has declared that a right to privacy exists when there is an expectation of privacy and when society is ready to accept that expectation of privacy as reasonable. Though current jurisprudence and statutory regulations do not directly attempt to regulate ITS technology designs, a number of state legislatures and courts have begun to write and interpret laws concerning data practices, vicarious criminal liability, and privacy tort actions in ways that may affect the use of ITS.

One ITS technology application with potential legal implications is automated enforcement of traffic laws. Red-light intersection cameras, license plate recognition systems, and photo-radar technologies have begun to be tested and used in a number of jurisdictions around the United States. Proponents of these technologies cite increased road safety and needed relief for understaffed law enforcement agencies. Although these technologies have not been found to violate any stated privacy regulation, legal challenges centered on the issue of vicarious criminal liability have succeeded.

In a 2006 challenge to Minneapolis red-light enforcement cameras, the Minnesota Supreme Court ruled a Minneapolis ordinance—which held owners responsible when their vehicles were caught on camera running a red light—invalid, as it conflicted with state statutes that made the driver the liable party. Because the law held



Frank Douma and Jordan Deckenbach are investigating privacy law related to emerging ITS technologies.

owners responsible for infractions committed in their vehicles, it deprived them of due process through the automatic assignment of guilt. Proponents of automated enforcement technologies have countered that the issue of due process under criminal procedure requirements need not apply, as only civil penalties are levied on owners of a vehicle for red-light violations. Though this rationale has been accepted in Ohio and Washington, D.C., district court, the Minnesota Supreme Court rejected that argument, claiming petty misdemeanors, though not crimes, still fall under the rules of criminal procedure that demand a presumption of innocence.

Other legal issues with ITS technologies center on questions of the kind of data that are collected and who has access to that information. As much as ITS can be used to create safer and more efficient transitways, law enforcement agencies could also use ITS in fighting crime and advancing homeland security. ITS technologies might allow law enforcement officials to backtrack the activities of a suspect's vehicle or discover what vehicles were in a particular location at a certain time. Though at first consideration these uses seem beneficial to society, without proper legal limitations these technologies could be used to invade the private lives of innocent parties.

In *The Company v. United States*, the United States Court of Appeals for the Ninth Circuit found that the FBI's tapping of an onboard navigational system with a built-in cell phone in order to listen in on the private conversation of the vehicle's occupants was inappropriate. However, the court stated that the problem was not due to a potential privacy invasion, but because the tapping disabled the services of the system, most notably, the ability of the system to be continually available to contact emergency services at any moment. Consequently, it appears that should this technical problem be resolved, the knowledge that in-vehicle conversations can be legally tapped may deter people from using or buying this type of ITS technology, despite

the opportunity to otherwise obtain significant safety benefits from them.

Although the current privacy regulations do not pose a direct challenge to successful development and implementation of new ITS technologies, the current legal landscape still contains barriers that must be considered. Consequently, as ITS planners and engineers continue to develop new technologies, they may also find it useful to advocate for continued development of privacy and related protections that facilitate and support efforts to produce safer and more efficient transportation systems while also respecting the expectations of the users.



More information on the research projects listed in this section can be found on the ITS Institute's Web site at www.its.umn.edu/Research.

HUMAN PERFORMANCE AND BEHAVIOR

Janet Creaser and Michael Manser, Department of Mechanical Engineering
Development and Evaluation of a Second Generation In-Vehicle Driver Assistance for Teenagers to Facilitate a Reduction in Crash Rates

Status: *In progress*

Motor vehicle crashes are the leading cause of death for teenagers, with speeding, seat belt noncompliance, alcohol, and distractions serving as the primary contributors to an unacceptably high crash rate. In an effort to mitigate this situation, a prototype teen driver support system (TDSS) has been designed and developed. This computer-based system provides real-time feedback to teens on speed limit violations and warns of upcoming speed zone changes. A unique feature of this system is that speed limit feedback is relative to the speed limit posted on the roadway on which the teen is driving. By informing teens of speeding behavior, it is hoped this system will reduce teen crash rates.

To date, this project has integrated a smart-phone-based TDSS system into a vehicle, which has been tested within a small road network around the University of Minnesota. Additionally, a usability study of the TDSS has been completed for which a small sample of teen drivers (aged 18–19) drove with and without the system and then answered questionnaires about the TDSS and its functions. Data collection for this task is complete and data analysis is currently under way.

The second phase of this project is to develop a mechanism within the TDSS structure to provide feedback to parents when their teens have committed an infraction and to identify a tentative structure for graduated driver licensing (GDL)-related incentives and restrictions that will contribute to the overall goal of reducing the rate of teen deaths due to motor vehicle crashes.

Usability Evaluation of the Teen Driver Support System

Status: *Newly funded*

Motor vehicle crashes are the leading cause of teen fatalities. One approach to

reduce fatalities is graduated driver licensing (GDL) programs that limit teens' exposure to risky situations. However, these programs suffer from weak compliance monitoring because they are based on an honor system and depend on parent reporting. A teen driver support system (TDSS) is currently being developed by the ITS Institute that will allow parents to accurately monitor teens' driving behavior, with or without GDL restrictions. Additionally, the system provides real-time feedback to drivers about unsafe behaviors that are known risks factors for teen crashes.

The goal of this project is to conduct a usability review of the TDSS that will identify the extent to which parents and teens perceive it meets proposed expectations for monitoring behavior and increases safe driving behaviors, with and without GDL restrictions, and to make suggestions for design changes to improve the effectiveness and acceptance of the system.

Kathleen Harder, College of Design
Psychological and Roadway Correlates of Aggressive Driving (Phase II)

Status: *In progress*

This research was conducted to better understand the psychological and roadway correlates of aggressive driving. The study had two phases. In Phase I, survey data were used to investigate the relationship between personality, emotional, and behavioral variables and self-reported driving behavior. In Phase II, the findings were validated in a driving simulator experiment. The data yielded a number of interesting findings; in particular, there were significant differences in driving behavior between drivers characterized as "high hostiles" and those characterized as "low hostiles." The research focus on psychological traits, emotional states, and behavioral tendencies is proving to be a valuable way to understand aggressive driving behavior. A future goal is to begin the process for determining mitigating strategies.

Kathleen Harder and John Bloomfield, College of Design
The Effectiveness and Safety of Traffic- and Non-Traffic-Related Messages Presented on Changeable Message Signs (Phase II)
Status: *In progress*

This project is the second phase of a study conducted to examine the effects of changeable message signs (CMSs) on driver behavior. That research, which was conducted as a baseline study to provide an initial understanding of their effects, found that some drivers decrease their speed in the presence of CMSs currently used by the Minnesota Department of Transportation (Mn/DOT), and drivers decrease their speed more in response to AMBER Alerts than to time-specific traffic-related CMSs. Further, the study revealed that the content of both the AMBER Alert and the time-specific traffic-related CMSs was not readily understandable to drivers, and this affected their response to the signs.



This second phase of research compares the effects of newly developed messages (both a time-specific traffic-related message and an AMBER Alert) with data from the first phase of research. Comparisons focus on two areas: message comprehensibility and driver slowing behavior. In addition, given Mn/DOT's interest in knowing the effects on driver behavior of posting travel-time information on CMSs, another component of this study assesses the perceived value of travel-time information to the drivers who participate in the study. Real-world data associated with selected traffic incidents, collected at areas with CMSs by the Regional Traffic Management Center, are being analyzed to assess the effects of messages on driver behavior. A comparison of

real-world traffic data and driver simulator data will be made to the extent possible.

Michael Manser, Department of Mechanical Engineering (previous principal investigator: Nic Ward, formerly with the Department of Mechanical Engineering and now at Montana State University)
Generational Perspectives on Teen and Older Drivers on Traffic Safety in Rural and Urban Communities

Status: *In progress*

Traffic fatalities are a significant issue for society, especially for those who live in rural environments. On a state and national level, two distinct demographic groups emerge with the highest risk of traffic fatalities: teen drivers (under 20 years old) and older drivers (age 65 and above). To significantly reduce traffic fatalities, it is necessary to implement traffic safety interventions designed to target each of these high-risk groups.

The current study employed focus groups and structured questionnaires administered to each age group of at-risk drivers, and a draft final report has been submitted to the project sponsors. The data obtained from this study can be employed to support recommendations for the type and form of interventions likely to be most effective and acceptable within each risk group and community area.

Thomas Smith, School of Kinesiology, and Nikolaos Papanikolopoulos, Department of Computer Science and Engineering
Warning Efficacy of Active Versus Passive Warnings for Unsignalized Intersection and Mid-Block Pedestrian Crosswalks
Status: *In progress*

This study evaluated the efficacy of active versus passive warnings at uncontrolled pedestrian crosswalks by comparing how these two warning types influenced the behavior of drivers approaching such crosswalks. Vehicle-crosswalk interactions were observed at 18 sites with passive, continuously flashing, or pedestrian-activated warnings, yielding 7,305 interactions

in which no pedestrians were present and 596 interactions in which pedestrians were present. Vehicle velocities and accelerations were averaged for each interaction. Findings show no significant effect of warning type on overall velocities for either interaction type. With pedestrians present only, for average velocities at successive 5-meter distances from the crosswalk, a downward trend in velocities from 25 meters to 5 meters was observed for passive and active warning sites, but not for pedestrian-activated warning sites. Various lines of evidence point to a number of sources of ambiguity regarding the salience of uncontrolled crosswalk warnings, resulting in behavioral uncertainty by drivers interacting with such warnings. Mixed findings on the effects of warning type in this study point to the need for further analysis of this problem area.

Nic Ward (formerly with the Department of Mechanical Engineering, now at Montana State University)
Driving Performance During 511 Information Retrieval and Cell Phone Conversation Tasks, Combined Under Varying Levels of Traffic Density
Status: *Completed*

As a logical and necessary extension of previous research (Rakauskas, et al., 2005), this study aimed to assess the risk of cell phone use for traveler information applications—namely, while using Minnesota's 511 interactive voice response (IVR) menu.

First, detailed usage, utility, and usability evaluations of the MN511 were conducted. The goal of this design was to help harmonize the transfer of knowledge between access methods while also easing implementation concerns for the MN511 developers. Next, a simulated driving experiment was conducted with the goal of discovering whether using an IVR menu leads to more risky driving behavior compared to driving while not accessing a menu. It also allowed the researchers to see if changing the MN511 menu might affect driver performance. While using both phone menus, drivers seemed to compensate for the additional mental workload by delaying their

reactions until they felt comfortable taking action. There were no differences between the two menu types for the majority of driving performance measures.

This study addresses issues with the 511 IVR menus identified during the study and offers recommendations for future development.

Nic Ward (formerly with the Department of Mechanical Engineering, now at Montana State University) and **Michael Rakauskas**, Department of Mechanical Engineering
Rural and Urban Safety Cultures

Status: Completed

The number of annual traffic fatalities and the rate of fatalities per vehicle-mile traveled are considerably higher in rural areas compared to urban areas. This project aimed to be one of the first studies to systematically explore the contribution of rural driver attitudes and behavior that may be a causal factor of these trends.

The researchers first conducted a survey of self-reported driver behavior and traffic safety attitudes. The analysis of this survey examined differences between rural and urban drivers in terms of risk taking and attitudes toward safety interventions proposed as part of the Minnesota Comprehensive Highway Safety Plan. The results suggest that rural drivers engage in riskier behavior such as seat belt noncompliance and driving while impaired because they have lower perceptions of the risks associated with such behaviors. Moreover, rural drivers perceive lower value in government-sponsored traffic safety interventions than their urban counterparts.



The researchers then measured driver behavior from driving simulator experi-

ments that compared the driving behavior of rural and urban drivers during traffic scenarios that embodied common crash factors (distraction, speeding, car following, intersections). The results suggest that the rural environment may encourage less safe driving. This study provides policy suggestions for developing safety interventions designed for the psychosocial factors that define rural culture.

Xun Yu, Department of Mechanical and Industrial Engineering (Duluth)
Real-Time Nonintrusive Detection of Driver Drowsiness

Status: In progress

Driver drowsiness is a major cause of serious traffic crashes. Continuous monitoring of drowsiness is therefore important for reducing crashes that result from it. This research aims to develop a real-time, non-intrusive driver drowsiness detection system. Biosensors will be built on the automobile steering wheel to measure a driver's heartbeat. This will enable heart rate variability (HRV), a physiological signal with established links to waking and sleeping stages, to be analyzed to detect driver drowsiness. The novel design of measuring heart rate from biosensors on the steering wheel means the system will cause little annoyance for the driver, while the use of physiological signals will ensure the accuracy of the drowsiness detection.

To date, the researchers have developed the heart-rate measurement systems both on the steering wheel and on the back of the driver's seat. An adaptive noise cancellation system has also been developed for canceling baseline measurement noise. Both systems have been tested in the lab with several subjects and for different situations, such as the measurement on the seatback with different cloth materials. They are currently working on the HRV analysis and building a driving simulator. Human subjects will be recruited for lab tests in the second phase, and the researchers also plan to prototype the system and install it on an actual vehicle for real-world data collection.

Real-Time Nonintrusive Detection of Driver Drowsiness (Phase II)

Status: Newly funded

This project is an extension of a previous project (Real-Time Nonintrusive Detection of Driver Drowsiness) that aims to develop a real-time, nonintrusive detection system to reduce crashes resulting from driver drowsiness. In this phase, biosensors will be built on the vehicle's steering wheel and the driver seatback to measure the driver's heart beat. Heart-rate variability (HRV), a physiological signal that has established links to waking/sleepiness stages, can thus be analyzed from the pulse signals to detect driver drowsiness. The novel design of the system (measuring heart rate from biosensors on the steering wheel and seatback) causes minimal annoyance for a driver, and the use of physiological signals ensures the accuracy of drowsiness detection.

In Phase I, a biosensor with a pair of electrodes built on the steering wheel was tested for measuring heart rate for HRV analysis. However, this design requires a driver to place both hands on the steering wheel. In Phase II, the researchers will design a biosensor that can measure heart rate when only one hand is on the steering wheel, which occurs more often in actual driving situations. In Phase II, the project will also incorporate real-world data acquisition and tests.

COMPUTING, SENSING, COMMUNICATIONS, AND CONTROL SYSTEMS

Max Donath and Craig Shankwitz, Department of Mechanical Engineering
Toward a Multi-State Consensus on Rural Intersection Decision Support

Status: In progress

The intersection decision support (IDS) research project was originally sponsored by a consortium of states (Minnesota, California, and Virginia) and the Federal Highway Administration (FHWA), whose objective was to improve intersection safety. The Minnesota team's focus was to develop a better understanding of the causes of crashes at rural unsignalized intersections and then develop a technology solution to address the cause(s).

