HUMAN-CENTERED TECHNOLOGY TO ENHANCE SAFETY AND MOBILITY

INTELLIGENT TRANSPORTATION SYSTEMS INSTITUTE

ANNUAL REPORT 2005-2006

UNIVERSITY OF MINNESOTA

CENTER FOR TRANSPORTATION STUDIES

INTELLIGENT TRANSPORTATION SYSTEMS INSTITUTE

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University of Minnesota

Center for Transportation Studies

Intelligent Transportation Systems Institute

2005–2006 Annual Report

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 2005–2006

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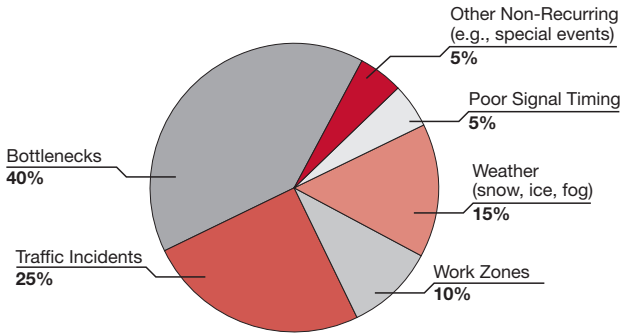
MESSAGE FROM THE DIRECTOR

A report released in May 2006, titled *National Strategy to Reduce Congestion on America's Transportation Network*, describes the USDOT's recent initiatives. At the ITS Institute we are, in fact, already pursuing research in many of the identified areas. For example, we have developed, and continue to develop, new technologies that facilitate novel road-pricing strategies and that facilitate additional use of inexpensive and ubiquitous road shoulders as busways for bus rapid transit service.

This USDOT report states that approximately 25 percent of all traffic congestion is "non-recurring" and can be traced to traffic incidents. The 2004 Texas Transportation Institute mobility report indicates that non-recurring congestion continues to increase nationally, exceeding 2.9 million hours annually. A current FHWA report on traffic incident management estimates that, on average, every minute during which a freeway crash is not cleared generates five minutes of delay for motorists. Consider then the impact on congestion of the nearly 11,000 crashes that occurred on Twin Cities metro area freeways in 2004.

Secondary Causes of Highway Congestion



Source: USDOT (2006), National Strategy to Reduce Congestion on America's Transportation Network

Our researchers have studied extensively the nature of freeway crashes. John Hourdos, Panos Michalopoulos, and Gary Davis have identified specific crash types and causal factors associated with such crashes, using the new Beholder tool developed by Ted Morris and John Hourdos and deployed at a number of sites along the I-94/I-35W "commons" area (pictured at left). In a separate study, Davis determined that many drivers exhibit reaction times longer than their following headways. As a result, relatively small individual differences in following distances, reaction times, speeds, and decelerations determine whether or not a stopping shock wave results in a collision. This is exacerbated by driver distraction. Furthermore, drivers often maintain relatively short following distances in order to discourage others from merging in front of them. Because short following headways translate into higher traffic flows, one could argue that short headways make more effective use of limited freeway capacity. Unfortunately, Davis's findings also suggest that short headways often lead to a disproportionate number of crashes for the drivers following upstream.

As Davis says, "Reducing the frequency of such collisions—for example, by improving the competency of drivers or deploying in-vehicle collision-avoidance technology—could help reduce travel delays without resorting to expensive additions to highway capacity."

We continue to work on such efforts. We believe that our research will make a difference.

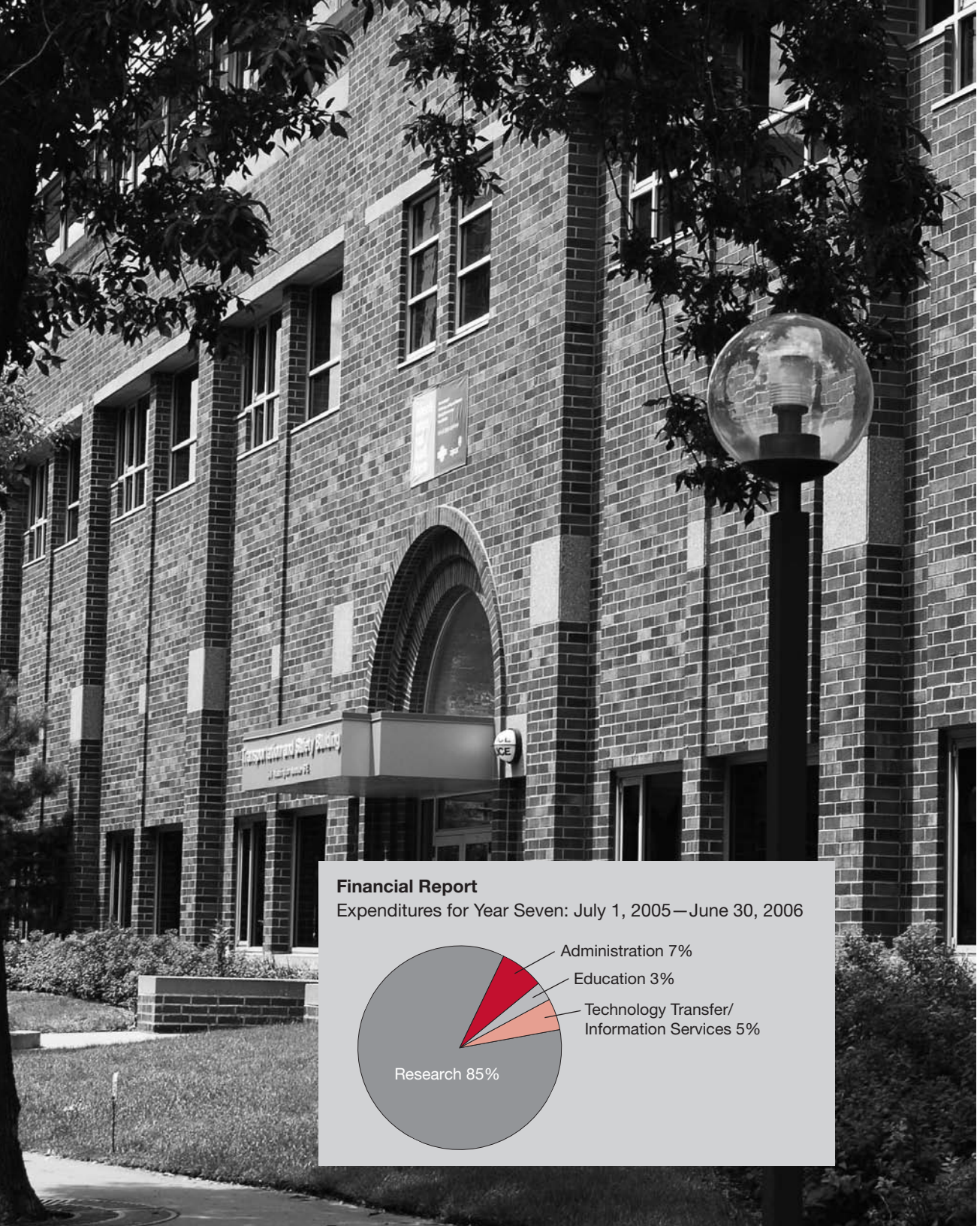
Although Institute research takes many varied approaches, its goal is always the same: to improve the safety and mobility of transportation through a focus on human-centered technology. We will continue to support our multidisciplinary researchers as they explore new ideas and connect with students and practitioners to inform and educate them about what is discovered. All our activities are described in the pages of this annual report.

We have many partners in the operations of the Institute. I would like to thank the people on our board who have given their time to help us make decisions and fulfill our obligations. This past year, Al Steger, Barbara Sisson, Anthony Strauss, and Bob Winters stepped down as their responsibilities took them in different directions; we are grateful for their service.

Finally, I would like to express sincere thanks for the vital efforts of the members of our research selection and review panels; our Institute staff, researchers, and students; the Minnesota Department of Transportation; the USDOT's University Transportation Center Program in the Research and Innovative Technology Administration (RITA); and the taxpayers and their legislative representatives. Without them, we would not have made any progress, and their belief in our mission and support of our work is deeply appreciated.

Max Donath, Director
ITS Institute

The 2004 Texas Transportation Institute mobility report indicates that non-recurring congestion continues to increase nationally, exceeding 2.9 million hours annually.



Financial Report

Expenditures for Year Seven: July 1, 2005—June 30, 2006

MISSION STATEMENT

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

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

Our focus is human-centered technology that enhances the safety and mobility of road- and transit-based transportation. To that end, we direct the collective energies of researchers from multiple disciplines to advance the state of the art in the core ITS technologies of computing, sensing, communications, and control systems in order to surmount the significant transportation problems of the day.

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

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

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

The Institute's board guides and oversees the implementation of the Institute's work. The board works with the director to ensure that the USDOT's Research and 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 disseminate knowledge related to intelligent transportation systems through research, education, and technology transfer activities. In addition, the leadership and staff of CTS provide connections and access to an extensive transportation research and education network. The Institute's affiliation with the Center allows it to work seamlessly with CTS staff and benefit from its diverse outreach, administration, and communications capabilities.

Board members whose terms ended during the fiscal year:

Barbara Sisson
(FTA liaison)
Associate Administrator, Office of Research, Demonstration and Innovation, Federal Transit Administration

Al Steger
(Ex Officio)
Director of Field Services–East, Federal Highway Administration

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Robert Johns
(Chair)
Director, Center for Transportation Studies

Sue Lodahl
Director of Research Services, Minnesota Department of Transportation

Tom Sorel
Minnesota Division Administrator, Federal Highway Administration

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Bob Winter
Director, District Operations Division, Minnesota Department of Transportation

Back row: Chad Rathmann, Charlie Grussing-Neitzel, C.J. Loosbrock, Cadie Wright, Michael McCarthy, Chen-Fu Liao, Jan Lucke, Peter Park Nelson. Middle row: Dawn Spanhake, Arlene Mathison, Gina Baas, Linda Preisen, Pam Snopl, Liang Zhu, Max Donath. Front row: Stephanie Jackson, Penny Harris, Cindy Holton, Amy Friebe. Not pictured: Laurie McGinnis, Ted Morris, Rick Odgers.

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Bryan Newstrom
Curt Olson
Rajesh Rajamani
Mick Rakauskas
Craig Shankwitz
Nicholas Ward

Northland Advanced Transportation Systems Research Laboratories
The NATSRL program director is Eil Kwon. Technical support is provided by Stanley Burns, professor and head, Department of Electrical and Computer Engineering (ECE); Donald Crouch, professor and head, Department of Computer Science; Taek Mu Kwon, professor, ECE; and David Wyrick, professor and head, Department of Mechanical and Industrial Engineering. Program management of NATSRL is provided by Carol Wolosz, with Jeanne Hartwick serving as program accountant, David Keranen as infrastructure engineer, and Ed Fleege as research fellow.

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

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John Evans

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Donald Crouch
Richard Maclin

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Stanley Burns
Rocio Alba-Flores
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Taek Kwon
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Natural Resources Research Institute
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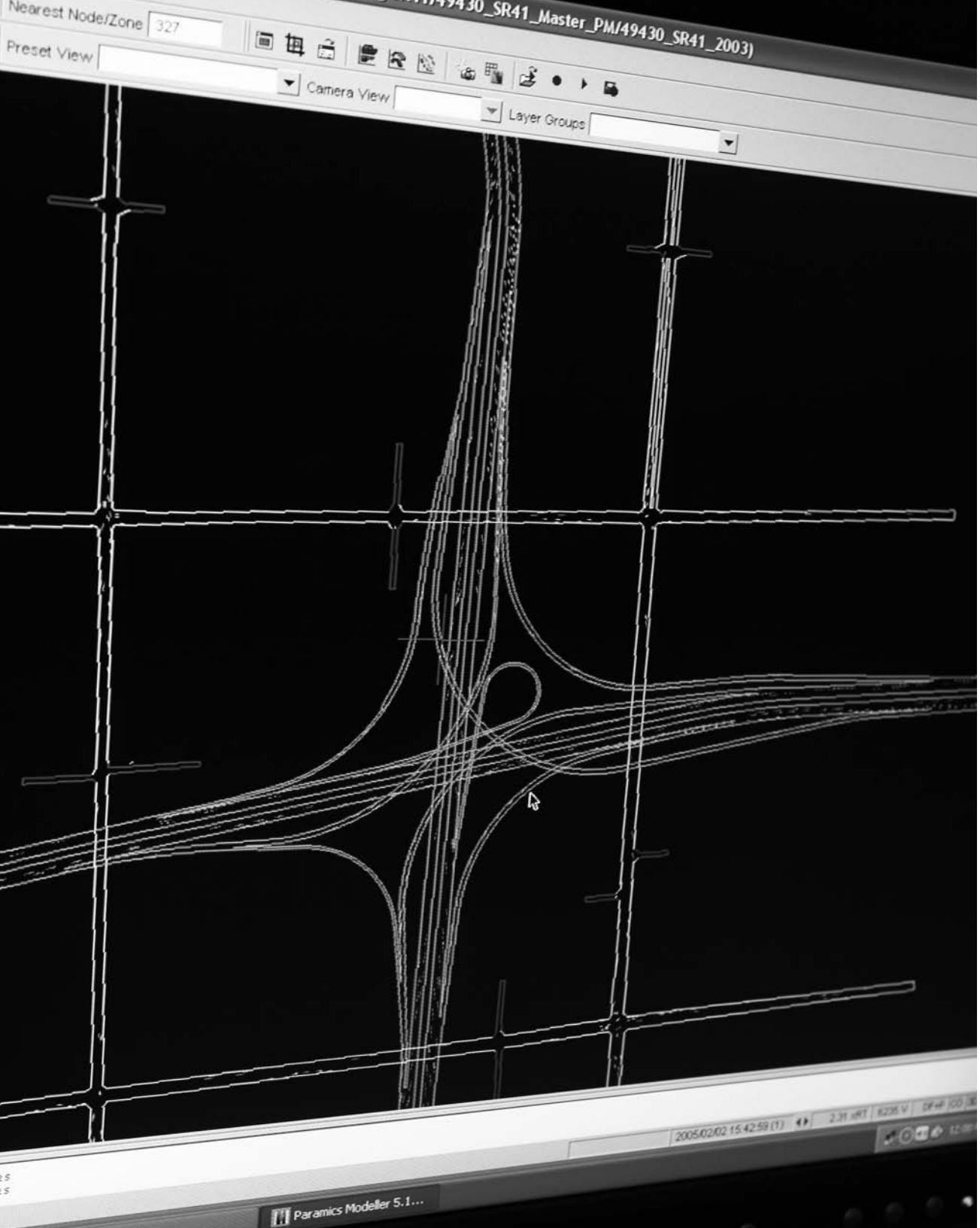


ITS INSTITUTE LABS AND FACILITIES

Traffic Laboratory

This fall, the Institute's ITS Laboratory enters a new phase of operations—with new capabilities and a new location in the University's Civil Engineering Building. The new traffic laboratory will focus on the specific requirements of traffic flow research, including the development of advanced data-gathering and signal-processing systems and support for the computer infrastructure needed for signal processing and traffic-flow modeling.

Along with its new location and new director, John Hourdos, the traffic laboratory will benefit from increased autonomy as an independent research program with its own steering committee. Hourdos's recent work with Professor Panos Michalopoulos on video-based traffic pattern monitoring resulted in the development of a powerful new data-gathering tool. Lab manager Ted Morris, who has worked closely with researchers and students for more than six years, will continue to manage the day-to-day operations of the facility. Professor Gary Davis of the Department of Civil Engineering will serve as principal investigator of the laboratory's ongoing research.

As an independent program, the traffic laboratory will be able to more actively pursue funding opportunities based on the needs of University of Minnesota researchers in a variety of academic departments and also work closely with clients outside the University, such as the Minnesota Department of Transportation.

Supporting education in traffic modeling and management will be one of the lab's core missions. Senior systems engineer Chen-Fu Liao will continue to develop and support the online simulation systems that have become a key element of the ITS Lab's operations in recent years. Liao works closely with faculty to create learning tools that help advanced students experiment and understand traffic patterns in complex road networks.

As part of the move to its new facilities, the traffic laboratory is exploring a range of potential enhancements to its

capabilities in order to meet the changing needs of transportation researchers, Morris said. As more ITS projects are implemented nationwide, the new traffic laboratory will offer researchers and students a cutting-edge environment for experimentation and learning.

Intelligent Vehicles Laboratory

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

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 IV Laboratory staff has developed expertise in wireless communications, embedded computing, visibility measurement and quantification, geospatial databases, virtual environments, image processing, driver-assistive technologies, control systems, and sensors.

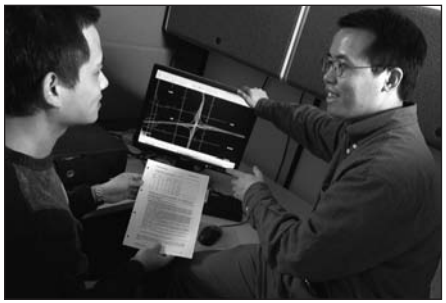
IV Laboratory research seeks to increase driver safety in difficult driving conditions through the use of vehicle-guidance and collision-avoidance technologies. Several vehicles serve as experimental testbeds, including the SAFETRUCK (an International 9400 tractor-trailer), the SAFEPLOW (an International 2540 crew-cab snowplow), a state highway patrol car, and the TechnoBus (a Metro Transit bus). Using these vehicles, IV Laboratory researchers are developing, testing, and integrating advanced technologies including

New civil engineering professor focuses on traffic management

Henry Liu joined the Department of Civil Engineering as an assistant professor in 2005, bringing a strong focus on advanced traffic management techniques and ITS applications. Liu's research interests complement the department's growing capabilities in traffic analysis and management; he will also play a central role in the Institute's new traffic laboratory.

One of Liu's research interests is the design of effective traffic control systems for evacuating large areas in the event of natural or man-made disasters. Difficulties experienced during the recent hurricane evacuations in Louisiana and Texas serve as unpleasant reminders of the need for better evacuation systems. These extreme situations feature traffic behavior that is very different from the conventional operations for which road networks are designed. Liu's approach to real-time traffic control during evacuations incorporates information about current traffic conditions into an adaptive control strategy.

