UNIVERSITY OF MINNESOTA

2002/2003
ANNUAL REPORT

INTELLIGENT TRANSPORTATION SYSTEMS INSTITUTE

HUMAN-CENTERED TECHNOLOGY TO ENHANCE SAFETY AND MOBILITY
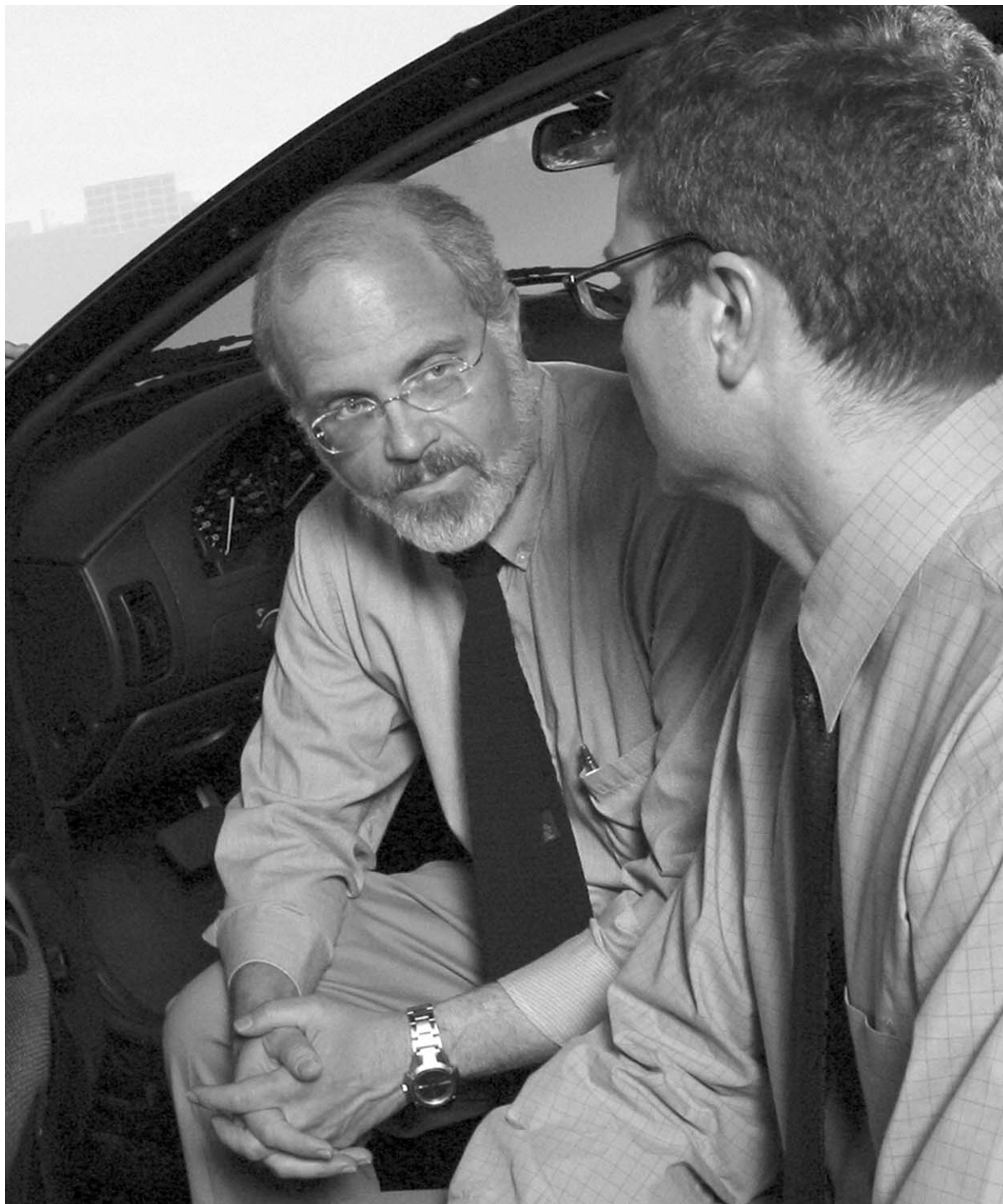
UNIVERSITY OF MINNESOTA

INTELLIGENT TRANSPORTATION SYSTEMS INSTITUTE

2002/2003 ANNUAL REPORT

A REPORT OF RESEARCH, EDUCATION, AND
TECHNOLOGY TRANSFER ACTIVITIES,
FISCAL YEAR 2002/2003, OF THE
INTELLIGENT TRANSPORTATION SYSTEMS INSTITUTE
AT THE UNIVERSITY OF MINNESOTA

CONTENTS

The year 2002 saw the number of car crash fatalities in Minnesota rise to 657, an increase of more than 15 percent from the previous year, when fatalities totaled 568. Although the year 2001 represented a major positive milestone with the fewest fatalities since 1993, in 2002 we suffered the largest number of fatalities since 1981, the last year that fatalities hovered at numbers greater than 750.

These numbers are much more meaningful when considered in terms of exposure. For example, our fatality rate per 100 million vehicle miles traveled (VMT) rose from 1.07 in 2001 to 1.21 in 2002. Compared with the rest of the country (with a rate of 1.5 fatalities per 100M VMT in 2001), we in Minnesota still seem to be doing better (see fig. 1). And when compared with our fellow states by most any measure of road fatalities, we consistently rate among the lowest ten. This, however, does not give comfort to the families of the 657 who lost their lives. Consider these numbers in the context of other countries. The United States is doing significantly worse than Sweden or the United Kingdom—this despite the fact that the UK has higher speed limits on its motorways (see fig. 2).
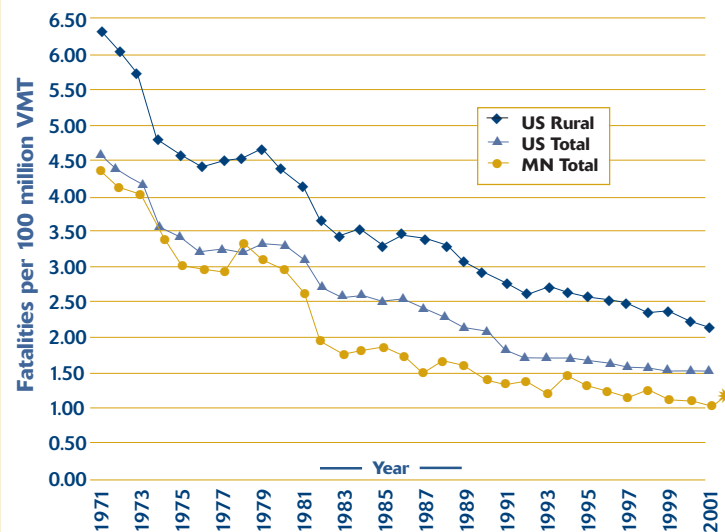

Fig. 1. Fatalities per 100 Million Vehicle Miles Traveled
(U.S. Rural, U.S. Total, and MN Rural)

Source: FHWA Highway Statistics 2001 and Minnesota Motor Vehicle Crash Facts

ITS Institute director Max Donath (left), with Nic Ward

Over the decades prior to the early 1990s, we saw a remarkable drop in fatalities all over the country. This drop was associated with factors such as better car design, the introduction of seat belt laws and air bags, significant changes in DWI laws, improved child restraints, and the steady increase in the use of medians on limited-access highways to separate opposing traffic. What is most bothersome is that we have seen very little change in fatalities per VMT in the U.S. for more than ten years and almost no change in the last three. And for Minnesota, the situation is getting worse rather than better. Is the increase in Minnesota's rate an aberration, or is it a harbinger for what is to come across the country? Will we be seeing increases in the fatality rates in the future? What can we do to effect change? Where do we focus our efforts? One direction that we ought to consider is to direct our attention to rural fatalities, which have consistently and significantly outnumbered urban fatalities.

In order to address these issues, the state of Minnesota has decided to pursue a new tack, with a program called Toward Zero Deaths. This positive development will attempt to focus activities on reducing fatalities and Type A injuries—the most severe form of trauma-type injuries. Striving to achieve a zero-fatality rate is what we should be doing. We are pleased to be a partner in this endeavor. The ITS Institute has focused on research related to reducing fatalities and crashes for many years, and the projects described in this annual report demonstrate that we are committed to thinking "out of the box" so that we can change the trend lines and foster significant reductions in fatalities and crashes.

One example: This year, we received major new funding from the Infrastructure Consortium (a partnership drawing together the FHWA and the three state DOTs of Minnesota, California, and Virginia), to deal with rural intersection crash mitigation. We will be focusing specifically on using new sensing and wireless communication systems and new human interfaces to help drivers correctly gauge the gap size necessary for safely turning into or crossing a traffic lane at rural unsignalized intersections. This has been identified as a key objective necessary to fulfill the AASHTO Strategic Highway Safety Plan. Previous studies have shown that 60 percent of right-angle crashes at rural intersections in Minnesota involve a driver stopping and then proceeding into the intersection, an indicator that the problem indeed is one of poor gap selection.

We have many partners in the operations of the Institute. I would like to thank the people on our board who have given of their valuable time to help the Institute make decisions and fulfill its obligations. This past year, Susan Coughlin, Steve Crouch, Dave Ekern, Asam El

Fakahany, Dick Hansen, Pat Hughes, Adeel Lari, Dick Stehr, and Edward Thomas have all stepped down as their responsibilities took them in different directions. We owe them a great deal of gratitude. We also welcome several new members to the board this year who represent diverse areas of transportation research. We are certain to benefit from the unique knowledge and experience each brings. All of our current board members and their respective affiliations are listed on page five of this report.

As always, we are very appreciative of our local partners, the Minnesota Department of Transportation and the Minnesota Local Road Research Board, for their continued support across the breadth of our activities. We also wish to recognize the USDOT's Research and Special Programs Administration staff for their assistance and encouragement. It is the commitment of all our partners that enables us to advance our mission. We thank you all.

Max Donath
Director
Intelligent Transportation Systems Institute

We ought to consider directing our attention to rural fatalities, which have consistently and significantly outnumbered urban fatalities.
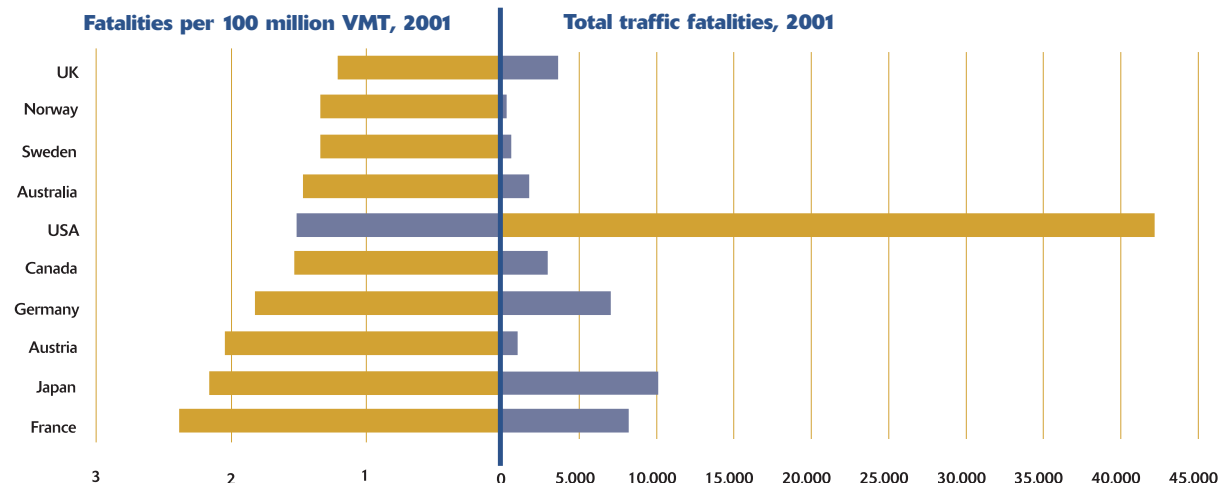

Fig. 2. Fatalities Per 100 Million Vehicle Miles Traveled vs. Total Traffic Fatalities, Selected Countries
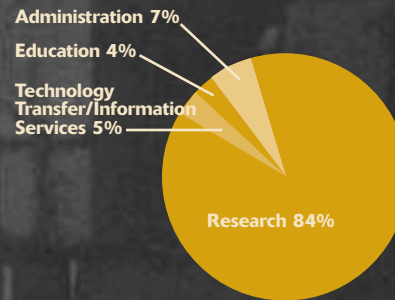
Source: International Road Traffic and Accident Database (Organisation for Economic Co-operation and Development)

Financial Report

**Expenditures for Year Four
July 1, 2002 – June 30, 2003**

Administration 7%

Education 4%

Technology
Transfer/Information
Services 5%

Research 84%

Funding Sources
**Total Annual Budget:
$4.0 million including matching
funds from:**
- **Minnesota Local Road
  Research Board**
- **Minnesota Department of
  Transportation**
- **University of Minnesota**
- **Private industry**

Mission Statement

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

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

The Institute's activities are guided by its theme of enhancing the safety and mobility of road- and transit-based transportation through a focus on human-centered technology. To that end, the Institute focuses 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 its theme, the Institute brings together engineers and cognitive psychologists from the University with its partners, which include 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, the Institute addresses issues related to transportation in a northern climate, investigates technologies for improving the safety of travel in rural environments, and considers social and economic policy issues related to the 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 can be attributed to its state and national partnerships, including those with CTS, the Minnesota Department of Transportation, private industry, and county and city engineers.