In the study mentioned above, a review of Minnesota's rural crash records and past research identified poor driver gap selection as a major contributing cause of rural intersection crashes. Consequently, the design of the rural IDS technology has focused on enhancing the driver's ability to successfully negotiate rural intersections by communicating information about the available gaps in the traffic stream to the driver. In order to develop an IDS technology that has the potential to be nationally deployed, the regional differences at rural intersections must first be understood. Only then can a universal solution be designed and evaluated. To achieve this goal of national consensus and deployment, the University of Minnesota and the Minnesota Department of Transportation initiated a state pooled-fund study in which nine states are cooperating in intersection-crash research, and collecting data on driver behavior at selected intersections in participating states.



Max Donath, Michael Manser, and Craig Shankwitz, Department of Mechanical Engineering
CICAS Stop Sign Assist (SSA) System

Status: In progress

This research project is an extension of the intersection decision support (IDS) research initiative. Important results from IDS research include: (1) An analysis of rural expressway intersection crashes in Minnesota, including the development of a technique to identify intersections having crash rates higher than expected; (2) a statistical model that can be used to estimate or project the societal benefits of deploying a rural stop-sign assistant at rural intersections; (3) the design, development, and implementation of a comprehensive rural intersection surveillance and data acquisition system; and (4) a task analysis, design study, and simulator-based evaluation of innovative driver-infrastructure interface (DII) concepts.

As a follow-on to the IDS research, this project is a five-year effort culminating in a field operational test (FOT) performed at the Minnesota test intersection in Goodhue County. This research is separated into two components: a three-year, pre-FOT effort to finalize the design of the DII, and a two-year FOT to validate the safety benefits and driver acceptance of the system.

This project examined the possibility of integrating a cooperative element into the IDS system. Under the IDS program, no vehicle or driver information was delivered from the vehicle to the infrastructure. The infrastructure, however, did estimate vehicle classification using a laser-scanner-based system. This system was used to determine differences in gap acceptance as a function of vehicle length, height, and profile and to test the hypothesis that larger vehicles and older drivers require larger gaps.

John Evans, Department of Chemistry and Biochemistry (Duluth)
Detection of Water and Ice on Bridge Structures by AC Impedance and Dielectric Relaxation Spectroscopy (Phase I)

Status: In progress

This research aims to develop low-cost sensing systems for monitoring ice and water on bridge deck surfaces. These sensing systems are based on the measurement of impedance of the sensor in contact with or in close proximity to ice, water, or aqueous solutions of deicing chemicals. The researchers will explore two alternative technologies: impedance analysis at lower frequencies will determine the presence of deicing electrolyte solutions (a sort of “conductivity measurement”), while high-frequency dielectric relaxation using time domain reflectometry will probe the physical state of precipitation and deicing chemicals on the deck or road surface (via dielectric relaxation). In both approaches, the methodologies will use low-cost electrodes in the impedance analysis schemes.

Detection of Water and Ice on Bridge Structures by AC Impedance and Dielectric Relaxation Spectroscopy (Phase II)

Status: Newly funded

Based on the evaluation of competitive technologies in Phase I (impedance spectroscopy versus time domain reflectometry (TDR)), the researchers have decided to focus on the more viable choice of TDR. Experiments were carried out with prototype passive stainless steel sensors using TDR in a laboratory test fixture. These sensors gave unique responses when immersed in air versus liquid, and solid water versus liquid and solid electrolyte. Preliminary data analysis suggests that these media may be distinguished reliably at the 90 percent confidence level with appropriate pretreatment of the transients acquired from a given sensor. Future work will require examination of the need to calibrate each sensor and will also focus on more sophisticated chemometric- and neural network-based software to automate the analysis.

These software refinements are likely to become more important as the researchers move toward the second generation of sensor designs, which have appropriate geometries to be embedded in bridge deck and road bed installations. The first set of these second-generation sensors will be

evaluated in experiments carried out in the lab using a temperature-controlled testing stand. Pending these results, the researchers will apply refinements to the sensor design, hardware, and software and construct an outdoor test stand incorporating the optimized cell designs in a concrete pad to simulate the ultimate application. Although this test pad will not simulate all aspects of the final deployment format (e.g., traffic flow over sensors), it will provide a preliminary experience of installing sensor systems in a simulated bridge deck, including issues associated with cabling, fixture of the sensors, and the like.

Taek Kwon, Department of Electrical and Computer Engineering (Duluth) Development of a Portable Eight-Channel Weigh-in-Motion (WIM) Analysis System Based on Analog WIM Signals

Status: Completed

Weigh-in-Motion (WIM) data provide vital information for pavement design and maintenance. The purpose of this research project was to improve the present piezoelectric WIM technologies through a better system design and signal processing algorithms. Current WIM systems are only available as proprietary systems—i.e., the internal system design and algorithms are highly guarded, making it difficult to compare and improve the underlying technology. Therefore, the second objective of this research was to develop a WIM system based on an open architecture, using a standard personal computer and off-the-shelf components, and to publish the details of the design to promote an open architecture for continuous future improvements by other developers. The research team was able to successfully develop a working eight-channel WIM system, and the details are described in the project’s final report.

The main innovation introduced in this research is a hardware-in-the-loop (HIL) WIM simulator that can generate analog axle and loop signals through software control. The HIL simulator can create ideal axle signals as well as erroneous signal conditions that can be fed directly into WIM systems. The main advantage of using

a WIM HIL simulator for developing a WIM system is that the developers may run an unlimited number of signal tests without actually driving a single vehicle through the WIM sensors, thereby significantly reducing the development time and cost. The erroneous signal conditions generated by the HIL simulator can also identify the error-handling capabilities of a WIM system. The proposed HIL simulator for WIM system development is new and provides an elegant solution to the unavailability of an ideal axle signal.

Cellular Wireless Mesh Sensor Network for Comprehensive Spatial Traffic Movement Detection and Data Fusion (Phase II)

Status: In progress

This project continues research begun in fiscal year 2006–07 under the same project title, with the overall research goal of developing a practical method for detailed monitoring of traffic movements using a mesh network of wireless sensor nodes. The motivation for this approach is that low-power wireless nodes naturally form cell coverage areas that can be easily configured as a mesh network and used to detect the motion of vehicles in the coverage area. In the first year, anisotropic magnetoresistive (AMR) sensor nodes were designed and integrated with commercially available 802.15.4 chip sets to form the basic wireless node. Basic node-to-node protocols were then developed and implemented.

The objective of the second year of the study is to complete the development of the rest of the required protocols and software for the mesh network so that the network functions as a working prototype. The performance of the prototype will then be evaluated for tracking vehicle movements in an intersection. The main protocols required include a congestion control protocol and a set of network and sensor management protocols. Upon completion of the protocol implementation, a vehicle-tracking algorithm based on the aggregated sensor data will be developed. The completed system will be installed in a live intersection to evaluate the perfor-

mance of the network and to learn about the field installation and operational issues.

Development and Field Test of Advanced Dynamic LED Warning Signals for Unsignalized High-Speed Rural Blind Intersections Powered by Renewable Energy

Status: In progress

Motorists traveling through unsignalized, high-speed rural blind intersections, for which views of approaching or crossing vehicles are blocked, are known to be at high risk for crashes. Because static advanced warning signs or flashers at such intersections are largely ineffective at reducing crashes, the goal of this research is to develop and evaluate a new advanced warning system that economically integrates static signs described in the *Minnesota Manual on Uniform Traffic Control Devices* (MN MUTCD) into a dynamic sign system. The only difference in the sign itself is the addition of light emitting diodes (LEDs) on the circumference of the sign, a practice that is already approved by the Federal Highway Administration and used in Minnesota. In addition, the proposed advanced warning system actively detects vehicles in the proximity of the sign or intersection and utilizes that information for initiating or terminating the flashing of LEDs.

The first phase of this project comprises system design and instrumentation, and the second focuses on field implementation and evaluation. The main ITS technologies integrated in the system under development are low-power LED signals, wireless vehicle detection, and a self-sustainable renewable power supply.



Development of Data Warehouse and Applications for Continuous Vehicle Class and Weigh-in-Motion (WIM) Data

Status: In progress

The Mn/DOT Office of Transportation Data & Analysis (TDA) manages 29 vehicle classification (VC) sites and 6 weigh-in-motion (WIM) sites installed on various roadways in Minnesota, and the numbers are expected to grow significantly. With the potential growth of the number of VC/WIM sites and the corresponding amount of data, development of an efficient data warehousing and management system has become essential.

The purpose of this research is to develop an efficient VC/WIM data warehouse at the UMD Transportation Data Research Laboratory (TDRL) to provide the data analysis and reporting needs of TDA through online automation. This effort is an expansion of the present data system at TDRL that provides online data services to TDA, and a similar data service system will be developed and deployed for the VC/WIM data. For the data warehouse design, the characteristics of VC and WIM data will be carefully analyzed, and then the two types will be integrated as a single data resource from which data can be queried directly from both types. Since TDRL currently archives the statewide Road/Weather Information Service (R/WIS) data and the Twin Cities freeway traffic data, the addition of WIM and VC data is expected to increase the amount and quality of information by allowing cross-reference to various types of transportation data.

Development of a Weigh-Pad-Based Portable WIM System

Status: Newly funded

With the emphasis on mechanistic designs in the 2002 AASHTO design guide, weigh-in-motion (WIM) data have become more important, as the information is used as a primary input to pavement design. Also, the recent increase in heavy truck volumes on local roads raised great concerns for the life of existing roadway infrastructure, elevating the necessity of truck-weight data and enforcement. Installing many WIM sites could address these needs, but the in-

infrastructure cost for installing a permanent WIM site is expensive (over \$200,000) and requires recurring costs of electricity and communication. For county roads with limited average daily traffic (ADT), such a high cost of installation and maintenance is rarely justifiable.

One solution for bringing WIM technologies to local roads is to develop a low-cost portable WIM system. This research aims to develop a weigh-pad-based portable WIM system that can be easily installed and used much like a tube counter. The developed system will be battery operated, low cost, and easy to install on both rigid and flexible pavements. An additional benefit of the weigh-pad-based WIM system is that, since it does not cut into pavements during installation, it does not weaken the pavement structure. As a result, the system can be safely used in structurally sensitive areas such as bridge decks.

David Levinson, Department of Civil Engineering, **Kevin Krizek** (formerly with the Humphrey Institute of Public Affairs, now at the University of Colorado) and **Ahmed El-Geneidy** (formerly with the Department of Civil Engineering, now at McGill University)

Using Archived ITS Data to Improve Transit Performance Management

Status: Completed

The widespread implementation of automated vehicle location (AVL) systems and automatic passenger counters (APC) in the transit industry has opened new venues in transit operations and system monitoring. Metro Transit, the primary transit agency in the Twin Cities, Minnesota region, has been testing various intelligent transportation systems (ITS) since 1999. In 2005, it fully implemented an AVL system and partially implemented an APC system. To date, however, there has been little effort to employ such data to evaluate different aspects of performance.

This research capitalized on the availability of such data to better assess performance issues of one particular route in the Metro Transit system. The researchers used the archived data from the location systems of buses running on an example

cross-town route to conduct a microscopic analysis of performance and reliability issues. They generated a series of analytical models to predict run time, schedule adherence, and reliability of the transit route at two scales: the time point segment and the route level. The methodology included multiple approaches to display ITS data within a GIS environment to allow visual identification of problem areas along routes. The methodology also used statistical models generated at the time point segment and bus route level of analysis to demonstrate ways to identify reliability issues and what causes them. The analytical models showed that while headways are being maintained, schedule revisions are needed in order to improve run time. Finally, the analysis suggests that many scheduled stops along this route are underutilized and so should be consolidated.



Nikolaos Papanikolopoulos, Department of Computer Science and Engineering

Freeway Network Traffic Detection and Monitoring Incidents

Status: Completed

Shadow detection is an important part of any surveillance system, as it makes object shape recovery possible as well as improves accuracy of other statistics-collection systems. As most such systems assume video frames without shadows, shadows must be dealt with beforehand. This research proposes methods to distinguish between moving cast shadows and moving foreground objects in video sequences, including a multi-level shadow identification scheme that is generally applicable without restrictions on the number of light sources, illumination conditions, surface orientations, and object sizes.

The first level uses a background segmentation technique to identify foreground regions that include moving shadows. In the second step, pixel-based decisions are made by comparing the current frame with the background model to distinguish between shadows and actual foreground. In the third step, this result is improved using blob-level reasoning that works on the geometric constraints of identified shadow and foreground blobs. Results on various sequences under different illumination conditions show the success of the proposed approach. Finally, the researchers propose methods for physical placement of cameras in a site so as to make the most of the number of cameras available.

Counting Empty Parking Spots at Truck Stops

Status: In progress

This research is working to develop an automated truck stop management system that can compute occupancy rates at stops and notify drivers about the availability of parking spots using variable message displays located about 30 or 40 miles before the stop. The proposed system will detect, classify, and localize vehicles on the truck stop's grounds by using a set of video cameras, from which video frames will be analyzed in real time. Since precise knowledge of which stops are occupied will be available, variable message displays at the site of the stop itself will be able to direct drivers to free spots. Since in some cases it would be possible for two or more smaller vehicles to share a single parking spot, the system will also determine partial spot occupancy. The system will operate in two basic modes—a day mode and a night mode—which would typically require different methods for vehicle detection. In order for vehicle dimensions to be accurately estimated, the managed sites will be calibrated so that the correspondence between the camera views and actual site dimensions are available.

Data Mining of Traffic Video Sequences

Status: In progress

This project addresses the problem of data extraction from traffic video-sequenc-

es. The researchers automatically learn the layout of a traffic site (e.g., intersection) from trajectories of vehicles obtained by a vision-tracking system. This approach enables the automatic extraction of sophisticated and complex data such as unusual events, near misses, and vehicle trajectory clusters. The contributions of this work are focused on a novel adaptive technique for detecting moving shadows and distinguishing them from moving objects in video sequences.

Most methods for detecting shadows work in a static setting with significant human input. To remove these limitations, the researchers devised a more general semi-supervised learning technique to tackle the problem. First, they exploit characteristic differences in color and edges in the video frames to come up with a set of features useful for classification. Second, they use a learning technique that employs support vector machines and the co-training algorithm, which relies on a small set of human-labeled data. The research team observed a surprising phenomenon: co-training can counter the effects of changing underlying probability distributions in the feature space.

From the standpoint of detecting shadows, once deployed, the proposed method can dynamically adapt to varying conditions without any manual intervention and is better at classifying than previous methods on static and dynamic environments alike. The strengths of the technique are that it requires a small quantity of human labeled data and that it is able to adapt automatically to changing scene conditions.

Rajesh Rajamani, Department of Mechanical Engineering
Automated Winter Road Maintenance Using Road Surface Condition Measurements

Status: Completed

Real-time measurement of tire-road friction coefficient is extremely valuable for winter road-maintenance operations and can be used to optimize the kind and quantity of the deicing and anti-icing chemicals applied to the roadway.