Liu has already attracted funding for new research to be carried out in cooperation with the traffic laboratory following its move from its current location in the Transportation and Safety Building to the Civil Engineering Building in fall 2006. Simulation and modeling systems housed in the lab will serve as a key resource for Liu and his graduate students as they seek to develop new control strategies. Liu is also working with Chen-Fu Liao, the traffic lab's senior systems engineer, to develop online tools for teaching and interactive learning.



Graduate student Wenteng Ma (left) and Assistant Professor Henry Liu

IV Lab researchers include (from left) Arvind Menon, Pi-Ming Cheng, Alec Gorjestani, Lee Alexander, Bryan Newstrom, and program director Craig Shankwitz

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 instance, 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. The data collected at the intersection is 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.

Additional research topics include the design and 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

Intelligent Vehicles Lab enhances driver-assistive system with infrared vision

The Intelligent Vehicles Lab has deployed its driver-assistive system in a total of seven vehicles to date. The system is designed to help drivers operate in reduced-visibility conditions (such as severe snowstorms) by providing an electronic visual display of obstacles and road boundaries via a transparent head-up display (HUD) similar to that used by military pilots. Recent work by research associate Pi-Ming Cheng and IV Lab director Craig Shankwitz aims to improve these sensing and display systems by incorporating images from an infrared camera into the HUD.

According to the researchers, the system has proven particularly effective for snowplow drivers, who must sometimes operate in white-out conditions caused by blowing and drifting snow, which makes it difficult to see land boundaries, cars, or other obstacles. As deployed, the system uses high-accuracy digital maps combined with onboard radar sensors to create an accurate picture of what's going on outside the vehicle.

Although radar has proven effective in finding exactly where obstacles are in relation to the HUD-equipped vehicle, objects detected by radar can only be displayed as square "targets," making it difficult for the user to determine what is being tracked. Infrared sensors, by contrast, are better at showing what objects look like but are unable to determine exact locations.

As developed by the IV Lab, images from an infrared camera are processed by machine-vision algorithms to extract features of interest—moving objects or other potential obstacles. Visual information about these features, such as their shapes, is then combined with information from a radar sensor to create a more useful display for the driver.

Combining radar and infrared sensors offers definite advantages for driver-assistive systems. However, persuading the two very different types of sensors to cooperate is a considerable challenge. The images produced by the infrared camera must be mathematically processed to match the resolution and apparent perspective of the HUD and the existing radar system. Computer-vision techniques are also required to extract features of interest—such as vehicles and persons—from the camera data. Finally, the display system must provide relevant information to the driver in a reliable and intuitive format.

The integration of infrared and radar data has been linked to improvements in the basic software architecture of the IV Lab's driver-assistive system. These changes will make it easier for the development team to integrate data from different types of sensors and improve the overall performance of the system.

also has relationships with a number of other organizations and government agencies, including the U.S. Department of Transportation's Research and Innovative Technology Administration, Federal Highway Administration, and Federal Transit Administration; Twin Cities' Metro Transit; Minnesota's Local Road Research Board; and various counties. These partnerships provide additional support for implementing research that will influence transportation safety in the United States and around the world.

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

Intersection research to help drivers gauge the gap

Intersections make up only a small part of the U.S. highway network, yet intersection crashes account for more than 40 percent of all vehicle crashes annually. Specifically, many crashes at unsignalized rural intersections are attributable to errors made by drivers entering the main highway. To address this problem, researchers from the HumanFIRST Program, in conjunction with the Institute's Intelligent Vehicles Laboratory, are working on an innovative approach to decrease the occurrence of such crashes using advanced technologies that minimize driver error.

Although some rural intersections employ traffic lights to indicate when drivers can "go," most use stop signs instead as the only means of traffic control. In this case, drivers have to decide for themselves when it is safe to proceed. Researchers are now studying intersection decision support (IDS) systems that are specifically developed to handle stop-controlled intersections where the driver on the minor road has the stop sign and the driver on the major road continues through the intersection. The idea is to provide stopped drivers with better information about vehicles approaching the intersection, which leads to better decision making, fewer driver mistakes, and ultimately, fewer crashes.

At the heart of this study is a virtual-reality, wrap-around driving simulator that enables researchers to test multiple IDS interface configurations in a safe yet relatively realistic environment. By simulating a wide range of traffic and weather conditions during both day and night, the scientists can get test subjects to generally behave as they would if driving on a real road. This in turn yields much more credible and reliable data.

In a recent simulator test, researchers created an exact replica of a rural Minnesota intersection deemed to be particularly dangerous. Because different age groups have crashes at intersections for different reasons, these scientists studied two groups: drivers aged 20 to 40 years old and those aged 55 to 75. During a series of experiments, test subjects "drove" up to the intersection as the simulated traffic passed them, leaving different-sized gaps. A dynamic sign provided the driver with information about the size of the gap, and from that information, the test subject determined if it was safe to pull out into the intersection or not.

In this first round of testing, the team analyzed the usability of four different sign prototypes and now has a better idea of which designs work best. From here, researchers will narrow the options to two or three, tweak the designs as needed, and head back to the simulator to test them again. Although real-world field testing is still a few years away, these simulated experiments go a long way in helping this team develop effective methods that will one day greatly improve intersection safety.

HumanFIRST researchers include, in back: Mike Manser, Peter Easterlund, program director Nic Ward, and Mick Rakauskas; in front: Gerald Cowart, Janet Creaser, and Praveen Balachandran.

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
- bus rapid transit using dedicated narrow shoulders
- intelligent driver-support systems such as vision-enhancement, collision-avoidance, hazard-awareness, and lane-keeping systems for passenger and specialty-purpose vehicles
- alcohol impairment
- attention-deficit/hyperactivity disorder and novice 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

Solar/Wind Integrated Renewable Light Pole

Recent advances in sensing, communication, and computing technologies have produced a wide range of intelligent transportation systems (ITS) and related devices that could directly improve traffic safety and efficiency in rural areas. As beneficial as these new ITS technologies are, however, the lack of an easily accessible power source and the high cost of bringing electric power to remote rural areas has made deployment of such systems economically unjustifiable to most transportation agencies.

A group of NATSRL researchers, led by Taek Kwon of the electrical and computer engineering department, has developed a prototype renewable power station using a hybrid technology that integrates a small wind turbine and a photovoltaic (PV) solar panel. Unlike conventional PV-only based technologies, this new system generates electricity under all weather conditions, sunny or not. In winter, northern regions tend to have stronger winds and shorter, cloudier days. By supplementing the solar power with wind, this system solves the problem of significantly reduced daylight hours, which previously impeded the performance of the PV panels.

The prototype power station, which is being tested at the Mn/DOT District 1 maintenance area in Duluth, has been successfully operating a street light using only the natural solar and wind resources since the summer of 2005. The solar- and wind-generated electric power is stored in a battery bank and is sufficient to operate the lighting system for approximately 10 days without charging. Kwon's team is further testing this technology for use with remote variable message signs (VMS) and traffic signals.

Taek Kwon. Inset: The solar/wind integrated light pole.

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 that can create virtual environments that precisely reproduce any geospecific location. In addition, specialized visual-effect software can produce realistic weather and lighting—including light and 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 (2.5 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.

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.

Northland Advanced Transportation Systems Research Laboratories

The Northland Advanced Transportation Systems Research Laboratories (NATSRL) is located at the University of Minnesota Duluth. Its mission is to study comprehensive winter transportation systems and the transportation needs of cities in small urban areas. To accomplish this, NATSRL collaborates with the Minnesota Department of Transportation, city and county engineers, and other agencies on research that covers a wide range of topics, such as optical and electronic traffic and road sensors, transportation data management, and benchmarking of transportation infrastructure.

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

Other NATSRL projects include development of a traffic counter for low-volume roads and student development of software tools to manage large volumes of transportation-related data.

In addition, NATSRL partners with Mn/DOT District 1 each year to provide a day-long formal presentation of ongoing research efforts.

UMD hires new director for transportation programs office

With the expansion of the University of Minnesota Duluth research programs in the field of transportation, the University has hired a full-time director to lead the research efforts. Eil Kwon will direct the NATSRL program and serve as UMD's co-director for the Great Lakes Maritime Research Institute. He joins UMD from the Minnesota Department of Transportation's Office of Traffic, Security and Operations, where he had been serving as the director of traffic research. While working for Mn/DOT, Kwon also served on the NATSRL Advisory Board, where he was involved in the selection process for UMD's transportation research projects.

In 2000, Kwon was at UMD as a 3M McKnight Visiting Professor in the Electrical and Computer Engineering Department. During this appointment, he helped lay the groundwork for the establishment of NATSRL.

Eil Kwon

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 TEA-21 legislation, the Federal Highway Administration, the Federal Transit Administration, and the Department of Homeland Security. Other funding partners include the Minnesota Department of Transportation (Mn/DOT), the Minnesota Local Road Research Board, and Metro Transit in addition to local governments, agencies, and private companies that contribute funding and in-kind match.

Activities undertaken by the Institute support all 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.

Reseachers Kevin Krizek, Gavin Poindexter, and Ahmed El-Geneidy

Research funding sources for all ITS-related research projects

The total funding for ITS-related research projects was over $8.8 million in FY06. Sources for projects receiving funding in FY06 are shown in the chart to the right.

During this period, 59 faculty and research staff and 75 students were involved in ITS-related research.

In-Vehicle Driver Assistance for Teenagers

Parents of teenagers often worry when their child starts driving—and not without reason. Teens are among the most risk-prone groups of drivers, experiencing higher crash rates than drivers with a few more years of experience and having the highest traffic fatality rate of any age group. Several researchers with the ITS Institute are working to address this serious public safety issue by developing in-vehicle technology to monitor and correct inexperienced drivers' unsafe behaviors behind the wheel.

Professor Stephen Simon of the Law School is leading the project, which includes ITS Institute director Max Donath and HumanFIRST Program director Nic Ward as coinvestigators and mechanical engineering graduate student Shawn Brovold, who has designed much of the technology to date.

According to Simon, what can be done among certain groups of high-risk drivers (such as DWI repeat offenders) in terms of controlling or monitoring their driving behavior is limited, but with teenagers, "a parent has absolute control over their car," he says.

The research team's Teen Driver Support System (TDSS) is aiming to address the primary causes of most fatal teen-driver crashes: speeding, lack of seat belt use, alcohol impairment, and driver inexperience. The system uses a combination of forcing, feedback, and reporting functions. The forcing function consists of an ignition interlock that will prevent a driver from starting a car if he or she is not buckled up or is not sober. The feedback function provides real-time in-vehicle warnings about illegal or unsafe speeds. The reporting function records vehicle information for later review by parents or licensing agencies.

An example of how the reporting function might operate is that the system would call or send a text message to parents if their teenager continuously exceeds the speed limit past a time threshold. This timing is significant, Simon says, because the quicker an intervention is applied, the more effective it is in stopping the behavior.

To date, the team has developed a prototype system for speed-limit feedback and reporting within Hennepin County. The system links the speed-limiting function to a digital map (derived from a road-classification database maintained by the Minnesota Department of Transportation and a speed limit database from Hennepin County) and a GPS sensor to determine the road on which the vehicle is operating and the road's speed limit. If the driver's current speed exceeds the road's posted limit, an audible warning is used to notify the driver, and details (e.g., time, location, speed) of the infraction are recorded for later review.

Shawn Brovold demonstrates the Teen Driver Support System.

The system's ability to calculate the vehicle's location means an even more ambitious safety feature might be possible: driver warnings and intervention based on road geometry and weather conditions. Young drivers are involved in a disproportionate number of "run-off-the-road" crashes because they lack the driving experience to recognize hazardous conditions until it is too late to adjust. By "looking ahead" to see if the vehicle is approaching a sharp curve or other potentially hazardous road feature, the system could issue a warning to inexperienced drivers before they get into trouble. In addition, the system could use Mn/DOT's weather recording devices to get real-time information on current driving conditions, such as icy roads or fog, and adjust the car's maximum speed limit accordingly.

By "looking ahead" to see if the vehicle is approaching a sharp curve, the system could warn inexperienced drivers before they get into trouble.

Brovold points out that most vehicles already have various technologies needed for the TDSS built into them. Vehicle navigation systems could serve as a platform for speed warning systems. Some newer cars even have an event data recorder—a sort of "black box"—that records data leading up to and at the time of a crash (how fast the car was traveling, the seat belt status, etc.). Cars also have an ignition interlock that prevents them from being started if it's in the "drive" gear. Automakers, who already install seat belt sensors, could

Professor Stephen Simon

combine these features to make a seat belt ignition interlock. However, these types of safety features have yet to be implemented or offered as factory options.

Next steps in the research are to continue testing the system locally for functionality, test attitudes about the system and how feedback is delivered with teenagers in a driving simulator, conduct multi-vehicle field operations tests, and conduct market analysis. The researchers hope to receive a start-up grant to build, install, and test additional prototypes. From the market analysis, they also hope to gauge the public's interest in the system as well as learn how to package and market the product.

Chromatic Perception Effects on Collisions with Snowplows

Snowplow operators frequently face the hazardous task of clearing slippery, snow-covered roads to make them safe for travel. But in the process of clearing roads, plows can temporarily create even worse conditions for the drivers behind them. Under these low-contrast conditions, drivers often can see that a snowplow is ahead, but cannot tell how far away it is or even that they are approaching it. Some recent experiments also indicate that under low-contrast conditions, people perceive themselves to be traveling significantly slower than they actually are. To compensate, they speed up. Together, these issues constitute some of the most dangerous conditions drivers in Minnesota commonly experience and are why snowplows are so vulnerable to rear-end collisions.

Researchers now understand why: the visual mechanism that perceives motion is insensitive to color differences, and instead, it depends on brightness, or luminance contrast. Thus, in the absence of luminance contrast, the ability to perceive motion disappears. Albert Yonas, with the University's Institute of Child Development, and Lee Zimmerman, with the University of Minnesota Duluth's electrical and computer engineering department, have studied this phenomenon and are working to minimize its contribution to rear-end collisions with snowplows.

According to Yonas, two distinct problems must be tackled. First is the need to get drivers' attention and let them know a snowplow is ahead. Second is the need to enable drivers to see that they are gaining on it, and how fast they are doing so. Until now, Yonas says, there has not been clear differentiation between these two issues.

Using a simple computer driving simulator to replicate the effects of blowing snow and fog, these researchers monitored test participants who were asked to decide whether a simulated "truck" approached or withdrew as the brightness contrast of the simulator display was varied. This unique experimental setup allowed the team to study snowplow designs and the effects of flashing warning lights on a driver's detection of approach and impending collision.

Through these efforts, Yonas and Zimmerman observed that lowering the luminance contrast between the simulated image of a vehicle and the background greatly reduces a driver's ability to perceive approach. Specifically, they found that the low-contrast environment created by snow or fog significantly reduces drivers' ability to see that they are approaching the snowplow. They also discovered that the flashing lights mounted on snowplows to attract attention interfere with motion perception and make it even harder for drivers to see that they are approaching the snowplow.

From this work, the team has developed a set of recommendations for properly outfitting snowplows with lights that better enable drivers to see that they are approaching the plow.

"There must be a balance in the snowplow lighting and coloring to attract attention, yet not interfere with the ability to tell whether or not a driver is approaching it," Zimmerman explained. "Our current experiments are getting us closer to finding that balance."

One suggested design approach is to ensure that rear-facing lights and markings on snowplows create optimal luminance contrast while reducing the offending color contrasts.

This can be accomplished by putting two solid light bars on either side of the rear of the snowplow, as far away from each other as possible, and by making the light as bright as possible. A second possibility involves structuring rear-facing markings to help drivers better tell when they are approaching a snowplow. This involves making sure the flashing lights are placed in such a way that they do not interfere with the ability to see the steady burning lights. For example, steady burning light bars could be positioned on the sides of the snowplow and a flashing light could be placed above the center of the rear of the snowplow.

In the future, these researchers would like to team up with Mn/DOT for real-world testing. The overall findings will likely improve driving safety through the careful choice and placing of color warning markings, as well as through better public education.

The flashing lights mounted on snowplows to attract attention interfere with motion perception and make it even harder for drivers to see that they are approaching the snowplow.

Technologies for Modeling, Managing, and Operating Transportation Systems

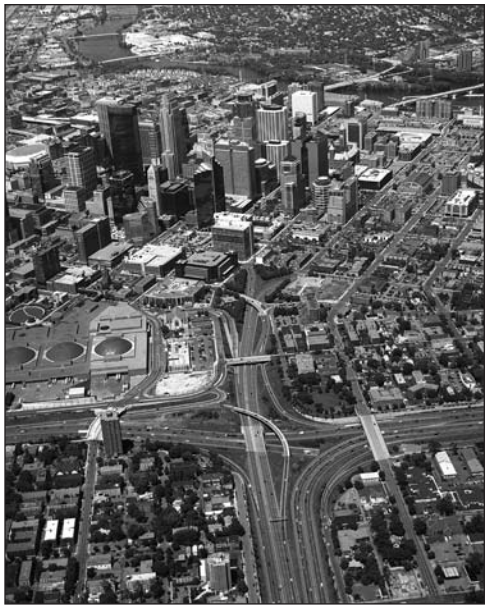
ROV Surveillance for Transportation Management and Security

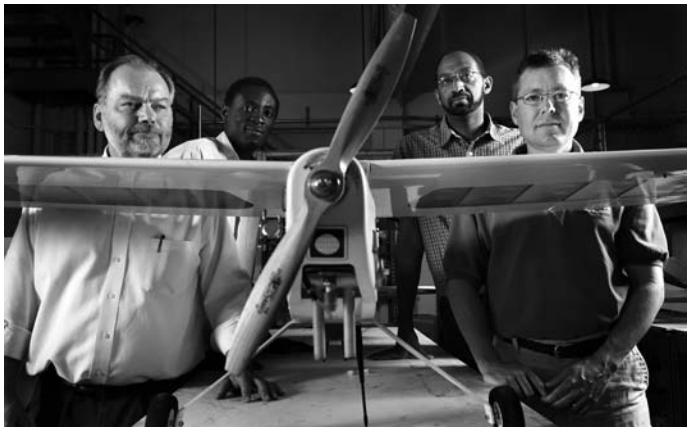
The bird's-eye view afforded by an aerial platform offers many advantages for gathering data on traffic movements and general surveillance of transportation infrastructure, including a wide field of view and the capability of moving rapidly between different monitoring sites or following a single vehicle as it traverses a network. But the expense and risk associated with keeping a piloted plane in flight for hours at a time—not to mention the highly trained personnel and maintenance required—limit the effectiveness of conventional aircraft as monitoring platforms.