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

The Institute's board guides and oversees the implementation of the Institute's work. The board's responsibilities include working with the director to ensure that the USDOT's Research and Special Programs Administration requirements are met, approving annual plans and budgets, and meeting 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 term ended during the fiscal year:

Dave Ekern
Formerly of the American Association of State Highway and Transportation Officials and Minnesota Department of Transportation

Richard Hansen
St. Louis County and Local Road Research Board (retired)

Esam El-Fakahany
University of Minnesota

Dick Stehr
Minnesota Department of Transportation

Edward L. Thomas
Formerly of the Federal Transit Administration

Susan Coughlin
Formerly of the American Transportation Research Institute

Steven Crouch
University of Minnesota

Pat Hughes
Minnesota Department of Transportation

Adeel Lari
Minnesota Department of Transportation

ITS Institute Board Members   Current members as of June 30, 2003

Robert Johns
(Chair)
Director, Center for Transportation Studies

Anthony Kane
Director, Engineering and Technical Services, American Association of State Highway and Transportation Officials

Anthony Strauss
Acting Assistant Vice President, Patents and Technology Marketing, University of Minnesota

Mike Asleson
Major, Minnesota State Patrol, Minnesota Department of Public Safety

Vince Magnuson
Vice Chancellor for Academic Administration, University of Minnesota Duluth

Kathryn Swanson
Director, Office of Traffic Safety, Minnesota Department of Public Safety

Rebecca Brewster
President and Chief Operating Officer, American Transportation Research Institute

Marthand Nookala
Director, Operations, Safety and Technology Division, Minnesota Department of Transportation

Don Theisen
County Engineer, Washington County

Ted Davis
Dean, Institute of Technology, University of Minnesota

Richard Rovang
Director, Engineering and Facilities, Metro Transit

Toni Wilbur
(Ex Officio)
Director, Office of Operations Research and Development, Federal Highway Administration

Richard Graham
President, Dakota Area Resources and Transportation for Seniors

Richard Sanders
County Engineer, Polk County

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

Randy Halvorson
Director, Program Management Division, Minnesota Department of Transportation

Barbara Sisson
Associate Administrator, Office of Research, Demonstration and Innovation, Federal Transit Administration

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

Al Steger
(Ex Officio)
Division Administrator, Federal Highway Administration

Standing from left: Chen-Fu Liao, Max Donath, Dawn Spanhake, Gina Baas, Michael McCarthy, Laurie McGinnis, Robin Dolbow, Arlene Mathison, Peter Nelson, Pat Rouse, Jamie Yue, and Amy Friebe. Front row from left: Pamela Snopl, Cindy Holton, Linda Pelkofer, Ted Morris, and Sharon Day. Not pictured: C.J. Loosbrock, Eil Kwon, and Rick Odgers.

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School of Kinesiology
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Michael Wade

Institute of Child Development
Herbert Pick
Albert Yonas

Humphrey Institute of Public Affairs
Richard Bolan
Frank Douma
Thomas Horan
Kenneth Keller
Kevin Krizek
Lee Munnich

Institute of Technology
Civil Engineering
Gary Davis
John Hourdakis
Eil Kwon
David Levinson
Panos Michalopoulos

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Mats Heimdahl
Osama Masoud
Nikolaos Papanikolopoulos
Shashi Shekhar

Electrical and Computer Engineering
Mohamed-Slim Alouini
Vladimir Cherkassky

Mechanical Engineering
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Pi-Ming Cheng
Max Donath
Will Durfee
Peter Easterlund
Alec Gorjestani
Perry Li
Michael Manser
Bryan Newstrom
Curt Olson
Rajesh Rajamani
Mick Rakauskas
Craig Shankwitz
Nicholas Ward

Northland Advanced Transportation Systems Research Laboratories

The NATSRL program is directed by Dr. James Riehl, dean of the College of Science and Engineering. Technical support is provided by Dr. Stanley Burns, professor and head, Department of Electrical and Computer Engineering (ECE); Dr. Donald Crouch, professor and head, Department of Computer Science; Dr. Taek Mu Kwon, professor, ECE; and Dr. David Wyrick, associate professor and head, Department of Mechanical and Industrial Engineering.

Administrative oversight of the NATSRL program is managed by Carol Wolosz, with Jeanne Hartwick serving as the program accountant and David Keranen as the infrastructure engineer.

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

University of Minnesota Duluth, College of Science and Engineering
James Riehl, Dean

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

Computer Science
Carolyn Crouch
Donald Crouch
Richard Maclin

Industrial Engineering
Ryan Rosandich
Martha Wilson
David Wyrick

Natural Resources Research Institute
Brian Brashaw
Larry Zanko
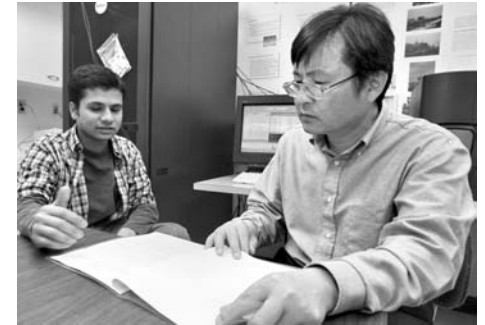
From left: student Nirish Dhruv and Taek Kwon

From left: students Junmin Wang and Piyush Agrawal with Lee Alexander

NATSRL staff and students, left to right: Michael Perkins, Donald Crouch, Deodatta Bhoite, Hemal Lal, Aniruddha Mahajan, Rich Maclin, Jeffrey Sharkey, and Carolyn Crouch (front).

ITS Laboratory

The Intelligent Transportation Systems Laboratory is a dedicated facility supporting ITS research and education. The lab's mission is to develop or provide state-of-the-art resources for researchers, students, and collaborators pursuing research in ITS. Focused on supporting research in surveillance, monitoring, and management of traffic systems, the ITS Laboratory works in partnership with other University of Minnesota research facilities including the HumanFIRST Program and the Intelligent Vehicles Laboratory to enable a full spectrum of ITS research.

The lab's facilities are used by faculty and students in civil, mechanical, and electrical engineering, computer science, and affiliated disciplines. Additionally, the lab hosts training events.

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

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

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

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

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

Putting the researcher inside the simulation is the goal of the ITS Laboratory's Digital Immersive Environment, or DEN. Three large rear-

The ITS Lab's Digital Immersive Environment, or DEN

From left: graduate student Vishnu Garg, research fellow John Hourdakis, and ITS Lab manager Ted Morris

projection screens surround the user; behind the scenes, a bank of six computers controls a visual environment developed using Open Scene Graph (OSG) and driven by data from an AIMSUN2 traffic simulator.

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

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

Reducing crashes where they occur most often

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

The ITS Lab's Beholder system is playing an integral role in helping two University researchers do just that.

Professor Panos Michalopoulos and research fellow John Hourdakis of the Civil Engineering department are working to develop a crash avoidance/prevention system for crash-prone freeway locations. Their first step is to learn the reasons for and mechanics of crashes by recording them and extracting raw traffic-detector measurements. The Beholder system is providing them with real-time video and traffic measurements, allowing them to observe and verify the incident represented in the recorded measurements.

Conditions that are being analyzed include traffic pressure, speed, volume, occupancy, quality of flow, weather, pavement conditions, and other factors before, during, and after a crash occurs.

The advantage of using the Beholder system, Hourdakis explains, "lies in the detail and resolution of the collected measurements. There is no other site in the world that [reliably] collects such information." For a stretch of highway that is approximately a mile long, Beholder provides continuous individual vehicle speeds and headways around the clock. Having such detailed measurements for a specific location is essential for the success of the study, Hourdakis adds.

So far, the researchers have collected data on approximately 50 crashes and 50 near-misses. From this, Hourdakis says they've gained a good understanding of the nature of crash mechanisms and are now analyzing the measurements in order to detect specific patterns signaling the crash-prone conditions. As the project progresses, they will attempt to enhance the Beholder system with algorithms that will automatically detect these conditions. If successful, their research will seek ways to either alert drivers during such conditions, such as through an automated crash-prevention system, or communicate to a traffic management center that such crash precursor conditions exist and recommend mitigative procedures.

Portable monitoring stations transmit freeway traffic data to the ITS Lab.

The program's research strategy is based on a driver-centered approach, considering the "human first" within the transportation system.

Human Factors Interdisciplinary Research in Simulation and Transportation

The Human Factors Interdisciplinary Research in Simulation and Transportation (HumanFIRST) Program's mission is to apply human factors research to the design and evaluation of usable intelligent transportation systems to improve traffic safety and mobility. 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 cognitive psychologists and software engineers linked to a broader interdisciplinary network of other psychologists, engineers, computer scientists, and public health and safety practitioners. This network is supported by affiliations with additional University research units and industry, which allows the program to create responsive interdisciplinary teams to investigate a broad range of complex human factors research issues. These affiliations include formal appointments as visiting scientists and visiting professors from Nissan Research Center, the University of Calgary, and the University of Groningen (the Netherlands).

Moreover, the HumanFIRST Program has close relationships with the Minnesota Department of Transportation and the Department of Public Safety, as well as with traffic engineering consultants. These connections provide additional support for implementing research that will influence transportation policy in response to real-world problems both regionally and nationally.

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 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.

Current research topics include driver distraction from in-vehicle tasks, cell phones, and alcohol; bus rapid transit using dedicated narrow shoulders; intelligent driver-support systems such as vision-enhancement for specialty purpose vehicles (State Patrol vehicles, snowplows); infrastructure-based driver support systems for intersection safety; driver training for young drivers with attention-deficit disorders; alcohol impairment of cognitive and emotive behavior in driving; effects of sleep deprivation on driving; and new methods for increasing driver situation awareness regarding traffic hazards.

HumanFIRST Program staff. Back row: Curt Olson, Mike Manser, Rick Odgers, Mick Rakauskas, program director Nicholas Ward, Nobuyuki Kuge, and Amit Chohan. Front: Peter Easterlund (kneeling), Ben Chihak, Ma Zhu, and Praveen Balachandran (kneeling)

Much of the research of the HumanFIRST Program uses a state-of-the-art driving simulator engineered specifically for human factors research in surface transportation. This Virtual Environment for Surface Transportation Research (VESTR), provided by AutoSim, is an extremely versatile and realistic simulation environment that can be used for a variety of theory- and application-based research. This simulator is involved in a series of methodological tests to validate simulators and tune each simulator to correspond with actual driving conditions.

Among the features that make VESTR one of the most advanced academic simulators in North America are a 2002 SC2 full-vehicle cab (donated by Saturn) that provides realistic operation of the controls and instrumentation, including force-feedback steering and the feel of power-assisted braking; high-fidelity simulation for all sensory channels; a visual scene projected to a high-resolution, five-channel, 210-degree forward field of view, with rear and side mirror views provided by a rear screen and LCD monitors; software (provided by OKTAL) that can generate any type of road environment, including precise reproductions of geospecific locations, and produce a range of realistic weather and lighting effects; and auditory and tactile feedback provided by a three-dimensional surround-sound system, car body vibration, and a three-axis electric motion system. It also has the capacity to simulate and configure any type of display interface using versatile graphics software that can interact with data from the simulator.

To support the use of VESTR, the program has access to a variety of additional research facilities and locations such as closed test tracks and road network field sites for on-road studies with instrumented vehicles. To support these research activities, the HumanFIRST Program has state-of-the-art measurement tools, including a mobile psychophysiology recording system, an eye-tracking system, a vision-testing system, certified breathalyzers, and comprehensive psychomotor test batteries validated for driver assessment.

Capturing the driving experience

For human factors researchers, one of the most significant challenges in working with human test subjects is obtaining reliable data about the subjects' experience during the test. Post-test questionnaires and interviews are commonly used to obtain this data, but such tools are limited in that they require test subjects to remember and report their thoughts and reactions after the test is over.

The HumanFIRST Program has recently purchased specialized equipment to enable researchers to monitor subjects' psychophysiological reactions in real time during in-vehicle testing. The portable system can be used both in vehicle simulators and on the road while driving. Using small electrodes attached to the test subject, the system collects data on muscle (EMG) and brain (EEG) activity, as well as heart rate (EKG) and eye movement (EOG).

The expertise required to operate the system has been developed through partnerships with Professor Christopher Patrick of the University of Minnesota's Department of Psychology and visiting scientist Dr. Dick de Waard from the University of Groningen, the Netherlands.