In this project, a wheel-based tire-road friction coefficient measurement system was first developed for snowplows. Unlike a traditional Norse meter, this system is based on the measurement of lateral tire forces, has minimal moving parts, and does not use any actuators, making it reliable and inexpensive. A key challenge was quickly detecting changes in the tire-road friction coefficient while rejecting the high levels of noise in measured force signals. Novel filtering and signal processing algorithms were developed to address this challenge, including a biased quadratic mean filter and an accelerometer-based vibration-removal filter.

Detailed experimental results are presented on the performance of the friction estimation system on different types of road surfaces. Experimental results show that the biased quadratic mean filter works very effectively to eliminate the influence of noise and quickly estimate changes in friction coefficient. Further, the use of accelerometers and an intelligent algorithm enables elimination of the influence of driver steering maneuvers, thus providing a robust friction measurement system.

In the second part of the project, the developed friction measurement system was used for automated control of the chemical applicator on the snowplow. An electronic interface was established with the Force America applicator to enable real-time control. A feedback control system that utilizes the developed friction measurement sensor and a pavement temperature sensor was developed and implemented on the snowplow.



Automated Vehicle Location, Data Recording, and Applicator Control for Winter Road Maintenance

Status: In progress

The first component of this project is a detailed evaluation of the ability of a new friction measurement system to provide an accurate measure of road conditions and correspondingly a reliable performance measure for determining how well winter road maintenance has been performed. This component includes the development of a system that records friction coefficient as a function of road location, as well as studies to evaluate the ability of visual inspection to predict road surface conditions and whether recordings from the friction coefficient measurement system can serve as a reliable performance measure of all winter road maintenance tasks completed by a snowplow. The second component of this project is a detailed evaluation of the performance of a closed-loop system that utilizes friction measurement for automatic applicator control. This includes evaluating the performance of the applicator control system in terms of its ability to adequately apply deicing chemicals or sand on slippery spots on a road. Finally, the project enhances the developed automatic applicator control system by using real-time data from a geographical information system (GIS) that provides information on upcoming geometric road alignment and known problematic segments of roadway.

Automatic Safety Alert System for Work Zones with Flag Operators

Status: *In progress*

This project focuses on the development and evaluation of an automatic alert system for work zones that provides audio warnings both to the violating vehicle and to the flag operator and crew in the work zone so as to ensure their safety. The proposed system will be portable and will use radar-based threat assessment to predict potential work-zone intrusion. A special thin-film audio speaker system that provides a clear warning to a specific vehicle in the desired lane, while being less audible to neighboring vehicles in other lanes, will be developed. The project will also evaluate and compare a number of different audio warning signals to test their effectiveness.

In work completed so far, an audio system that can deliver directed acoustic warnings, which are 10 decibels louder in the intended highway lane compared to adjacent lanes, has been developed. Experiments have been conducted to evaluate the developed system.

New Battery-less Wireless Traffic Sensors as a Replacement for Loop Detectors

Status: *In progress*

See page 20 for coverage of this project.

Rajesh Rajamani, Department of Mechanical Engineering, and John Hourdos, Department of Civil Engineering Enhancement and Field Test Evaluation of New Battery-less Wireless Traffic Sensors

Status: *Newly funded*

In a previous project, this research team developed a new type of battery-less wireless traffic sensor. Each sensor consists of a very thin beam-like structure embedded in the roadway and includes all required electronics inside its structure. The sensor requires no batteries, electrical supply, or any other power source. It provides wireless transmission of traffic flow rate measurements to a roadside receiver several hundred feet away. Compared to existing inductive loop detectors, the new sensors have the additional advantages of being much easier to install (smaller, no power lines or any other wires) and of being significantly less expensive, more reliable, and consuming no energy.

In this project, the design of the sensor will be enhanced so as to significantly increase its wireless telemetry distance. It will be able to directly transmit traffic flow rate measurements to a circuit board in a regular traffic cabinet on the freeway. This would eliminate the need to have a roadside computer to receive signals. Since cabinets exist every 0.5 miles on all freeways and within 500 feet of all major traffic intersections, the traffic flow measurements can subsequently be received directly at the Mn/DOT Traffic Operations Center. Furthermore, the sensors will be enhanced so as to accurately measure vehicle speed (in addition to flow rate and number of

axes). Vehicle speed measurement will not require two consecutive sensors but will be done using just one embedded sensor in the roadway. Finally, the sensors will be used in a field test where their performance will be compared to traffic flow rate measurements from a camera-based infrastructure available at the Minnesota Traffic Observatory. Conducting the field tests and verifying the performance of the sensors under a variety of real-world conditions will firmly establish their credibility and lead to their subsequent use and commercialization.

Craig Shankwitz, Department of Mechanical Engineering Analysis of Highway Design and Geometric Effects on Crashes

Status: *In progress*

Forty percent of fatal highway crashes in Minnesota are road-departure crashes. Road geometry (e.g., curves or tangential sections) and road design (e.g., lane width, shoulder width, shoulder pavement type) likely play a role in these crashes. Previous research indicates that two key elements of design (horizontal curvature and shoulders) are primary factors affecting crash frequency and severity. However, the actual effect on crash frequency is not well documented; most of the cited safety strategies are considered experimental or tried (as opposed to proven), so that effectiveness ratios are questionable; also, none of the supporting data are from Minnesota.

This research will address these shortcomings. The first objective is to identify the features or characteristics associated with shoulders (type and width) and curve geometry (degree of curve and frequency) that affect road-departure crashes. The second objective is to determine, where design changes or countermeasures have been deployed, whether these practices or other countermeasures have quantifiably decreased the frequency and/or severity of these crashes. The third objective is to identify which emerging technologies could be used as an appropriate countermeasure(s) to reduce the frequency and/or severity of these crashes.

GPS Augmentation for Robust Lane Assistance

Status: *In progress*

To support a new non-contact sensor installed on a test bus, an improved means to estimate vehicle heading is required. Previous embodiments of the IV Lab system found that heading estimates with one-degree accuracy were sufficient to properly guide the bus, maintaining an error of approximately 10 centimeters in a narrow lane. However, when GPS is lost, the sensitivity of the non-contact guidance of the bus is extremely sensitive to heading initial conditions errors. Because of this, work is under way to improve the heading estimation of the bus when DGPS is available to improve the accuracy of the vehicle heading. The performance and design will be used to pursue a patent for this technique.

Guidance Augmentation Using a Vehicle Positioning System (VPS) for Transit Applications, Year 2

Status: *In progress*

In urban areas, Differential Global Positioning System (DGPS) devices suffer from problems with satellite view and with the reception of DGPS corrections over the cellular phone network. Moreover, the signals that do reach a GPS antenna suffer from multipath interference, producing high-variance position estimates. These DGPS issues are addressed by fusing the position information provided by a vehicle positioning system (VPS) based on radio frequency identification (RFID) technology with data from scanning laser sensors. VPS provides "which lane" in the "lateral" direction, and a path distance from a known reference in the "longitudinal" direction. From this, the location of a bus in a particular lane can be computed. Position within the lane can be determined using a horizontal laser scanner mounted on the bus, which identifies the presence and location of curbs in order to determine the position of the bus in the lane with respect to the curb. Integration of VPS information, laser scanner information, and a "map" representation describing the optimal distance of the bus from the curb as a function of distance traveled along a lane,

will provide the lane information needed for driver assistance in a dedicated lane. This project will produce a demonstration of a VPS-laser scanner-based positioning system capable of operating the IV Lab driver-assist system on an urban road in Minneapolis.



Multiuse, High-Accuracy, High-Density Geospatial Database

Status: *In progress*

High-accuracy (2–8 cm) DGPS and high-accuracy (5–20 cm) geospatial databases are the primary components of the IV Lab's driver-assistive systems. In addition to vehicle-based systems, the IV Lab geospatial database has found utility in other applications. For instance, the database has recently been used for the Intersection Decision Support (IDS) project, where 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. The geospatial database is used in this application 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 provides real-time access to extremely accurate, dense geospatial data. Because of this optimization, its functionality in other applications is somewhat limited. As new applications arise, a more global approach to the design of the existing geospatial database is required. This research is pursuing a redesign of the geospatial database and database manager and the development of a new front end to serve a wide application base.

In-Site Testing of State Patrol Vehicle Lighting, Retro-reflectors, and Paint

Status: Newly funded

More U.S. law enforcement officers are killed in collisions during roadside stops than are killed by felonious acts. A number of causal factors affect police safety at roadside stops, including conspicuity of the officer, conspicuity of the squad car, weather conditions, and the attention and fatigue level of drivers in oncoming traffic. Many officers have opinions as to what constitutes an optimal light bar arrangement (colors, vertical rows of lights, lighting patterns, brightness) and what are optimal markings and retro-reflective treatments for squad cars. This project will test lighting, retro-reflectors, and possibly paint (subject to State Patrol opinion) to determine whether particular combinations improve “move over” behavior of oncoming traffic. Tests will be performed at a fully instrumented rural intersection (U.S. 52 and County Highway 9 in Goodhue County) and will rigorously quantify and document the effects that lighting, retro-reflective markings, and (possibly) paint colors have on oncoming traffic during roadside stops. This project is a cooperative effort between the Minnesota Department of Public Safety, the ITS Institute, Emergency Automotive Technologies, Inc., and police safety equipment manufacturers. The goal is to provide insight and guidelines that may ultimately improve officer safety at roadside stops.

2-D Optical Sensor for DGPS Augmentation

Status: Newly funded

The Differential Global Position System is susceptible to outages due to blocked or missing satellite signals and/or blocked or missing DGPS correction messages. Outages arise primarily due to environmental reasons: passing under bridges, passing under overhead highway signs, adjacent foliage, etc. Generally, these outages are spatially deterministic and can be accurately predicted. The outages distract drivers using DGPS-based driver-assistive systems and limit the system robustness. Inertial measurements have been proposed as an augmentation

for DGPS. Tests have shown, however, that error rates for even emerging technologies are still too high; a vehicle can maintain lane position for less than three to four seconds. Ring laser gyros can do the job, but \$100,000 per axis is still too expensive for road-going vehicles. To provide robust vehicle positioning in the face of DGPS outages, the Intelligent Vehicles Lab has developed a technique (and applied for a patent) by which a non-contact, two-dimensional true ground velocity sensor is used to guide the vehicle. Although far from fully developed, the system can maintain vehicle position within a lane for more than 20 seconds. This research may lead to the development of an inexpensive two-dimensional non-contact velocity sensor optimized for vehicle guidance during periods of DGPS outages.

Shashi Shekhar, Department of Computer Science and Engineering Decision Support System for Evacuation Route-Schedule Planning

Status: Completed

Given a transportation network having source nodes with evacuees and destination nodes, the researchers aimed to find a contraflow network configuration, i.e., ideal direction for each edge, to minimize evacuation time. Contraflow is considered a potential way to reduce congestion during evacuations in the context of homeland security and natural disasters (e.g., hurricanes). This problem is computationally challenging because of the very large search space and the expensive calculation of evacuation time on a given network.

To the best of the researchers' knowledge, this work presents the first macroscopic approaches for the solution of contraflow network reconfiguration, incorporating road capacity constraints, multiple sources, the congestion factor, and scalability. The researchers formally defined the contraflow problem based on graph theory and provide a framework of computational structure to classify their approaches. A “Greedy” heuristic was designed to produce high-quality solutions with significant performance. A “Bottleneck Relief” heuristic was developed to deal with

large numbers of evacuees. They evaluated the proposed approaches both analytically and experimentally using real-world data sets. Experimental results show that their contraflow approaches can reduce evacuation time by 40 percent or more.

Hua Tang, Department of Electrical and Computer Engineering (Duluth) Development of a New Tracking System Based on CMOS Vision Processor Hardware (Phase I)

Status: In progress

This project is developing a hardware-based vehicle tracking system, retaining key elements of video-based tracking system design and using customized hardware whenever possible to shorten execution time, ultimately enabling real-time tracking at a high frame rate. Vehicle tracking processes on roads are computationally intensive. In the past, the different algorithms employed in vehicle tracking have been implemented using various software-based approaches. While software approaches have the advantage of flexibility in implementation and future modifications, the long computational time of these approaches often prevents real-time vehicle tracking from high-resolution spatial or temporal data.

The goal of this project is to build a tracking system with a new algorithm based on vehicle motion detection, which is implemented in hardware whenever possible so that the computation time for tracking is minimized. The proposed overall tracking system consists of two major components: a hardware processor for vehicle motion detection, and a tracking algorithm based on motion estimation. Developing this hardware-based tracking system requires three steps: first, validation of the tracking algorithm using realistic video inputs; second, implementing the algorithm in hardware; third, construction and testing. To date, tracking results have been largely validated and technical issues identified. Improvements to the algorithm are being made, and customized hardware design is on the way.

Peter Willemssen, Department of Computer Science (Duluth), Al Yonas,

Institute of Child Development, and Lee Zimmerman

Snow Rendering for Interactive Snowplow Simulation—Supporting Safety in Snowplow Design (Phase I)

Status: In progress

During a snowfall, following a snowplow can be extremely dangerous. This danger comes from the human visual system's inability to accurately perceive the speed and motion of the snowplow, often resulting in rear-end collisions. For this project, the researchers' goal is to use their understanding of how the human visual system processes optical motion under the conditions created by blowing snow to create a simulation framework that could be used to test emergency lighting configurations that reduce rear-end collisions with snowplows. Reaction times for detecting the motion of the snowplow will be measured empirically for a variety of color set-ups on a simulated snowplow that slows down while driving on a virtual road with curves and hills. The simulated driving environment will utilize a head-mounted, virtual reality display to render an improved snow cloud model behind the snowplow. This driving simulator environment will serve as the basis for testing the effects of color and lighting alternatives on snowplows. The results of this work will move the researchers closer to determining optimal color and lighting configurations on actual snowplows.



Snow Rendering for Interactive Snowplow Simulation—Supporting Safety in Snowplow Design (Phase II)

Status: Newly funded

In this project, the researchers will refine the snow simulation developed in previous work to provide a more realistic simulation

of blowing or falling snow surrounding a snowplow. This includes determining the optimal parameters for phase scattering, transparency, and ambient lighting terms. Aggregate snow modeling will also be included to produce a more thorough rendering system.

The researchers will develop the 3-D models for alternative lighting configurations on their 3-D snowplow model. Alternative paint color and materials will also be detailed. Based on experimental data collected in the last quarter of their previous project, the researchers will develop lighting configurations and paint colors and will run experiments to determine the best options. Finally, the data from those experiments will be analyzed and reported.

Since following a snowplow or any vehicle in snowing conditions is dangerous, designing snowplows that work within the limits of human perception may help prevent accidents. More generally, the results from this work may be applicable to all vehicles.

TECHNOLOGIES FOR MODELING, MANAGING, AND OPERATING TRANSPORTATION SYSTEMS

Gary Davis, Department of Civil Engineering
Cross-Median Crashes—Identifications and Countermeasures

Status: In progress

A cross-median crash occurs when a vehicle leaves its traveled way, 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 recognizes two countermeasures for prevention of cross-median crashes: (1) medians wide enough to provide adequate "clear zones" in which a driver can stop or regain control of the vehicle before crossing into the opposing traffic stream, and (2) when 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 reviewed the state of the art in median-crossing 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 goal of identifying those locations where countermeasure installation is most likely to pay off. Finally, this project will investigate method(s) for predicting the crash-reduction benefits of median barrier treatments on particular highway sections.