One solution to these limitations is to find an alternative to the pilot—the most sensitive and expensive component in the system. Demoz Gebre-Egziabher of the Department of Aerospace Engineering and Mechanics, along with a team of other researchers, is developing remotely operated aerial vehicles (ROVs) as monitoring platforms specifically targeted at surveillance and inspection of the surface transportation system. Through advances in navigation and guidance systems, sensors, and flight operations techniques, ROVs may play an important role in future transportation data collection and security.

As a remote sensing platform, the usefulness of an unmanned aerial vehicle depends on how well its position can be determined at all times. This is critical not only for the safe operation of the ROV in a complex aerial environment that includes restricted airspace and navigational obstacles such as tall structures, but also for the accurate location of events and conditions observed on the ground.

The navigation and guidance system of the Minnesota team's ROV is based on high-accuracy Global Positioning System (GPS) receivers. Basic position and velocity can be determined with GPS using the Federal Aviation Administration's (FAA) Wide-Area Augmentation System (WAAS), which enhances the accuracy of the basic GPS





Demoz Gebre-Egziabher (back right) leads a research team including research scientist Greg K. Nelson, graduate student Romeo Ahohe, and research engineer Curt Olson.

The bird's-eye view afforded by an aerial platform offers many advantages for gathering data on traffic movements and general surveillance of transportation infrastructure.

signal. Attitude determination for the small craft is a more difficult problem, one which has led Gebre-Egziabher to develop an approach based on three GPS receivers. These receivers track and process the GPS carrier signal (rather than the digital information encoded within the signal) to achieve centimeter-scale range measurement accuracies. Monitoring the relative positions of the three antennas enables the onboard computer to calculate accurate estimates of pitch, roll, and yaw (movement about the lateral, longitudinal, and vertical axes of the vehicle in flight).

The researchers are exploring the possibilities of a novel "click-to-navigate" system that integrates position sensing and an operator interface based on flight simulator display technology. This software uses aerial photographs of the operating area to provide a realistic picture of the terrain below, in pseudo-3D perspective. By feeding the location of the ROV to the flight simulation software, the researchers succeeded in creating an artificial view from the aircraft in real time, which can be presented to the operator side-by-side with the actual camera view. The system can also display the boundaries of prohibited airspace in relation to the ROV. The artificial perspective could be immediately useful as an aid to the operator, providing a clear and unobstructed view of landmarks below. It also shows the potential for displaying augmented information such as map data. Gebre-Egziabher is now investigating the potential to build the simulator approach into a "click-to-navigate" system that would allow an operator on the ground to send the ROV over a designated point on the ground.

While a remotely operated vehicle has advantages over a piloted aircraft, a partially or fully autonomous craft offers even more intriguing possibilities. Designing a degree of autonomy into the ROV's guidance system would allow the vehicle to move from location to location, or around a patrol route, without requiring an operator on the ground to guide it through each turn.

Being pilotless, however, does not exempt ROVs from the FAA's strict regulations governing all aircraft operations, including the requirement that aircraft operating in controlled airspace possess the capability to autonomously "sense and avoid" other aircraft. Gebre-Egziabher describes the development of autonomous sense-and-avoid systems as the greatest challenge facing ROV researchers today. Such systems will make it possible for autonomous and semi-autonomous ROV sensor platforms to operate in a wide range of areas. Because highly accurate and dependable navigation is a necessity for future sense-and-avoid capability, much of the Minnesota researchers' work is directed at developing operational techniques and navigation systems that provide verifiable levels of navigation safety consistent with FAA requirements. For most aviation applications, the threshold navigation integrity during normal operations—i.e., the likelihood that a navigation system will report a position outside the protection levels—is set at one in ten million, or 10^{-7}.

Due to inherent inaccuracies, a system based purely on GPS cannot guarantee positional integrity at the small scales required for safe navigation. The design of algorithms that combine data from different types of sensors is a challenge in itself. The goal is to take advantage of the strengths of each type of sensor while minimizing its weaknesses. As different sensor types produce data at different rates and with different levels of accuracy, successful "sensor fusion" depends on factoring out a large number of possible sources of error.

The Minnesota researchers' work has important implications for all types of ROV applications. Unmanned vehicles that can operate autonomously or semi-autonomously could one day replace piloted aircraft in a wide variety of dull, dirty, and dangerous missions—reserving pilots for those tasks where local human decision making is critical for success.

Crash Prevention Based on Automatic Detection of Crash-Prone Traffic Conditions: Phase I

Researchers have long hypothesized that certain traffic conditions create a greater risk for freeway crashes and that if these conditions were detected, certain actions could be taken to lower the crash risk. Although previous research by others has proven the existence of crash-prone conditions, the study methods used were not based on real-time information, and therefore research results did not facilitate development of appropriate crash-prevention countermeasures. Professor Panos Michalopoulos and research fellow John Hourdos, both with the University's Department of Civil Engineering, set out to develop the real-time algorithms needed to create a driver-warning system designed to help prevent crashes in high-risk areas.

Their first step was to study the reasons for, and mechanics of, crashes by recording them and extracting raw traffic detector measurements. The researchers designed and assembled a set of unique sensors and surveillance equipment, which they deployed along I-94 westbound through downtown Minneapolis—the stretch of road with the highest rate of crash occurrences in Minnesota. With these instruments, the researchers collected individual vehicle speeds, headways, and lengths at 52 points along the freeway. In addition, they simultaneously recorded video 12 hours a day for two years, capturing all of the crashes and near misses occurring during that time.

As they reviewed the data collected, the researchers pinpointed the entire sequence of events leading to each crash and identified three specific elements contributing to nearly all crashes in this area: congestion shock waves that propagate backwards from the merge area of a downstream entrance ramp; the large difference in driving speeds between the right and middle lanes, which makes lane-changes difficult and therefore dangerously distracting for drivers; and last, the fact that in the area where the shock waves begin, vehicles are simply too close to each other to allow drivers time to take evasive actions.

Researchers also verified that the same elements contributing to crashes also cause "near miss" events. They recorded four times the number of near misses as crashes and observed that the difference is a matter of split seconds. With these findings, the team developed an algorithm capable of accurately detecting the presence of crash-prone conditions nearly 70 percent of the time.

In the second phase of this project, currently under way, the researchers will integrate their previously developed detection algorithm into a real-time driver warning system specifically designed for the I-94 westbound commons section. Through a variety of driving simulator experiments, Michalopoulos and Hourdos are working to narrow down the multitude of options for such systems to one or two and will proceed with additional testing from there. One of the systems under consideration includes pavement lights that light up to simulate the shock wave and alert drivers to congestion ahead. The researchers are looking at a number of geometric reconstruction solutions as well as electronic breaking systems capable of vehicle-to-vehicle communications.

Based on the Phase I research results, Mn/DOT is already making changes in the road geometry in the commons area. It will alter the striping at the merge area where the shock waves are generated, a strategy that may significantly reduce crashes in this area. Although it is hard to predict just how many crashes can be avoided, a reduction of even 50 percent would result in millions of dollars in savings from crash costs as well as reduce related congestion, travel time delays, and system productivity losses for drivers throughout the freeway system.

Research fellow John Hourdos and Professor Panos Michalopoulos examine their system to collect data on the most crash-prone section of highway in the state.

Lateral Stability of a Narrow Commuter Vehicle

The predictions are bleak. By 2010, urban freeway congestion is expected to double in urban areas of every size, resulting in unbearable gridlock and rising costs to motorists in the form of wasted time and fuel consumption. Since most transportation planners agree that we can't "build our way out of congestion," other solutions to this growing problem are needed.

A relatively unexplored but promising idea is the use of narrow commuter vehicles that, like motorcycles, can double the capacity of existing freeways since they take up only half a traffic lane. Although smaller, more fuel-efficient vehicles could greatly reduce both congestion and fuel demand, for many people, a motorcycle is not practical or feasible. For the general population to adopt narrow vehicles as a form of personal transportation, the vehicle must be as easy to use and provide the same level of safety as full-size passenger sedans.

Graduate student Samuel Kidane (in vehicle), research fellow Lee Alexander, and associate professor Rajesh Rajamani with the narrow commuter vehicle

A team of University researchers from the mechanical engineering department—including Rajesh Rajamani, Lee Alexander, Patrick Starr, Max Donath, and Samuel Kidane—recently finished redesigning and building a second-generation prototype narrow commuter vehicle. Unlike the team's first concept model, which was operated and tested via remote control, the improved version is capable of carrying a driver. This model also has a more powerful engine that enables it to travel at highway speeds and several improved safety features, including a driver-protective roll cage.

Perhaps the most significant upgrade to this concept vehicle is the reengineered electronic tilt-control system, which did not work at slower speeds in the first design. The tilt-control system helps the driver balance this three-wheeled, rear-wheel-drive vehicle, which is relatively tall compared to its track width. The benefit of this narrow, tall design is to provide a travel height comparable to that of other vehicles on the highway; however, this design reduces the vehicle's lateral stability. The electronic tilt-control system helps the driver easily balance the vehicle and keeps the vehicle from tipping or rolling over.

The new steering tilt-control system uses both direct control, which was unavailable in the previous model, and steer-by-wire technology, offering great improvement over the previous version in terms of balancing and overall handling, especially on curves where the vehicle must lean into the curve to ensure tilt stability. The team developed an innovative algorithm that satisfies both the driver handling and tilt stability requirements and incorporated the algorithm into the tilt-control system design. With the steer-by-wire system, the front-wheel steering angle is used to control tilt, while at the same time allowing the driver to use this steering angle for lateral control. The direct tilt-control system incorporates an electric motor in a novel vehicle suspension to achieve directly actuated tilt control. Experimental results show that the control system sufficiently stabilizes the vehicle without all of the limitations of the original design.

The team's next step is to secure additional funding. With financial support in place, the researchers will work toward further improving the vehicle's crashworthiness by incorporating front and side air bags and collision-avoidance features. Future work will also involve the study of human-machine interfaces, the addition of drivability and comfort improvements, and improvements to the propulsion system. The results of this study are likely to inform the development of future transportation technologies for reducing congestion on freeways in Minnesota, around the country, and throughout the world.

Decision Support System for Evacuation Route-Schedule Planning: Determining Optimal Contraflow Network Configuration

As Hurricane Rita sped toward Houston and the upper Texas Gulf Coast in late September 2005, hundreds of thousands of people attempting to evacuate the area were stuck in their cars, many running out of gas and sweltering on roadsides in 100-degree heat. This mass, traffic-snarled exodus created colossal 100-mile-long traffic jams, with traffic crawling at just a few miles per hour at best and completely stopping for hours at worst. One method often used to minimize evacuation snafus like this is known as contraflow, or lane reversal. It's a relatively simple way of increasing the number of lanes available for outbound evacuation traffic.

Although considered a potential remedy to reduce evacuation time and congestion during emergencies, contraflow as it exists today relies on configuration algorithms that address only a single-source/multiple-destination situation. These approaches cannot handle a multiple-source problem and so are not effective in cases when the number of evacuees is finite, road capacities are constrained, or specific destination nodes are prescribed. Researchers Shashi Shekhar and Sangho Kim from the University's computer science and engineering department are exploring alternative algorithms that address the limitations of current approaches.

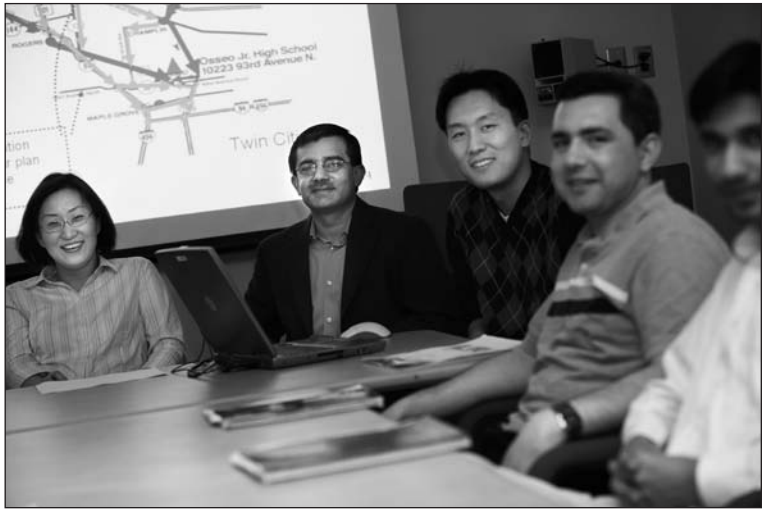
Using graph theory, the team has developed a set of new algorithms and software tools that can help disaster planners determine the optimal network configuration given both the physical transportation network and traffic demand for a particular evacuation scenario.

In the initial stage of this project, Shekhar and Kim evaluated algorithm alternatives analytically and experimentally using real-world data sets based on evacuation scenarios for the Monticello nuclear power plant and the Twin Cities metro area. In experiments using the Monticello scenario, the team found that evacuation times could be reduced more than 40 percent by selectively reversing just 10 percent of the entire road segment, which mainly included major highways I-94 and MN-Hwy 10 from St. Cloud to Maple Grove, and some roads around the evacuation shelter at the Osseo high school.

The team then developed a computerized evacuation route system for the Twin Cities metro area to generate large-scale evacuation scenarios for user-specified locations. This system enables evacuation planners to explore multimodal evacuation options, such as pedestrian versus vehicle-based evacuation processes, and observe the differences among contraflow configurations affected by the options.

In addition, the researchers studied the effects of overload degree—that is, the ratio of the number of evacuees to bottleneck capacity of a transportation network without contraflow. They discovered that overload is a key determinant of overall evacuation time and need for contraflow. In situations when there are only a small number of people needing to evacuate, contraflow offers little or no benefit. The real benefits of lane reversal appear once the transportation network reaches overload and it becomes computationally possible to identify an optimal contraflow reconfiguration.

Shekhar and Kim are now working to refine the algorithms to allow for incoming emergency vehicles and to account for resource or infrastructure limitations to implementing contraflow. Ultimately, these efforts will provide improved tools to help evacuation planners come up with the most effective disaster evacuation routes and schedules. This will greatly minimize evacuation times and presumably avoid the Hurricane Rita-type chaos when quickly moving a large number of citizens out of harm's way.



Professor Shashi Shekhar (second from left) with research assistants, from left: Jin Soung Yoo, Sangho Kim, Mete Celik, and Vijay Gandhi

Social and Economic Policy Issues Related to ITS Technologies

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

In 2000, Metro Transit, the local transit provider for the Twin Cities region, served more than 73,000 unlinked passenger trips. In 2003, this number fell to slightly more than 67,000. This indicates a decline in demand for public transit service in the Twin Cities during this period—a decline not found in other major transit agencies around the country.

Then, in 2005, the opening of the Hiawatha Light Rail line led to a 30 percent increase in transit ridership relative to the previous year. Still, Metro Transit faces other challenges that relate to serving a diverse population made up of people of all ages and backgrounds with varying riding habits, needs, and preferences.

University researchers Kevin Krizek from the Hubert H. Humphrey Institute of Public Affairs and Ahmed El-Geneidy, who holds a joint appointment with the Humphrey Institute and the Department of Civil Engineering, recently wrapped up their analysis of results from two surveys conducted in the Twin Cities metropolitan region over the past few years: one of existing riders and the other of non-riders. Their objective was to better understand the attitudes and preferences of current and potential riders and recommend transit technologies that could help increase the ridership of the Metro Transit system.

Associate Professor Kevin Krizek with State and Local Policy Program research associates

Conventional travel analysis typically focuses on only two types of transit users: captive and choice riders. Captive riders are usually those who lack an alternative to transit and so use it as their main mode of travel to reach their destination. Choice riders are those who typically choose to use transit or a different mode (driving or walking) to reach their destination. Krizek and El-Geneidy also considered the regularity of commuting habits, enabling them to classify transit riders into four categories: captive with regular commuting habits, captive with irregular commuting habits, choice with regular commuting habits, and choice with irregular commuting habits. Similarly, they classified non-transit riders into four categories: captives with regular commuting habits, captives with irregular commuting habits, potential riders with regular commuting habits, and potential riders with irregular commuting habits.

Using statistical factor analysis followed by a cluster analysis, these researchers examined the relative importance of different factors to different survey populations, especially those who choose to ride the bus even though they have access to private automobiles, and potential riders who may be interested in using public transportation but feel that it does not meet their needs. Through this analysis, they identified a number of factors affecting the decision to use public transportation, including safety, reliability, driver attitude, amenities, and wait time for service.

Krizek and El-Geneidy then developed a list of technological advancements Metro Transit could use to address several of these attitudes and preferences. For example, installing cameras inside buses increases security; automating stop announcements could help riders with disabilities or people unfamiliar with the route; encouraging the use of swipe cards could decrease travel time by reducing the delay during passenger boarding. Other technologies, such as automatic vehicle locator (AVL) systems, are gaining popularity as ways of improving transportation service by providing information—via electronic displays in stations or by cellular

phone—about schedules and wait times and by helping drivers stay on schedule.

Using technology to decrease transit wait and travel times appears to provide the best opportunities for increasing ridership, especially when expanding routes is not an option, Krizek and El-Geneidy concluded. So, although Metro Transit previously used an AVL system chiefly for monitoring drivers' on-time performance, it is currently testing the system to inform riders about arrival and departure times at selected bus stops in the region. In addition, Metro Transit is now armed with a better understanding of the attitudes and preferences of the eight types of commuters classified in this research and can use this knowledge to improve its efforts to retain current riders and attract new ones.

Sustainable Technologies Applied Research Initiative: Privacy and ITS

Since 2001, researchers from the Hubert H. Humphrey Institute of Public Affairs' State and Local Policy Program (SLPP) and the ITS Institute have been working together to conduct a set of federally sponsored studies, collectively called the Sustainable Technologies Applied Research (STAR) initiative, on how transportation systems can be planned in an increasingly complex social, political, economic, and technological environment. As part of this interdisciplinary team, SLPP director Lee Munnich and graduate student Adam Kokotovich are beginning research on ways to identify and address privacy issues related to the use of intelligent transportation systems.