Initial uses for the system will include investigation of alcohol impairment of driver cognitive and emotional performance in a simulated environment. Future projects include using psychophysiological data to measure mental effort and stress related to distraction, fatigue, and other performance impairments.

Electrodes are attached to a test subject in the driving simulator (left), while data are collected on muscle and brain activity, heart rate, and eye movement (right).

Intelligent Vehicles Laboratory

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

The IV Laboratory's core staff is made up of engineering and computer science professionals. They work closely with an interdisciplinary team of specialists, including cognitive psychologists specializing in human factors from the ITS Institute's HumanFIRST Program and experts in visibility, geospatial databases, road-weather and other traveler information systems, virtual environments, image processing, and traffic-signal operations.

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 recently added TechnoBus, a Metro Transit bus. Using these vehicles, IV Laboratory researchers are leading the way in developing, testing, and integrating advanced technologies such as 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), virtual mirror, and other graphical displays; and haptic and tactile feedback.

The IV Laboratory's 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.

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

View of the head-up display showing the location of other vehicles and lane boundaries

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

The IV Laboratory's partnership with the Minnesota Department of Transportation provides access to roads and other infrastructure, including the Minnesota Road Research Project (Mn/ROAD) test track, which consists of a freeway and a low-volume road pavement test track with 40 different road material test sections; 4,500 electronic sensors; a weigh-in-motion scale; a weather station; and DGPS correction signals. The IV Laboratory also has relationships with a number of other organizations and government agencies, including the U.S. Department of Transportation's Research and Special Programs Administration, Federal Highway Administration, and Federal Transit Administration; Twin Cities' Metro Transit; and Minnesota's Local Road Research Board. These partnerships provide additional support for implementing research that will influence transportation safety in the United States and around the world.

IV Lab staff aboard the TechnoBus. From left: Bryan Newstrom, Lee Alexander, Alec Gorjestani, program director Craig Shankwitz, Curt Olson, Pi-Ming Cheng, and Walter Trach

Finding clear solutions for driving in low visibility

One significant research component of the IV Laboratory is the Intelligent Vehicle Initiative Field Operational Test Program, funded by the USDOT through the Minnesota Department of Transportation. Over the course of this recently-completed three-year program, IV Lab engineers, in cooperation with researchers from the Institute's HumanFIRST Program and the University of Minnesota Duluth's Department of Electrical and Computer Engineering, developed, tested, and evaluated a variety of vehicle-guidance and collision-avoidance technologies designed to help drivers navigate in low-visibility situations including snow, fog, and darkness.

The inside of a State Patrol car showing equipment used for the HUD. Inset: Road view on the HUD.

In the study's first year, researchers conducted a series of human factors studies of visual, tactile, and audible lane-departure and collision-avoidance warnings. Simulator and closed-course testing was completed in the second year. Following these tests, four snowplows, an ambulance, and a State Patrol car were released for the field operational test. All of the equipment designed to assist the driver, including the head-up display (HUD), driver's seat (which provides the tactile warning), audio warnings, sensors, and computers, was installed in each vehicle. Data acquisition equipment was installed to record driver-response to the system during operational testing.

The driver-assistive system was tested on the Highway 7 corridor for two years. Unfortunately, during this time, snowfall amounts were low, and opportunities to use the system under conditions for which it was designed were limited. As a result, only a small amount of data exists that can be used to quantify performance and economic benefits of the system. In order to better compare the benefits associated with this driver-assistive system, a second set of closed-course tests was designed and executed at the Mn/ROAD pavement research facility. During these tests, driver performance and stress levels were measured under low-visibility conditions both while driving with the system on and with the system off. Comparing test results for both conditions should allow conclusions to be drawn regarding the benefits of these driver-assistive systems. Preliminary analysis and feedback from drivers was positive, and plans are moving forward to re-deploy the technology on vehicles operating in areas with low-visibility conditions.

For complete project information, visit www.its.umn.edu/research/ivifieldtest/index.html.

Sensing changes on the road

NATSRL's Advanced Sensor Research Laboratory (ASRL) is currently investigating three disparate sensor technologies: one each for meterological applications, real-time road surface snow and ice detection, and non-intrusive vehicle identification and speed measurement.

Initial work is underway at ASRL's off-campus facility, where the necessary infrastructure is now in place to support the calibration and installation of a multi-purpose meteorological sensor suite, controlled experimentation with the Infrared Road Ice Detection (IRID)

An IRID System sensor mounted on a bridge structure at NATSRL's I-35 research facility

System, and development of inductive loop detector circuitry to aid analysis of inductive changes and their resultant vehicle-specific signature characteristics. Specifically, the Biral Model 730 sensor will allow the lab to collect weather data such as air temperature, visibility, fog density, precipitation intensity, rain rate, and snowfall rate. It will be used in conjunction with a Coastal Roadway Weather Information Sensor, which will measure air temperature, relative humidity, dew point, wind speed, and wind direction. After integration with a Zeno 3200 programmable logic controller, the sensors will allow the lab to generate real-time weather information for that specific location.

The IRID System incurred substantial damage from a suspected lightning strike, but repairs have been completed, and the system was installed at the lab in March. The IR sensors on the unit will be used in conjunction with polarizing filters to examine spectral reflectance in the near-IR region for water, ice, and various de-icing solutions as well as contaminants often found on the roadway.

Finally, the inductive loop detectors (ILD) used to mark the passage of vehicles are operational. Researchers are modifying existing circuitry and developing new circuitry to facilitate increased sampling rates and acquire more informative vehicle signatures. Development of algorithms to calculate vehicle speed by analyzing magnetic field profiles and their subsequent analog responses would then provide a low-cost practical solution for speed detection using existing single ILD infrastructure.

Northland Advanced Transportation Systems Research Laboratories

The mission of the Northland Advanced Transportation Systems Research Laboratories (NATSRL), located at the University of Minnesota Duluth, is to study comprehensive winter transportation systems and the transportation needs of cities in small urban areas. Research covers a wide range of topics, including optical and electronic traffic and road sensors, transportation data management, and benchmarking of transportation infrastructure. NATSRL is collaborating with the Minnesota Department of Transportation, city and county engineers, and other agencies to address transportation-related needs, especially those specific to northern areas and climates.

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

Other NATSRL research includes projects on traffic data automation for Mn/DOT's traffic monitoring program, an automatic visibility measurement system based on video imaging, and the utilization of satellite images for detecting traffic conditions.

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

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

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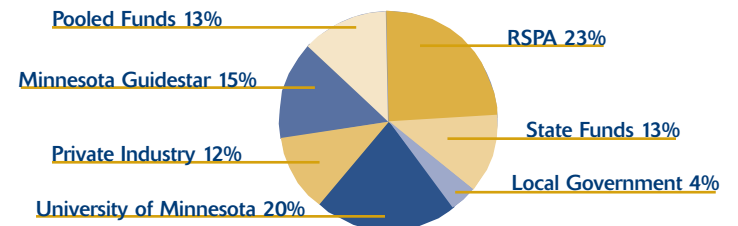- social and economic policy issues related to ITS technologies

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

The Institute's geographic location gives it a unique advantage for developing research applicable to transportation in a northern climate and 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 both ISTEA and TEA-21 legislation, the Federal Highway Administration, and the Federal Transit Administration. Other funding partners include the Minnesota Department of Transportation (Mn/DOT), the Minnesota Local Road Research Board, and Metro Transit, in addition to local governments, agencies, and private companies who contribute funding and in-kind match.

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

Research funding sources for all ITS-related research projects at the Institute
Funding sources shown for projects receiving initial funding in FY03. Funding received prior to that or for continuing projects is not shown. Over $5.8 million was received in FY03 for ITS-related research.

- Pooled Funds 13%
- Minnesota Guidestar 15%
- Private Industry 12%
- University of Minnesota 20%
- RSPA 23%
- State Funds 13%
- Local Government 4%

Human Performance and Behavior

Intelligent Driver Support Systems

For all the demands of driving, the task still relies in large part on what a driver sees of the road and his or her surroundings. Institute researchers, however, are exploring ways to give drivers information through multiple senses—which in turn may help drivers better control their vehicles and manage distractions that could lead to crashes.

The Institute's HumanFIRST Program was last year awarded a three-year project with Japanese automaker Nissan to investigate the potential of intelligent driver-support systems. The systems under study communicate the demands of a driving environment to the driver in a multi-sensory fashion, using a number of sensors that look at the environment and the driver. The HumanFIRST Program is evaluating various system prototypes, drawing on the program's expertise in these areas and employing its state-of-the-art driving simulator and its test tracks, according to Nicholas Ward, HumanFIRST director. Besides Ward, members of the HumanFIRST team include research associate Mike Manser, simulator engineers Curt Olson and Peter Easterlund, and Nissan visiting scientist Nobuyuki Kuge. Two research assistants, Praveen Balachandran and Amit Chohan, are completing coursework and a master's degree as part of this project.

Ward explains that with current vehicle systems, drivers take in information relevant for safe vehicle control through their vision. For example, a driver can see cars traveling ahead, see their brake lights, and gauge how close they are and whether that distance is changing due to deceleration. "We can see these things, but only see them. In many cases, we cannot also hear or feel them," he says. "If we could also get this same safety-relevant information through other sensory channels we would be less likely to miss it, and that might also free up some visual attention that could be devoted to other priority tasks."

The current prototype system uses haptic feedback to communicate the presence of hazards to the driver by the "feeling" imparted (such as a vibration) through the steering wheel and pedals. In this way, driver awareness will be improved through touch, Ward says. This human-centered driver support system will be grounded in theories of human perception, cognition, and vehicle control in a multi-task environment.

How and when this multi-modal information is presented to the driver depends not only on the driving conditions but also on driver state (e.g., drowsy, distracted), as well as sensor and system uncertainties. Nissan and Institute researchers are working closely together to determine how it may be possible to better support drivers in driving safely and comfortably.

The multidisciplinary research project with Nissan involves a consortium of universities in the United States, Canada, Japan, and Europe.

Overall research is focusing on the exploration of new ways to better support drivers and design prototype systems that will primarily be evaluated by the HumanFIRST team. Thus far, the HumanFIRST team has analyzed the types of scenarios that are typical of the crash types the Nissan system is expected to benefit. These scenarios were then reproduced within the driving simulator under conditions of driver distraction to determine if the proposed system could increase driver awareness of traffic hazards to support driving. In the first study, the system did appear to reduce the number of distraction-related crashes. Research planned for the upcoming year will focus on the comparison of this system to other longitudinal support systems such as adaptive cruise control and crash warning systems.

The universities in the research consortium will collaborate to gain an understanding of how to best communicate driving demands to the driver given that drivers may be fatigued, distracted, drowsy, or simply involved in complex driving situations such as merging onto a freeway. The overall goal is to learn how well the new multi-modal driving ecology works as an integrated extension of its natural complement, and how much it improves a driver's ability to manage attention and respond effectively to changes that may impair safety. At the project's conclusion, researchers plan to have developed prototype driver-support systems for simulators and test vehicles and will have evaluated the potential benefits of these systems.

HumanFIRST director Nicholas Ward in the program's driving simulator, which is being used to evaluate prototypes for an intelligent driver support system.

The current prototype system uses haptic feedback to communicate the presence of hazards to the driver by the "feeling" imparted (such as a vibration) through the steering wheel and pedals.

Issues of attention and distraction are not easy to address, and until now, have not been tackled in the large body of previous CMS message research.

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

Millions of motorists across the country rely on intelligent transportation systems for timely, accurate, and useful information to improve their commute. Changeable message signs (CMSs)—also known as variable message signs and dynamic message signs—have long been used as one such ITS tool to provide motorists with real-time travel information in a wide range of applications.

Originally, these highly visible signs were intended to warn motorists about traffic tie-ups and weather conditions. But today, the Minnesota Department of Transportation (Mn/DOT) is considering other possible uses, including the presentation of promotional, safety, law enforcement, and travel quality messages. As part of the nationwide program, CMSs are now also used in the Amber Alert System to flash emergency alerts to motorists when a child is abducted.

All of these possible traffic-related and non-traffic-related uses of CMSs have provoked a number of issues about their effectiveness and the safety impacts they may have on traffic. Human factors research associates Kathleen Harder and John Bloomfield, of the University's College of Architecture and Landscape Architecture, are attempting to answer several key questions Mn/DOT has raised regarding these

issues, namely:

- Should messages be presented on CMSs only when they are necessary, or should there always be some message on them?
- Do the messages presented on CMSs cause slowdowns?
- Do the messages on CMSs actually work?
- What is the impact of CMS messages on traffic flow?

Using a STISIM™ low-cost driving simulator with an automotive-style seat and three 17-inch CRT displays, Harder and Bloomfield recently conducted two back-to-back experiments in which they examined how drivers responded to traffic-related and non-traffic-related messages. In one experiment, the team investigated the effectiveness of site-specific, time-critical messages; in the second, they focused on Amber Alert messages.