Gary Davis and Chen-Fu Liao, Department of Civil Engineering
Bus Signal Priority Based on GPS and Wireless Communications (Phase II: Signal Priority System Development)

Status: In progress

Providing signal priority for buses has been proposed as an inexpensive way to improve transit efficiency and productivity and to reduce operation costs. Bus signal priority has been implemented in several U.S. cities to improve schedule adherence, reduce transit operation costs, and improve customer ride quality. Current signal priority strategies implemented in various U.S. cities mostly utilize sensors to detect buses at a fixed or preset distance away from an intersection. Traditional presence detection systems, ideally designed for emergency vehicles, usually send signal priority request after a preprogrammed time offset as soon as transit vehicles are detected without the consideration of bus readiness.

The objective of this study is to take advantage of the already equipped GPS/AVL system on the buses in Minneapolis and develop an adaptive signal priority strategy that could consider bus schedule adherence, number of passengers, location, and speed. Buses can communicate with intersection signal controllers using wireless technology to request signal priority. Communication with the roadside unit (e.g., traffic controller) for signal priority can be established using the readily available 802.11x WLAN or the DSRC (Dedicated Short Range Communication) 802.11p protocol currently under development for wireless access to and from the vehicular environment.

This work is exploring proposed priority logic and its evaluation using microscopic traffic simulation. Simulation results indicate that a 12%–15% reduction in bus travel time during morning peak hours (7 a.m.–9 p.m.) and 4%–11% reduction during afternoon peak hours (4 p.m.–6 p.m.) could be achieved by providing signal priority for buses. Average bus delay time was reduced in the range of 16%–20% and 5%–14% during peak periods, respectively. The Phase II study is developing a prototype system

using GPS and wireless technologies to provide signal priority for buses. A test site at Como and 29th Avenues was selected, and the researchers will test the Minneapolis and University of Minnesota wireless coverage at the intersection.

Gary Davis and Henry Liu, Department of Civil Engineering

Access to Destinations: Arterial Data Acquisition and Network-Wide Travel Time Estimation (Phase II)

Status: In progress

This research (Phase II) is a continuation of the project on arterial travel time estimation (Phase I). In Phase I, a suite of link-performance functions based on the demand flow, traffic control, and geometric characteristics is being developed and evaluated. The expectation is that the recommended performance functions will produce plausible default estimates of travel times when given predicted flows and that these can be updated where and when field measurements are available.

In Phase II, field measurement data such as traffic volumes, speeds, and traffic control plans are being acquired and a relational database will be constructed through the integration of appropriate geographical information systems (GIS). The prime objective of Phase II is not only to compute default estimates of arterial travel times on all Twin Cities arterial links by applying the methods developed in Phase I, but to update these default estimates using the collected traffic data and incorporate these into the GIS-based relational database. Considering the correlation among network links, the travel time update with the link performance functions is significant and the methodology needs to be designed carefully. The final product of this project will be a database of arterial link travel times on the Twin Cities network for the years 1995 and 2005.

Robert Feyen, Department of Mechanical and Industrial Engineering (Duluth)

Assessing Coordination Between Agencies Involved in Traffic Incident Management

Status: In progress

One role of any state's department of transportation is managing adverse incidents that affect traffic flow within the interstate highway system under its purview. In most urban locations, management is accomplished through different agencies (e.g., police, fire, maintenance, and traffic operations), each with a stake in the overall traffic incident management (TIM) system. A literature survey indicates that, although prior studies have examined interagency coordination issues, relatively few have examined how the effectiveness of interagency efforts can be externally compared or internally assessed quantitatively. Further, numerous TIM systems in the United States report performance evaluation of interagency TIM activities as one area of activity for which little success has been attained.

This research project takes a two-pronged approach in proposing a quantitative basis for comparison and performance assessment. The first is an external benchmarking study, providing potential baseline metrics and methodologies for interagency TIM activities for use in justifying and communicating the benefits of TIM systems both to the public and to officials whose decisions significantly affect TIM resources. Along these lines, existing data sources and surveys administered to TIM personnel in seven urban areas across the country with similarities to the Minneapolis-St. Paul metro area have been used to document and compare the effectiveness of interagency coordination efforts. For the second prong, an internal analysis of interagency coordination will be conducted at the Minnesota Department of Transportation's (Mn/DOT) Regional Transportation Management Center, which oversees the Twin Cities metro highway system. In this prong, a review of communications during past incidents and in-person observations will be used to ascertain the current work procedures, information requirements, and knowledge sharing needed to coordinate efforts between various TIM stakeholders.

Demoz Gebre-Egziabher, Department of Aerospace Engineering and Mechanics, and **Ted Morris**, Department of Civil Engineering

Remotely Operated Vehicle Surveillance for Transportation Management and Security

Status: In progress

This project is investigating the technical and operational issues associated with using Unmanned Aerial Systems (UAS) for surveillance in support of transportation infrastructure management and security. The objectives are to develop a UAS from off-the-shelf components and to identify technical and regulatory issues that need to be addressed before UASs can be routinely and effectively used in intelligent transportation system (ITS) applications.



The work associated with the first objective resulted in the development of a low-cost, miniature, hand-launched aerial vehicle and supporting ground systems suitable for surveillance of highways and traffic infrastructure. Except for the ground station software, this system was built completely from off-the-shelf components.

The researchers also developed software that enhances ground station operators' situational awareness and allows simultaneous analysis of the data transmitted from the aerial vehicle.

Work on the second objective resulted in the development of an open-source guidance, navigation, and control (GNC) software suite for autonomous operation of small aerial vehicles.

Demoz Gebre-Egziabher and Greg Nelson, Department of Aerospace Engineering and Mechanics
Analysis of Uninhabited Aerial Vehicles—ITS Concept of Operations

Status: *In progress*

See page 21 for coverage of this project.

Nikolas Geroliminis and Panos Michalopoulos, Department of Civil Engineering
Development of the Next Generation Stratified Ramp Metering Algorithm Based on Freeway Density

Status: *Newly funded*

This project is a natural next stage of earlier successfully completed projects for improving Mn/DOT's stratified ramp metering strategy. One important potential improvement could be obtained if the total metering rates per zone were not calculated from flow measurements but rather from freeway density estimation. This is because (as shown in earlier research) while values of occupancy near capacity are quite stable, bottleneck capacity has stochastic variations, and a control strategy based on flow thresholds is likely to underload the freeway or, conversely, lead to traffic congestion.

This research will suggest ways of developing a new strategy by providing a methodology to accurately estimate densities based on data from loop detectors and explore the feasibility of integrating densities in the calculation of metering rates without violating the maximum ramp delay objective. Finally, the effectiveness of the new stratified ramp control strategy will be assessed by comparison with the current prototype version through microscopic simulation. Critical parts for this research are (1) the development of a methodology to accurately estimate densities for different lengths of stratified metering zones (0.5–3 miles long); and (2) the design of new ramp metering strategies. The metering strategy will explore two possibilities: a multilayer strategy similar to the existing algorithm employed by Mn/DOT, and a redesigned, coordinated (i.e., global) metering strategy using control theory.

M. Imran Hayee, Department of Electrical and Computer Engineering (Duluth)
Development of a Low-Cost Interface Between Cell Phones and DSRC-Based Vehicle Unit for Efficient Use of Vii Infrastructure

Status: *Newly funded*

To save lives and prevent injuries on roadways, intervehicle communication as well as communication between vehicles and the roadside is required. Dedicated Short Range Communications (DSRC), which was approved for licensing by the FCC in 2003, promises to partially fulfill this goal.

This research aims to take advantage of the DSRC infrastructure by designing, building, and demonstrating a wireless communication interface device that can act as a traffic-safety-information transportation agent between a DSRC vehicle radio unit and a cell phone (or a navigation system) inside a vehicle. By having this interface device along with the DSRC radio unit in a vehicle, any driver will be able to receive the valuable traffic safety messages on a cell phone or from an in-vehicle navigation unit. Furthermore, the feasibility of communicating directly with the DSRC roadside unit from this interface device to reduce the cost of widespread use will be explored.



John Hourdos and Gary Davis, Department of Civil Engineering
T.H.-36 Full Closure Construction: Evaluation of Traffic Operations Alternatives

Status: *In progress*

Transportation professionals are sensitive to public dissatisfaction with work-zone congestion, delay, and safety and are continually developing new approaches to

improve traffic operations in and around work zones. Transportation agencies are also challenged to balance the increasing need for work zones with mobility and safety concerns expressed by the public and government agencies. Full-road closure is one method that transportation agencies are giving increased consideration to during project planning and design as a potential way to balance these conflicting needs.

The purpose of this study is to analyze the effects and to measure the benefits of utilizing full-closure construction. This study has the unique advantage of using an actual ongoing project as a test case. Metro District has selected the full closure of Trunk Highway (T.H.) 36 to construct a project in North St. Paul. The current phase of the study is evaluating traffic operations and extracting performance measures from the four basic alternatives: no-build, build, non-full-closure construction, and full-road closure construction. This phase will provide valuable data for the cost/benefit analysis as well as effective traffic management on future full-road closure projects. The final product of this study will be a guide for engineers considering full road closure as a construction alternative in future projects.

The evaluation of the T.H.-36 full-road closure is accomplished in two different ways. First, detector and other measurements were retrieved and analyzed for the time periods before, during, and after the full-road closure. Second, a comprehensive microscopic model of the area of influence of the T.H.-36 construction project will be built and used to quantify the traffic operations performance during the full-road closure as well as the alternative partial closure. The field measurements have so far shown a larger-than-anticipated area of influence for the full closure and have suggested that the road users did not always follow the prescribed alternative routes serving the area. In addition, a number of local streets around the project area have shown higher than expected traffic patterns, but without leading to major congestion problems. The project is progressing with the development of the simulation model as well as with interviews with major proj-

ect stakeholders to gauge their opinion and retrospective comments regarding lessons learned.

Chen-Fu Liao and Gary Davis, Department of Civil Engineering
Bus Signal Priority Based on GPS and Wireless Communications (Phase III)—Bus to Roadside Infrastructure Communication Framework for Intelligent Transit Applications

Status: *Newly funded*

This study seeks to develop a shared wireless communication framework using the already installed 802.11x equipment on Metro Transit buses for various transit-related ITS applications. The research will explore the opportunity and investigate the feasibility of developing a scalable and multiple-use solution by utilizing the existing bus onboard systems (GPS/AVL and wireless radio systems) to communicate with other roadside equipment through the 802.11x protocols for signal priority request, security gate/garage door opening, or other ITS transit-related applications. Utilizing the existing hardware operating on the buses will reduce the additional expenses of hardware installation, labor, and maintenance. Development of a general wireless communication framework between a transit vehicle and a roadside unit for related ITS applications will eliminate potential system compatibility issues and help facilitate the deployment of ITS technologies for transit management and operation.



This study will build upon the knowledge from previous research work—Bus Signal Priority Based on GPS and Wireless Communications (Phases I and II). The goal of the Phase I study was to develop an adaptive signal priority strategy and to conduct evaluation and simulation of the Franklin

corridor from Dupont to 27th Avenues South in Minneapolis. The Phase II project is developing a prototype system using the existing AVL/GPS systems and evaluating the performance of the Minneapolis Wi-Fi infrastructure and a DSRC implementation, the 5.9GHz WAVE (Wireless Access in Vehicular Environment) radio for providing signal priority for buses.

Henry Liu, Department of Civil Engineering
Development of a Platoon-Priority Control Strategy and Smart Advance Warning Flashers for Isolated Intersections with High-Speed Approaches

Status: *In progress*

This research is in response to the Mn/DOT problem statement on traffic safety and operations requesting the development of an intelligent control system for isolated intersections with high-speed approaches, including platoon-priority control strategy and smart advance warning flashers (AWF). A significant number of Mn/DOT signalized intersections operate under isolated control. At many of these signals, it is common for an approaching vehicle platoon to face a red signal because of a single vehicle on one of the conflicting approaches. In addition, advance warning flashers, which warn motorists on high-speed approaches that the signal phase will be turning yellow, are used by Mn/DOT for selected intersections. However, the system introduces a trailing overlap of a fixed interval (leading flash) at the end of the arterial phase every cycle, which may cause some dilemma zone problems. To address these issues, the researchers aim to develop an intelligent traffic control system for detecting and moving forward platoons approaching a traffic signal with or without AWF to eliminate the dilemma zone problem and adapt to time-variant traffic conditions. To evaluate and improve the proposed control system, hardware-in-the-loop simulation will be used and system performance improvements will be quantified in terms of operational efficiency and safety.

The research team has developed an analytical model that can evaluate platoon-

priority traffic signal strategy under various conditions and is testing the platoon-priority strategy using the hardware-in-the-loop simulation.

Evaluation of Cell Phone Traffic Data

Status: In progress

Cellular phone tracking is a promising vehicle probe method that is likely to produce reliable travel-time information. To demonstrate the capabilities of a cell phone traffic data system, a pilot demonstration project was initiated by Mn/DOT in cooperation with a private contractor. As part of the demonstration project, traffic data provided by the contractor through cell phone tracking were evaluated and compared with data from alternative sources. The alternative travel-time data collected in the evaluation study include the freeway travel times generated using inductive loop detectors, travel-time runs using instrumented probe vehicles, and “ground truth” travel times determined by matching license plates through recorded video. A statistical data comparison and analysis was conducted, and results were summarized in the final report, currently in final review at Mn/DOT.

Responding to the Unexpected: Development of a Dynamic Data-Driven Traffic Operation Model for Effective Evacuation

Status: In progress

This research is responding to the current needs for innovative evacuation operation strategies and for evaluation of current evacuation planning models with advanced traffic models. The goal of this project is to advance the current state-of-the-art evacuation modeling from the planning stage to real-time and dynamic-operation stages by developing a suite of conceptual, analytical, and simulation models that are expected to function as real-time online tools for evacuation traffic management.

Recent natural and man-made disasters around the world have demonstrated the need for effective evacuation traffic management to maximize use of the transportation system. To “squeeze” the

spare capacity out of the current traffic network system and fully utilize the available network capacity within the evacuation time window, the researchers propose to develop a system optimal model that can generate time-dependent evacuation routes and intersection control strategies to minimize the total evacuation time. The computer model should take dynamic inputs such as road closures into consideration and must be able to generate solutions quickly. The transportation network of downtown Minneapolis is used in the model for testing purposes.

The research team has developed the analytical model that can provide the above functionalities and is coding the theoretical model into computer software, which will provide a user-friendly graphical interface.