ITS technologies are experiencing widespread growth, from OnStar technology to automatic toll collection. The growth in technology, however, is leading to more concerns about privacy, says Munnich. As a result, a primary policy challenge related to the use of ITS technology will be ensuring the privacy of the users.

In addition to a broad examination of transportation privacy issues, Munnich and Kokotovich are focusing on specific ITS technologies that are generating privacy concerns: electronic toll collection and Global Positioning Systems used in value or congestion pricing (charging drivers fees for road use that vary according to time of day or traffic conditions) and mileage-based fees.

The researchers want to determine what the privacy concerns are, and how they can be mitigated by incorporating this information into the framework of ITS systems. To date, little research has been done on privacy as it relates to transportation, the researchers say. "The need is there not just because people are concerned about [privacy] but because, for the implementation of these intelligent transportation systems, public acceptance is key," Kokotovich says.

The public may be more likely to accept these technologies if the processes for collecting and using data are transparent, and if people understand the processes, Munnich says. "It's not only about how you are collecting information, but also what people's perception is of what you're doing," he says.

In addition to its use for transportation financing options, emerging ITS technologies are being developed to improve

Using technology to decrease transit wait and travel times appears to provide the best opportunities for increasing ridership.

Research assistant Adam Kokotovich

safety. In-vehicle systems can track a particular car on the roadway and individual driving behaviors inside the car. Such a system might give a warning or reminder to the car's driver to encourage safer driving. This information that is generated, however, could be used in ways that would invade privacy, Munnich says. For example, if you were driving in your car and received a message advertising a nearby business, you might perceive that as a benefit, or you might consider it an intrusion, Munnich says.

Transportation planners need to anticipate these issues before they arise, he adds. "If you move too quickly with the technology and the public isn't ready for it, you may have to backtrack."

People have different perceptions and acceptance levels of privacy, and the definition is constantly changing, Kokotovich says. Whereas few people might object to technology that prevents a repeat DWI offender from starting a car without passing a Breathalyzer test, "monitoring traffic on a freeway and having it personally identifiable to the vehicle and who's driving the vehicle—everyone is going to object to that," he says. "There's a need to find the middle ground as far as what's acceptable technology-wise."

When ITS is used to improve safety or convenience for a driver, such as with OnStar, that may be an acceptable trade-off, Munnich adds. "It may be that the overall benefits to the individual and to society outweigh the privacy concerns. There may be significant benefits but it may not be possible to guarantee that privacy won't be negatively affected."

So far, the researchers have met with a nationally recognized expert on privacy, Professor Colin Bennett from the University of Victoria, who also spoke on the issue of privacy at the Center for Transportation Studies' annual Transportation Research Conference. Kokotovich is now working on a paper to frame the issue of privacy related to transportation and suggest some specific issues to examine in-depth. The researchers' ultimate goal is to provide relevant, useful information for planners and policymakers to incorporate into future transportation systems.

Graduate student and SLLP research assistant Tyler Patterson (left) with SLLP director Lee Munnich

Human Performance and Behavior

Janet Creaser, Department of Mechanical Engineering

Evaluation of Minnesota's NightCAP

Status: In progress

Discussions with Minnesota's Office of Traffic Safety indicate a strong need for an analysis of Minnesota's saturation patrol enforcement strategy to reduce alcohol-related crashes. With 32,100 DWI citations and alcohol-related crashes costing $350 million in Minnesota last year alone, reducing the number of impaired drivers is a key focus for Minnesota's Comprehensive Highway Safety Plan.

Minnesota conducts saturation patrols under a program called Operation NightCAP (Nighttime Concentrated Alcohol Patrol) as an alternative to sobriety checkpoints, which cannot be conducted legally in Minnesota. Although anecdotal evidence suggests that more DWI offenders are caught through the use of saturations, the actual effectiveness of the campaign in reducing alcohol-related crashes and deterring individuals from driving while intoxicated is unknown. Since its inception no formal, rigorous analysis of Operation NightCAP has been conducted. Moreover, little research has been conducted on saturation patrols in general as an enforcement tool against drunk driving.

This project aims to describe the potential effect of saturations on DWI offenses and alcohol-related crashes in Minnesota, conduct a survey of Minnesota drivers to learn what they know about DWI enforcement and the NightCAP program, and conduct a brief survey of enforcement officers involved with NightCAP to identify any potential issues associated with conducting saturation patrols.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2006032

Kathleen Harder, College of Architecture and Landscape Architecture

Low-Cost Innovative Approaches to Improve Safety at Unsignalized Intersections on Four-Lane Highways

Status: In progress

Intersection crashes represent a significant portion of total crashes nationwide, accounting for an average of 9,000 fatalities and 1.5 million injuries annually. Without resorting to roundabouts or grade separations, there are a number of relatively low-cost approaches—either already in use in other countries or that could be developed—to improve the safety of unsignalized intersections on four-lane divided highways.

In the first stage of this research, the principal investigators (PIs) will use their expertise, along with computer simulation, to develop innovative and viable safety improvements at unsignalized intersections. A select group of traffic engineers will participate in a roundtable discussion to give input on the recommendations of the PIs, who will incorporate their suggestons. In the second stage, the recommended strategies will be tested at one representative intersection. Mn/DOT will implement the recommended interventions and provide data-collection technology. The PIs will conduct the field test, analyze the data collected, and write the final report. Recommended improvements will likely have a significant impact on reducing the number and severity of crashes at unsignalized intersections on four-lane divided highways, benefiting motorists in Minnesota and across the United States.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2006049

Psychological and Roadway Correlates of Aggressive Driving (Phase II)

Status: In progress

This study was conducted to better understand the psychological and roadway correlates of aggressive driving. The study had two phases: In Phase I, survey data was 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 to determine strategies for mitigating aggressive driving behavior.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002034

Stephen Simon, Law School

In-Vehicle Driver Assistance for Teenagers

Status: In progress

See page 15 for coverage of this project.

Thomas Smith, School of Kinesiology

Warning Efficacy of Active Versus Passive Warnings for Unsignalized Intersection and Mid-Block Pedestrian Crosswalks

Status: Newly funded

Results of past research on the efficacy of active warnings show that, relative to passive warnings, active warnings at railroad crossings and in advance of signalized intersections are clearly more effective. In contrast, results regarding the relative efficacy of active versus passive pedestrian crosswalk warnings are mixed. Given that the cost of active crosswalk warnings is substantially higher, relative to passive warnings, further research is needed to ascertain the comparative warning effectiveness of active versus passive pedestrian crosswalk warnings, and explore low-cost alternative designs for pedestrian crosswalk warnings. This project will carry out a literature review of research findings relevant to crosswalk warning systems; a field study of the relative warning efficacy of active versus passive warnings at selected pedestrian crosswalks; and a design analysis of low-cost alternatives for pedestrian crosswalk warnings.

Project URL: www.its.umn.edu/research/2007Projects/WarningEfficacy.html

Nic Ward, Department of Mechanical Engineering

Driving Performance During 511 Information Retrieval and Cell Phone Conversation Tasks

Status: In progress

Minnesota currently has a 511 service that users can access while driving. There is considerable debate about cell phones as a risk factor in traffic crashes. In 2003, Phase I research assessed the relative risk of cell phone use compared with other common risk factors, including existing in-vehicle tasks and alcohol. As a necessary extension of that research, this new project will assess the distractibility and usability of 511 applications with revised menu structures and content.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2006028

Computing, Sensing, Communications, and Control Systems

Rural and Urban Safety Cultures

Status: In progress

Motor vehicle crashes are a predominant cause of mortality in rural areas. Persons involved in a rural crash are three times more likely to die than persons involved in an urban crash. Since most rural crashes involve rural drivers, it is necessary to consider the pertinent human factors by examining the relationship between the personalities and attitudes of rural drivers toward safety and the higher rural crash rate and driving style relative to the urban context. This project attempts to support the development of a human-centered intervention to reduce the loss of life resulting from the high rural crash rate in Minnesota by investigating psychological and social factors that may predispose rural drivers to drive less safely.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005058

Albert Yonas, Institute of Child Development

Chromatic Perception Effects on Collisions with Snowplows

Status: Completed

See page 16 for coverage of this project.

Improving the Ability of Drivers to Avoid Collision with Snowplows in Fog and Snow

Status: Completed

The researchers have created a laboratory test bed for investigating the effects of blowing snow, fog (luminance contrast), flashing warning lights, and color on the ability of drivers to perceive that they are approaching or withdrawing from a simulated vehicle. Findings indicate that lowering the luminance contrast between the image of a vehicle and the background greatly decreases a driver's ability to perceive approach. In a low-contrast, equiluminant situation, drivers required twice as much retinal motion as normal to begin to sense approach. Flashing lights, such as those mounted on snowplows to attract attention, also interfere with motion perception.

The researchers plan to characterize completely the chromatic contrast effect of blowing snow and fog on the color space by making systematic physical measurements on a selected number of carefully chosen color surfaces. In addition, they will use a computer-controlled laboratory simulation, and well-understood psychophysical methods, to investigate the effect of vehicle color and lighting enhancements. Results will make it possible to form recommendations to increase the safety of Minnesota drivers.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005023

Mohamed-Slim Alouini, Department of Electrical and Computer Engineering

Bandwidth and Power-Efficient Modulations for Multimedia Transmissions over Wireless Links

Status: Completed

This project was motivated by the demand of spectrally and power-efficient transmission systems of multimedia traffic data (image and video as well as voice) over wireless links. The main objective was to design and evaluate the performance of hierarchical constellation systems that have the advantage of offering different degrees of error protection and/or different rates for various bit streams.

Research achievements include the development and performance analysis of a variable rate non-coherent M-FSK modulation scheme for power-limited systems, the derivation of the exact-bit error-rate expressions for a variety of hierarchical PSK and QAM constellations, and the investigation of the effect of fading as well as timing and phase synchronization errors.

This project also pursued several applications of hierarchical constellations—in particular, for simultaneous voice and data transmission over fading channels, multi-resolution data transmission, and multi-user opportunistic scheduling.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2003017

Max Donath and **Craig Shankwitz**, Department of Mechanical Engineering

Toward a Multi-State Consensus on Rural Intersection Decision Support

Status: In progress

Minnesota has partnered with California and Virginia in a pooled-fund consortium, the Intersection Decision Support (IDS) project, to improve safety at intersections. The consortium is looking at both near- and long-terms solutions that are effective, deployable, affordable, and beneficial to not only the participating states, but to the nation as a whole.

The Minnesota effort is focusing on rural intersection safety. Crashes at rural intersections, although less frequent than those at urban or suburban intersections, are often more catastrophic than their counterparts because of the high vehicle speeds associated with them. The National Safety Council estimates that 32 percent of all rural crashes occur at intersections, and approximately one in every four fatal crashes occurs at or near an intersection.

To create a system that can be deployed nationwide, the extent of the national problem must be understood, and a nationally applicable solution to that problem must be designed, developed, tested, and evaluated. The University of Minnesota and the Minnesota Department of Transportation have initiated a state pooled-fund study to gain a national basis for deployment of its IDS Project.

The plan consists of three facets. The first is a review of state intersection crashes for each participating state. The second facet is to develop a portable intersection surveillance system that can be used to instrument candidate intersections as a means to acquire data regarding the behavior of drivers at rural intersections over a wide geographical base. The third facet is to deploy the surveillance system at the identified intersection in each of the member states in order to determine if there are regional differences in how drivers accept gaps when entering the intersection.

The portable system has been developed and tested at the Minnesota test intersection at U.S. 52 and County 9 near Cannon Falls, Minn. The system was run for one month; a few problems were identified but have been corrected. The next step is to acquire data in each of the partner states.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004039

Ahmed El-Geneidy, Department of Civil Engineering

Using Archived ITS Data to Improve Transit Performance Management

Status: Newly funded

In the past, in order to measure transit performance, collecting the necessary data was difficult and costly. With the recent implementation of intelligent transportation systems (ITS)—and especially advanced public transit systems (APTS)—data collection is no longer an issue, but there is a concern with how this data can be meaningfully analyzed, creating information relevant for service planning and control.

Metro Transit, the local transit authority in the Twin Cities, has recently implemented an APTS, which it has been testing since 1999. Metro Transit uses the data obtained from the APTS for live transit operations through its transit management center to identify

early and delayed buses and apply some strategic decisions in the field to address such problems. Metro Transit also archives this information for future research to help improve its operations and planning process.

This research will use this abundance of archived ITS data to introduce and explore various research methodologies that can help Metro Transit improve service reliability, schedule adherence, and on-time performance.

Project URL: www.its.umn.edu/research/2007Projects/UseData.html

Taek Kwon, Department of Electrical and Computer Engineering (Duluth)

Integration of RTMS and SQL to Mn/DOT Next Generation R/WIS (Phase II)

Status: Completed

Road Weather Information System (R/WIS) and traffic data have mostly been managed in isolation. Researchers believe, however, that historical and real-time traffic data integrated with R/WIS data could lead to a better understanding of traffic by correlating road weather conditions to the traffic data.

The objective of this project was to develop a new data warehouse model from the ground up, starting with sensor data and building up to applications to demonstrate the benefits of data integration. Based on this, a new data warehouse model was developed to integrate the heterogeneous nature of R/WIS and traffic data.

The research resulted in the development of a data model and implementation of a prototype. The functions of the prototype include a data aggregation model from sensors, a data archiving method, and multiuser data access and retrieval environments through a network. The key to this data model was utilization of a network storage model, referred to as a parallel first-in-first-out (FIFO) data storage, where various sensor data are deposited as they are aggregated while different types of data-consuming modules obtain data without an explicit protocol requirement. For the prototype implementation, four different data aggregation methods from traffic and R/WIS sources were used to demonstrate that diverse data types and collection methods could be seamlessly integrated.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005046

Section Travel-Time Measurement and Vehicle Classification Using Inductance Signatures of Loop Detectors

Status: Completed

This research sought to develop a new computational approach that could accurately measure travel time from two sets of spatially separated loop detectors using re-identification of vehicle inductance signatures generated by the loops. Although measuring travel time using loop inductance signatures is not new, all past approaches essentially relied on pattern matching of raw inductance waveforms without restoring the loss of detailed features caused by a large detection zone of inductive loops.

The main effort in this research was to develop a new computational algorithm that restores the lost details from the raw inductance waveforms by modeling the output of loop detectors as a convolution of the original vehicle signature and the loop system function. This restoration problem was formulated as a blind deconvolution problem, since neither the impulse response of the loop detectors nor the original vehicle signature was known.

To solve this blind problem, two basic blind deconvolution approaches were used. The first estimates the loop system function using a speed estimate obtained from the inductance waveform. The estimated loop system function is then used in constructing a constrained least squares (CLS) inverse filter that restores the lost information. The second approach used is an adaptive iterative method referred to as the Godard blind deconvolution. This approach finds the inverse filter through repeated iterations without the knowledge of the system function.

Experimental results showed that both methods performed well and significantly exposed the original signature information with unique vehicle characteristics, suggesting that blind deconvolution is an effective technique for extracting the lost information from the loop inductance outputs.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2003027

Development of Eight-Channel WIM Analysis System Based on Analog WIM Signals

Status: In progress

Weigh-in-motion (WIM) data has long served as a key component for traffic data. Over the past few years, Mn/DOT has begun moving from the traditional expensive bending plates and load-cell-based systems to low-cost quartz Lineas technologies. In using quartz Lineas technology, one of the challenges has been determining how trustworthy the sensor readings are, since the only available outputs from the present systems are the converted weight and axle data.

This research aims to significantly improve WIM data quality by developing an eight-channel WIM analysis system that could simultaneously probe and analyze eight channels of analog signal and provide signal diagnostic data.

During the preliminary study on WIM funded by NATSRL over the past year, the researcher found that adding WIM measurement to the probe is not significantly difficult. The new system should be developed to operate in two operational modes: a probe mode and a data-collection mode. In the probe mode, it will simultaneously probe eight WIM channels, analyze the raw analog signals of each channel, and report the analysis results. In the data collection mode, the system should compute real-time weight translation and record the data so that it can operate as a stand-alone WIM data-collection system of up to eight channels (four lanes). The base system will be developed based on off-the-shelf components so that Mn/DOT can easily reproduce in-house WIM data collection systems at a low cost.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2006022

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

Status: Newly funded

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 within a few years. Consequently, the amount of data is expected to grow substantially, requiring an efficient data warehousing and management system.

This research will develop a VC/WIM data warehouse at the UMD Transportation Data Research Laboratory (TDRL) and provide the data reporting needs of TDA through online automation. 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 a statistical summary can be queried directly from both types of data. TDRL currently archives the statewide R/WIS data and the Twin Cities' freeway traffic data. The addition of WIM and VC data would give Mn/DOT an easy single point of access to various types of transportation data and would increase the quality of

statistical data reports through inference by related data.
Project URL: www.its.umn.edu/research/2007Projects/DevData.html

Nikolaos Papanikolopoulos, Department of Computer Science and Engineering

Deployment of a Tracking-Based Monitoring and Data-Collection System

Status: Completed

This project developed a series of vision-based algorithms for data collection at traffic intersections. The researchers have purposed an algorithm for obtaining sound spatial resolution, minimizing occlusions through an optimization-based camera-placement algorithm. Along with this camera calibration algorithm, the research produced a camera calibration-guided user-interface tool and a computationally simple data collection system using a multiple cue-based tracker. Extensive experimental analysis of the system was performed using three different traffic intersections. The research also proposes solutions to the problem of reliable target detection and tracking in unconstrained outdoor environments as they pertain to vision-based data collection at traffic intersections.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2003042

Freeway Network Traffic Detection and Monitoring Incidents

Status: In progress

Freeway management requires advanced data collection methods. In particular, special emphasis is given to data such as vehicle trajectories, gaps, lane changes, and accelerations in weaving sections, freeway bridges, tunnels, and freeway segments around airports, rail, and bus stations.

The process of collecting traffic data and recognizing patterns or events of interest is complex, since it often involves crowded scenes. The researchers suggest using cameras in the visible range in order to collect data and classify certain events as meriting further examination by a human operator. Examples include a car stopped on a bridge or a car driving erratically.