The research participants, 120 licensed drivers, "drove" along simulated highways while various CMS messages were presented. In both experiments, participants were asked to respond either by reacting to the CMS message or by reporting the message. Researchers recorded the accuracy of the participants' responses.

In the first experiment, more than half of the 120 participants followed the CMS instructions, which directed them to take an alternate exit due to a crash. But of those who did not follow the CMS instructions, nearly 40 percent ignored the CMS message either because they did not think it applied to them or because they did not understand it. Nearly a quarter of the participants who did not take the exit claimed they did not see the message.

While the results indicate that gender did not affect how a participant responded, the research team determined that age did have a statistically significant effect: the older the driver, the more likely he or she was to follow the directions presented on the CMS. But Harder and Bloomfield believe it is possible that prior exposure to other CMS messages affected the response to the exit message. In the experiment, participants who were not exposed to non-time-critical, non-site-specific CMS messages were more likely to take the alternate exit.

In the second experiment, the participants were assigned to one of four categories on the basis of their Amber recall scores: Poor, for participants who remembered nothing or responded with incorrect information; Fair, for those who remembered "Amber Alert" and some vehicle information; Good, for participants who remembered "Amber Alert," some vehicle information, and part of the license plate number; and Excellent, for those participants who recalled "Amber Alert," vehicle information, and five or six alphanumerics on the license plate. In the end, only 10 of 120 of the participants were in the Excellent category; 62 participants were in the Good category, 38 were in the Fair catego-

In one of the simulated driving scenarios, an Amber Alert was presented on the changeable message sign.

ry, and 10 participants were in the Poor category.

Other findings revealed that neither the age of the participants nor prior exposure to non-time-critical, non-site-specific CMS messages affected the Amber recall scores. In contrast, gender did significantly affect the Amber recall scores—there were many more females than males in the Excellent category.

Additionally, the results show that age has a significant effect on slowdowns associated with Amber Alerts. Older drivers (ages 55 to 65) were eight times more likely than younger drivers (ages 18 to 24) to slow down when presented with an Amber Alert message.

Based on these, and other, findings, Harder and Bloomfield came up with a series of recommendations they believe will help increase the effectiveness of CMS messages, including Amber Alerts. First, the team suggests that the Minnesota Department of Public Safety increase its efforts to make the public more aware of the Amber Alert system. The researchers also recommend changing the Amber Alert messages themselves. Since the experiments show that it is particularly difficult for drivers to remember the license plate number flashed on a CMS, the Amber Alert messages should, instead, tell drivers to tune into an appropriate radio station, whose call sign will be easier to remember. Then, when drivers tune into that station, the full Amber Alert message, including the license plate number, should be repeated frequently. According to Harder and Bloomfield, this will greatly increase the likelihood that if a driver encounters the vehicle mentioned on the Amber Alert he or she will be able to recognize it. This also will likely result in fewer slowdowns than occurred in the experiment.

Their other recommendations include changing the crash-related CMS messages to say "ROAD CLOSED," which should greatly increase the number of drivers who take the exit, or "LANE CLOSED," so that the information is conveyed more clearly to drivers, allowing them to make an informed choice about whether or not to stay on the freeway.

Technologies for Modeling, Managing, and Operating Transportation Systems

Development of Dynamic Route Clearance Strategies for Emergency Vehicle Operations

For a heart attack victim, a few minutes of delay in receiving medical attention can mean the difference between life and death. The nationwide 911 system saves thousands of lives by reducing the response time of emergency vehicles. But after being dispatched, even highly skilled emergency response personnel can be slowed down by red lights or, worse, find themselves stuck in traffic as motorists struggle to clear the roadway.

At the ITS Institute, a research group led by Dr. Eil Kwon is exploring dynamic route clearance for emergency vehicles, a technology that promises to reduce emergency response times while minimizing traffic disruption for other motorists.

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

Several commercial systems are available to accomplish this goal. Known as Traffic Signal Preemption systems, they consist of some form of vehicle-mounted signal emitter (such as an infrared beam or low-powered radio transmitter) combined with sensors mounted on or near traffic signals. When triggered by the emergency vehicle's transmitter, these sensors activate a control mechanism that alters the traffic signals' timing cycle. The result is that traffic signals change to green more quickly when a transmitter-equipped vehicle is approaching, and stay green until the vehicle has cleared the intersection.

Intersection-based signal preemption with local detection, however, has several limitations. Chief among these is the fact that a vehicle-mounted signal transmitter must have a clear "line of sight" to the traffic signal in order to trigger the preemption routine. Further, it is possible to have unnecessary preemption for the intersection signals that are not on the emergency route if they happen to be located in the line of sight.

This problem becomes particularly acute in urban areas, where emergency vehicles must make frequent turns and where closely spaced buildings block the preemption signal at corners. And in congested city traffic, even when the preemption signal is received relatively early in the emergency vehicle's approach to a traffic signal, it may be difficult

From left: University police officer Josh Betts, Mn/DOT signal engineer Robert Betts, research assistant Sangho Kim, and principal investigator Eil Kwon

Eliminating red lights along the route of an emergency vehicle can give it a critical speed boost.

Sensors mounted on or near traffic signals can alter a signal's timing cycle in response to an approaching emergency vehicle.

Emergency vehicle travel times under the dynamic systems showed travel time reductions from 10 to 16 percent on a complicated route.

for motorists to clear the intersection in time.

Dynamic route clearance goes beyond intersection-based signal preemption by managing the entire route that the vehicle takes from dispatch to emergency scene. In a dynamic system, a network-monitoring module continually gathers traffic information and passes these data to a route selection subsystem. The subsystem then calculates an optimal route based on current conditions. As the emergency vehicle travels along this route, its location is monitored by the central system, which intervenes in signal timing as appropriate.

Mathematically determining the best (i.e., lowest travel time) route is an example of the "single-source shortest path" problem; to solve it, the route selection module employs the well-known Dijkstra's algorithm. In this case, the network monitoring module first computes travel time between points considering current traffic conditions, and the algorithm computes the "shortest" route in terms of time rather than space.

As soon as the emergency vehicle clears an intersection, the system initiates a signal-timing recovery procedure to return the signal to its original pattern. Kwon's system, designed around the signal policies of Minneapolis, adjusts the "Walk" interval of the crossing street (whose signal was blocked during preemption) to return the system to its original state.

To evaluate the route-based dynamic preemption system, Kwon and his team used VisSim™ microscopic traffic simulation software interfaced to an external virtual control center module, which was developed by the researchers using the C programming language. Key capabilities of VisSim for this application included its ability to model a set of detectors that can detect only emergency vehicles. A virtual intersection controller module was also developed to emulate different types of signal

preemption strategies including the existing method with local detection. Because the current version of VisSim does not permit the route of an emergency vehicle to be specified during the simulation, testing the online route selection module was not performed in this study; this phase of testing focused purely on the effectiveness of dynamic signal preemption with a pre-specified route.

The streets around the University of Minnesota's Minneapolis campus were selected as the sample network for this evaluation. Geometric data on the test area were collected from aerial photographs, and detailed traffic data including volume, signal timing, and current preemption sequences were provided by the City of Minneapolis Traffic Operations Center.

For calibrating the simulation model, actual travel time data for emergency vehicles on three routes were collected in cooperation with the University Police Department. Two of the three routes chosen are equipped with the Opticom™ signal preemption system, which uses a vehicle-mounted light beam to activate the preemption routine.

Simulation of multiple distinct routes revealed that route-based dynamic signal preemption produced superior results on relatively long and complicated routes when compared to the existing intersection-based preemption method. For example, emergency vehicle travel times under the dynamic systems showed reductions ranging from 9 to 12 percent on a relatively straight route, and from 10 to 16 percent on a complicated route.

Network-wide traffic performance was also evaluated from the point at which the emergency vehicle was introduced into the simulation until the end of the simulation period 30 minutes later. Total vehicle-hours of travel and delay per vehicle data show comparable or better results under the dynamic preemption method when compared to intersection-by-intersection signal preemption, even while the emergency vehicle itself realizes a significant travel-time reduction.

Simulating Snowplow Scheduling in District 1

For cities and counties in northern Minnesota, few maintenance operations are as critical—or as unpredictable—as snow removal. Differences in snow conditions, temperature, wind, and snowfall duration call for different snowplowing and deicing techniques, which makes keeping the roads open a challenge for plow drivers as well as for the managers who schedule and direct the plows. The fact that snowplows are owned and operated by entities in different geographic areas, including cities both large and small as well as counties, adds to the logistical puzzle. Snowplow schedulers must also worry about reloading plows with sand

and deicing compounds, refueling, and minimizing "deadheading" that occurs when a plow is traveling over plowed roads from one area to another.

A research team led by Martha Wilson, a professor of industrial engineering at the University of Minnesota Duluth, is working to develop a decision support tool for snowplow managers that will help them deploy their plows in the way that best addresses current weather conditions and system priorities. Other team members include Tim Sheehy, area superintendent, and Greg Pierzina, area supervisor, both with Mn/DOT in Virginia, Minn.; graduate student Kwasi Dadie-Amoah; Ed Fleege, with the Department of Electrical and Computer Engineering; and other Mn/DOT personnel in Duluth.

Current management practices rely primarily on the experience of supervisors and snowplow operators. Although this has provided an acceptable level of service, documenting the snowplow operations process would help in understanding it and might suggest potential improvements.

Analytical techniques, Wilson says, are not suitable for capturing the complexity of plow scheduling operations. Instead, the team chose to develop a simulation and modeling system to determine alternative plowing methodologies for a range of conditions.

The simulation model is a discrete event simulation that uses ProModel. The model is relatively simple; exchanging data between spreadsheets and the model is probably more complex than the simulation model itself, Wilson says. Data are exchanged between a user interface using Excel and Visual Basic. The data used are collected from Mn/DOT reports, the Road Weather Information System (R/WIS), and "expert" opinions of key personnel (such as meteorologists) where no data exist. Next year, however, the data collection process will be greatly aided with the planned installation of GPS on the snowplows.

The first phase of the project involves developing a user interface and simulating a single season's worth of storms for selected routes. This will allow the model to be validated, correlating weather conditions with snowplow operations. The end result will be a tool that helps snowplow schedulers determine the best way to deploy their plows to provide maximum mobility and safety to the driving public. The tool will work primarily as a planning tool by running through selected "what-if" scenarios.

So far, the team has completed the basic model, and now needs to add several features and work on model verification and validation. A lack of snow in northeastern Minnesota this past winter impeded efforts to validate the model.

For next year, the team hopes to expand the model to include more cost features and to make it as flexible as possible so that it could be
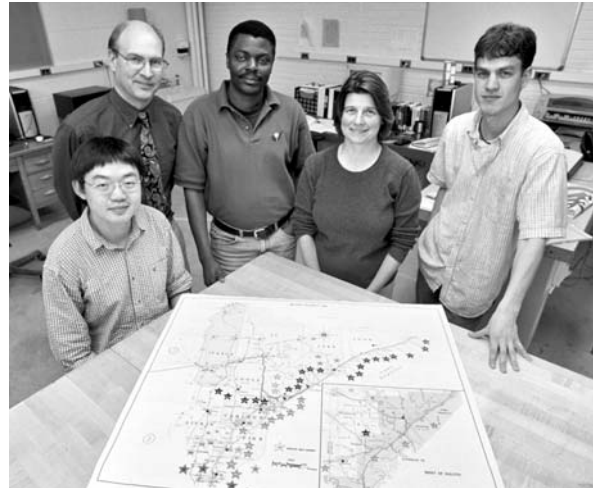
Yanpeng Zhang, David Wyrick, Kwasi Dadie-Amoah, Martha Wilson, and Brandon Storhaug

applied in other districts. This could be achieved by using Excel spreadsheets as an interface to the model, which may be modified by the user. In addition, the team would like to address the problems and operational issues associated with conditions of freezing rain.

In light of the state budget crisis, Wilson says the tool will also have the capability to demonstrate the effect of budget cuts on snowplow operations. "For example, if the state cuts the number of drivers assigned to a particular district, we believe that we can demonstrate where other operational costs will increase," she says.

According to Wilson, an advantage of their system is the level of operational detail included in the model and its potential for customization. The model is being developed based on decisions that the user feels are most important in planning operations, which may differ from region to region, and from storm to storm. And, she adds, "cost can't be overlooked. We're a low-cost operation."

Wilson says she expects the system to be both practical and feasible to implement because of the involvement of Mn/DOT operations personnel in its development. The simulation software is less costly than other systems currently on the market, and the design should keep training time to a minimum, she says.

In developing the model, Wilson says that Mn/DOT has had to examine how it manages, plans, and carries out its operations in order to help the research team model the process. "That, in itself, has sometimes been illuminating for both Mn/DOT and us," Wilson says. "We've enjoyed the partnership that has developed."

The end result will be a tool that helps snowplow schedulers determine the best way to deploy their plows to provide maximum mobility and safety to the driving public.