Systematic Monitoring of Arterial Road Traffic and Signals (Phase II)

Status: Newly funded

This project is a continuation of the principal investigator’s ongoing research that focuses on the development of an arterial performance-measure system using traffic data available from existing signal systems. As part of the ongoing project, the SMART-Signals (Systematic Monitoring of Arterial Road Traffic and Signals) system is being developed and evaluated on 11 consecutive intersections of France Avenue in Hennepin County, Minnesota. The SMART-Signal system will be also tested on T.H.55 for 6 to 10 intersections, supported by Mn/DOT’s Innovative Ideas Program.

Currently, the SMART-Signal system can simultaneously collect and archive event-based traffic signal data and automatically generate real-time performance measures such as travel time and number of stops along an arterial, and delay, queue length, and level of services for intersections. This project aims to extend SMART-Signal’s capability for automatic diagnosis of operational problems and fine-tuning of signal control parameters. The ultimate goal is to develop a holistic framework that systematically measures, automatically fine-tunes, and realistically and practically models traffic flow on signalized urban

arterials. A significant opportunity to achieve this project goal lies in the fact that systematic monitoring of traffic signal systems is now feasible and implementable, given the recent advances in data collection technologies as demonstrated by the SMART-Signal system.



Henry Liu and Panos Michalopoulos, Department of Civil Engineering Development of a Real-Time Arterial Performance Monitoring System Using Traffic Data Available from Existing Signal Systems

Status: In progress

Despite recent developments in real-time measurement of freeway performance using routinely available loop detector data, no similar approaches exist for monitoring the performance of urban arterial street networks. This project aims to fill in that gap by developing a real-time online performance monitoring system for arterial streets. The arterial performance data will also be archived and made available to various stakeholders for operations, planning, research, and traveler information systems, similar to the way freeway performance data are used. In this project, data availability and requirements from existing signal systems will be analyzed, and algorithms for the estimation and prediction of real-time arterial travel time and speed will be developed depending on data resolution. The project has two distinct phases: the first will focus on the data from the existing system only, without additional field instrumentation; the second will attempt to obtain higher resolution data through the installation of additional field instrumentation.

Development of Algorithms for Travel-Time-Based Traffic Signal Timing (Phase I)

Status: In progress

With nationwide demonstrations taking place on vehicle infrastructure integration (VII), high-resolution probe data from VII-equipped vehicles may one day soon be available to traffic engineers. But the existing signal-timing optimization techniques are based on traditional loop-detector data and historical field data, and these models cannot utilize the full potential of VII-probe data. To fill this gap, this research aims to develop a real-time online or offline performance monitoring and signal optimization system for isolated and coordinated signalized intersections. How to combine multiple data sources (VII and non-VII sources) to provide a reliable and efficient traffic signal control will also be explored. To evaluate and improve the proposed control system, the researchers will use hardware-in-the-loop simulation and quantity system performance improvements in terms of operational efficiency and safety. The purpose of this project is to support Mn/DOT and its partners in evaluating uses and benefits of VII-related data in traffic management. As such, the project complements parallel efforts of the USDOT, VII-C, and others to design and deploy the VII network, vehicle equipment, and initial applications.

Panos Michalopoulos, Department of Civil Engineering

Access to Destinations: Twin Cities Metro-Wide Traffic Microsimulation: Feasibility Investigation

Status: Completed

Under the umbrella of the Access to Destinations Study, several research teams are working to produce new metrics for transportation system performance based on the concept of accessibility. A key challenge of this research effort is how to estimate future levels of accessibility based on today’s growth estimates, land use decisions, and development plans.

One way to overcome these obstacles lies with the recent rapid advances in simulation and modeling, specifically

microscopic simulation. A simulation model encompassing the entire metropolitan area has the potential to greatly improve researchers’ ability to estimate travel times across the entire transportation network under actual or hypothetical demand, control, and event scenarios.

This project investigated the feasibility of such a large simulation project. The researchers completed a comprehensive search of the state of the art in large urban simulation projects both nationally and internationally. Through extensive interviews the project team surveyed the needs and data availability of local stakeholders including city and county governments, the local metropolitan planning organization, Mn/DOT, and area consultants. Based on this information and a survey of state-of-the-art commercially available simulation applications, the research team concluded the investigation with two important findings. First, a correlation of the needed data based on simulator methodology and the closest available data set in the Twin Cities was concluded and reported. Then, based on this “reality check,” the research team proposed a feasible modeling framework that would serve most of the stakeholders’ needs as well as the needs of the Access to Destinations Study.

Employment of Traffic Management Laboratory for the Evaluation and Improvement of Stratified Metering Algorithm (Phase III)

Status: Completed

The evaluation results (done in Phase II) demonstrated that the stratified zone metering (SZM) strategy was generally beneficial. However, they also revealed that freeway performance was degraded by reducing the ramp delays. Therefore, the effectiveness of the current SZM control should be improved.

There were two objectives in this study. One was to improve the control logic of the current SZM strategy through an estimation algorithm for the refined minimum release rate. The simulation results indicate that the improved SZM strategy is very effective in postponing and decreasing

ing freeway congestion while resulting in smoother freeway traffic flow compared to the SZM strategy.

The second objective was to improve the current queue-size estimation. Depending on the counting error of queue and passage detectors, freeway ramps are classified into three different categories, and different methods are applied respectively for improved queue-size estimation. The surveillance video data were recorded and used to verify the improvement of the proposed methods. The results indicate that the proposed methods can greatly improve the accuracy of queue-size estimation compared to the current methodology. Also, the proposed method was evaluated by microsimulation, results of which indicate the performance of the freeway mainline is significantly improved, and total system performance is better than with the original SZM control.

Development of Real-Time Traffic Adaptive Accident Reduction Measures for the I-94/35W Commons Section

Status: In progress

The project had two major objectives: utilize the Minnesota Traffic Observatory's Digital Immersive Environment (DEN) to design and visualize different driver warning systems for the I-94 westbound high-crash location, and investigate the use of existing microsimulation models in the evaluation of safety improvements for the high-crash area. Although these objectives were not accomplished, the project has produced a number of meaningful results and contributions. These are: (1) development of an I-94 westbound 3-D model and vehicle trajectory integration and model-building methodology; (2) development of an I-94 westbound microscopic model; (3) a historical review of car-following models, as well as identification of the research needs behind the use of simulators for safety assessment; and (4) an analysis of empirical safety-related data and an understanding of the I-94 high-crash location traffic patterns.

Enhanced Microsimulation Models for Accurate Safety Assessment of Traffic Management ITS Solutions

Status: In progress

In recent years, various safety concepts and innovative ITS technologies have been proposed, developed, and/or implemented in the field aimed at improving roadway safety. To achieve the desired safety benefits while avoiding prohibitive and potentially hazardous field testing, it is critical that proposed safety treatments be extensively evaluated during the design stage and prior to actual deployment. To this end, microsimulation is potentially the most viable tool of choice due to its level of resolution and modeling realism. However, existing microsimulation models by design only target normal driver behavior in typical traffic conditions—e.g., either the functional structure or the parameter distributions of these models are deliberately constrained to outlaw unsafe behavior; thus explicitly excluding the occurrence of vehicle crashes.



Recognizing such limitations of microsimulation, this research developed an enhanced behavioral car-following model to be implemented in microscopic simulation for facilitating design, testing, and evaluation of safety treatments. Compared to existing models, this new model is built on findings from traffic engineering, human factors, and psychological research, taking into account drivers' perceptual thresholds, perception errors, anisotropy of reaction times, and anticipatory behaviors to allow for vehicle crashes while still capturing typical freeway traffic patterns. High-resolution real-life, crash-inclusive, and crash-free vehicle trajectories collected from the field, in conjunction with aggregated loop detector data, were employed to aid the model

development, calibration, and validation. The project utilized fully the Minnesota Traffic Observatory I-94 Field Lab, a permanent deployment of sensors and cameras at the area with the highest crash rate in the Twin Cities freeway network. The project has been concluded and the final report is currently being written.

Transportable Low-Cost Traffic Data Collection and Wireless Surveillance Device for Rapid Deployment for Intersections and Arterials

Status: In progress

See page 22 for coverage of this project.

Panos Michalopoulos and Henry Liu, Department of Civil Engineering Employment of Traffic Management Laboratory for the Evaluation and Improvement of Stratified Metering Algorithm (Phase IV)

Status: Completed

Freeway ramp control has been successfully implemented since the mid-1960s as an efficient and viable freeway management strategy. However, the effectiveness of any ramp control strategy largely depends on optimum parameter values, which are preferably determined prior to deployment. This is certainly the case with the current stratified zone metering (SZM) strategy deployed in the 260-mile freeway network of the Minneapolis–St. Paul metropolitan area.

To improve the performance of the SZM, which depends on the values of more than 20 parameters, this research first proposed a general methodology for site-specific performance optimization of ramp-control strategies using a microscopic simulation environment, as an alternative to trial-and-error field experimentation, and implemented the methodology with the SZM. The testing results show that the new SZM control with site-specific optimum parameter values significantly improves the performance of the freeway system compared to the original SZM strategy.

Second, this research proposed a methodology to explore the common optimum parameter values for the current SZM strategy for the entire Twin Cities freeway

system in order to replace the site-specific optimum values, which have little practical value because they are difficult to implement and it is time-consuming to search the site-specific optimum values for all freeway sections. The common parameter values are identified applying the response surface methodology (RSM) based on four specific freeway sections that represent all types of freeway sections in the metropolitan area.

Carissa Schively Slotterback, Humphrey Institute of Public Affairs, and John Hourdos, Department of Civil Engineering

Technology in Planning and Participatory Processes: Identifying New Synergies Through Real-World Application

Status: In progress

This project is examining the use of planning support systems (PSS) or technological enhancements in transportation planning processes. The goal is to identify opportunities for using technology in various types of participatory processes, such as open houses, public hearings, and technical/advisory committee meetings. The study will develop a typology of participatory processes, identifying their characteristics, including goals, participants, inputs, and outputs. Researchers will then identify associated technological enhancements tailored to the unique characteristics of different types of planning and participatory efforts and will examine the strengths and weaknesses of each technological enhancement, working closely with planning practitioners to identify an appropriate application and practical solutions. The results of the analysis will produce important feedback about ways to integrate technology into planning and participatory processes and further insights related to the importance of tailoring technology to various settings.

Xun Yu, Department of Mechanical and Industrial Engineering (Duluth) Intelligent Pavement for Traffic Flow Detection

Status: Newly funded

This project aims to explore a new approach for detecting vehicles on a

roadway by making a roadway section itself act as a traffic flow detector. Sections of a given roadway are paved with carbon-nanotube (CNT)/cement composites, and the piezoresistive property of carbon nanotubes enables the composite to detect the traffic flow. Meanwhile, CNTs can also work as reinforcement elements to improve the strength and toughness of the concrete pavement. In contrast to current traffic flow detection technologies that require separate devices to be installed in either the pavement or over the road, this proposed sensing approach would enable the pavement itself to detect traffic flow parameters. The proposed sensor, therefore, is expected to have a long service life requiring little maintenance and to have wide-area detection capabilities.

SOCIAL AND ECONOMIC POLICY ISSUES RELATED TO ITS TECHNOLOGIES

John Bryson, Melissa Stone, and Barbara Crosby, Humphrey Institute of Public Affairs

TechPlan—Technology and Collaboration in Effective Transportation Policy

Status: In progress

The problems faced by public managers today are often too large to be solved by a single entity and require collaboration across government, nonprofit, and business sectors. As new technologies and systematic approaches transform the transportation field, cross-sector collaboration has become an increasingly important policy development and implementation approach for policy-makers and managers. Intelligent transportation systems (ITS) and other technologies provide tools that both drive and enable collaboration to occur. Particularly within the transportation field, an assemblage of technologies is often critical to implementing system-wide strategies aimed at, for example, mitigating traffic congestion, ensuring highway safety, and increasing the mobility of people and goods. In many cases, designers and implementers of effective transportation policies must combine a variety of technologies with deft relationship building and management. Through in-depth analysis of the political, technical, and management processes required in the development and implementation of the Urban Partnership Agreement at multiple levels of government, this research study is examining how technology and collaborative processes may be combined to achieve important transportation goals and create public value more generally.

Frank Douma, Humphrey Institute of Public Affairs

Improving Car Sharing Transit Service with ITS

Status: In progress

In partnership with the Minnesota Department of Transportation and the University of Minnesota's Center for Transportation Studies, the State and Local Policy Program (SLPP) at the University of Minnesota's Humphrey Institute of Public Affairs has performed a wide range of previous research regarding development of

transportation policies enabled by intelligent transportation systems (ITS). Most recently, that research examined how ITS can serve Minnesota's increasingly diverse population and the increasingly diverse types of trips they take. Findings from that research showed that car sharing and advanced traveler information services (ATIS) were two ITS applications that could offer significant benefits.

The focus of this project is twofold: (1) to understand if and how being a member of a car-sharing program affects travel behavior and auto ownership of its members. In particular, the travel behavior and auto ownership of students at the University of Minnesota is of interest; and (2) to empirically investigate how citizen use of an e-government Web site (e.g., transit planning site) affects citizen/user trust and confidence in the related government service (e.g., the public transit system) and the public service agency (transit authority). Representatives from ZipCar, HourCar, and Metro Transit have agreed to serve on a technical advisory panel, which will help to inform and guide the research process. The results of this research will aid in developing policies for a diverse population with increasingly diverse transportation needs. Data collection for the car-sharing work is complete and analysis under way. Data collection is under way for the ATIS task, hosted on the Metro Transit Web site.



ITS and Privacy: Developing New Rules for Virtual Roads

Status: In progress

See page 26 for coverage of this project.

Thomas Horan, Humphrey Institute of Public Affairs and Claremont Graduate University

ITS and Safety Planning: ITS and EMS System Data Integration for Safety and Crisis Information and Decision-Making System

Status: In progress

SAFETEA-LU legislation mandates the creation of Strategic Highway Safety Plans (SHSPs) that are collaborative, comprehensive, and based on accurate and timely safety data. Transportation planners are challenged to identify and use a range of new data sources beyond traditional crash data systems. They must also identify strategies for sharing a wide range of data across multiple agencies to support evidence-based safety planning and emergency response. Correspondingly, while ITS has long promised safety benefits, there has traditionally been little emphasis on examining the extent to which emergency medical services (EMS) and trauma systems could provide safety-related data for both real-time benefits and assessment and planning purposes.

This research project is examining the linkages between EMS and trauma information systems and safety planning, focusing on the role of EMS and trauma to provide timely and visual-oriented safety data for system performance improvement and informed decision making. It will also consider how these systems might be adapted to the context of large-scale emergency and crisis planning.

Methods employed in this project include analysis of existing health-related data from safety reports (SHSP), EMS, trauma, and related health information systems. Analysis of these data sets will provide a multilayered understanding of statewide safety performance features. Feedback analysis from policymakers, planners, public health officials, EMS, safety engineers, and citizens will inform the usability, success factors, and value proposition of an enhanced ITS and EMS data system. Policy and planning recommendations, including those for safety and crisis planning, will be constructed, presented, and reported.