Currently, several states and federal agencies use humans to observe these events and collect data. This project is working toward developing an automated system to collect this information and notify human operators about interesting data or events in the vicinity of the freeway network.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005070

Multi-Camera Monitoring of Human Activities at Critical Transportation Infrastructure Sites

Status: In progress

This research is investigating the use of multiple cameras for monitoring human activities at critical transportation infrastructure sites, leveraging work performed in the researchers' Department of Homeland Security (DHS) project. The methods deal with detecting specified activities and counting humans in crowded scenes. The researchers will further develop methods to automatically detect and spatially estimate an occlusion (common in crowded outdoor scenes) in world coordinates. The algorithms will be tested at the transit stations where the DHS system is currently deployed and will cover activities that are not of interest to the DHS but are of major interest to Metro Transit (e.g., loitering, graffiti, drug dealing). The proposed methods, which focus on human activities, are directly applicable to a wide variety of transportation infrastructure sites.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2006018

Portable Traffic Video Processor

Status: In progress

This project is working to produce a visual traffic data processor, in the form of a PC-based system that accepts video recorded by cameras mounted near road sections (such as intersections, weaving sections, or other areas of interest) and processes that video signal to produce data on the traffic or to identify interesting events. Depending on the traffic domain, events of interest could be clear-cut occurrences that are pre-specified by the system user (such as vehicle crashes) or deviations from normal traffic flow, given a specified threshold.

The system will be designed to operate in a wide range of uncontrolled environments, where target condition identification may be affected by the camera type, viewpoint, road geometry, and other factors. To provide this portability, the system should be able to learn normal target behavior patterns by analyzing previously recorded target vehicle trajectories.

Extracting target trajectories from image sequences in unconstrained environments such as outdoors is difficult due to the dynamic nature of the scene that affects accurate target registration. Hence, the main challenge in a vision-based sensing application is achieving robust target tracking. Most vision-based trackers for outdoor scenes make use of a single visual cue that can provide good target detection as long as certain assumptions about the content of the scene are met. As soon as the scene changes in ways that violate these assumptions, however, the cues fail to provide any useful information, thereby rendering the tracker inaccurate. This research will make use of multiple visual cues, so that the range of successful operation of the tracker can be increased by reducing the scene constraints.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2006033

Data Mining of Traffic Video Sequences

Status: Newly funded

This project proposes to address the problem of data extraction from traffic video sequences. The researchers plan to automatically learn the layout of a traffic site (e.g., an intersection) from trajectories of vehicles obtained by a vision tracking system. This approach will enable the automatic extraction of sophisticated and complex data such as unusual events, near misses, and vehicle trajectory clusters. The researchers will use a similarity measure that is suitable for use with spectral clustering in problems that emphasize spatial distinctions between vehicle trajectories. The researchers will evaluate the robustness of the method to small perturbations and its sensitivity to the choice of parameters, and will integrate the algorithms with a previous system recently delivered to Mn/DOT.
Project URL: www.its.umn.edu/research/2007Projects/DataMining.html

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

Automated Winter Road Maintenance Using Road Surface Condition Measurements

Status: In progress

This project aims to develop an automated sander control system for a snowplow using the friction coefficient of the road surface and pavement temperature as key measurements for feedback. The project consists of two major technical activities: First is development of an improved tire-road friction measurement system on the SAFEPLOW. The performance of the friction measurement system in terms of accuracy and reliability will be evaluated using experimental tests on different types of road surfaces with the snowplow. The second activity is automation of the snowplow sander using real-time measurements from the friction measurement system and a pavement temperature measurement sensor.

Significant progress has been

made on both of the above project activities. This project will lead to the development of valuable winter maintenance technology in which knowledge of pavement conditions is used to keep roads in safe condition. The technology will help reduce material costs, help better utilize maintenance crews, and lead to safer roads in winter.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005037

Lateral Stability of a Narrow Commuter Vehicle

Status: In progress

See page 20 for coverage of this project.

Craig Shankwitz, Department of Mechanical Engineering

Driver-Assistive Systems for Rural Applications: A Path to Deployment

Status: Completed

Deployment of any system is driven by market demand and system cost. Initial deployment of the Intelligent Vehicle Lab's Snowplow Driver-Assistive System (DAS) was limited to a 45-mile section of Minnesota Trunk Highway 7 west of I-494 and east of Hutchinson, Minn. To better gauge demand and functionality, St. Louis and Polk Counties in Minnesota tested the system during the winter of 2003–2004; Polk County also tested it during the winter of 2004–2005.

Operational benefits were drastically different in the two counties. Low visibility was not an issue with the St. Louis County snowplow routes, so the system offered few benefits. In contrast, the topology of Polk County is flat with few trees. High winds combined with few visual cues create significant low-visibility conditions. Polk County was pleased with its original system and obtained a second system that it tested during the 2004–2005 winter.

A key component of the DAS is a high-accuracy digital map. With the exception of the mapping process, the present cost of the DAS is well documented. Research results describe a system designed to collect and process geospatial data to be used by the driver-assistive system, and the costs and time associated with collecting map data and creating a map from that data. With cost data complete, counties can use it to determine whether or not to acquire these systems.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002009

Gang Plowing Using DGPS

Status: Completed

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

To improve the gang-plowing process, a DGPS-based gang-plowing system has been developed. This system uses advanced technology to allow a trailing snowplow to automatically follow a lead snowplow at an operator-specified lateral and longitudinal offset. The system is designed to improve both safety and productivity.

Results of this research are described in a final report in which the researchers 1) describe an implementation of a virtual mirror to the left side of the trailing plow in order to improve driver visibility; 2) describe the lateral and longitudinal performance of a two-vehicle gang on Minnesota Trunk Highway 101; and 3) propose a system architecture for gangs of more than two vehicles and document its potential performance through simulation.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002038

Quick Edge: Rapid Underbody Plow Cutting Edge Changing System

Status: Completed

Currently, cutting edges on snowplows are bolted to the plow blade with three or four fasteners. To ensure clear pavement plowing, substantial downward force is placed on the cutting edges, resulting in rapid wear and frequent replacement of the cutting edge. The process of changing cutting edges is time-consuming and tedious. Also, the limited space available forces mechanics to work in awkward positions and leads to back and joint injuries.

This project explores an alternative to the current bolting process. The new system will be designed with the objective of reducing time and effort required in the change and decreasing the risk of injury compared to the current labor-intensive bolting process. The alternative system has been designed and fabricated, and presented to the Minnesota Department of Transportation. It has been used by Mn/DOT's Golden Valley Maintenance Group since January 2006. The users have reported that the system functions as expected and that they are pleased with it. A Golden Valley representative demonstrated the system for the public at the Minnesota Spring Maintenance and Training Expo in April 2006.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004058

Advanced BRT: Innovative Technologies for Dedicated Roadways

Status: In progress

In the United States, a number of transit agencies are either currently operating bus rapid transit (BRT) systems or are in the process of initiating this service. For example, Twin Cities Metro Transit operates a BRT system using a network of 200 miles of road shoulders to allow bus passage during periods of high traffic congestion.

The present Intelligent Vehicles (IV) Lab lane-assist system is based on precise vehicle positioning technology and a high-accuracy digital road map. This system requires a reasonably clear view of the sky overhead in order to receive GPS satellite information.

This work aims to augment the present IV Lab lane-assist system with ranging and positioning technology that will allow the system to operate in difficult environmental conditions (e.g., urban canyons, roads with tall trees located close to the roadway, bridges). Alternative ranging and positioning sensors will be analyzed, modeled, and eventually incorporated into the IV Lab lane-assist system.

Researchers will address technologies that help drivers deal with traffic adjacent to or crossing over the dedicated bus lanes as a first step to move BRT operations from dedicated to mixed-traffic environments. As a means to this end, the IV Lab will work with transit agencies and bus manufacturer(s) to deploy an augmented DGPS-digital map lane-assist system for BRT narrow-lane applications in the United States.

To date, position-sensing methodologies have been developed; a vehicle positioning system (VPS) has been installed on vehicles and tested at the MnROAD low-volume pavement test facility. Researchers have applied for a patent on this technology. A second system, using an array of laser scanners to detect the known entities in the local landscape, has also been developed and briefly tested on the University of Minnesota Transitway.

The remote sensing system designed to ease a bus driver's task of dealing with merging and exiting traffic at entrance and exit ramps will be tested in live traffic in 2006. In addition, because the Minnesota Valley Transit Authority (MVTA) has shown an interest in field testing a number of buses on the Cedar Avenue corridor, researchers have mapped a section of the cor-

ridor and planned demonstrations for MVTA management and driver/trainers.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002041

Infrared Sensor for Driver Assistive Systems

Status: In progress

Automotive radar suffers two fundamental shortcomings. The first is its inability to detect and "follow" obstacles moving perpendicular to a vehicle's direction of travel. The second shortcoming is that it will provide information pertaining to where an obstacle is (range, range rate, and azimuth angles) but not information regarding what the obstacle is. Infrared sensors can provide information regarding what is detected, but unless stereo sensors are used, cannot provide accurate information regarding where an obstacle is.

Imaging and radar technologies clearly complement one another. This research project is investigating the applicability of infrared imaging sensors for use as a driver-assist display interface for general specialty vehicle operations and as a sensor integrated into the IV Lab driver-assistive system. Based on deployment timelines and budgets, it may be that imaging systems are deployed prior to the deployment of comprehensive driver-assistive systems. It is important to ensure that these imaging systems work well alone and that they can be integrated into driver-assistive systems as they are deployed in the future.

As a means to this end, the researchers have evaluated and selected a camera and are working on the integration of the IR image with geospatial data provided by database queries. OpenSceneGraph will be used to streamline the integration of visual data from these two sources. Technically, the primary challenge is to merge images of two different resolutions, and this work is currently under way. Once lab work is complete, the system will be implemented on the SAFEPLOW research vehicle, tested, and demonstrated on-road.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004056

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 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 (e.g., the need to integrate high-accuracy geospatial data into a driving simulator, the desire by departments of transportation to more accurately represent roads), a more "global" approach to the design of the existing geospatial database is required. This research is attempting a redesign of the geospatial database and database manager and the development of a new front end to serve a wide application base.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005047

Documentation of Crash Characteristics and Safety Strategies at Horizontal Curves on Rural Highways

Status: Newly funded

Forty percent of fatal crashes in Minnesota involve road departure crashes; of these, 40 percent appear to have occurred on horizontal curves. This research intends to develop an understanding of the crash differences between tangent sections and horizontal curves specific to Minnesota's rural two-lane highways. With a better understanding of the crash problem on Minnesota's horizontal curves, Mn/DOT and its safety partners can be more effective at addressing the state's crash problem, accelerating the Toward Zero Deaths initiative.

Researchers will conduct a survey to identify locations where a safety countermeasure was applied to a horizontal curve and will review the crash records to determine actual performance. Knowledge of the actual effectiveness is important to highway agencies, especially if they are to use their limited resources effectively and proactively, as suggested by the Minnesota Comprehensive Highway Safety Plan. Based on the understanding of the Minnesota horizontal crash problem and the effectiveness of traditional countermeasures, alternative countermeasures will be proposed and their potential effectiveness analyzed. These alternatives may include infrastructure- or vehicle-based active curve-ahead or curve speed warnings.
Project URL: www.its.umn.edu/research/2007Projects/RuralDocumentation.html

Safety Effectiveness of Narrow Paved Shoulders: Development Strategies to Reduce Lane Departure Crashes and Fatalities

Status: Newly funded

Run-off-the-road crashes constitute a considerable portion of Minnesota's traffic fatalities. One traditional solution to this problem has been to pave and/or widen shoulders. Many highway agencies are adding shoulder rumble strips, while some agencies are experimenting with shoulder rumble strips combined with narrow paved shoulders. In Minnesota, the state-of-the-practice is to pave shoulders if at least six feet can be provided.

This research begins by quantifying the difference in crash characteristics for shoulders with different pavement types and widths. This will quantify the additional safety benefit associated with widened shoulders. Researchers will conduct a before-and-after analysis for traditional and innovative shoulder treatments for Minnesota's highways, allowing engineers to better select the appropriate shoulder treatment given the usual constraints (e.g., cost, right-of-way, environmental impact). Finally, the costs and benefits of adding shoulders to Minnesota's roads will be compared to the cost and benefit of deploying an in-vehicle lane-departure warning capability. Minnesota is deploying a wide-area, high-accuracy GPS correction network that could be used as a basis for an in-vehicle lane-departure system. Comparing improved road shoulders to in-vehicle solutions will produce an optimal deployment strategy leading to improved safety.
Project URL: www.its.umn.edu/research/2007Projects/EffectiveShoulder.html

Shashi Shekhar, Department of Computer Science and Engineering

Decision Support System for Evacuation Route-Schedule Planning: Determining Optimal Network Configuration

Status: In progress

See page 21 for coverage of this project.

Technologies for Modeling, Managing, and Operating Transportation Systems

Gary Davis, Department of Civil Engineering

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

Status: Completed

This project was divided into three phases. In Phase I, ten fatal run-off-the-road crashes were reconstructed from crash scene diagrams and investigation reports. The researchers found evidence of excessive speed in five of these, and a failure to properly use seat belts in eight of the ten. For seven of the crashes, the researchers found that barriers complying with Test Level 3 of NCHRP Report 350 would probably have stopped the crashing vehicle's encroachment.

In Phase II the researchers developed a vehicle trajectory simulation model and used it to reconstruct five fatal median-crossing crashes. They found clear evidence of excessive speed in one of these, and in three of the five the encroaching vehicle would probably have been restrained by barriers compliant with Test Level 3.

In Phase III, five teams of traffic safety professionals reviewed accident reports from a sample of fatal rural crashes, with the aim of identifying possible causal factors and potential countermeasures. The most frequently identified causal factors were driver inexperience and failure to properly use restraints, while provision of rumble strips, improvements to roadsides or cross-slopes, and provision of guardrails or barriers were the most frequently cited countermeasures.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2003014

Access to Destinations: Estimation of Arterial Travel Times

Status: In progress

This project aims to develop, test, and recommend methods for network-wide estimation and prediction of travel time on arterials. The researchers expect the recommended method to produce plausible default estimates when given predicted demand flows and to update these default estimates where and when field measurements are available.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2006016

A Case-Controlled Study of Driving Speed and Crash Risk

Status: In progress

In the United States, the imposition and subsequent repeal of the 55 m.p.h. speed limit has led to an increasingly energetic debate concerning the relationship between speed and the risk of being in a fatal crash. In addition, research done in the 1960s and 1970s suggested that crash risk is a U-shaped function of speed, with risk increasing as one travels both faster and slower than what is average on a road. Debate continues as to the causes of this relationship, and there is reason to suspect that it may be an artifact of measurement error and/or mixing of different crash types

For this study, the researchers undertook two case-control analyses of run-off-road crashes, one using data collected in Adelaide, Australia, and the other using data from Minnesota. In both analyses the speeds of the case vehicles were estimated using accident reconstruction techniques while the speeds of the controls were measured for vehicles traveling the crash site under similar conditions. Bayesian relative risk regression was used to relate speed to crash risk, and uncertainty in the case speeds was accounted for by treating these as additional unknowns with informative priors. Neither data set supported the existence of a U-shaped relationship, although crash risk clearly tended to increase as speed increased. The resulting logit model was then used to estimate the probability that a given speed could be considered a causal factor for each of the 10 Minnesota crashes.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2001032

Bus Signal Priority Based on GPS and Wireless Communications

Status: In progress

The Minneapolis-St. Paul metropolitan transit agency has installed Global Positioning System (GPS) equipment in transit vehicles for the purpose of monitoring vehicle locations and schedules in order to provide more reliable transit services. This research project evaluates the potential use of vehicle-mounted GPS to develop a transit signal priority system that improves the efficiency of transit.

Bus signal priority has been implemented in several U.S. cities to provide more reliable travel and improve customer ride quality. Current signal priority strategies implemented in various U.S. cities have mostly used sensors to detect buses at a fixed or at a preset distance away from the intersection. Signal priority is usually granted after a preprogrammed time offset after detection. The strategy developed in this research will consider the bus's timeliness with respect to its schedule, location, and speed.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005038

Cross-Median Crashes: Identification 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: medians wide enough to provide adequate "clear zones" where a driver can stop or regain control of the vehicle before crossing into the opposing traffic stream, and installation of median barriers when medians are less than 10 meters wide and annual daily traffic is greater than 20,000 vehicles per day.

As with any safety countermeasure, installation should begin with those locations showing the greatest expected benefits. This project will first review the state of the art in median-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 object 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.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005057

Safety Effect of Left-Turn Phasing Schemes at High-Speed Intersections

Status: In progress

In recent years increased attention has been given to predicting the effects of roadway improvements on traffic safety. Tools have been developed in cooperation with the Federal Highway Administration and the Transportation Research Board that attempt to predict crash experience, and these require estimates of crash modification factors (CMF) to produce predicted reduction benefits. The tools make use of empirical Bayes statistics, which currently require that crash data be overdispersed. This research illustrates an alternative method for estimating CMFs that can be applied whether the crash data are overdispersed or not. The method combines the hierarchical Bayes model with a model that allows for

temporal changes in the covariates. The method was used to compute estimates for the CMFs associated with signalizing or changing the left-turn phasing of sets of non-rural intersections.

This research was especially interested in the effect on left-turn crashes. Marginally significant results found that signalization does not produce a definite effect on major-approach left-turn crashes; phase-changes on the major approaches from permitted/protected to protected phasing decreases the number of major-approach left-turn crashes; and phase-changes on the minor approaches from permitted to permitted/protected do not significantly affect the number of minor-approach left-turn crashes.

Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002043

Bus Signal Priority Based on GPS and Wireless Communications, Phase II: Signal Priority System Development

Status: Newly funded

Signal priority for transit has been proposed as an efficient way to improve transit travel and operation. Bus signal priority has been implemented in several U.S. cities to provide more reliable travel and improve customer ride quality. Current signal priority strategies implemented in various U.S. cities utilized mostly sensors to detect buses at a fixed or at a preset distance away from the intersection. Signal priority is usually granted after a preprogrammed time offset following detection. This research will take advantage of the GPS system installed on buses in Minneapolis and develop a signal priority strategy that could consider a bus's schedule adherence, number of passengers, location, and speed.