Computing, Sensing, Communications, and Control Systems

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

In the 1997 science fiction film *The Fifth Element*, the problem of increased roadway demand is solved by creating multiple tiers of moving traffic—in the air—filled with cars capable of flight. Although this film offers a fantasy view of urban transportation for the year 2215, the lesson here is that building more roads to carry more traffic may not be a viable option in the future. Experts acknowledge that in many areas, constructing new roadways or adding lanes to existing ones is no longer feasible or credible as the primary solution to traffic congestion.

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

Researchers from the Intelligent Vehicles Laboratory are adapting lane-keeping and forward collision-avoidance technologies originally developed for snowplows. Significant enhancements to the snowplow-based

system have been made to specifically address issues involved with guiding a wide bus on a narrow lane. One such enhancement is the provision of torque feedback through the steering wheel to help a driver maintain the proper position in the narrow shoulder. Should the bus stray from the center of the shoulder, a corrective torque is applied to the steering wheel to gently guide the driver back to the lane center.

A second enhancement is the incorporation of side and rear sensors used for collision avoidance. Mirrors on transit buses are typically kept close to the bus to minimize collisions with signs and bus stops, but doing so creates "blind zones" for a driver. Sensors mounted in the bus body, combined with a computer-driven display, can provide collision-avoidance information without the limitations associated with optical mirrors.

To aid system development and facilitate testing, the team has outfitted an experimental vehicle—a Metro Transit bus dubbed the TechnoBus—with advanced technology. The TechnoBus is fitted with a steering actuator, which provides torque feedback to a driver. This feedback system uses a differential global positioning system (DGPS) and an inertial sensor to determine bus position and orientation. Position of the bus as determined by the DGPS system is compared to the location of the shoulder as provided by a digital lane-level geospatial database, or digital map. Using the error between where the bus is and where it should be, a corrective torque proportional to that error is applied to the steering wheel. This torque is felt by the driver's hands and helps the driver stay in the lane. When the bus is on a trajectory to leave the lane, the system also vibrates the driver's seat on the side to which the bus is departing, providing a second feedback path to the driver.

The Twin Cities area in particular offers a variety of infrastructure elements already in place that will enable the use of lane-assist technologies as they emerge. Mn/DOT, for example, has installed a virtual reference station (VRS) capable of providing the required centimeter-level corrections throughout the Twin Cities. The VRS uses Mn/DOT's existing con-

The Twin Cities area offers a variety of infrastructure elements already in place that will enable the use of lane-assist technologies as they emerge.

tinuously operating reference stations correction network, thereby providing the Twin Cities metro region with DGPS corrections.

Because the use of shoulders and other specialized lanes along with lane-assist technology will fundamentally change the environment and role of the bus driver, researchers are also studying related human factors issues and are working to quantify how driver performance and stress are influenced by this change in driving environment. Researchers have already conducted a pilot study in which 12 drivers were trained and tested under three conditions during rush-hour traffic: normal traffic lane without lane-assist technology; shoulder use without lane-assist technology; and shoulder use with lane-assist technology. Preliminary results suggest that the system may be a valuable aid to support bus driving on dedicated shoulders for BRT applications and also indicate that drivers themselves like the system.

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

To date, this work has been a partnership of the University of Minnesota, Metro Transit, and the Federal Transit Administration.

Lateral Stability of a Narrow Commuter Vehicle

Adding to the problem of crowded highways is the fact that often our only transportation option is to get into a vehicle designed to carry five passengers and drive to our destinations alone. While many trips could be made more efficiently on, say, a motorcycle, for most people—especially those in northern climes—this type of vehicle isn't practical. But what if you could drive a one- or two-passenger vehicle, narrow like a motorcycle, that was comfortable and safe to operate in any weather, released fewer emissions and achieved higher gas mileage, and virtually doubled the traffic capacity on the roads you travel?

In efforts to explore technological solutions to increasing the carrying capacity of urban highways, researchers from the University of Minnesota's Department of Mechanical Engineering have developed a prototype of one such narrow vehicle. The width of this vehicle, about one meter (3.3 feet),
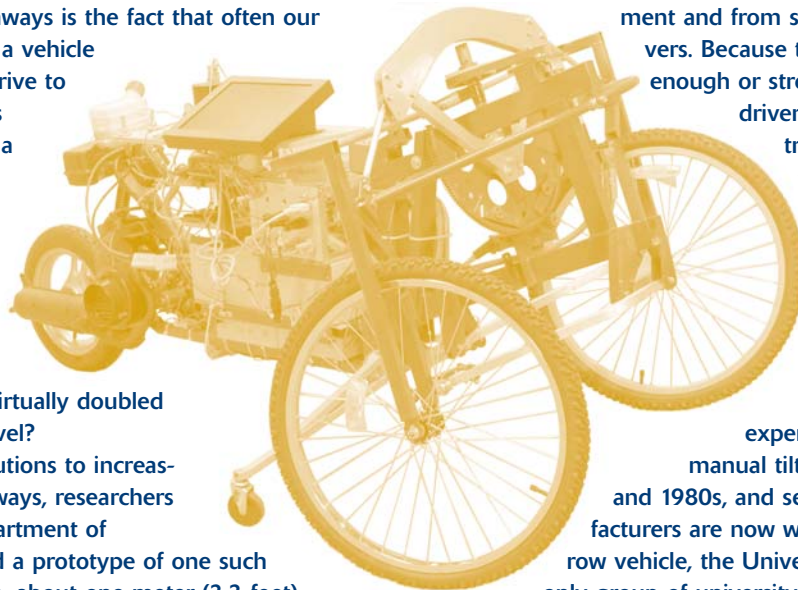
would allow two vehicles to drive side by side down a standard 12-foot-wide (3.7-meter-wide) traffic lane, thereby substantially increasing the number of vehicles per hour the lane can handle. A major obstacle the researchers are working to overcome is that a narrow vehicle is unstable when turning at highway speeds unless it has the ability to tilt from side to side like a motorcycle to maintain its center of balance. One potential solution to the tilt-control problem is to develop an electronic control mechanism that countersteers and pre-tilts the vehicle automatically whenever a turn is initiated.

Assistant Professor Rajesh Rajamani and research fellow Lee Alexander, the principal investigators with this project, teamed up with Professor Patrick Starr and graduate student Jesse Gohl to design an automatic suspension and control system that determines the vehicle trajectory and tilts automatically so the driver doesn't have to do it manually. The team began the project by evaluating various types of suspension geometry and considered power sources for both the vehicle and the control system. After a suitable geometry and power source were chosen, Starr, an expert in vehicle design, essentially started from scratch to design the rear-wheel-drive vehicle, which has two wheels in the front and one in back. Alexander and Gohl then built a working prototype of the vehicle that includes the control system designed by Rajamani.

With the physical model constructed, the team conducted a set of experiments that progressed from dry to slippery pavement and from simple to more complex maneuvers. Because the prototype vehicle isn't safe enough or strong enough to carry an actual driver, researchers used remote control to guide the vehicle around their testing grounds. The experiments yielded promising results and demonstrated that by using the automatic control system, the vehicle was able to tilt and balance itself while executing complex turns. Although General Motors first experimented with a difficult-to-drive, manual tilting vehicle back in the 1970s and 1980s, and several other automobile manufacturers are now working on some form of a narrow vehicle, the University of Minnesota team is the only group of university researchers working on such
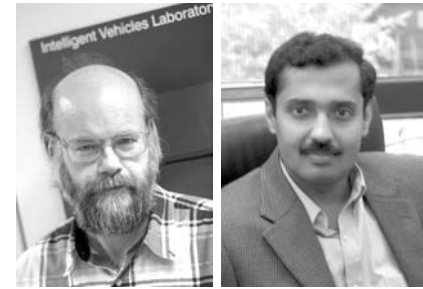
Lee Alexander   *Rajesh Rajamani*

The experiments demonstrated that by using the automatic control system, the vehicle was able to tilt and balance itself while executing complex turns.

Future work will include the study of human-machine interfaces, including drivability and comfort, and collision avoidance for such a machine.

technology. And while the team has made excellent progress toward designing a vehicle that promises to make commuting easier, faster, and less expensive, according to Rajamani, there is much more work to be done. "We need to improve the crashworthiness of the vehicle, which is currently nonexistent." He added that the control algorithms are far from completely reliable, and that continued testing and refinement are needed to improve the stability of the system before building a larger prototype.

The next step, however, is to secure additional funding. The team is currently working on an application for National Science Foundation (NSF) funding, which will be awarded to winning applicants sometime in the fall of 2003. With financial support in place, the team will work toward building a safer, second-generation vehicle capable of higher speeds and of actually carrying a passenger. Future work will also include the study of human-machine interfaces, including drivability and comfort, and collision avoidance for such a machine. The results of this work are likely to inform the development of future transportation technologies that may reduce congestion on freeways in Minnesota and across the country.

Social and Economic Policy Issues Related to ITS Technologies

Sustainable Technologies Applied Research Initiative: Network Dynamics

In 2001, a team of researchers from the Hubert H. Humphrey Institute of Public Affairs' State and Local Policy Program (SLPP) began the Sustainable Technologies Applied Research (STAR) program to build upon SLPP's previous research on the relationships between advanced transportation technologies, economic development, the environment, and overall community sustainability. Since the program's inception, STAR researchers have investigated sustainable transportation technologies by systematically examining the impacts of intelligent transportation systems and telecommunications along five dimensions: spatial location, community design, accessibility, network performance, and productivity. The major theme of this work—the relationship between technological networks and places—is being explored in an interdisciplinary fashion with perspectives ranging from urban development to network analysis.

As part of this interdisciplinary team, David Levinson, assistant professor in the Department of Civil Engineering, is researching the dynamics of the Twin Cities metropolitan area freeway network. The goal of this work is to develop a better understanding of transportation network dynamics over time, that is, how networks grow and decline, and to develop a model to replicate that process. It is hoped that planners and transportation managers will use the model to forecast future networks, just as current models are used to forecast population and travel demand. In particular, this new model will provide a tool to
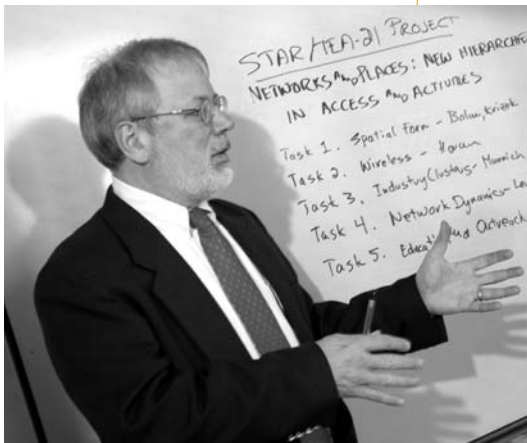
Lee Munnich

STAR researchers, from left: Peng Xu, Richard Bolan, James Lenhoff, David Levinson, Pete Bernardy, Lee Munnich, and Kevin Krizek

From left: Student Wei Chen, David Levinson, and student Lei Zhang

illustrate the implications of current decisions on the future shape of the network.

Despite the critical role of infrastructure in shaping travel patterns, previous transportation planning model research has focused on understanding travel behavior in order to predict demand patterns without any consideration of the existence and continual expansion of the road network. Levinson, who brings a strong economic component to his analyses of transportation issues, is analyzing the ways in which current network expansion and contraction decisions alter the choices of future decision-makers as well as the means by which expectations of the future alter current decisions. He explains that transportation planners currently respond to, and try to shape, demand by recommending investments in new infrastructure and changes in public policy. While small segments of the network may be changed at any given time, he says, those investments are limited by decisions that have come before. And perhaps more important, today's decisions constrain future choices.

The research, which involves theoretical, empirical, and simulation modeling, is considering the growth of networks as endogenous, a contrasting approach to current transportation planning practice that attempts to exogenously direct such growth. Rather than focus on "induced demand" (the changes in travel behavior resulting from new road construction), Levinson is focusing on the enigma of "induced supply"—how the network changes in response to travel demand. While this project deals primarily with urban highway networks, Levinson anticipates the work can be extended to urban transit networks and intercity passenger and freight networks.

A long-term database describing the Twin Cities highway network and land use covering the period between 1920 and 2000 has been constructed. This database is used to estimate empirical models of network growth as a function of changes in land use, demand, and previous network expansion decisions. Such a long-term view is necessary because the results of investments take many years not only to implement, but also to influence and change travel demand and land use patterns.

Using simulation, the researchers have discovered that the hierarchy of roads, which differentiates movement (long-distance travel) on facilities like freeways (at the high end of a hierachry) and land access on local roads, is in fact an endogenous property of networks—that is, it occurs in networks even without any hierarchy of land use.

This research is being extended to simulate realistic networks such as the Twin Cities planning network, as well as looking at the question of link and node formation. The results of this work will deliver an improved understanding of long-term network dynamics. This in turn will help decision-makers within state departments of transportation and regional councils of government, who must decide how to best invest scarce resources, assess the effects of expanding existing facilities or routes, building in new rights-of-way, or offering new services. These should ultimately lead to better planning and design of transportation networks.