Case studies and development of emergency planning data architecture are under way. The literature search is largely complete, and researchers expect to begin receiving feedback on a preliminary product in the latter half of 2008.

David Levinson, Department of Civil Engineering

TechPlan—The Role of Social Networks and ICT on Destination Choice

Status: In progress

This research is investigating the impact of traditional social networks and information and communications technology (ICT) on travelers' destination choice. The extent to which social networks and information and communication technologies affect where destinations are located is an area that is gaining more focus. This research focuses on two areas of interest. The first is the role that social networks and communication technologies play in establishing individuals in long-term arrangements such as finding their work. The second is the role that social networks play in day-to-day activities that individuals choose to engage in outside of work. By using a survey about how people identified their current job, the physical locations of their social activity destinations, and the social networks and communication technologies they adopt to mediate these long-term and short-term decisions, this study aims to advance the researchers' understanding of the role of social networks in everyday travel decisions.

Thus far, a two-phase survey has been designed and administered to over 500 participants. In addition to data on work-finding mechanisms, detailed data on travel for different social activities including precise activity location, time, and purpose as well as relationship and individual characteristics, have been collected. The researchers hope to understand the behavior of social travel and to develop models that incorporate important elements of social networks and ICT for different trip purposes



Elizabeth Wilson, Humphrey Institute of Public Affairs, Kevin Krizek, University of Colorado (formerly, Humphrey Institute of Public Affairs), and Julian Marshall, Department of Civil Engineering

School Travel and the Implications for Advances in Transportation Technology

Status: In progress

See page 24 for coverage of this project.

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Liu, H., He, X. Z., and Jabari, S. (2008, January). A time constrained heuristic solution algorithm for dynamic system optimal routing under emergency evacuation. 87th Annual Meeting of the Transportation Research Board, Washington, D.C.

Liu, H., Wu, X. K., and Michalopoulos, P. (2008, January). Real-time freeway capacity estimation and implementation to ramp control. 87th Annual Meeting of the Transportation Research Board, Washington, D.C.

Liu, H., and Jabari, S. (2008, January). Evaluation of corridor traffic management and planning strategies using microsimulation: case study. 87th Annual Meeting of the Transportation Research Board, Washington, D.C.

Maclin, R. (2008, May). Early warning system for RWIS sensor malfunctions. 2008 NATSRL Annual ITS Research Day, Duluth, Minn.

Maclin, R., and Crouch, C. (2007, December). RWIS automatic sensor analysis tools. NATSRL annual board meeting, Duluth, Minn.

McGehee, D., Lee, J., Rakauskas, M., Ward, N., and Wilson, B. (2007, October). The effect of lateral drift and curve speed warnings on driver response. The 51st Annual Meeting of the Human Factors and Ergonomics Society, Baltimore, Md.

McGehee, D.V., Youland, R. S., Boer, E. R., Anton, D. C., Meyers, A. R., and Manser, M. P. (2007, September). The use of EMG and video to decompose driver crash avoidance and bracing response. 4th Driving Simulator Conference—North America, Iowa City, Iowa.

Papanikolopoulos, N. (2007, December). Camera networks for security applications. Computer Science Department, University of Southern California, Los Angeles, Calif.

Papanikolopoulos, N. (2007, June). Camera networks for security applications. Goodrich Corporation, Eagan, Minn.



Nikolaos Papanikolopoulos

Papanikolopoulos, N. (2007, October). Camera networks for security applications. Honeywell ACS Fellows Symposium, Minneapolis, Minn.

Papanikolopoulos, N. (2008, April). Camera networks for security applications. Lockheed Martin Corporation, Eagan, Minn.

Papanikolopoulos, N. (2008, January). Camera networks for security applications. Metro Transit, Minneapolis

Rakauskas, M. E. (2007, July). Using utility theory to evaluate IVR menu structure and reduce driving distraction. The 4th International Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design, Stevenson, Washington.



Michael Rakauskas

Rakauskas, M. E., and Ward, N. J. (2007, July). Identifying fatality factors of rural and urban safety cultures. The 4th International Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design, Stevenson, Washington.

Somasundaram, G., Hammond, C., Smith, T. J., and Papanikolopoulos, N. (2008, May). A vision-based system for studying the efficacy of pedestrian crosswalk warnings. Poster Presentation. CTS 19th Annual Transportation Research Conference, St. Paul, Minn.

Tilahun, N., and Levinson, D. (2007, July). Value of time comparisons in the presence of unexpected delay. Third International Conference on Transport Network Reliability, Delft, Netherlands.

Tang, H., and Kwon, T. (2007, August). Designing CMOS hardware processor for vehicle tracking. IEEE International Symposium on Circuits and Systems (MWSCAS 2007), Montreal, Canada.

Willemsen, P. (2008, May). Rendering falling snow for interactive snowplow simulation. 2008 NATSRL Annual ITS Research Day, Duluth, Minn.

Wilson, E. J. (2007, November). School travel and the implications for advances in transportation related technology. Advanced Transportation Technologies Seminar Series, University of Minnesota, Minneapolis.



Panos Michalopoulos

Xin, W., Hourdos, J., and Michalopoulos, P. G. (2007, October). Modeling collision-inclusive car following models. 14th ITS World Congress, Beijing, China.

Xin, W., Hourdos, J., and Michalopoulos, P. G. (2008, May). Crash data collection, processing and implementation to collision-inclusive traffic flow modeling. Applications of Advanced Technologies in Transportation (AATT) 2008 Conference, Athens, Greece.

Xin, W., Hourdos, J., and Michalopoulos, P. G. (2008, January). A vehicle trajectory collection and processing methodology and its implementation to crash data. 87th Annual Meeting of the Transportation Research Board, Washington, D.C.

Xin, W., Hourdos, J., Michalopoulos, P., and Davis, G. (2008, January). The less-than-perfect driver: model of collision-inclusive car-following behavior. 87th Annual Meeting of the Transportation Research Board, Washington, D.C.

Xing, Z. (2008, May). Modeling and bounding low cost inertial sensor errors. IEEE Position Location and Navigation Symposium 2008, Monterey, Calif.

Zhang, Y., and Tang, H. (2008, June). Towards a hardware-based system for real-time vehicle tracking. 2008 IEEE Intelligent Vehicles Symposium, Eindhoven, Netherlands.

Zhu, S., Levinson, D., and Zhang, L. (2007, January). An agent-based route choice model. 87th Annual Meeting of the Transportation Research Board, Washington, D.C.



Education

The ITS Institute's education activities consist of a multidisciplinary program of coursework and experiential learning that supports 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 supporting and sponsoring a variety of 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, giving 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.

SEMINAR SERIES BRINGS TRANSPORTATION EXPERTS FROM INDUSTRY, ACADEMIA TO MINNESOTA

The Fall 2007 Advanced Transportation Technologies Seminar Series featured University of Minnesota faculty and visiting researchers presenting their recent ITS-related work on a variety of transportation topics.

The burgeoning popularity of cellular phones, PDAs, and other mobile electronic devices has sparked heated debate about the potential for increased crash risk due to driver distraction. Louis Tijerina, a human factors researcher and driver distraction expert with the Ford Motor Company, presented an overview of recent research on this important safety question and on the more general issue of interface design for driving safety at a November 13 seminar.

Srinivas Peeta, director of the NEXTRANS Center at Purdue University, presented a December 4 seminar on methods for modeling the complex interdependencies

among civil infrastructure systems. The rapid growth of large urban centers, coupled with the expansion of networks providing transportation, energy, and communications, presents enormous new challenges to infrastructure managers, Peeta said. Recently, natural and man-made disasters have led to cascading system failures in many areas, highlighting the need to understand how multiple interdependent systems interact with each other.

Other presentations in the series were:

- “Driver Performance During 511 Traveler Information Retrieval,” Michael Rakauskas, research associate, HumanFIRST Program
- “Bus Signal Priority Based on GPS and Wireless Communications,” Chen-Fu Liao, senior systems engineer, Minnesota Traffic Observatory
- “Mass Transit Surveillance and Early Warning System,” Vassilios Morellas, program director, Department of Computer Science and Engineering
- “Influence of a Haptic Driver Support System on Information Processing, Attentional Resource Management, and Driving Performance,” Michael Manser, director, HumanFIRST Program
- “School Travel and the Implications for Advances in Transportation-Related Technology,” Elizabeth Wilson, assistant professor, Humphrey Institute of Public Affairs



Max Donath, seminar speaker Srinivas Peeta, and Henry Liu

This was the seventh year the Institute sponsored the multidisciplinary seminars, during which researchers report on findings from their work and bring new information to the ITS community. The series, which is a required course in the University’s Graduate Certificate Program in Transportation Studies, is offered as a one-credit graduate-level course, or attendees can earn one professional development hour for each seminar. Presentations are recorded onto DVD and are available for loan by request. Presentations can also be viewed as webinars, either live or downloaded at a later date, at www.its.umn.edu/Events/SeminarSeries/2007.

INTERACTIVE COURSE MODULES ENHANCE LEARNING

Understanding the complex dynamics that underlie traffic flows and intelligent vehicle guidance systems is a challenge many transportation engineering students grapple with every semester. Adding to the difficulty is the fact that simulation and modeling rely on expensive dedicated software and powerful computer servers, so students rarely have the opportunity to experiment and explore outside of course labs.

Now, University of Minnesota students are benefiting from greater access to simulation tools both in and out of the classroom, thanks to the work of Chen-Fu Liao, the Minnesota Traffic Observatory’s senior educational systems engineer. Liao has developed several interactive course modules to help students understand complex ITS topics such as intersection signal control and vehicle guidance.

Liao developed the Online Application for Signal Intersection Simulation (OASIS) and Roadway Online Application for Design (ROAD), both of which have been incorporated into the curriculum of the civil engineering department’s Introduction to Transportation Engineering course. OASIS allows students to examine the effects of different signal timing strategies on a simulated



An online learning module helps students examine the effects of different signal timing strategies.

intersection; ROAD is used to teach geometric design techniques for planning road alignments.

In the vehicle realm, Liao's Simulation Visualizer for Vehicle Guidance Control was used in the mechanical engineering department's Introduction to Robotics course in spring semester 2008.

The modules have been well received by instructors, and Liao is continuing to improve them and develop new tools that support interactive learning. He is already at work on a second-generation OASIS, which will incorporate hardware-in-loop interaction with the same signal controller hardware used by many traffic management agencies.

Pre-college students are also being exposed to transportation engineering issues through an online intersection control game aimed at high school science classrooms. The game is being integrated into a high school curriculum that will be used and tested at the University of Minnesota's Institute of Technology Summer Exploration in Engineering, Science and Math Camp. The camp, for women and diverse students, will be held in the summer of 2008. Liao's game is designed to help students understand the importance of predictable traffic timing and the effect of differing traffic flows on signal timing—all part of Liao's efforts to increase K-12 students' familiarity with transportation issues.

RAKAUSKAS NAMED STUDENT OF THE YEAR

Michael Rakauskas, a doctoral student in the University of Minnesota's Cognitive and Biological Psychology program, was presented with the ITS Institute's 2007 Outstanding Student of the Year Award at the Transportation Research Board's annual meeting in Washington, D.C., on January 12, 2008.

The award is sponsored by the USDOT Research and Innovative Technology Administration (RITA). Honorees receive a \$2,000 award as well as funding to travel to the TRB annual meeting.



*Michael Manser, Student of the Year recipient
Michael Rakauskas, and Gina Baas*

Rakauskas's current research focuses on reducing crashes and fatalities by improving the design of road environments and discovering ways to reduce driver impairment. He has led a number of studies evaluating driving performance when affected by alcohol intoxication or distractions such as phone conversations, information seeking, and common in-vehicle tasks. He has also worked on a number of other topics including the development and implementation of ITS technology to prevent crashes at high risk rural intersections; the design of visualizations and warnings to raise driver awareness of the road environment; nighttime pedestrian visibility; and safety cultures of rural and urban populations.

In addition to maintaining a 4.0 grade point average, Rakauskas has received several awards during his graduate studies. Before commencing his doctoral research at Minnesota, Rakauskas earned a master of science degree in applied psychology from Clemson University and a bachelor of arts degree in psychology from Miami University. He was nominated for the award by Michael Manser, director of the HumanFIRST program.

STUDENTS GET INSIDE LOOK AT TRANSPORTATION TECHNOLOGY

The ITS Institute hosted several groups throughout the school year interested in learning more about the types of advanced transportation research carried out at the University.

In August, a group of prospective Institute of Technology students were given a tour of the Minnesota Traffic Observatory (MTO) facilities as part of their visit to the University of Minnesota campus. The group, whose members were interested in pursuing science and engineering education at the University, heard from senior educational systems developer Chen-Fu Liao and MTO lab manager Ted Morris about the lab's data gathering, simulation, and visualization capabilities.

Center for Transportation Studies (CTS) director

Robert Johns welcomed a class of first-year engineering students to the MTO in October. The class, which focuses on writing and communication skills for science and engineering, heard about the importance of communicating research results to foster successful implementation.

In February, a group of undergraduate and graduate students from the University of Manitoba (Canada) viewed the ITS Institute's facilities, toured the Minnesota Valley Transit Authority bus with IV Lab program director Craig Shankwitz, and learned about bus signal priority research in the MTO.

Twelve students and two teachers from the Blaine High School Center for Engineering, Math, and Science visited CTS and the ITS Institute on April 23. The Center is a specialty program within Blaine High School offering an integrated and rigorous, in-depth program in mathematics, science, and engineering. The visit aimed to give students a perspective on transportation engineering and transportation careers. Students spent time learning about the uninhabited aerial vehicle in the aerospace engineering department, traffic monitoring and simulation research in the MTO, and earthquakes and structures in the civil engineering department.

Shawn Haag, program coordinator for CTS, said the students' reactions were enthusiastic. "The visit really opened their eyes," he said, referring to the variety of work and research in transportation. When asked who would consider transportation as a potential career, over half raised their hand.

COMMUTER VEHICLE A HIT WITH YOUNG LEARNERS

A prototype narrow commuter vehicle being developed by University of Minnesota researchers with ITS Institute funding proved a popular attraction at the University's Institute of Technology Alumni Society annual TechFest. The event, which aims to interest grade-school-age students in science and technology, is held every year at The

Works, a "hands-on" science and technology museum for children aged 5 to 15. This year's event drew more than 1,000 visitors—the largest one-day attendance in the museum's history.

Lee Alexander, a member of the team of engineers developing the vehicle, accompanied the prototype and explained the vehicle's cutting-edge features to children—and their commute-savvy parents.

The design features two wheels in front and a single wheel in the rear, and the vehicle tilts automatically when turning. Tilting is necessary to achieve stability and safety with a relatively tall and narrow chassis. The driver never has to worry about how to tilt—a sophisticated computerized steering system handles all the necessary wheel and suspension adjustments to keep the vehicle safely upright when taking corners.