The goal of Phase I of this study was to develop an adaptive signal priority strategy and to conduct an evaluation and simulation of the Franklin Avenue corridor from Dupont Avenue South to 27th Avenue South in Minneapolis. Preliminary data show that up to 20 percent of bus travel time along Franklin Avenue was the result of intersection signal delay during the morning and afternoon peak hours. This research project, Phase II, will develop a prototype system using GPS and wireless technologies to provide signal priority for buses.

Project URL: www.its.umn.edu/research/2007Projects/BusSignal.html

Toward the Next Generation of Traffic Counting and Prediction Methods, Phase I: Model Identification and Validation

Status: Newly funded

Estimates of life-cycle traffic volumes are frequently used in highway design, and the information relevant to these usually comes in three forms: continuous counts from permanent traffic counters, short-count samples from nearby or similar roads, and a short count from the road of interest. The ultimate of goal of this project is to develop and deploy methods for combining these sources of information so as to produce optimal estimates of daily and annual traffic volume, by vehicle class, for any road segment in Minnesota. As with any statistical estimation procedure, the starting point is a defensible model of the processes generating these counts, and the goal of Phase 1 is to apply some recent advances in statistical estimation methodology to identify and validate the required model.

Project URL: www.its.umn.edu/research/2007Projects/NextGen.html

Demoz Gebre-Egziabher, Department of Aerospace Engineering and Mechanics

Methodology for Evaluating the Concept of Operation for Traffic Management and Infrastructure Security Using Remotely Operated Aerial Vehicles

Status: Newly funded

Recently, the idea of using remotely operated aerial vehicles (ROVs) for traffic management and infrastructure security has received a significant amount of attention. The economic and social motivations for using ROVs in this application are very compelling. For this vision to become a reality, however, methods for inexpensively building and safely operating these ROVs must be developed. Safety is paramount, since these ROVs are expected to operate over populated areas and potentially share the same national airspace with passenger-carrying aircraft.

This work will aim to develop and demonstrate a systematic methodology for evaluating whether the operational concept of using multiple ROVs to monitor vehicles and other traffic management parameters meets safety requirements established by regulation. The methodology involves identifying hazards associated with the concept of operation and quantifying the likelihood of their occurrence. For hazards for which the likelihood of occurrence is judged to be too great, risk mitigation strategies will be developed. This methodology will be useful for establishing certification standards by federal and state agencies responsible for the safe operation of ROVs and for designers of ROVs, since they could be used to map operational requirements into hardware specifications. Operational procedure designers could also use them to determine the required operator qualifications.

Project URL: www.its.umn.edu/research/2007Projects/AerialVehicles.html

ROV Surveillance for Transportation Management and Security

Status: In progress

See page 17 for coverage of this project.

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: Newly funded

This research is in response to a request from Mn/DOT for the development of an intelligent control system for isolated intersections with high-speed approaches, including a 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 not uncommon for an approaching platoon of vehicles to face a red signal because of a single vehicle on one of the conflicting approaches. In addition, Mn/DOT uses advance-warning flashers—which warn motorists on high-speed approaches that the signal phase will be turning yellow— 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 vehicle platoons approaching a traffic signal with or without AWF to eliminate dilemma

zone problems and adapt to time-variant traffic conditions. To evaluate and improve the proposed control system, the researchers will use hardware-in-the-loop simulation and quantify system performance improvements in terms of operational efficiency and safety.
Project URL: www.its.umn.edu/research/2007Projects/DevPlatoon.html

Development of a Real-Time Arterial Performance Monitoring System Using Traffic Data Available from Existing Signal Systems

Status: Newly funded

As mandated in the new transportation bill, SAFETEA-LU, the USDOT will establish a real-time system management information program to provide the capability to monitor the traffic and travel conditions of the transportation network. Despite recent developments in the 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 this gap. Its goal, therefore, is to develop a real-time online performance monitoring system for arterial streets. The arterial performance data will be also archived and made available to various stakeholders for operation, planning, research, and traveler information systems, similar to freeway performance data. In this project, the researchers will analyze data availability and requirements from the existing signal system, and will develop algorithms for estimating and predicting real-time arterial travel time and speed depending upon the data resolution. Researchers will first test these estimation algorithms with a microscopic simulation model, and, if successful, will field-test a prototype system.
Project URL: www.its.umn.edu/research/2007Projects/DevArterial.html

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

Status: Newly funded

This project is in response to a request for innovative evacuation and incident operation strategies and evaluation of current evacuation planning models. The goal is to advance current state-of-the-art evacuation modeling from the planning stage to a real-time and dynamic operation stage by developing a suite of conceptual, analytical, and simulation models that function as real-time online tools for evacuation traffic management.

Recent natural and man-made disasters around the world have stressed 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 will adjust the traffic operation strategies adaptively by comparing the difference between the system optimal states and real-world observations. The system optimal states will be generated using a reference model in a rolling horizon manner, and a feedback control mechanism will be developed using the data from real-world observations. The proposed model will be tested and evaluated using microscopic traffic simulation software with the network data set from the Twin Cities' Metropolitan Council.
Project URL: www.its.umn.edu/research/2007Projects/ModelEvac.html

Panos Michalopoulos,
Department of Civil Engineering

Development of Portable Wireless Measurement and Observation Station

Status: Completed

For this project, the researchers designed, assembled, and deployed a temporary detection and surveillance system to collect real-time data on traffic conditions. This information is critical for construction of advanced traffic management systems, advanced traffic information systems, and other design and operational activities. Because traditional, permanent systems collect data by sensors in the pavement and transmit the data through land-based communications, the equipment is subject to failure in construction areas. Through advancements in wireless technology, the developed system integrates machine vision sensors to collect data, compress digital video for surveillance, and use wireless communications for information retrieval and remote control. This new system can be added to current installations or used to create temporary traffic monitoring systems.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2002030

Employment of the Traffic Management Laboratory for the Evaluation and Improvement of Stratified Ramp Metering Algorithm through Microscopic Simulation

Status: Completed

A new ramp metering strategy implemented on the Twin Cities freeway system to reduce ramp waiting times was evaluated through microsimulation of freeway activity. The study compared the stratified ramp metering strategy with the previous zone metering strategy and with no control strategy. Comparison with zone, which was designed to favor freeway flow, showed that the new strategy succeeded in greatly reducing ramp delays and lines. When compared to the results of no control strategy, it reduces freeway travel time, increases freeway speed, smoothes the flow of traffic, and reduces the number of stops. However, travel time, fuel consumption, and pollutant emissions are unpredictable under the newer system. Compared to no control strategy, such measures of effectiveness may improve or worsen depending on the freeway patterns and demand. Based on these findings, the researchers will seek improvements to the design of the stratified ramp metering algorithm so as to factor in disruptive traffic patterns.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2001047

Crash Prevention Based on Automatic Detection of Crash-Prone Traffic Conditions: Phase 1

Status: In progress

See page 19 for coverage of this project.

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

Status: In progress

According to Mn/DOT statistics, the westbound section of Interstate 94 at the I-94/35W commons south of downtown Minneapolis, Minnesota, has the highest crash rate in the Twin Cities. In an ongoing project related to crash prevention and the detection of crash-prone conditions, this site was heavily instrumented and observed, and detailed traffic measurements were analyzed. Data showed that these incidents occur under certain traffic conditions that can be detected prior to a crash.

This project is capitalizing on the results of the ongoing research by utilizing the available techniques for the early detection of crash-prone conditions to develop a traffic calming/driver warning system for reducing crashes. The system will be specifically tuned for maximum effectiveness on the I-94 section. The goals of this first phase are to define relevant solutions based on available technologies

and site characteristics; implement the designs in an appropriate visualization environment; and perform a preliminary evaluation and prioritization of the proposed solutions. The most promising solutions will later undergo thorough human factors analysis (e.g., driving simulator studies). Work will commence on the development of new and improved microscopic simulation models. These models should overcome the current model deficiency—the inability to emulate unsafe driving behavior—and will be capable of evaluating traffic safety solutions based on intelligent transportation systems approaches.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005056

Employment of the Traffic Management Laboratory for Improving the Stratified Metering Algorithm (Phase III)

Status: In progress

This project is a continuation of previous research related to testing and evaluating the effectiveness of the stratified ramp metering strategy through rigorous microscopic simulation. The stratified ramp metering strategy has been proven to be generally effective in keeping ramp wait times below the maximum allowed for each ramp after one year of field operation and a preliminary evaluation. However, some inherent limitations of the strategy need to be further explored.

This research project aims to attack these limitations by developing a credible, efficient, and feasible methodology that can balance the control objectives of freeway performance and ramp delays and provide more accurate online ramp-queue size estimation. All the enhancements and improvements to the stratified ramp control strategy will be computationally feasible and their effectiveness will be assessed by comparison with the current prototype version using microscopic simulation.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2005044

Employment of the Traffic Management Laboratory for Improving the Stratified Metering Algorithm (Phase IV)

Status: In progress

This project continues the work of the currently ongoing project related to improving and evaluating the effectiveness of Mn/DOT's stratified zone metering (SZM) strategy.

From field operations and offline evaluation, the improved SZM strategy was found to be effective in meeting the maximum ramp delay objective, but at the expense of the freeway and system performance as expected. However, the strategy can be further improved in several ways. This research aims to address the most promising improvements by developing an efficient and streamlined optimization methodology to identify the best control parameter set for the strategy based on site and demand characteristics. Currently these parameters are estimated by trial and error and are constant for the entire freeway system.

In addition, this research aims to produce a more reliable ramp demand-prediction technique and an improved location-dependent bottleneck capacity estimation methodology based on real-time traffic conditions. All the enhancements and improvements to the SZM strategy will be computationally feasible and their effectiveness will be assessed by comparing it with the current prototype version through microscopic simulation. This will avoid costly, uncertain, and time-consuming field testing as well as disruption of traffic flow.
Project URL: www.umn.edu/research/projectdetail.pl?id=2006074

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

Status: In progress

In recent years, much research has been conducted in the development, implementation, and evaluation of various innovative ITS technologies aiming to improve traffic operations and driving safety. As part of the process, microsimulation has become an increasingly indispensable tool for assisting in system design and evaluation. Existing microsimulation models, however, are deficient when evaluating sophisticated safety-related ITS techniques because they target only normal driving behavior under typical traffic-flow conditions. Vehicle collisions are artificially excluded from simulation. To date, realistic car-following models pertinent to the true nature of driver behaviors—taking into account subjective judgments, misperceptions, and randomness in driver's reactions—are lacking.

The goal of this research is to expand, or create new if necessary, car-following models capable of replicating real-life car-following behaviors with all their risks and imperfections. The research will capitalize on detailed car-following data collected in Germany, Japan, and from Twin Cities freeways to assist in model development, calibration, and validation. Concepts such as less-than-adequate perception-response times, stochastic selection of desired space headways, and driver inattention and misperception will be introduced to the improved (or new) car-following model. The outcomes of this research will help advance the understanding of real-life car-following behavior while improving the microsimulation modeling to facilitate the assessment of freeway safety concepts at the high-definition microscopic level.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2006043

Streamlining of the Traffic Modeling Process for Implementation in the Twin Cities Freeway Network

Status: Completed

This project sought to streamline the traffic modeling process for practical implementation, thereby improving Mn/DOT engineers' productivity in view of the new federal requirements for the design and planning of roadway improvements. The result is the development of comprehensive methodologies for improving the quality of both freeway and arterial intersection traffic volumes for the purpose of enabling and improving traffic simulations. Specifically, established and enhanced procedures for checking and correcting freeway temporal errors are integrated with an optimization-based algorithm for reconciling spatial inconsistencies in freeway traffic counts. In addition to this, an empirical methodology is further integrated to balance arterial intersection traffic counts.

The proposed methodologies have been successfully automated and implemented as two computer programs: TradaX for processing freeway volume and ArtBaT for arterial intersection traffic counts. Initial evaluations of these tools suggest that they could potentially reduce total modeling time by 25–30 percent while resulting in improved calibration of simulation models, more reliable analysis, and better use of Mn/DOT staff resources for meeing project deadlines.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004030

Social and Economic Policy Issues Related to ITS Technologies

Frank Douma, Humphrey Institute of Public Affairs
Developing ITS to Serve Diverse Populations
Status: In progress

In 2003, the State and Local Policy Program at the University of Minnesota's Humphrey Institute of Public Affairs began research into how ITS technologies can be used to deliver transportation services to an increasingly diverse population in Minnesota. The research objective is to identify the nature of the gap between emerging needs and existing services and to propose ways of using technology to bridge the gap, both in terms of providing better transportation options and in reducing the cost of these options.

This project continues that general theme through a series of analyses of ITS applications that appear most promising for improving mobility and access for Minnesota's increasingly diverse population. These applications include technologically advanced community-based transit (CBT), car sharing, use of ITS to implement value pricing through conversion of a high-occupancy vehicle lane to a high-occupancy toll (HOT) lane, and evaluation of Web-based advanced traveler information systems (ATIS).

Work has been completed on the community-based transit task, with work on the car sharing and ATIS tasks in the final stages. The HOT lane study is in progress. Preliminary findings for these tasks indicate that technology could help in the coordination of CBT services, but a greater hurdle lies in continuing to understand the wide range of existing providers. As for car sharing, it could have a positive impact on the transportation-disadvantaged population if subsidized.

Findings from a baseline and second wave (one year later) of attitudinal surveys show support for the HOV conversion across all income levels and gender. Most significantly, both users and non-users perceived that congestion went down after the lane was converted.

Finally, preliminary findings from the ATIS evaluation show that Web-based tools are useful and found to be reliable by those that use them, but different attributes have different benefits, depending on the background of the user.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2004047

Lee Munnich, Humphrey Institute of Public Affairs
Sustainable Technologies Applied Research (STAR) Initiative
Status: In progress

The STAR project is investigating the intersection of various networks—including ITS-infused transportation networks—and how they interact with physical places, as well as the changes that are occurring among and between networks and the dimensions (e.g., access, activity) that concern the STAR researchers. Year five activities have led to the following focus areas for year six (FY 05):

Spatial Impacts

With the rapidly increasing penetration of the Internet in day-to-day activities, its ability to affect travel behavior either in the form of increasing or decreasing travel demand may have a considerable impact on transportation policies. Work is now under way for the final phase of this task—the development of an approach based on systems theory and complexity theory. In the coming year a survey of various model forms, including system models, cellular or Markov models, and agent-based models will be completed. Other objectives include working to refine a multinomial logit model to better understand the reasons that lead to varying frequencies of buying products online; tracking changes in use, attitudes, and ICT-use-penetration from a 1998 study completed by Handy and Yantis; and producing an academic paper on the browse-to-buy aspect of this research.

Modeling of Wireless Rural EMS Performance

With the rapid growth in mobile-based 911, specific research objectives are to design a system architecture that characterizes rural EMS; examine the rural EMS system architecture within the context of an embedded case study in rural Minnesota; devise an end-to-end-performance metric that characterizes overall system performance, including simulation of performance; use a framework to outline operational, organizational, and governance issues that could affect EMS use in Minnesota; conduct case studies and expert interviews that examine these dimensions to EMS performance; and conduct local presentations and national workshops. Year six of this project will conclude with an academic paper summarizing research results or a comparable product. A key result of this research will be an institutional framework for deploying ITS in support of collaborative EMS activities in Minnesota.

Privacy and ITS

See page 23 for coverage of this project.

Networks and Productivity

Further research will continue to improve urban transportation mobility and accessibility by developing an agent-based model of network growth that integrates land use, travel demand, cost functions, pricing schemes, and investment rules to simulate the growth (and decline) of urban transportation networks. The following objectives will guide the research work in year six: refine the cost functions and the land use module of the network growth model; apply the network growth model to evaluate alternative policies (in addition to those already tested) using the Twin Cities road network as a case study; develop an agent-based travel demand model and demonstrate it on the Twin Cities road network; and replace the sequential trip-based demand model with the new behavioral demand model in the network growth simulator.

Education Forums, Outreach

Planned activities include a variety of roundtables, conferences, workshops, and forums. These will include participation in the annual TRB, CTS, and ITSA conferences as well as selected specialty workshops. Working in collaboration with the ITS Institute, noteworthy speakers will be invited to the University to speak to faculty and students. Year six will see the formation of the University Consortium on Metropolitan Studies, and contributions to regional policy development, in addition to other outreach and activities that will occur during the year.
Project URL: www.its.umn.edu/research/projectdetail.pl?id=2006019

Kevin Krizek, Humphrey Institute of Public Affairs
Understanding the Potential Market of Metro Transit's Ridership and Services
Status: In progress

See page 22 for coverage of this project.

Selected Publications

Alexander, L., Cheng, P., Donath, M., Gorjestani, A., Newstrom, B., and Shankwitz, C. (2006). Rural expressway intersection surveillance for an intersection decision support system. *Compendium of Papers for the 85th Annual Meeting of the Transportation Research Board (TRB).*

Andrews, J., and Douma, F. (2006). Developing a model for carsharing potential in Twin Cities neighborhoods. *Compendium of Papers for the 85th Annual Meeting of the Transportation Research Board.*

Billings, D., and Yang, J.S. (2005). A time series approach to arterial travel time modeling and prediction. *Proceedings of the 2005 IASTED International Conference on Intelligent Systems and Control.*

Bird, N., Atev, S., Caramelli, N., Martin, R., Masoud, O., and Papanikolopoulos, N. (2006). Real-time, online detection of abandoned objects in public areas. *Proceedings of the 2006 IEEE International Conference on Robotics and Automation.*

Boer, E.R., Ward, N.J., Manser, M.P., Yamamura, T., and Kuge, N. (2005). Driver performance assessment with a car following model. *Proceedings of the 3rd International Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design.*

Chen, W., and Levinson, D. (2006). Effectiveness of learning transportation network growth through simulation. *ASCE Journal of Professional Issues in Engineering Education and Practice.*

Davis, G.A. (2006). Bayesian networks, falsification, and belief revision in accident reconstruction. *Compendium of Papers for the 85th Annual Meeting of Transportation Research Board*.

Gary Davis

Davis, G.A., and Morris, P. (2006). A reanalysis of Hutchinson and Kennedy's encroachment frequency data. *Transportation Research Record*.

Davis, G.A., and Swenson, T. (2006). Collective responsibility for freeway rear-ending accidents? An application of probabilistic causal models. *Accident Analysis and Prevention*.

Douma, F., Zmud, J., and Patterson, T. (2006). Pricing comes to Minnesota: baseline attitudinal evaluation of the I-394 HOT lane project. *Compendium of Papers for the 85th Annual Meeting of the Transportation Research Board*.