Sustainable Technologies Applied Research Initiative: Community Telecommunications Planning and Access

Whether you live in a rural community and frequently travel rural roadways or just pass through occasionally, highway emergencies—particularly vehicle crashes—in rural areas can impact all of us. In Minnesota, for example, 30 percent of miles driven are on rural roads, but an alarming 70 percent of fatal crashes occur on these roads. Statistics also reveal that for crash victims who survive the moment of impact, most fatalities occur within a few minutes after the accident. Although rapid response by emergency medical crews can save lives within this critical window, in rural areas, calling for help often means finding a phone in a sparsely populated area. The situation is changing, though, as wireless telecommunications becomes more widely available.

Today, wireless services provide a safety net previously unavailable to travelers on rural roads; however, the increased demand created by over-calls (when too many callers report an incident), inadvertent calls, and location pinpointing problems puts more and more pressure on the 911 system. The spread of high-speed and wireless telecommunications throughout rural areas is creating far-reaching social impacts. In response, University of Minnesota researchers are examining how to enhance technology's contribution to the development of small communities and the transportation networks that serve them.

As part of their analysis of community telecommunications and intelligent transportation systems, researchers from the

Visiting scholar Thomas Horan of the Claremont Graduate University

Hubert H. Humphrey Institute of Public Affairs are studying the relationship between wireless communications and the transportation system, including wireless Emergency Medical Services (EMS), and the
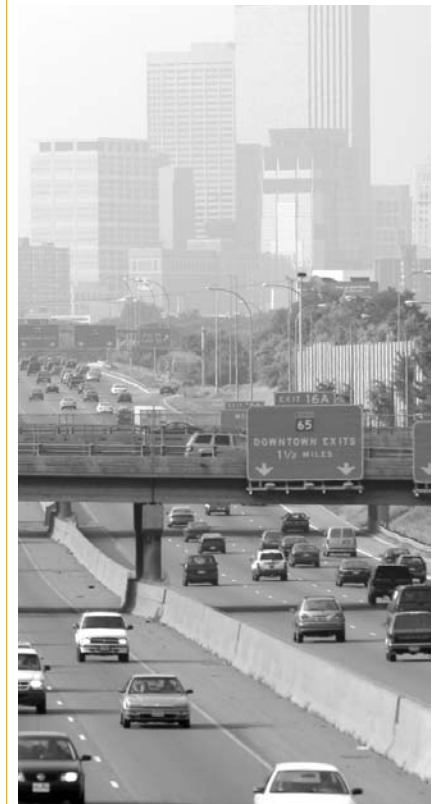
role wireless systems play in ensuring safety and mobility for the traveling public.

Drawing upon the ITS national systems architecture, the team, including Humphrey Institute researchers Lee Munnich and Frank Douma, along with visiting scholar Thomas Horan of the Claremont Graduate University, is examining policy, organizational, and technical challenges to the seamless flow of wireless communications for motorists.

Over the past year, these researchers developed a framework for assessing the public policy, organizational, and technical demands on Minnesota's wireless emergency management system. This framework was first devised through a series of interviews with experts in Minnesota and from around the country. The framework was further verified through an in-depth case study in Virginia, Minn. As a result of this first round of analysis, the research team made several recommendations on matters such as improving mobile coverage in rural areas, providing training to enhance cross-agency collaboration, and enhancing the integration of EMS program plans and technologies into the broader transportation planning and financing priorities.

The project is now in the second phase, during which the researchers will integrate data on the performance of rural EMS systems into a Web-based version of the EMS framework. This Web-based version is being devised to test the ability to develop and track the performance of wireless EMS systems using new Internet systems. A second case study in Brainerd, Minn., is being conducted to test this Web system. The research team is also meeting with local and national stakeholders to determine the feasibility of developing a cooperative database system for tracking rural EMS system growth and performance. One area of particular interest is how performance can be tracked or simulated under conditions where the EMS system responds in worst-case situations, such as during a natural disaster or terrorist attack.

Using all of these tools, researchers hope to better understand the EMS system to ultimately ensure that the speed, accuracy, and efficiency in dealing with 911 calls improve despite the fact that the volume of calls continues to increase. In addition, Minnesota's Department of Transportation and the Minnesota State Patrol are implementing a network of nine Transportation Operation and Communication Centers (TOCCs) to address this challenge. The goal of these centers is to establish an integrated statewide communication and transportation operations network serving rural Minnesota, including coordinated 911 coverage.

Although these centers represent an advance in dispatching proce-

Wireless services provide a safety net previously unavailable to travelers on rural roads; however, the increased demand it creates puts more and more pressure on the 911 system.

dures for emergency personnel, obstacles such as incomplete cellular coverage—particularly in thinly populated northern Minnesota—and a constantly evolving wireless infrastructure still remain. This unique research will be an important component in Minnesota's attempt to develop optimal solutions for residents of all areas of the state.

Human Performance and Behavior

John Bloomfield and **Kathleen Harder**, *College of Architecture and Landscape Architecture*

Fatigue Detection: Can Fatigue Detection Devices Predict the Driving Performance of Sleep-Deprived Drivers?

Project status: **In progress**

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

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

To date, the simulator scenario development is nearing completion. The researchers are negotiating with the Minnesota Trucking Association in order to obtain participation of truck drivers in the study. The Human Subjects Approval process is almost complete, and the researchers are working with the University's General Clinical Research Center so that when the driving simulation portion of the study is complete, the subjects will be escorted to the GCRC, where they will be monitored until they are able to leave.

Project URL: www.its.umn.edu/research /projects/2002031.html

Kathleen Harder, *College of Architecture and Landscape Architecture*

Guidelines for Using Rumble Strips

Project status: **In progress**

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

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

Project URL: www.its.umn.edu/research /projects/2003032.html

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

Project status: **In progress**

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

The objective of the current project is to investigate the effect of in-lane rumble strips on the stopping performance of sleep-deprived drivers. The study will be conducted with the new advanced driving simulator in the HumanFIRST Program at the University of Minnesota, piggybacking on a larger study examining the effects of sleep deprivation on driving performance (see Fatigue Detection: Can Fatigue Detection Devices Predict the Driving Performance of Sleep-Deprived Drivers?).

Project URL: www.its.umn.edu/research /projects/2003001.html

Psychological Roadway Correlates of Aggressive Driving (Phase II)

Project status: **In progress**

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

Project URL: www.its.umn.edu/research /projects/2002034.html

Reducing Crashes at Controlled Rural Intersections

Project status: **In progress**

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

The implications of these findings are: 1) by stopping closer to the stop signs, drivers should have a better view of the major road and be better able to judge gaps in the traffic on it; 2) by beginning to slow down further from the intersection, drivers will stop in a more controlled fashion and be less likely to inadvertently run the stop sign; and 3) if a vehicle pulled into the intersection from the minor road, necessitating an emergency braking maneuver by the vehicle on the major road, the speed reductions would produce even greater reductions in the stopping distances if the proposed mitigation methods were implemented. Right-angle crashes would be less likely to occur, and if they could not be avoided, their severity would be reduced.

Project URL: www.its.umn.edu/research /projects/2001008.html

User-Centered Auditory Warning Signals in Snowplows

Project status: **In progress**

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

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

Analysis of data from 28 participants showed the side collision-avoidance warnings were equally effective; lane change response times were approximately 1.1 seconds for both a single- and double-beep car horn warning (although participants said that the double-beep warning sounded more urgent). Analysis of the forward collision-avoidance warning data, obtained from 32 participants, showed that the mean response time with a warning consisting of two bursts of screeching-tire sounds was significantly faster than with a single-screech warning—with both warnings significantly faster than the mean time obtained when no warning was given. The poorest collision outcomes occurred with no warning; outcomes were better with the single-screech warning, and better still with the double-screech warning. In the field test, six of seven snowplow operators preferred the double-beep side-collision warning. As a result, the researchers recommend that an auditory icon sounding like the double-beep of a car horn be used as a side collision-avoidance warning, and an auditory icon sounding like two successive bursts of screeching tires be used as a forward collision-avoidance warning.

Project URL: www.its.umn.edu/research /projects/2000038.html

Herb Pick, *Institute of Child Development*

Older Drivers' Influence of Wayfinding While Driving

Project status: In progress

This work builds on previous work done by the principal investigator on driving and navigating in which older drivers seem to be less oriented in a newly learned environment than younger drivers. This second project is looking at the consequences of this problem at the level of vehicle control. If driving while wayfinding causes problems for older drivers, it seems reasonable to see this problem as a so-called dual-task, or mental workload, problem.

Experiment participants were confronted with two tasks: driving, and driving while wayfinding, in a simulator. Drivers under one condition simply had to drive without paying attention to where they were going, while drivers under the other condition needed to keep track of the layout of the environment and their route through it. Three measures of mental workload were taken and compared as a function of age. The data have been collected on this project and are currently being analyzed.

Project URL: www.its.umn.edu/research /projects/2001053.html

Spatial Orientation and Navigation in Elderly Drivers

Project status: In progress

Most of the research on elderly drivers is understandably concerned with vehicle control. The elderly are an increasing proportion of the total population and they are already overly represented in the number of crashes occurring (per mile driven).

However, because of this emphasis on control, research on the elderly and the main function of driving—i.e., getting from one place to another—has received little attention. A major facet of this topic involves, at a practical level, spatial orientation and navigation. Besides being of interest in its own right, difficulties maintaining orientation and finding one's way may interact with vehicle control as a driver becomes distracted or even alarmed by losing his or her way, and as a result pays less attention to vehicle control or possibly makes erratic corrections en route.

Research was carried out to determine whether elderly drivers have more difficulty than young drivers in maintaining orienta-

tion when they learn routes in unfamiliar neighborhoods. Drivers learned an approximately three-mile irregular route through a novel neighborhood. After they could drive the route without errors or prompting, they were asked to indicate the direction of out-of-sight landmarks from various station points along the route. The judgments of direction were measured in terms of angle of pointing at the landmarks and were compared to the correct angles. Elderly drivers (60 years and older) made almost double the size errors in their judgments than the younger drivers (25–35 years). Unexpectedly, there was also a gender difference with women, especially elderly women, making larger errors than men.

Although driving along an actual route gives the experimental task significant face validity, the situation lacks considerable experimental control. Traffic and weather conditions can vary, road construction may be present, etc. The nature of the route itself cannot be experimentally manipulated. With all these factors, it is difficult to investigate how orientation affects vehicle control. Much greater control can be gained by driving in a simulator, and it is safer. The orientation study described above was replicated in a simulator with similar results. Initial crude observations indicated that when attention was on wayfinding, vehicle control was poorer. A more refined study of how vehicle control is affected is currently underway.

Project URL: www.its.umn.edu/research /projects/1999022.html

Tom Smith, *School of Kinesiology*

Reducing Risk Taking at Passive Railroad Crossings with Active Warnings

Project status: In progress

This simulated driving study involves a

human factors evaluation of driver interaction with a low-cost active warning system (AWS) being developed for potential installation at highway-rail intersections (HRIs) currently equipped with passive signage. The objective of the study is to ascertain if, relative to HRIs with passive signage, drivers interact more cautiously with HRIs equipped with AWS technology.

A disproportionate number of vehicle-train crashes in Minnesota occur at passively signed HRIs (about 100 in 1999). About 70 percent of HRI fatalities occur at passively signed HRIs, representing a $14 billion problem nationwide. Thus, use of AWS technology to abate driver risk-taking at HRIs will yield safety benefits.

The high percentage of (mostly rural) passively signed HRIs is attributable to the high cost of conventional active warning technology. However, Mn/DOT is sponsoring a project to develop a low-cost AWS (projected at $10,000 to $15,000 per crossing) that makes use of solar-powered active warnings that are respectively started and stopped via detection of start- and end-of-train radio signals from a train approaching the HRI. A distinctive feature of the system is that it features both grade and advance active warnings.

The study was conducted using a simulated driving environment consisting of various highway-rail intersection scenarios. Among the results are that the presence or absence of a train, fog, or signage significantly affects dependent variables for all measurement intervals; the incidents of vehicles beating a train or hitting a train are higher with passive signage conditions, relative to active signage conditions; with a train present, and for all measurement intervals, active warning signs are associated with lower mean vehicle speeds, compared to mean speeds observed with passive warning signs; with a train present, and with active signage, mean vehicle speeds near the HRI are lower with a variable message sign advance warning, compared with speeds observed with a flashing light advance warning; and finally, advance warning variable message signs are preferred to flashing light signs. These results support the conclusion that installation of low-cost active warning systems at passive railroad crossings, with both advance and HRI active warnings, will benefit driving safety during vehicle-train interactions at

highway-rail intersections.
Project URL: www.its.umn.edu/research /projects/2000041.html

Mike Wade, *School of Kinesiology*

Accident Analysis for Low-Volume Roads

Project status: In progress

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

This database and the proposed analysis should provide useful information for engineers in the counties to better determine the impact of signage and seasonal variation along with other aspects that go into the decisions made relative to intersections where collisions occur more frequently.