While the narrow commuter vehicle may be years away from appearing on city streets, some of the young learners who visited TechFest might find themselves at



Lee Alexander demonstrates the narrow commuter vehicle for kids attending TechFest.

the controls of a similar set of wheels when they are old enough to drive—or they might be inspired to go on and design their own innovative vehicles.

INSTITUTE FUNDS STUDENT TRAVEL

University of Minnesota students joined ITS Institute researchers again this year at the Transportation Research Board Annual Meeting in Washington, D.C. Twenty-two students received travel awards from the Institute to travel to the meeting, where they attended presentations and workshops by researchers from around the world and enjoyed networking with fellow scholars. The students sponsored were Adam Danczyk, Joran Deckenbach, Saif

Jabari, Wenteng Ma, Jory Schwach, Nebiyu Tilahun, Carly Turgeon, Ryan Wilson, Xinkai Wu, Feng Xie, Hui Xiong, Kelcie Young, and Shanjiang Zhu.

During the past year, the Institute also funded Michael Rakauskas to attend the 4th International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design in Stevenson, Wash.; Chinweikje Eseonu to attend the American Society for Engineering Management National Conference in Chattanooga, Tenn.; Zhiqiang Xing to attend the Position, Location, and Navigation Symposium in Monterey, Calif.; and Pavithra Parthasarathi to attend the Women's Transportation Seminar International conference in Atlanta, Ga.



Students attending the Summer Transportation Institute toured the Minnesota Traffic Observatory.

CAREER EXPO HIGHLIGHTS TRANSPORTATION CAREERS

The ITS Institute teamed up with CTS, the Minnesota Local Road Research Board, the Minnesota Local Technical Assistance Program, the Women's Transportation Seminar, and the Council of Supply Chain Management Professionals to host the 13th annual Transportation Career Expo, held March 13 in Minneapolis. Speakers from the public and private sectors shared advice with students on three transportation-related career tracks: engineering and intelligent transportation systems (ITS) careers, transportation planning and policy careers, and transportation logistics careers.

TRANSPORTATION CAMP SPARKS INTEREST IN SCIENCE CAREERS

Surrounded by a 3-D box in the Minnesota Traffic Observatory and fitted with a University of Minnesota baseball cap and sunglasses, ninth grader Sean Perrin expressed his excitement about the virtual world he had just entered.

“It was sweet,” he said. “The buildings, the light poles—it’s just like going out into the street.”

Creating the attitude that the work of engineers is “sweet” is exactly what the Summer Transportation Institute hopes to achieve each summer when it visits the University of Minnesota. The Institute is a camp held by the Fond du Lac Tribal and Community College and funded by the U.S. Department of Transportation. For its fifth consecutive year, high school students from Cloquet, Minn., and the surrounding communities, including the Fond du Lac Reservation, viewed some of the newest research projects at the Minnesota Traffic Observatory and the Department of Aerospace Engineering as well as Mn/DOT’s FIRST (Freeway Incident Response Safety Team) vehicle. The freeway service patrol vehicle is used on Minnesota roads in an effort to reduce any additional traffic problems that can occur after car crashes.

The summer camp’s stop at the University last July was one of many parts of the program that offers high school students the opportunity to explore the sciences for a full week in hopes of encouraging more young people to go to college and seek degrees in “STEM” disciplines—science, technology, engineering, and math.

“Some of these kids will be the first in their families to go to college,” said director Holly Perlerin. “They have a new mindset and start thinking about college and careers.”

This year, the participants took a peek at the Minnesota Traffic Observatory’s various projects, including a satellite aerial map of Denali National Park projected onto the interactive GIS table and streaming video of traffic in the Twin Cities. Perrin and others also tested the 3-D box in the observatory, which allows people to walk through the University campus projected on the surrounding walls. The aerospace department gave students a first-hand look at flight simulations and a miniature aircraft. Finally, they learned about Mn/DOT’s FIRST vehicle and the role it plays in improving safety on Minnesota highways.

Perlerin said the program is meant to give the kids a “hands-on approach” to what they can do if they pursue careers in math and science and, she hopes, give them the confidence to eventually attend the University.

CIVIL ENGINEERING STUDENT RECEIVES HUBER AWARD

Nebiyu Tilahun, a student in the University’s civil engineering Ph.D. program whose research includes ITS-related work, was one of two recipients of this year’s Matthew J. Huber Award for Excellence in Transportation Research and Education. Tilahun is in the final year of his civil engineering Ph.D. program and has done “much innovative work,” said David Levinson, his advisor. Tilahun’s work on the value of different features of bicycle facilities, which made up his master’s thesis, was incorporated into National Cooperative Highway Research Program (NCHRP) report 552, *Guidelines for Analysis of Investments in Bicycle Facilities*. Tilahun said the Huber award encourages him to continue his work in the field.

The Huber award is presented annually to University of Minnesota graduate students demonstrating an outstanding contribution in research, writing, and educational activities in the field of transportation.



David Levinson, Huber award winner Nebiyu Tilahun, and Gina Baas



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 printed pieces, 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.

PROFESSOR WORKS WITH COUNTY ON 'SMARTER' SIGNALS

A University researcher's work with Hennepin County could offer some relief for congested city streets. Assistant civil engineering professor Henry Liu's project, "Development of a Real-Time Arterial Performance Monitoring System Using Traffic Data Available from Existing Signal Systems," is researching and developing an online performance monitoring system that will allow traffic signals on arterial streets to adjust automatically based on traffic conditions.

The effort was funded by the ITS Institute and the Minnesota Local Road Research Board, with significant in-kind support from Hennepin County. Liu and his students began working on the project in July 2006 by developing the software and hardware necessary to collect signal data and calculate the performance measures.

The system they developed is called SMART-Signals, short for “Systematic Monitoring of Arterial Road Traffic Signals.” The technology has already been implemented on 11 signals along busy France Avenue in Edina and Bloomington, Minnesota (pictured, opposite page).

In areas where the project is being implemented, Hennepin County has allowed the SMART-Signal devices to be installed in signal controller cabinets, from which they count cars and record the traffic signal phases.

“We’ll know when a phase started, ended, when a vehicle crossed through the intersection, and over time, how many vehicles passed by,” said Liu. This will allow engineers to set individual signals to the right timing schedules.

Although Liu and his team designed and created SMART-Signals, Hennepin County has devoted a great deal of time to maintaining and operating the system. “The partnership with Hennepin County has been a key factor for the success of this project,” Liu said.

Hennepin County officials believe SMART-Signals will provide performance data that will help guide the development of effective strategies for dealing with oversaturated conditions. According to Eric Drager, traffic operations engineer for Hennepin County, the SMART-Signals program has already helped confirm the results of an engineering consulting firm’s signal timing study of the corridor, which found that the program helped improve efficiency and performance.

“The SMART-Signals project will be able to tell us how our systems are functioning in real time and at any time,” said Drager. “The county is looking to develop more ITS-related applications and implementations, so this project fits quite nicely with that goal.”

The SMART-Signals project is expected to be completed in October 2008. Thanks to an additional \$111,000 from the National Cooperative Highway Research Program, however, Liu will continue this work as part of a new project, “Operation of Traffic Signal Systems in Oversaturated Conditions,” until 2010. (That project is led

by Douglas Gettman of Kimley-Horn and Associates; Liu is a co-investigator along with Monty Abbas of Virginia Tech and Alex Skabardonis of the University of California, Berkeley.) Drager said Hennepin County will continue to provide technical support as well as access to the signal systems.

FEDERAL VISITORS EXPERIENCE NEW TECHNOLOGIES FIRST HAND

The ITS Institute welcomed visitors from the federal government’s Research and Innovative Technology Administration (RITA) and a delegation of Congressional staffers gathering information on transportation issues in May and June. Both groups of visitors had the opportunity to tour the Institute’s research facilities and see first-hand how new technologies are being developed and deployed to improve the nation’s transportation system.

RITA, a division of the U.S. Department of Transportation, is charged with administering the University Transportation Centers (UTC) program, under which the ITS Institute was established. RITA representatives carry out periodic site visits to UTC locations around the country to review their operations and consult with researchers about new and ongoing initiatives in research, education, and outreach.

In addition to hearing presentations by ITS Institute staff, the visitors toured the HumanFIRST Program’s advanced driving simulator and the Minnesota Traffic Observatory and rode a transit bus equipped with driver-assistive systems developed by the Intelligent Vehicles (IV) Laboratory. They also met with Professor Demoz Gebre-Egziabher of the Department of Aerospace Engineering, who presented his current work on uninhabited aerial vehicles for traffic surveillance and remote sensing.

RITA staff members accompanied the congressional staff delegation that arrived in Minnesota for a one-day tour of Institute facilities May 29. IV Lab director Craig



Institute staff Shawn Haag and Craig Shankwitz; RITA staff Curt Tompkins, Tom Marchessault, and Lydia Mercado; and Institute staff Linda Preisen and Dawn Spanhake toured a bus outfitted with IV Lab driver-assistive technology.



Ronald Medford, senior associate administrator with NHTSA, spoke at an Institute-sponsored luncheon.

Shankwitz led a demonstration of the Institute’s driver-assistive systems for bus rapid transit and explained the motivation for developing new technologies that can provide better transit options to urban and suburban residents.

Staff members experienced some of the bus’s systems by sitting in a second driver’s seat equipped with haptic feedback devices that transmit vibration when the bus deviates from its lane. The onboard wireless access point proved to be equally impressive, allowing the busy staffers to check their e-mail while riding—a feature that will be included on the “Bus 2.0” vehicles rolled out in the coming year by the Minnesota Valley Transit Authority.

SPEAKER ADDRESSES FUTURE OF VEHICLE SAFETY

Tomorrow’s safety systems, particularly those that prevent crashes, will save many lives, said Ronald Medford, senior associate administrator with the National Highway Transportation Safety Administration (NHTSA). Their widespread deployment, however, hinges on a key question: What level of reliability will convince consumers that the systems work and are worth the money—and persuade manufacturers to install them?

Medford spoke at the Center for Transportation Studies’ Winter Luncheon on February 13. The ITS Institute sponsors the annual event, which features a presentation on an ITS-related topic by a national policy or technology leader.

Among other things, Medford highlighted NHTSA’s work on ITS safety initiatives with the USDOT’s Research and Innovative Technology Administration. One research initiative is the Cooperative Intersection Collision Avoidance Systems (CICAS) program, of which the ITS Institute is a participant (see page 12 for more coverage of this project). CICAS brings together federal agencies, automobile manufacturers, and university transportation centers with the goal of developing new

technologies to prevent collisions at intersections. The ITS Institute’s focus is on preventing crashes at rural unsignalized intersections

Another research area is vehicle-infrastructure integration, which is intended to allow communication between the infrastructure and vehicles, and from vehicles to other vehicles.

For any system, accuracy is key, and it must be reliable and accurate over the life of a vehicle, Medford said. “We can’t have false positives. The public won’t accept it.”

INSTITUTE RESEARCHERS SHARE EXPERTISE WITH MEDIA

Civil engineering associate professor David Levinson was quoted in a September 10 article in the *Star Tribune* on how commuters have adapted to new traffic patterns since the I-35W bridge collapse. Levinson is one of three University of Minnesota researchers who received a grant from the National Science Foundation to study the issue.

Levinson was also quoted in a story on Minnesota Public Radio about how traffic around the University of Minnesota was affected by the loss of the bridge.

In a news story in November about one of the Twin Cities’ most notorious freeway bottlenecks, the local NBC affiliate KARE-11 TV turned to the Minnesota Traffic Observatory. John Hourdos, director of the lab, explained that congestion on the one-lane eastbound I-394 ramp connecting three lanes of that highway with three lanes of eastbound I-94 is, unfortunately, by design, since it removes pressure from the Lowry Tunnel just east of the bridge on I-94. The tunnel was constructed many years before I-394, and any improvement should start at the tunnel, he said. Hourdos and others at the MTO have been studying that section of highway for years, and the story noted that Hourdos may know more about this section of road than “anyone else on the planet.” The story went on to describe the challenges of the entire area and what it would take to fix the problem,

with insight offered from both Hourdos and Jerome Adams, a senior engineer with Mn/DOT.

Hourdos also contributed to an analysis of merging behavior among Twin Cities drivers broadcast in a May 1 story on local television Fox 9 News.

Institute director Max Donath was interviewed by KSTP-TV for a November 14 story on how interactive road signs and “smart cars” might help reduce the number of fatal crashes that occur at intersections. Donath is working with Mn/DOT to develop a sensor-fusion-driven interactive, graphically animated traffic sign to be used at dangerous intersections.

University researchers that included Frank Douma of the Humphrey Institute and David Levinson of the civil engineering department participated in a broadcast debate on Minnesota Public Radio February 13. The event, held at the UBS Forum, showcased their expectations for the future transportation system.

The Minneapolis *StarTribune* ran a story on HumanFIRST program research that explored the differences in driving behavior and attitudes between urban and rural drivers. Research fellow Michael Rakauskas noted that more rural drivers believe their risky driving behaviors—not wearing seat belts and driving after drinking—are not that dangerous compared to their urban counterparts. The story was picked up by other papers, including the Detroit (Mich.) *Free Press* and the *Kanabec County (Minn.) Times*.

HumanFIRST program director Michael Manser was quoted in a story that aired on WCCO-TV news in February. The story explored the differences in driving ability and behaviors between men and women, as well as the statistics. Manser, who directs research into human behavior when driving, noted that the issue was far more complex than a gender issue and that many other variables influence crash rates.

The opening of the new Minnesota Traffic Observatory, along with researchers Hourdos, civil engineering professor Gary Davis, and engineers Ted Morris and Chen-Fu Liao, was featured in an article in

UMNnews (a University of Minnesota electronic newsletter highlighting University work) in April.

Institute research on teen driving and motorcycle safety was in the news in June, part of the coverage of a visit by U.S. Transportation Deputy Secretary Thomas Barrett. Barrett was on the University of Minnesota campus to announce the launch of a new national clearinghouse on rural transportation safety information. A *StarTribune* story titled “Teens who speed may soon meet cars that tattle” described the ITS Institute’s development of a teen driver support system (TDSS) that uses technology to monitor unsafe driving behavior—in this case, a cell phone that automatically sends a text message to the driver’s parents if he or she is speeding. Donath noted that the system, which he hopes to see in wide use in the next few years, might help reduce the high number of teenage driving deaths.

Local TV news affiliates KARE, WCCO, and KSTP as well as National Public Radio ran segments on Barrett’s visit that included coverage of the TDSS as well as research that is investigating the effects of alcohol impairment on motorcycle riding. HumanFIRST researcher Janet Creaser was among those interviewed (see related story on page 17).

EVACUATION RESEARCH NETS ADDITIONAL FEDERAL FUNDS

Shashi Shekhar, a professor of computer science, in collaboration with Henry Liu, an assistant professor of civil engineering, received a grant titled “Spatio-temporal Network Databases for Transportation Science” from the National Science Foundation (NSF). The grant is to further research into scalable computational methods for determining routes, schedules, and traffic management plans for evacuating metropolitan areas.