Horan, T. (2005). Evaluating trip planning quality in use: prototyping a metric for diverse trips. *Proceedings of the 12th Annual ITS World Congress.*

Tom Horan

Horan, T., and Schooley, B. (2005). Interorganizational emergency medical services: case study of wireless deployment and management. *International System Frontiers*.

Hossain, J., Alouini, M.S., and Bhargava, V.K. (2006). Hierarchical constellation for multi-resolution data transmission over block fading channels. *IEEE Transactions on Wireless Communications.*

Jackson, B., Bodor, R., and Papanikolopoulos, N. (2005). Deriving occlusions in static scenes from observations of interactions with a moving figure. *Advanced Robotics.*

Kang, T.K., and Alouini, M.S. (2005). Transmission of multiple description codes. *IEEE Transactions on Wireless Communications.*

Kidane, S., Alexander, L., Rajamani, R., Starr, P., and Donath, M. (2005). Control system design for full range operation of a narrow commuter vehicle. *Proceedings of the ASME International Mechanical Engineering Congress and Exposition*.

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Michael Manser

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Rajesh Rajamani

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Yang, J.S., and Zhang, N. (2005). A neural network-based simultaneous perturbation stochastic approximation approach to traffic signal timing control. *WSEAS Transactions on Systems*.

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Al Yonas

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Zhu, C., and Rajamani, R. (2006). GPS-based vehicle control for automated parking. *Journal of Automobile Engineering*.

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Craig Shankwitz

Alexander, L.,Cheng, P., Donath, M., Gorjestani, A., Newstrom, B., Shankwitz, C. (2006, January). Rural expressway intersection surveillance for an intersection decision support system. 85th Annual Meeting of the Transportation Research Board, Washington, D.C.

Andrew, J., and Douma, F. (2006, January). Developing a model of carsharing potential in Twin Cities neighborhoods. Transportation Research Board 85th Annual Meeting, Washington, D.C.

Frank Douma

Brashaw, B.K., Wang, X., Ross, R.J., Vatalaro, R., Wacker, J., Erickson, J., and Forsman, J.W. (2005, November). Development of flexural vibration inspection techniques to rapidly assess the structural health of timber bridge systems. 2005 Northland Advanced Transportation Research Laboratories Annual Research Day, Duluth, Minn.

Donath, M. (2005, November). BRT lane assist and other technologies. FTA/APTA meeting, San Francisco.

Donath, M. (2006, June). Cooperative intersection collision avoidance system (CICAS): stop sign assist. ITE Midwestern District 4 Annual Meeting, Rochester, Minn.

Donath, M. (2005, September). Designing human-centered systems: DGPS-based augmented reality—'seeing' the road. Department of Mechanical Engineering seminar, University of Alaska, Fairbanks; and (2006, April). Department of Mechanical Engineering seminar, University of Texas, Austin.

Donath, M. (2005, September). Driver-assistive technology for reducing teenage road fatalities. Annual Meeting of the Association for the Advancement of Automotive Medicine (AAAM), Boston, Mass.

Donath, M. (2006, May). Evacuation route real-time planning: minimizing evacuation time given capacity constraints. ITS America Annual Meeting, Philadelphia, Penn.

Donath, M. (2006, May). From IDS to CICAS: rural intersection crash avoidance. NJ DOT Transportation Center, Trenton, N.J.

Donath, M. (2005, September). Intelligent vehicles: designing human-centered systems for crash avoidance. IEEE Intelligent Vehicles Symposium, Las Vegas.

Donath, M. (2006, April). In-vehicle technology and GDL: addressing patterns of teen risk. Lifesavers Conference, Austin, Texas; (2005, November). NRC and National Institute of Medicine Committee meeting, The National Academies, Washington, D.C.

Donath, M. (2005, November). In-vehicle technology to correct teen driving behavior: addressing patterns of risk. Toward Zero Death Conference, St. Cloud, Minn.

Donath, M. (2005, September). Reducing fatalities and managing congestion: emerging technologies enabling "outside the box" solutions. FHWA Advanced Research Forum, Minneapolis.

Donath, M. (2005, November). Using ITS to reduce teenage road mortality: impact on privacy. CTS 17th Annual Transportation Research Conference, St. Paul, Minn.

Donath, M. (2006, January). Vehicle positioning system (VPS): safer and more productive trucking. 85th Annual Meeting of the Transportation Research Board, Washington, D.C.

Feng, B., Hourdos, J., and Michalopoulos, P. (2005, January) Improving Minnesota's Stratified Ramp Control Strategy. 85th Annual Meeting of the Transportation Research Board, Washington, D.C.

Horan, T. (2005, November). Evaluating trip planning quality in use: prototyping a metric for diverse trips. 12th ITS World Congress and Exhibition, San Francisco.

Hourdos, J., Garg, V., Michalopoulos, P., and Davis, G. (2006, January). Real-time detection of crash prone conditions in freeway high crash locations. 85th Annual Meeting of the Transportation Research Board, Washington, D.C.

Kwon, T., and Nookala, L. (2006, May). Weather impact on freeway traffic flow in relation to RWIS pavement conditions. CTS 17th Annual Transportation Research Conference, St. Paul, Minnesota.

Kwon, T., and Flinner, M. (2006, June). Automating acquisition of short-duration and continuous count data from ITS generated 30sec loop detector data. North American Travel Monitoring Exposition and Conference, Minneapolis.

Kwon, T. (2005, November). Introduction of TDRL projects: gravel road traffic counter, intersection movement counter, and renewable street light pole. 2005 Northland Advanced Transportation Research Laboratories Annual Research Day, Duluth, Minnesota

Kwon, T., and Parsekar, A. (2006, January). Blind deconvolution processing of loop inductance signals for vehicle reidentification. 85th Annual Meeting of the Transportation Research Board, Washington D.C.

Kuge, N., Boer, E., Yamamura, T., Ward, N., and Manser, M. (2006, April). Design and assessment of an active haptic support system that extends driver's car following ability. Society of Automotive Engineers World Congress, Detroit, Mich.

Kuge, N., Yamamura, T., Kimura, T., Kobayashi, Y., Ward, N., Manser, M.P., and Boer, E. (2005, September). Feasibility examinations of a driver support system with accelerator pedal force feedback and driving force control functions. Japan Society of Automotive Engineers Conference, Yokohama, Japan.

Laberge, J.C., Ward, N.J., Rakauskas, M., and Creaser, J.I. (2005, September). Information requirements for rural stop-controlled intersection decision support systems. 49th Annual Meeting of the Human Factors and Ergonomics Society, Orlando, Fla.

Rich Maclin

Maclin, R., Crouch, C., and Crouch, D. (2005, November). Automatic detection of RWIS sensor malfunctions. Northland Advanced Transportation Systems Research Laboratories Research Day, Duluth, Minn.

Manser, M.P., Ward, N.J., Kuge, N., and Boer, E.R. (2005, September). Driver behavioral adaptation in response to a novel haptic driver support system. 49th Annual Human Factors and Ergonomics Society Meeting, Orlando, Fla.

Manser, M.P. (2005, September). High fidelity driving simulator. 49th Annual Human Factors and Ergonomics Society Meeting, Orlando, Fla.

Munnich, L. (2005, September). Mn-PASS research evaluation. CTS Transportation and the Economy Council, Minneapolis.

Papanikolopoulos, N. (2006, March). Surveillance work at UMN. Honeywell Labs, Morristown, N.J.

Nic Ward

Rakauskas, M.E., Ward, N.J., Bernat, E.M., Cadwallader, M., and Patrick, C.J. (2005, November). Driver distraction combined with alcohol impairment. Toward Zero Deaths Conference, St. Cloud, Minn.
Rakauskas, M.E., and Ward, N.J.

(2005, September). Behavioral effects of driver distraction and alcohol impairment. 49th Annual Human Factors and Ergonomics Society Meeting, Orlando, Fla.

Simon, S. (2006, January). In-vehicle technology to correct teen driving behavior: assessing patterns of risk. 85th Annual Meeting of the Transportation Research Board, Washington, D.C.

Smalkoski, B., Li, N., and Levinson, D. (2006, January). Economic effects of lifting the spring load restriction policy in Minnesota. 85th Annual Meeting of the Transportation Research Board, Washington, D.C.

Vijayaraghavan, K., Rajamani, R., and Bokor, J. (2006, June). Quantitative fault estimation for a class of nonlinear Systems. American Control Conference, Minneapolis.

Wyrick, D. (2005, November). Fleet management research at UMD. Minnesota Society of Professional Engineers. Chisholm, Minn.

Wyrick, D. (2005, November). The fleet asset fountain of youth—a life cycle costing quest or just lost in a swamp? Northland Advanced Transportation Systems Research Laboratories Research Day, Duluth, Minn.

Xie, F., and Levinson, D. (2006, January). The decline of over-invested transportation networks. 85th Annual Meeting of the Transportation Research Board, Washington, D.C.

Xin, W., Hourdos, J., and Michalopoulos, P., (2005, January). Comprehensive evaluation of a new integrated freeway ramp control strategy. 85th Annual Meeting of the Transportation Research Board, Washington, D.C.

Jiann-Shiou Yang

Yang, J.S. (2005, November). Short-term arterial travel time prediction via the autoregressive integrated moving average approach—a case study. 2005 Northland Advanced Transportation Systems Research Laboratories Research Day, Duluth, Minn.

Yang, J.S. (2005, November). A time series approach to arterial travel time modeling and prediction. Eighth IASTED International Conference on Intelligent Systems and Control, Cambridge, Mass.

Yang, J.S. (2005, July). A neural network-based stochastic approximation approach to special events traffic signal timing control. Ninth World Multi-conference on Systematic, Cybernetics and Informatics, Orlando, Fla.

Yang, J.S. (2005, August). A study of travel time modeling via time series analysis. 2005 IEEE International Conference on Control Applications, CCA 2005, Toronto.

Zhang, L., and Levinson, D. (2006, January). Determinants of route choice and the value of traveler information: a field experiment. 85th 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 showcases varied work in ITS

This was the fifth year that the Institute sponsored its multidisciplinary seminar series at the University. These Advanced Transportation Technologies seminars featured presentations by local and national researchers addressing diverse areas of ITS research, such as traffic management and modeling, human factors, intelligent vehicles, sensing, controls, communications, and policy issues as they relate specifically to road- and transit-based transportation. The seminars give researchers a chance to report on recent research findings and bring new information to the ITS community.

The series is available as a one-credit graduate-level course, or attendees can earn one professional development hour for each seminar. The series is also a required course in the Graduate Certificate Program in Transportation Studies at the University of Minnesota. Seminars are recorded onto DVD and available for loan by request.

The past year's presentations were:

- "Minnesota Guidestar Program and Project Updates," given by Ray Starr, Assistant State Traffic Engineer (ITS), Minnesota Department of Transportation
- "Model Reference Adaptive Control Framework for Real-Time Traffic Management Under Emergency Evacuation," given by Henry Liu, Department of Civil Engineering
- "Multiple Model Techniques in Automotive Estimation and Control," given by Derek Caveney, Toyota Technical Center
- "Technologies and Human Factors Related to the Intersection Decision Support Project," given by Janet Creaser, HumanFIRST Program
- "In-vehicle Technology to Correct Teen Driving Behavior: Addressing Patterns of Risk," given by Shawn Brovold, Department of Mechanical Engineering
- "Understanding the Potential Market of Metro Transit's Ridership and Services," given by Kevin Krizek, Hubert H. Humphrey Institute of Public Affairs
- "Development of Flexural Vibration Inspection Techniques to Rapidly Assess the Structural Health of Timber Bridge Systems," given by Brian K. Brashaw, Northland Advanced Transportation Systems Research Laboratories, University of Minnesota Duluth

UMD team, vehicle rev up for competition

With the help of the ITS Institute, three students from the University of Minnesota Duluth spent months designing and building an independently guided robot to compete June 10–12 in Michigan at the 14th annual Intelligent Ground Vehicle Competition.

The UMD intelligent vehicle, MARVIN III

The UMD team started almost from scratch in the school's second year of competition. Electrical and computer engineering students Paul Bushey, Ryan Weidemann, and Jason Brownlee pit their vehicle, MARVIN III, against nearly 40 other teams at Selfridge Air National Guard Base in Harrison Township.

To win the competition, teams must design and build a vehicle that, without human aid, negotiates an obstacle course in the least time and navigates with precision to designated locations on a field, both while ferrying a 20-pound payload.

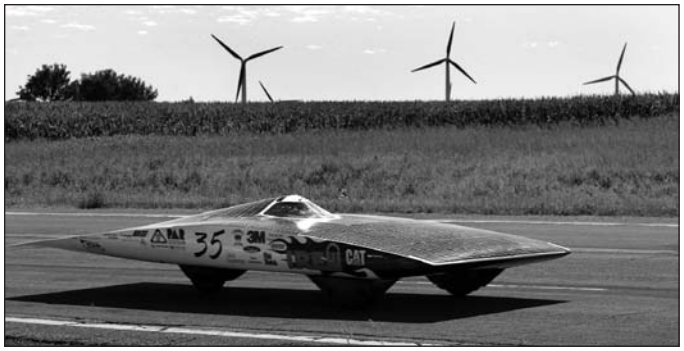
MARVIN III, which stands for Mobile Autonomous Robotic Vision-Aided Intelligent Navigator, features everything a robot needs to independently navigate a course wrought with pits and barriers: Global Positioning System, digital video camera, SICK laser sensor, onboard computer, and plenty of batteries.

Professor Rocio Alba-Flores, with UMD's Department of Electrical and Computer Engineering, said that even with classes and senior job searches going on, the team members always wanted to spend more energy and time on the vehicle. Maybe that's because, as team member Weidemann put it, "I learned more about troubleshooting, team work, and deadlines then I have in any of my classes."

Teamwork of students helps power solar car

Twenty-five hundred miles is a long way to drive, especially without air conditioning in July. But driver comfort isn't much of a priority in Borealis III, the University of Minnesota's competitive

Seminar presenters Kevin Krizek and Ahmed El-Geneidy with Institute director Max Donath



The University's solar car, Borealis III, traveling near Benton, Minn., on the fourth day of the 2005 North American Solar Challenge

solar car. Forty-six Minnesota students, with ITS Institute support, designed Borealis to capture energy from the blazing summer sun and maximize efficiency—keeping running weight, aerodynamics, and the weather in mind at every stage.

Borealis III finished second in the 2,500-mile North American Solar Challenge (NASC) July 17–27, 2005. After driving for 54 hours from Austin, Texas, to Calgary, Alberta, the team finished just 11 minutes out of first.

Instead of buying a solar array for the vehicle or the electronics system, team members won the NASC Design Innovation Award by fabricating their own. The team also designed peak power trackers to optimize the energy collection of the array and battery protection circuitry for safety, while saving $60,000 by doing it themselves.

The teamwork from the vehicle development stage carried over to the road, where the team developed strategies on how to balance power consumption with speed (and ended up winning the Team Spirit Award). Other teams usually don't let students make race strategy decisions, but the Borealis team's sole advisor, Professor Patrick Starr, saw the educational opportunity as more valuable than winning any race.

Minnesota has fielded another team and will compete again in 2007.

Steve Simon, Shawn Brovold, and Max Donath at the CTS awards ceremony, where Brovold was recognized as Student of the Year

Brovold awarded Student of the Year

Each year, the ITS Institute selects one graduate student for the Outstanding Student of the Year Award sponsored by the U.S. Department of Transportation's Research and Innovative Technology Administration (RITA).

This year's award winner is Shawn Brovold, a master's candidate in mechanical engineering at the University of Minnesota. Brovold received his bachelor of science degree in civil engineering with high honors from the University of Illinois at Urbana-Champaign.

Brovold's research, In-Vehicle Technology to Correct Teen Driving Behavior, focuses on recognizing behaviors such as speeding, aggressive driving, seat belt use, and driving while intoxicated and provides mechanisms to report these behaviors to parents.

Among the accomplishments that led to Brovold's selection as Student of the Year are his 3.87 GPA in his graduate studies, several awards he has received throughout his undergraduate and graduate career, his role as the 2005 team leader for the University of Minnesota's Intelligent Ground Vehicle robotics team, and the various publications to his credit.

Brovold received the award at the annual TRB meeting in Washington, D.C., in January; he was also recognized at the annual CTS awards ceremony in April, during which Professor Stephen Simon of the Law School, Brovold's advisor, lauded Brovold as a "can-do" person and "an indication of what smart young American adults can do in our society."

Huber Award goes to ITS student

An ITS Institute student was one of two recipients of the 2006 Matthew J. Huber Award for Excellence in Transportation Research and Education.

Harini Veeraraghaven, a doctoral candidate in computer science and engineering, was presented with the award by Cheri Marti, CTS associate director, at the center's annual meeting and awards ceremony held in April in Minneapolis.

The award is named in honor of the late Professor Matthew J. Huber, in recognition of his contributions to the teaching and study of transportation at the University of Minnesota.

Professor Nikolaos Papanikolopoulos, who serves as Veeraraghaven's advisor, says her work is "seminal, in the sense that it's the basis for the detection system" that his research is developing. The scene-monitoring software has

been deployed at the Minneapolis-St. Paul International Airport and is part of a project with the Department of Homeland Security. "Without this great student," he said, "these things wouldn't be possible."

Cheri Marti, left, and, Nikolaos Papanikolopoulos, right, present the Huber Award to Harini Veeraraghaven at the CTS annual luncheon.

Institute gives students chance to attend national conferences

This past year, the Institute sponsored 11 University of Minnesota students to attend and participate in the national meeting of the Transportation Research Board (TRB) in Washington, D.C. They were Nathan Aul, Shawn Brovold, Xiaozheng He, Wenteng Ma, Norah Montes de Oca, Tyler Patterson, Xinkai Wu, Feng Xie, Wu-Ping Xin, Hongbing Zhang, and Xi Zou.

Networking emphasized at Career Expo

The ITS Institute once again partnered 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 put on the 11th Annual Transportation Career Expo. Four main topics were covered by this year's panelists: networking, job searching, creating a resume, and interviewing. But nothing was emphasized more than the importance of establishing connections, be it with people, an organization, or the career itself.