Project URL: www.its.umn.edu/research /projects/2002008.html

Deer Avoidance Research: Use of Motion Detector Flashing Light

Project status: In progress

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

panel, and the research will be carried out at the University of Minnesota using a driving simulator. The data will be analyzed to determine the impact of the deer avoidance technology on driver behavior.

Project URL: www.its.umn.edu/research /projects/2002023.html

Nicholas Ward, *Department of Mechanical Engineering*

Driving Performance During Cell Phone Use and Common Secondary Tasks Combined Under Conditions of Driver Impairment

Project status: In progress

There is considerable debate (without sufficient research) about cell phones as a risk factor in traffic crashes and their relative risk compared to other existing secondary tasks drivers may perform in the vehicle. Now that many states intend to introduce traveler information systems that may be accessed while driving with cell phones, there is an even greater need for relevant research to determine the risk of this secondary task. A risk can be assumed for any task that demands driver attention such that there is less cognitive capacity remaining to cope with the primary driving task. Thus, the key question is not if cell phone use imposes a risk, but rather, if the amount of risk is unacceptable. An acceptable risk threshold can be assessed in relative terms by comparing cell phone use to other common risk factors.

First, there is a range of common in-vehicle tasks that are routinely engaged in by the driving population. The risk imposed by this common task set may be considered a baseline that is based on the notion of consensual risk. Second, demonstrable limits have been set for other impairment factors such as alcohol. The risk imposed by these legislated limits can also be considered as a

baseline that is based on the notion of sanctioned risk.

This project is assessing the relative risk of cellular phone use on driving impairment and driver mental effort compared to commonly accepted in-vehicle tasks (as well as the blood alcohol level of 0.10—currently legislated as an impairment threshold—if IRB approval can be obtained for this stage of the project).

Project URL: www.its.umn.edu/research /projects/2003040.html

Driving Performance During 511 Information Retrieval and Cell Phone Conversation Tasks, Combined Under Varying Levels of Traffic Density
Project status: **Newly funded**

Mn/DOT research funded to start in 2003 will assess the "relative" risk of cell phone use compared to other common risk factors, including existing in-vehicle tasks and devices (see Driving Performance During Cell Phone Use and Common Secondary Tasks Combined Under Conditions of Driver Impairment).

Cellular phone use is a secondary task in relation to the primary task of safely operating a vehicle to reach a desired destination. The cognitive demand of a secondary task may depend on the complexity of interaction required to engage in the task. In this case, primary driving demand will be operationalized in terms of traffic density (i.e., frequency and complexity of traffic interactions). Whereas a driver may be able to cope during normal conditions, he or she may be less able to manage resources for primary and secondary task demands in situations of higher traffic density.

As a logical and necessary extension of this research, this new project will assess cell phone use for 511 applications. This project will assess drivers' performance while using a cell phone to access 511 information or to converse at different levels of primary task

demand imposed by traffic levels. This will suggest the limits of primary task demand that can be accommodated during secondary in-vehicle task operations such as accessing and navigating 511 service functions with a cell phone. These data will be used to evaluate the usability of 511 in traffic and to give design recommendations that would allow the system to better accommodate the user depending on ambient traffic conditions.

Project URL: www.its.umn.edu/research /projects/2004036.html

Albert Yonas, *Institute of Child Development*
Chromatic Perception Effects on Collisions with Snowplows
Project status: **In progress**

Low-luminance contrast conditions, such as those created by blowing snow or fog, constitute some of the most hazardous conditions that drivers commonly experience. Recent experiments indicate that under fog-like conditions, people perceive themselves to be travelling significantly slower than they actually are. To compensate, they speed up. This low-luminance perceived slowing is comparable to the perceived slowing that occurs at equiluminance (no-luminance contrast), where motion information is carried by chromatic contrasts alone.

In this project, the researchers will perform a series of experiments to test whether these two phenomena are governed by the same neural mechanism. They also propose to make controlled color-contrast measurements under real fog and blowing snow conditions. The combination of physical measurements and perceptual experiments will allow them to determine the impact of low-luminance contrast conditions and color on an individual's perception of motion and space under real driving conditions. If such a relationship is demonstrated, this could lead to improvements in driving safety through the careful choice of color warning markings, chromatically controlled lighting, special fog tints, and better public education.

Project URL: www.its.umn.edu/research /projects/2003016.html

Computing, Sensing, Communications, and Control Systems

Mohamed-Slim Alouini, *Department of Electrical and Computer Engineering*
Bandwidth and Power-Efficient Modulations for Multimedia Transmission over Wireless Links
Project status: **In progress**

This project in wireless communications is motivated by the demand of spectrally and power-efficient transmission systems of multimedia (not only voice but also image and video) traffic data over wireless links. The main objective of the research is 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 directions include development of adaptive M-FSK modulations for power-efficient transmission over wireless links; design and performance evaluation of hierarchical constellations; and design, analysis, and simulation of adaptive hierarchical and MFK modulation systems for simultaneous multimedia transmission, in a bandwidth/power-efficient fashion, of ITS image and video data over wireless links.

Project URL: www.its.umn.edu/research /projects/2003017.html

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

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

Previous research (Phase I) focused on the technical issues important for quality of service (QOS), such as video compression (using off-the-shelf commercial hardware/software) and prioritization of video data in packet-switching (IP) networks. These issues have been addressed using the prototype system developed/installed at the ITS Lab at the University of Minnesota. Phase I research helped to understand and quantify the trade-offs between the amount of compression,

quality of video, available network bandwidth, and varying network traffic loads. Phase II research is concerned with practical design choices for implementing QOS under "typical" network configurations used at Mn/DOT. This includes implementing the QOS prioritization software in the prototype system at the ITS Lab; analyzing existing network configurations and application settings that require QOS implementation; and simulating these network configurations in the prototype system in order to evaluate practical effectiveness of the QOS approach for different application settings.

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

Project URL: www.its.umn.edu/research /projects/2003010.html

Max Donath *and* Pi-Ming Cheng, *Department of Mechanical Engineering, and* Shashi Shekhar, *Department of Computer Science and Engineering*
A New Approach to Assessing Road User Charges: Evaluation of Core Technologies
Project status: **In progress**

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

GPS receivers that are commonly used by automotive navigation systems do not have sufficient accuracy for road user charging applications. However, the GPS-determined

positions can be corrected, and thus made more accurate, using publicly and privately available wireless signals, namely, using differential GPS (DGPS). This experimental study based on road testing found that only certain DGPS receivers are capable of achieving the needed accuracy.

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

Project URL: www.its.umn.edu/research /projects/1999002.html

Max Donath *and* Craig Shankwitz, *Department of Mechanical Engineering*
Driver-Assistive Systems for Snowplows
Project status: **In progress**

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

Project URL: www.its.umn.edu/research /projects/2000042.html

IVI Specialty Vehicle Field Operational Test
Project status: **In progress**

The University of Minnesota has been a partner in the USDOT-sponsored Specialty Vehicles Field Operational Test (FOT). The project team is made up of Mn/DOT, the University of Minnesota, and 3M, who provided a magnetic-based lateral-guidance system. The purpose of the FOT was to integrate vehicle-guidance and collision-avoidance technologies into a comprehensive driver-assistive system used to improve driver vision under conditions of low visibility.

The FOT was originally proposed and exe-

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

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

Project URL: www.its.umn.edu/research /projects/2000037.html

Rural Intersection Crashes: Developing Intersection Decision Support Solutions to a National Problem
Project status: **In progress**

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

Minnesota is partnered with California, Virginia, and the FHWA in a pooled fund consortium (the Infrastructure Consortium) dedi-

cated to improving intersection safety. Each member of the consortium is tasked with addressing an aspect of intersection safety; the Minnesota team's objective is to develop a better understanding of the causes of crashes at rural intersections and then develop a toolbox of effective strategies to mitigate the high crash rate.

Rural Intersection Decision Support (IDS) focuses on enhancing the driver's ability to successfully negotiate rural intersections. The system uses sensing and communication technology to determine the safe gaps and then communicate this information to the driver so that he or she can make an informed decision about crossing the intersection or entering a major road traffic stream. The goal of the research is to reduce crashes and fatalities at such intersections without having to introduce traffic signals, which on high-speed rural roads often lead to an increase in rear-end crashes.

Project URL: www.its.umn.edu/research /projects/2001048.html

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

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

Project URL: www.its.umn.edu/research /projects/2003034.html

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

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

This project is exploring methods that can be used to address some of the problems raised by the Intelligent Vehicle Initiative Infrastructure Consortium. The researchers are seeking to develop a system that uses video cameras to continuously gather traffic data at intersections (e.g., vehicle speeds, positions, sizes, signal status.) and applies efficient algorithmic techniques to predict potential collisions and near-misses—all in real time. The goal is to establish the feasibility of this approach using both computer simulations and field tests at actual intersections (interregional corridors).

To date, work has proceeded along two fronts. On the vision side, researchers have developed efficient tracking algorithms based on Kalman filtering techniques. On the collision-prediction side, they have developed efficient algorithms to test for collisions between vehicles, represented by bounding boxes, using polygon clipping methods. The researchers have also developed a preliminary software-based simulator to allow them to experiment with their initial algorithms. Planned future work includes handling stop-and-go situations by using additional information from the image (e.g., color), improving the efficiency of the collision-prediction algorithm by considering alternative representations of the vehicles and the intersection, and improving the capabilities of the simulator.

Project URL: www.its.umn.edu/research /projects/2002025.html

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

Accurately measuring and reporting visibil-

ity is important for traffic safety, but it is difficult due to many variables that exist in the atmosphere. Most visibility meter apparatuses measure the amount of light-scatter effects from an active light source to compute visibility. Although this method works fairly well under foggy conditions, its accuracy tends to drop significantly in snow and rain. This is due to space-variant light-scatter coefficients and non-uniform atmospheric densities that are more prevalent under snowy and rainy conditions. Such differences result in measuring visibility that is significantly different from the visibility a human observer perceives.

Video-based measurement approaches provide an important intrinsic advantage over the light-scatter-based approaches due to the similarity of the image acquisition process between a camera lens and the human eye. The video-based approach was initiated by the principal investigator and works based on measurements of visual characteristics from the acquired video images instead of measuring atmospheric coefficients.

It was found that the human perception of visibility is influenced not only by atmospheric particle density but also by air-light and objects available in the angle of view (or surroundings). However, existing visibility meters do not provide any distinction on availability of referential objects of the actual visual conditions that motorists see. This suggests that an apparatus for measuring true visibility should measure human perception factors in addition to atmospheric physical coefficients.

In response, this research introduced a new concept referred to as "relative visibility," similar in concept to the relativity in humidity. That is, absolute measurement of humidity is less useful unless the temperature at that time and location is known. In the same analogy, visibility should be determined in relation to recognizable objects and air-light conditions available in the surrounding area. More specifically, visibility can be represented more accurately if, rather than given in terms of distance, it is referred to as "50 percent of relative visibility," which would mean that one could only see 50 percent of what one would be able to see on a clear day from the same surrounding visual conditions. Based on this theory, this research developed a method of measuring relative visibility using video imaging systems. A patent is currently pending for this new measurement apparatus.

Project URL: www.its.umn.edu/research /projects/2000024.html

Section Travel-Time Measurement and Vehicle Classification Using Inductance Signatures of Loop Detectors
Project status: **In progress**

On Twin Cities metro freeways, loop detector stations have been installed at a half-mile

spacing, forming sections. Each section thus comprises two sets of detector stations: one at the section entrance (upstream) and the other at the section exit (downstream). This research is studying a new way of measuring the average section travel time by tracing inductance signatures of the vehicles from two points, the section entrance and exit. This involves extracting the features of the inductance signatures generated by each vehicle passing through the upstream station and then re-identifying them at the downstream station by matching the features on both ends. For signal processing of vehicle inductance, several blind de-convolution approaches will be studied to develop an algorithm that leads to more clear discrimination of the inductance signatures. Another important issue in the feature-extraction process is normalization of the signatures such that each signature found is independent of the speed of the vehicles. An adaptive optimization approach will be developed for this normalization process. During the vehicle identification process, the features will be time-stamped with the arrival time and will be used to compute the travel time. Section travel-time has a significant advantage over other travel-time measurement approaches because once the travel time of all sections is known, travel time from any point to any other point can be computed by simply adding the section travel times along the route. Since this new section travel-time measurement works in real-time, if a network-wide system is installed, it would provide real-time route travel time.

Project URL: www.its.umn.edu/research /projects/2003027.html

TMS Traffic Data Automation for Mn/DOT's Traffic Monitoring Program
Project status: **In progress**

The Minnesota Department of Transportation (Mn/DOT) has been responsible for collecting, analyzing, and publishing traffic count data from the various roadway systems throughout the state. The traffic reporting system mainly developed by the Traffic Forecasting and Analysis Section (TFAS) of Mn/DOT has been used in several federal programs, for internal Mn/DOT applications, and by many private-sector firms. This project is continuing the TFAS automation efforts by computerized integration of the current manual effort to import, filter, and analyze the TMC portion of traffic data contributed to Mn/DOT's Traffic Monitoring System. The resulting system will allow users to specify the conditions for acceptance tests required by TFAS for both continuous and short-duration count volume data. Once the filtering procedures and parameters are set by an operator, the raw data can be automatically processed by the system without human intervention.