Two years ago Shekhar’s research team completed a system to coordinate local emergency evacuation plans in multiple communities. The system is designed to minimize potential congestion on major roadways, speed up



Local media covered U.S. Transportation Deputy Secretary Thomas Barrett’s visit to the University.



Max Donath and Nikolaos Papanikolopoulos, at the CTS 20th anniversary event

the evacuation process, and maximize safety for citizens.

The goal was to create a tool that would run more efficiently than the standard linear programming approach and allow users—such as transportation professionals and first responders—to quickly find the best escape routes, even for large scenarios. The result was a capacity-constrained route planning system with a simple, Web-based user interface. Mn/DOT used the software to develop a metro evacuation traffic management plan for the Twin Cities area.

Since then Shekhar has been refining his capacity-constrained routing software to make it more accessible and easy to use for the private sector.

PUBLICATIONS, NEW WEB SITES HIGHLIGHT INSTITUTE WORK

The Minnesota Traffic Observatory (MTO) and HumanFIRST Program launched new Web sites to provide information about research capabilities and projects.

The MTO is the ITS Institute’s dedicated traffic management laboratory, offering a range of capabilities in the areas of traffic data collection, simulation and modeling, and visualization. In addition to supporting

University of Minnesota researchers, the facility partners with other universities and corporations to carry out traffic research. HumanFIRST focuses on human factors research, and operates one of the most advanced immersive driving simulators at any academic institution in the United States.

“Researchers who are interested in working with us will be able to see what we have to offer and what we have already accomplished. We have a lot of unique capabilities, and we’re eager to let people know about them,” says MTO director John Hourdos.

“Our Web sites are a key part of our communication strategy,” agrees HumanFIRST director Michael Manser. “As we look for research partners—both academic researchers and private firms—these new sites will continue to evolve and expand.”

A new Web site for the Intelligent Vehicles Laboratory is currently under development by the ITS Institute communications staff.

In addition to ongoing work on the Institute’s Web sites, electronic communications continue to play an important role in quickly disseminating information to its audience. Electronic mail announcements were used to publicize upcoming events, including Advanced Transportation Technologies Seminars, conferences, luncheon presentations, and other ITS-related events.

Eight ITS-related research projects were featured in the Center for Transportation Studies’ *Research E-news* electronic newsletter, which is mailed to about 4,000 subscribers and is available on the Web at www.cts.umn.edu/news/rnews. These articles also provided links to more information about the projects.

Institute print publications continued to raise awareness of its work in academic and professional communities and share the results of research. The *Sensor* newsletter covered Institute research activities, education and technology transfer activities, upcoming ITS-related events, and recently published research reports. The *Sensor* is available in print and online and reaches about 2,100 subscribers three times each year. It has been one of the chief vehicles



for increasing the visibility of the ITS Institute, and its high circulation testifies to a broad interest in ITS research activities among academic and professional audiences.

The eighth annual report (fiscal year 2006–07), highlighting work by the Institute’s researchers and students, was published and mailed to more than 1,400 individuals and was also made available as a PDF file for download from the Institute’s Web site. The report won an American Graphic Design Award from Graphic Design USA in the annual reports category.

INSTITUTE SHARES SAFETY EFFORTS WITH INTERNATIONAL OFFICIALS

Officials from the country of Georgia visited CTS and the ITS Institute in April as part of the U.S. State Department’s International Visitor Leadership Program. The officials, who are developing a traffic safety program in Georgia, also visited with Mn/DOT staff and experts in other U.S. cities.

Gina Baas, CTS director of communications and outreach, provided an overview of safety-related research and outreach activities within the Institute and other CTS programs.

The International Visitor Leadership Program is a national initiative facilitated in Minnesota by the nonprofit Minnesota International Center. Visitors are invited by the U.S. Department of State to come to this country for approximately three weeks to meet with their professional counterparts and experience American culture without publicity or protocol.

INSTITUTE RESEARCHERS SHARE VIEWS ON TRAFFIC SAFETY AT NATIONAL, LOCAL EVENTS

In September, ITS Institute researcher Tom Horan spoke at the Toward Zero Deaths conference, an annual event that explores ways to reduce the number of fatalities and injuries on Minnesota’s roads. In a concurrent session on emergency medical services (EMS) response times and trauma, Horan, with the Humphrey Institute of Public



Gina Baas (third from right) with visitors from the country of Georgia, who toured CTS and ITS Institute facilities as part of an international leadership program

Affairs’s Center for Excellence in Rural Safety, described his work toward improving EMS response in rural areas.

At the Center for Transportation Studies’ 20th anniversary celebration in October, several ITS Institute researchers were among the University of Minnesota faculty panelists who reviewed how the University has contributed to state and national transportation issues in the past two decades and suggested future research possibilities.

Max Donath, director of the ITS Institute, noted that the Institute’s philosophy has been to focus its work on the highest risk areas—and in this country, that means rural areas. Institute researchers have developed and deployed lane-keeping technology, including the first use of high-accuracy GPS, on snowplows and other vehicles. Another area of Institute research looks at the policy implications of technology. Teens make up 5 percent of drivers but 14 percent of fatalities, yet there is continued resistance to tools like seat belt ignition locks. “We are all concerned with privacy,” Donath said, “but is it a red herring, an excuse, for not allowing some of this technology into our daily lives?”



Michael Rakauskas discussed rural fatal crash risk at the Center for Excellence in Rural Safety's annual Summer Institute.

Panos Michalopoulos, a professor in the Department of Civil Engineering, discussed how CE researchers, due in part to support from CTS and the ITS Institute, have made contributions in many dimensions of transportation such as an improved ramp metering strategy for Twin Cities metro freeways. Since the strategy was implemented in 2003, he said, benefits in reduced fuel consumption and delays are estimated at \$200 million per year. Other areas of research include traffic flow simulation, crash mechanics, and crash prediction.

Nikolaos Papanikolopoulos, director of the Security in Transportation Technology Research and Applications (SECTTRA) Program and a professor of computer science and engineering, noted how his video detection research, which began as a tool to detect drug dealers at bus stops, became a springboard for a \$4 million grant from the Department of Homeland Security. Papanikolopoulos credits seed support from CTS and the Institute as enabling his work to be competitive at the national level.

Speakers explored the connections between rural transportation safety and community health at the Center for Excellence in Rural Safety's annual Summer Institute, held last July at the University of Vermont in Burlington. Donath described human-centered technologies for reducing fatalities and life-changing crashes, and Mick Rakauskas, a research fellow with the HumanFIRST Program, discussed attitudes and behaviors associated with rural fatal crash risk. The two-day gathering of leading state and national transportation officials, researchers, policymakers, and professionals is aimed at sharing information, setting research priorities, and developing strategies for improving rural transportation safety.

Institute researchers were among those who presented their work at the Transportation Research Board's 87th annual meeting, held in January in Washington, D.C. Presentation topics covered traffic monitoring and signal control techniques, privacy law and ITS technologies, safety research, congestion pricing, and traffic simulation. University of Minnesota faculty, staff, and student presenters included, among many others:

- Gary Davis, John Hourdos, David Levinson, Chen-Fu Liao, Henry Liu, Wenteng Ma, and Panos Michalopoulos, Civil Engineering
- Xinyu (Jason) Cao, Frank Douma, Lee Munnich, and Elizabeth Wilson, Hubert H. Humphrey Institute of Public Affairs
- Bibhu Aryal and Taek Kwon, Northland Advanced Transportation Systems Research Laboratories (NATSRL)

In May, NATSRL held its sixth annual Research Day, during which ITS researchers at the University of Minnesota Duluth presented their ongoing work in transportation. The event was held at Mn/DOT District 1 headquarters in Duluth. NATSRL director Eil Kwon opened the half-day event.

Among the UMD presenters and topics were:

- Xun Yu, Mechanical and Industrial Engineering (MIE), "Real-Time Non-intrusive Detection of Driver Drowsiness"
- Richard Lindeke, MIE, "Extending the Snowplow Box/Bridge Impending Impact Avoidance Controller: Providing a Trainer Module and Testing the System in Service"
- Peter Willemsen, Computer Science (CS), "Rendering Falling Snow for Interactive Snowplow Simulation"
- Taek Kwon, Electrical and Computer Engineering (ECE), "Cellular Wireless Mesh Sensor Network for Vehicle Tracking in an Intersection"
- Hua Tang, ECE, "A Video-Based Tracking System with Practical Applications"
- John Evans, Chemistry, "Detection of Water and Ice on Bridge Structures by AC Impedance and Dielectric Relaxation Spectroscopy"
- Robert Feyen, MIE, "Assessing Performance and Interagency Coordination in Traffic Incident Management"
- Richard Maclin, CS, "Early Warning System for RWIS Sensor Malfunctions"

RESEARCHERS RECEIVE HONORS, AWARDS

Assistant Professor Henry Liu of the Department of Civil Engineering was the recipient of the 2007 New Faculty Award from the Council of University Transportation Centers (CUTC) and the American Road & Transportation Builders Association (ARTBA). The award is presented to an outstanding new faculty member in a field related to transportation who has not yet received tenure. He received the honor at CUTC's Tenth Annual Awards Banquet in Washington, D.C.

Liu's Institute-related research activities include arterial data collection and signal optimization, real-time traffic management for emergency evacuation, analytical dynamic traffic assignment, and application of microscopic traffic simulation models. In addition, Liu and CE associate professor David Levinson, a previous CUTC New Faculty Award winner, are leading a team that is analyzing traffic patterns after the loss of the I-35W bridge in Minneapolis, funded by a grant from the National Science Foundation, and a related project funded by Mn/DOT.

Elizabeth Wilson is a recipient of a 2008 McKnight Land-Grant Professorship. The goal of the program is to advance the careers of the University's most promising junior faculty at a critical point in their professional lives. McKnight recipients are honored with the title McKnight Land-Grant Professor, a special award they will hold for two years. The award consists of a research grant in each of the two years, summer support, and a research leave in the second year.

Wilson is an assistant professor of energy and environmental policy and law at the Humphrey Institute of Public Affairs. Among other research, Wilson is investigating the implications for advances in transportation-related technology as it relates to school travel (see page 24 for more on this ITS Institute-sponsored effort).

VISITING RESEARCHERS BRING EXPERTISE, BUILD PARTNERSHIPS

During the past year, the Institute continued to work with visiting researchers and instructors, allowing for an exchange of information and dissemination of research results to the visitors' students and colleagues.

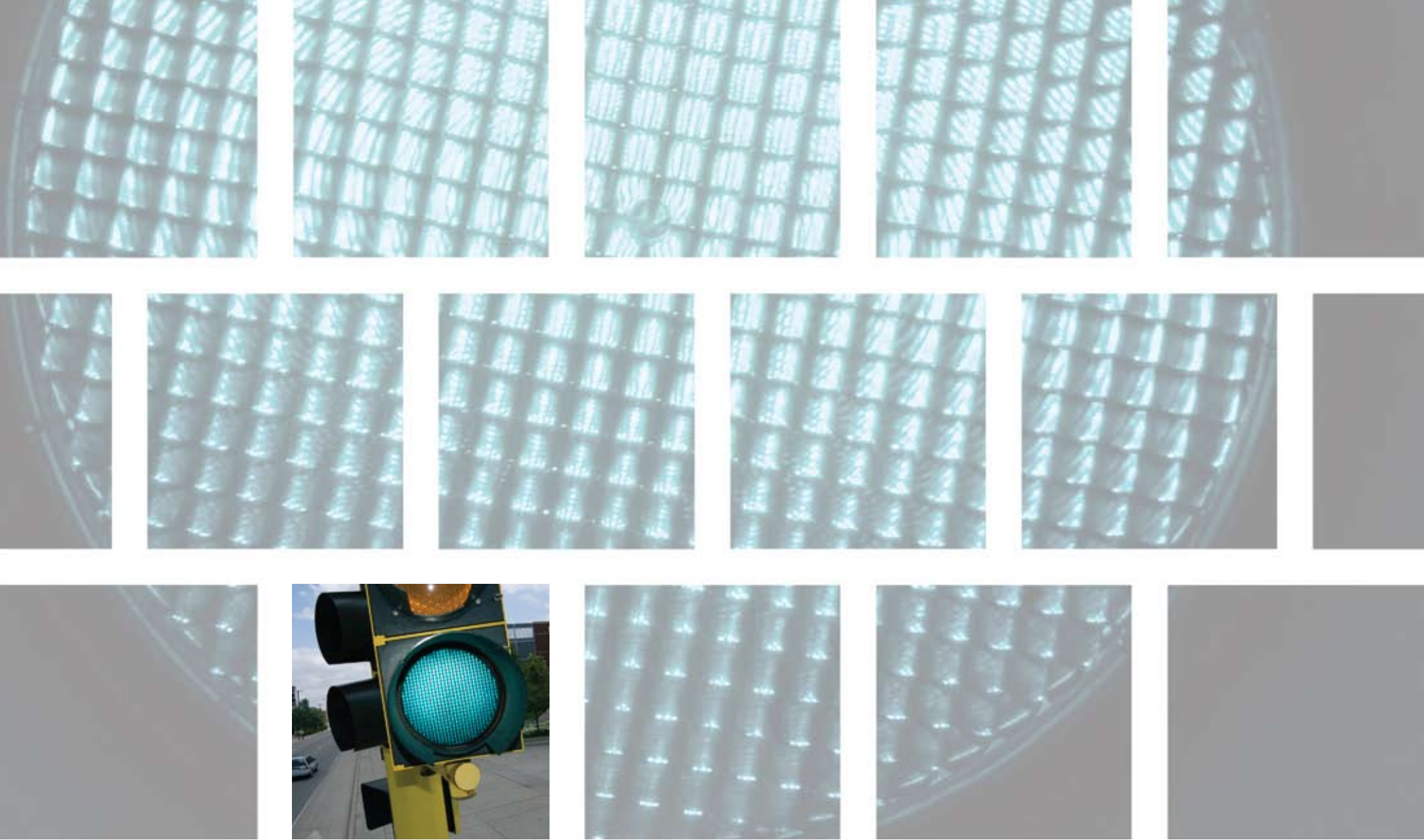
The Fall 2007 Advanced Transportation Technologies Seminar Series provided an opportunity to host two national researchers. Louis Tijerina, a human factors researcher and driver distraction expert with the Ford Motor Company, presented an overview of recent research on driver distraction related to mobile electronic devices and on the more general issue of interface design for driving safety. Srinivas Peeta, director of the NEXTRANS Center at Purdue University, presented on methods for modeling the complex interdependencies among civil infrastructure systems.

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 and the new TechPlan research program. Horan is investigating wireless emergency medical services (EMS) and telecommunication network planning and access in a rural context.

Other visiting researchers, all working with the Institute's HumanFIRST Program, include Nobuyuki Kuge and Tomohiro Yamamura of Nissan, Jeff Caird of the University of Calgary, and Dick de Waard of the University of Groningen.



Visiting researcher Tom Horan is studying wireless EMS and telecommunication network access in rural areas.



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