Approximately 65 college students from Minnesota and Wisconsin attended the event, which gives students the opportunity to ask questions, receive seasoned advice, hear feedback on their resumes, and network with industry professionals. Employers promoted their organizations with booth displays, and several company representatives led informational sessions on transportation-related careers in areas such as intelligent transportation systems, engineering, policy and planning, and logistics management.

Institute fosters undergraduate work

The Institute is continuing an undergraduate research program that will fund additional undergraduate students as research assistants. The program gives the students a hands-on research experience and the chance to learn more about ITS technologies.

Three students were awarded funding during the 2005–2006 academic year. HunWen Tao is assisting on a project on bus signal priority based on GPS and wireless communication under the direction of Gary Davis, a professor in the civil engineering department, and Chen-Fu Liao, senior systems engineer with the ITS Laboratory. The other two students, John Grittner and Maria Le, are working under the direction of Albert Yonas, a professor in the Institute of Child Development, on improving the ability of drivers to avoid collision with snowplows in fog and snow.

Student's research, design tested by state DOT

When Michael Etheridge was an undergraduate student in the University of Minnesota's mechanical engineering program, he presented his senior project to Mn/DOT maintenance staff and the University in April 2005. A year later, his design for a safer, quicker system to change snowplow blades is just beginning to show its potential.

The Quick Edge Rapid Underbody Plow Cutting Edge Changing System was designed, Etheridge said, with several objectives in mind. The design aims to reduce the risk of injury to workers changing snowplow cutting edges, reduce the amount of time it takes to do so, and achieve these objectives with minimal effects on the rest of the machine.

In January 2006, a prototype of the Quick Edge system was

mounted on an in-service snowplow truck in Golden Valley, at which time the system performed adequately in trials, according to Etheridge.

However, snowplow drivers were able to use the prototype only four or five times throughout the rest of the winter, said John Tarnowski, a Mn/DOT maintenance research project manager.

"We really haven't had a fair chance to test this out," Tarnowski said. "But it does show a lot of promise."

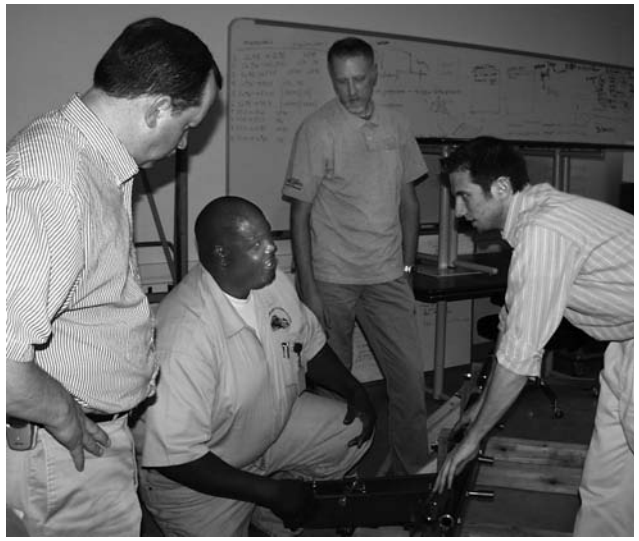
Etheridge said the University is also looking into patenting his design. According to Intelligent Vehicles program director Craig Shankwitz, who served as Etheridge's advisor throughout the project, the University's Patents and Technology Marketing office will first do a marketing analysis of the design. The next step would be gauging companies' interest in licensing the design.

But if nothing else, the Quick Edge system is an example of what can happen when students are able to use their abilities outside of the classroom.

"It provided a unique opportunity for an undergraduate engineering student to design a solution to a real-world problem identified by Mn/DOT maintenance staff," said Linda Preisen, CTS research program manager. "This project was an undergraduate research success."

Etheridge, who has graduated and is now a project engineer at 3M, said he is interested in seeing how far the design will go, but that its fate is mostly up to Mn/DOT researchers and the University.

"It would definitely be fun to see it move forward," Etheridge said. "It was pretty much the biggest undertaking of my undergrad career."



Michael Etheridge (far right) demonstrates the Quick Edge system for Mn/DOT staff and IV program director Craig Shankwitz (center, standing).

Topographic mapping and human factors modules released to Minnesota high schools

The ITS Institute launched two new Web modules to help high school students learn about transportation technologies.

The new Topographic Mapping module introduces students to techniques of accurate mapping and the role of digital maps in new transportation technologies.

The Human Factors module explores the important issue of how human capabilities and limitations affect the design of vehicles and transportation systems.

The new modules join previously developed modules on the Global Positioning System and freeway ramp metering. All were designed by Mark Tollefson, ITS Institute K-12 education coordinator and a high school science teacher. The Web modules are intended for classroom use and feature guided exploration of Web-based resources along with lab exercises that let students immediately practice using what they have learned.

To encourage teachers to try out the modules in their own classroom, a mailing of the two CDs, along with a poster explaining each topic as well as ITS, were distributed to 160 high schools around Minnesota. The modules are also available on the Institute's Web site at www.its.umn.edu/education/modules, making them available to educators and students around the world.

Summer transportation camp attracts area students

In June, the ITS Institute and CTS hosted 45 students from the National Summer Transportation Institute, a 20-day camp held by the Fond du Lac Tribal and Community College and funded by the U.S. Department of Transportation. Most students came from middle schools and high schools on the Fond du Lac Reservation near Cloquet, Minn., and the surrounding area, said director Holly Pellerin.

The group toured ITS facilities to learn about traffic safety technology and Web-based programs that help students design roads. They then got a taste of cutting-edge transportation research by visiting the HumanFIRST Program's driving simulator in the mechanical engineering department, and later made a stop at a Freeway Incident Response Safety Team (FIRST) vehicle outside of the Civil Engineering Building. Driver Julie Todora explained how Mn/DOT's FIRST program minimizes freeway congestion and safety risks through quick response to incidents like crashes and stalled vehicles.

The camp is designed "in the hopes of trying to get kids interested in careers in transportation and impact them at an early age," Pellerin said. "If they wait until after high school to think about careers, it's too late." Students said they enjoyed the camp because it gave them a chance to see things they wouldn't have otherwise. "I come every year and each year we get to go new places and see new stuff," said student Wesley Nikko.

Students from the National Summer Transportation Institute view the HumanFIRST Program's driving simulator.

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

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

Institute researchers discuss traffic safety at TZD conference

Institute research was highlighted at concurrent sessions of the annual Toward Zero Deaths Conference, held in November 2005 in St. Cloud, Minn. The conference, which drew about 450 attendees, served as a forum on how to reduce the number of fatalities and injuries on Minnesota roads.

Professor Max Donath, director of the ITS Institute, described innovative education programs to coax teens into driving more safely, and in-vehicle technologies to prevent them from driving if they are not buckled up or are intoxicated.

Researcher Mick Rakauskas of the University's HumanFIRST Program discussed a recent study that showed that sober drivers talking on a cell phone or operating in-vehicle controls such as the radio or fan performed worse than drivers who were intoxicated.

Transportation research presented at annual UMD event

In November 2005, the fourth annual Research Day event was held at the Mn/DOT District 1 headquarters in Duluth. This year's program featured a half-day look at UMD's ongoing research work in transportation. Taek Kwon, a professor in the electrical and computer engineering department, provided an update on his work in rural ITS applications. In addition to his renewable energy light pole that is on Mn/DOT property, he discussed his work in developing a gravel road traffic counter and his initial design efforts for an intersection traffic movement counter.

Rich Maclin, a professor in the computer science department, presented an update on the department's project in developing an automatic process to detect Road and Weather Information System (RWIS) sensor malfunctions. John Evans, a professor from the chemistry department, presented results from his work to explore a low-cost, optical fiber-based spectrophotometry and surface acoustic wave device for remote sensing of road conditions. Brian Brashaw, program director for the Natural Resources Research Institute (NRRI), provided an update on his development of inspection techniques to assess the conditions of rural bridge systems.

Other UMD presenters included Jiann-Shiou Yang, who provided an update on his study of short-term arterial travel time models; David Wyrick, who discussed his work in fleet management life-cycle cost analysis; and Stanley Burns, who presented his work in using magneto-resistive sensors for vehicle classification.

Intersection research travels to ITS World Congress

ITS Institute researchers traveled to the 12th ITS World Congress in San Francisco to demonstrate the sensing and communications technologies used in the intersection decision support system. Led by Intelligent Vehicles (IV) program director Craig Shankwitz, the team conducted technology demonstrations over multiple days for attendees at the prestigious international conference. Several hundred conference attendees participated in the technology demonstrations facilitated by Shankwitz and other researchers involved in the project. Topics covered in the demonstrations included sensing and vehicle tracking using multiple radar and video camera detectors, wireless communication, and human factors issues involved in designing effective variable information signs for drivers.

International visitors tour U of M research labs

Officials from 17 countries across the globe—from Norway to Uganda, Japan to New Zealand—came to Minnesota in April for a meeting of the Performance of Roads Administration Committee of the World Road Association (known as PIARC).

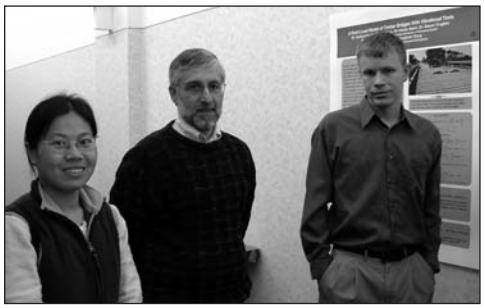
PIARC is a world leader in the exchange of knowledge on roads and road transportation policy and practices within an integrated, sustainable transportation context.

In addition to attending the meeting and touring other sites, the group visited ITS Institute facilities at the University of Minnesota. Craig Shankwitz, director of the IV Lab, gave an overview of the lab's activities, including a demonstration of driver-assistive technologies on the TechnoBus. Mike Manser, research associate with the HumanFIRST Program, provided an overview of the University's driver behavior research and provided a demo of the driving simulator.

ITS Institute board member Randy Halvorson, Mn/DOT Program Management division director, hosted the meeting as the United States' representative on the committee.

ITS Institute helps attract funding for security research

In recent years, the University of Minnesota has successfully attracted federal funds to address transportation security issues, in part due to seed funding from the ITS Institute and



UMD grad student Fenghuan Wang, Professor Harlan Stech, and grad student Joseph Erickson at NATSRL's annual Research Day

IV program director Craig Shankwitz describes the intersection decision support system to ITS World Congress attendees.

A group of international visitors toured the IV Lab's TechnoBus.

Professor Nikos Papanikolopoulos (standing) has done extensive work on automatic detection of vehicles and pedestrians with video cameras.

the Center for Transportation Studies (CTS). To expand the transportation security research, education, and outreach funding at the University, a new program is being developed to communicate University expertise to various federal funding agencies and take advantage of increased funding for research on transportation security technologies.

SECTTRA—Security in Transportation Technology Research and Applications—is a joint program of the Department of Computer Science and Engineering (CSE) and CTS. It will aim to earn recognition for the University of Minnesota as a world leader in the development and application of technologies for transportation security.

CSE professor Nikolaos Papanikolopoulos will lead SECTTRA, working with CTS and sponsors to attract funding, involve faculty and department staff in research activities, provide national and state leadership, and guide the delivery of research, education, and outreach efforts.

A joint memorandum of understanding was signed for SECTTRA in March by Robert Johns, CTS director; Papanikolopoulos; Max Donath, director of the ITS Institute; Vipin Kumar, CSE department head; and Steven Crouch, dean of the Institute of Technology.

The SECTTRA program will collaborate with the ITS Institute and the Safety Security Rescue Research Center (SSR-RC) in CSE. Funded by the National Science Foundation, SSR-RC is a cooperative research center that coordinates research with a spectrum of large general homeland security contractors, companies with a specific market share, and start-up companies with key enabling technologies.

SECTTRA's mission complements SSR-RC's goal of attracting private sector funding for a broad range of security-related research. It also complements the ITS Institute's goal of attracting funds for other transportation technology research.

Institute research featured in news

The ITS Institute is recognized as a national leader in ITS research, as evidenced by the media coverage it received during the past year.

University of Minnesota research designed to help drivers avoid crashes was featured July 2005 in a story aired by Minnesota Public Radio (MPR). Professor Max Donath, director of the ITS Institute, was interviewed about several types of technology. In one segment, Donath discussed adaptive cruise control (ACC) systems now available on some higher-priced cars. The ACC technology, which is the subject of ITS-funded research led by Professor Rajesh Rajamani of the Department of Mechanical Engineering, can take control of a vehicle to keep it from rear-ending the one ahead of it. Donath also described intersection decision support technologies that help drivers at rural intersections decide when it's safe to enter or cross a roadway.

The local NBC television news affiliate in the Twin Cities, KARE-TV, covered research by Kathleen Harder and John Bloomfield on driver aggression. The local FOX television news affiliate, FOX9 News, aired segments highlighting research by Professor Shashi Shekhar on evacuation route planning and research led by Professor Stephen Simon, Max Donath, and Shawn Brovold on the Teen Driver Support System project. In addition, the teen driver research was covered by the University's student-run newspaper, the *Minnesota Daily*.

The Minneapolis *Star Tribune* covered the ITS Institute's research and reauthorization in September 2005.

The national newsletter *Inside ITS* featured Institute safety research and the Minnesota Toward Zero Deaths program. *Minnesota Medicine* magazine, in an article titled "Public Health Enemy No. 1? American death rate from motor vehicle crashes," interviewed Max Donath and HumanFIRST Program director Nic Ward.

Finally, the University of Minnesota's *UMNnews*, an electronic newsletter highlighting University work, featured HumanFIRST Program cell phone research as well as the Institute's Teen Driver Support System research. The latter

article also mentioned the Institute's $16 million grant from the U.S. Department of Transportation as part of SAFETEA-LU, and how the funding will allow the Institute to conduct research on a wide array of safety and transportation topics.

Evacuation project wins award

Institute researcher Shashi Shekhar was one of the recipients of this year's CTS Research Partnership Award, presented at the CTS Annual Meeting and Awards Luncheon held in Minneapolis April 18.

The winning project, "Metro Evacuation Traffic Management Plan," developed a system to coordinate local emergency evacuation plans in multiple communities.

Seventy public and private agencies in the nine-county metro area, including the Minnesota Department of Transportation, were invited to create the plan, including transportation, fire, law enforcement, and emergency management officials.

Shekhar, a professor in the Department of Computer Science and Engineering, explained that the goal of his research team was to create a tool that would run more efficiently than the standard programming approach and allow users—such as transportation professionals and first responders—to quickly find the best escape routes, even for large scenarios. Mn/DOT has already used the algorithm to develop a metro evacuation traffic management plan for the Twin Cities area.

Institute researchers put their expertise in print

Mechanical engineering professor Rajesh Rajamani is the author of the recently published *Vehicle Dynamics and Control* (Springer, 2005). The textbook, one in the publisher's Mechanical Engineering Series, provides information on vehicle control systems including adaptive cruise control, automated highway systems, automated lane keeping, engine control, tire models, and tire-road friction estimation. The textbook is meant primarily for engineering faculty, graduate-level students, and researchers.

Associate Professor David Levinson, civil engineering, is the co-author with William Garrison of *The Transportation Experience: Policy, Planning, and Deployment* (Oxford University Press, 2005). The 460-page book explores the genesis of transportation systems; the roles that policy plays as systems are planned, innovated, deployed, and reach maturity; and how policies might be improved.

Visiting researchers foster beneficial 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 Advanced Transportation Technologies Seminar Series provided an opportunity to host Derek Caveney from the Toyota Technical Center in Michigan. Caveney spoke to the Institute on his current research project, "Multiple Model Techniques in Automotive Estimation and Control."

Thomas Horan, an associate professor at Claremont Graduate University and visiting scholar at the Humphrey Institute of Public Affairs, is part of the Sustainable Technologies Applied Research (STAR) Initiative. Horan is investigating wireless 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 of Nissan, Erwin Boer of the University of California, Jeff Caird of the University of Calgary, Andras Kemeny of the College de France, Jason Laberge of Honeywell, and Dick de Waard of the University of Groningen.

Web, publications promote Institute work

The Web continued to be an important tool for the ITS Institute to provide public information about its research, outreach, and education activities in 2005. Notable Web-related activities and milestones this year included the following:

Associate Professor David Levinson co-authored a recently published book on transportation system planning and policies

The winning project developed a system to coordinate local emergency evacuation plans in multiple communities.

- The database-powered research project publishing system introduced last year continued to perform well, with information on newly funded projects being added.

- Twenty-five ITS-related research projects were featured in articles in the Center for Transportation Studies' *Research E-news* electronic newsletter, available on the Web at www.cts.umn.edu/news/renews/. Many of these stories provided links to download final research reports.

- Electronic mail was used to publicize upcoming events, including Advanced Transportation Technologies Seminars, conferences, luncheon presentations, and other ITS-related events.

- Online subscription forms, on the ITS Institute Web site and the Center for Transportation Studies Web site, were revised to make it more convenient for Web users to sign up for electronic and print newsletters and event announcements.

- The new Human Factors and Topographic Mapping Web-based research modules developed for high-school students (described in the Education section of this annual report) were also added to the ITS Institute's Web site so students can use them directly online.

On the print communications side, Institute publications helped raise the profile of the ITS Institute in academic and professional communities and disseminate the results of research.

The sixth ITS Institute annual report, with photos and coverage of researchers, their students, and their projects, was published. Printed copies of the annual report were mailed to over 1,600 individuals as well as distributed at TRB, ITS World Congress, and other Institute-related events. In addition, the report was again made available as a PDF file for download from the Institute's Web site.

Circulation of the *Sensor* newsletter remained steady at around 2,300. The *Sensor* is one of the primary vehicles for increasing visibility of the ITS Institute, and its high circulation represents a wide knowledge of and interest in ITS research activities among academic and professional audiences.

For the ITS World Congress in San Francisco, the Institute produced an informational fact sheet giving an overview of the sensing, communications, and human factors research involved in developing a viable intersection decision support system. Institute staff distributed 500 copies of the fact sheet to interested conference attendees during their technology demonstration. The fact sheet was also made available as a PDF document on the Institute's IDS Web page (www.its.umn.edu/research/applications/ids/). Because transportation agencies from several states participate in pooled-fund research on IDS carried out at the University of Minnesota, generating additional awareness nationally and internationally is important for the success of IDS technology.