Project URL: www.its.umn.edu/research /projects/2001033.html

Nikolaos Papanikolopoulos, *Department of Computer Science and Engineering*

Monitoring Driver Activities
Project status: **Completed** (in FY03)

This project involved using a dashboard-mounted camera to monitor the direction a driver is looking. This was done by using the Framework for Processing Video developed at the University of Minnesota by Osama Masoud. The monitoring software works by first finding the lips on the driver's face using color analysis. Then, the skin color of the driver can be sampled and a face region is generated. The largest holes in this region are the lips and eyes. Once the eyes are found, the software finds the darkest pixels in the eyes and marks these as the pupils. The software uses the relative positions of the eyes and pupils to make statements about the gaze direction and uses a multi-tiered tracking algorithm to keep track of the eyes once they are found.

Project URL: www.its.umn.edu/research /projects/2002029.html

Managing Suburban Intersections Through Sensing
Project status: **Completed** (in FY03)

Increased urban sprawl and increased vehicular traffic have resulted in an increased number of traffic fatalities, the majority of which occur near intersections. According to the National Highway Traffic Safety Administration, one out of eight fatalities that occur at an intersection is a pedestrian. An intelligent, real-time system capable of predicting situations leading to accidents or near misses will be very useful for improving the safety of pedestrians as well as vehicles. This project investigated the prediction of such situations using current traffic conditions and computer vision techniques. An intelligent system can gather and analyze such data in a scene (e.g., vehicle and pedestrian positions, trajectories, velocities, etc.) and provide necessary warnings. This work focused on the monitoring aspect of the project. Certain solutions are proposed, issues with the current implementation are highlighted, and operational characteristics of the proposed low-cost system are presented.

The final report for this project is available at *www.its.umn.edu/pdf/CTS_02-07.pdf.*

Project URL: www.its.umn.edu/research /projects/2001029.html

Pedestrian Control Issues at Busy Intersections and Monitoring Large Crowds
Project status: **Completed** (in FY03)

In this project, the researchers explored a vision-based method for monitoring crowded urban scenes involving vehicles, individual pedestrians, and crowds. Based on optical flow, the proposed method detects, tracks, and monitors moving objects. Many problems confront researchers who attempt to track moving objects, especially in an outdoor environment: background detection, visual noise from weather, objects that move in dif-

ferent directions, and conditions that change from day to evening. Several systems of visual detection have been proposed previously. This system captures speed and direction as well as position, velocity, acceleration or deceleration, bounding box, and shape features. It measures movement of pixels within a scene and uses mathematical calculations to identify groups of points with similar movement characteristics. The system is not limited by assumptions about the shape or size of objects, but rather identifies objects based on similarity of pixel motion. Algorithms are used to determine direction of crowd movement, crowd density, and most-used areas. The speed of the software in calculating these variables depends on the quality of detection set in the first stage. Illustrations include video stills with measurement areas marked on day, evening, and indoor video sequences. The researchers foresee that this system could be used for intersection control, collection of traffic data, and crowd control.

Project URL: www.its.umn.edu/research /projects/1999021.html

Sensor-Based Ramp Monitoring
Project status: **Completed** (in FY03)

This project covers the creation of a system for monitoring vehicles in highway ramp queues. The initial phase of the project attempted to use a blob-tracking algorithm to perform the ramp monitoring. The current system uses optical flow information to create virtual features based on trends in the optical flow. These features are clustered to form vehicle objects, and these objects update themselves based on their statistics and those of other features in the image. The system has difficulties tracking vehicles when they stop at ramp queues and when they significantly occlude each other. However, the system succeeds by detecting vehicles entering and leaving ramps and can record their motion statistics as they do so. Several experimental results from ramps in the Twin Cities are presented in the final report of this project.

Project URL: www.its.umn.edu/research /projects/2002004.html

Development of a Tracking-Based Monitoring and Data-Collection System
Project status: **In progress**

This project is working toward the development and deployment of a flexible, portable, and reliable intersection-monitoring and data-collection system. The proposed

system will be based on vehicle-tracking methodologies implemented on a single or multiple camera(s). Researchers will compute a variety of traffic and behavior data such as turning vehicle counts, vehicle trajectories, vehicle classes, delays, lane changes, gap acceptance behavior by turning vehicles, speed variations, safety-related data, and other types of intersection data as needed by traffic engineers. The proposed system could be used for accessing the effectiveness of existing signal timing plans and operational methods and the level of intersection safety. The researchers' approach will include the development of a user-friendly interface and will chiefly employ existing camera hardware. The researchers also envision the proposed system to be used as the main tool for before/after study of the effectiveness of intersection and local area improvement treatments.

Project URL: www.its.umn.edu/research /projects/2003042.html

Recognition of Human Activity in Metro Transit Spaces
Project status: **In progress**

Monitoring large public spaces with sensors is a challenging task with a variety of important applications. A camera system monitoring public spaces (such as airports, bridges, workzones, truck weigh stations, tunnels, buses, planes, or trains) can be developed to detect all humans occupying those spaces and collect information about their activities. The proposed system is not limited to human detection, but rather can be extended to the detection of incidents that involve vehicles. Furthermore, certain types of incidents can be detected and alerts can be issued to human operators. The researchers propose the development and deployment of a system that will detect and classify human individual or group activities with the objective of notifying operators when pre-specified activities happen. They plan to evaluate the system's robustness by its deployment in an actual public space. In particular, they plan to

work with Metro Transit on applying this technology to monitor bus stops and thereby improve passenger safety on public transit. For example, one particular activity that will be monitored is individuals wandering aimlessly at a bus stop.

Project URL: www.its.umn.edu/research /projects/2003030.html

Finding What the Driver Does
Project status: **Newly funded**

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

Project URL: www.its.umn.edu/research /projects/P2004010.html

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

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

Project URL: www.its.umn.edu/research /projects/2004047.html

Rajesh Rajamani, *Department of Mechanical Engineering*
Adaptive Cruise Control System Design and its Impact on Traffic Flow
Project status: **Completed** (in FY03)

Adaptive cruise control (ACC) systems are currently being developed by automotive manufacturers for highway vehicle automation. An ACC system enhances regular cruise control by using on-board radar to maintain a desired spacing from a preceding vehicle that has been detected in the same lane on the highway. First-generation ACC systems are currently available in Japan and Europe and have just been introduced in the North American market.

Existing ACC systems have been primarily designed from the perspective of driver comfort. They suffer from several shortcomings when issues of traffic flow and safety are considered. This project analyzed ACC systems and showed how the development of intelligent algorithms can lead to significant increases in highway capacity and safety, as ACC systems are expected to become standard automotive equipment in the future.

This project concentrated on the following specific areas: 1) development of a unified evaluation framework for the evaluation of ACC algorithms, taking into account safety, comfort, and time-to-destination of individual vehicles as well as highway utilization and stability of traffic flow; 2) analysis of existing ACC control systems from the point of view of this evaluation framework; 3) development of new vehicle-following algorithms that overcome the shortcomings of existing ACC algorithms and naturally score highly in the new evaluation framework; and 4) study of the impact of ACC vehicles on highway traffic as a function of their percentage compared to the percentage of manually driven vehicles. The final project report summarizes the major technical results obtained.

Project URL: www.its.umn.edu/research/projects/2001040.html

GPS-Based Real-Time Identification of Tire-Road Friction Coefficient
Project status: **In progress**

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

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

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

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

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

Project URL: www.its.umn.edu/research/projects/2002026.html

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

This research is working to develop safe, economical methods to implement fault-tolerant, robust active lane-keeping and collision-warning systems for heavy vehicles. As a result, the robustness and reliability (and therefore, safety) of the driver-assistive systems under development will be significantly increased.

The primary applications for this technology in Minnesota are for buses operating on bus-only shoulders and on dedicated busways. The main thrust of this research will use the Institute's SAFETRUCK as a test bed to develop these robust, redundant vehicle-guidance and collision-avoidance technologies. At the conclusion of this project, the project results proven on the SAFETRUCK will be transferred to the Metro Transit/IV Lab research bus (TechnoBus) and used in an operational scenario.

Project URL: www.its.umn.edu/research/projects/2002041.html

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

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

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

Converting the collected raw data into geospatial information becomes the next task. From that data, smoothing, feature extraction, and formatting software will be developed that will allow for the automated creation of the digital map.

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

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

The Polk County plow has been equipped with the necessary technology, but because of a lack of snow during the winter of 2002–2003, no operational testing was undertaken. St. Louis County took delivery of the plow onto which the technology will be installed in February of 2003. Lack of snow in St. Louis County also delayed testing. The project received a no-cost extension until June 2004, with the hope that heavy snows in 2003–2004 will allow for thorough operational testing. Twenty-two lane miles of roads will be mapped in each county. Drivers will be trained prior to the first snow of the winter of 2003, and the systems will be released for operational testing when training is complete.

Project URL: www.its.umn.edu/research/projects/2002009.html

Gang Plowing Using DGPS
Project status: **In progress**

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

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

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

Project URL: www.its.umn.edu/research/projects/2002038.html

Infrared Sensors for Driver-Assistive Systems for Specialty Vehicles, Including Snowplows
Project status: **In progress**

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

normally under low- (including zero) visibility conditions.

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

Project URL: www.its.umn.edu/research /projects/P2003020.html

Narrow Lane Performance for Bus Rapid Transit
Project status: **Newly funded**

The FTA has identified narrow lane operation as a key component for BRT systems. Narrow lane operation is required because of limited available right-of-way in most urban and suburban areas. Narrow lane operation motivates the following two questions: How narrow is narrow? And how rapid is rapid?

Implicit to these two questions is the relationship between narrow and speed; clearly, the higher the speed, the more difficult it is to maintain the lateral position of the bus. In terms of operational efficiency, the greater the speed, the greater the capacity. However, the safety record of transit operations must not be compromised in the name of efficiency.

Two components are proposed. The first component is to improve the existing bus lateral controller. The second component is to perform and document a set of experiments showing lateral performance for various speeds and roadways (e.g., curves of various radii, roads with crowns, slopes, ruts, etc.). Completion of this project should motivate a human factors study to determine where within the envelope of speed and lane width a driver is comfortable with the lane-assist system.

Project URL: www.its.umn.edu/research /projects/P2004040.html

Remote Sensing for Bus-Only Shoulder Operations in Mixed Traffic
Project status: **Newly funded**

Metro Transit operates a Bus Rapid Transit (BRT) system in the Twin Cities area, using shoulder lanes to allow buses to bypass areas of high traffic congestion. The program is very successful, and now encom-

passes 200 miles of bus-only shoulders, with about 20 shoulder lane miles added per year.

Previous projects with Metro Transit have primarily dealt with the issue of the lateral guidance of a 9 1/2-foot-wide bus in a 10-foot-wide lane. Side collision avoidance has also been addressed via the implementation of the virtual mirror on the TechnoBus research vehicle. However, the sensor used for the virtual mirror (a Sick scanning laser sensor) exhibits performance limitations for many of the difficult conditions that these buses encounter.

Ninety percent of bus-only shoulder lanes used by Metro Transit are adjacent to limited access freeways and expressways. As such, buses operating on shoulders must frequently negotiate entrance- and exit-ramp traffic. Because these ramps either rise above or drop below grade, bus-mounted sensors are unable to consistently detect vehicles on these ramps. This often leads to a conflict for the bus driver. This project will produce a remote-sensing scheme to assist bus drivers with the difficult task of passing through entrance and exit ramps.

Project URL: www.its.umn.edu/research /projects/P2004041.html

Shashi Shekhar, *Department of Computer Science and Engineering*
Evacuation Route-Schedule Planning for Disasters Damaging Automatic Traffic Control Systems
Project status: **Newly funded**

Evacuation route-schedule planning identifies paths to move populations out to safe areas in the event of catastrophes, natural disasters, and terrorist attacks. Current approaches are based on assignment-simulation tools (e.g., DYNASMART). However, the quality of solutions from these tools depends on the logical configuration of the transportation network. Currently, engineering judgment is used to select logical network configuration. The researchers propose to develop algorithms and software tools to determine effective logical network configuration given physical transportation network and evacuation traffic demand. Developing efficient and effective algorithms for logical network design is a challenging research problem due to the exponential combinatorial search space of

possible solutions. The new algorithms will also be integrated with assignment simulation tools such as DYNASMART. Researchers will also evaluate the new algorithms under certain given scenarios. This research will provide new tools to help Mn/DOT find optimal logical network configuration to supply to assignment simulation models toward effective evacuation route-schedule planning.

Project URL: www.its.umn.edu/research /projects/2004051.html

Jiann-Shiou Yang, *Department of Electrical and Computer Engineering (Duluth)*
Traffic Flow Modeling Simulation and Signal Timing Plans Evaluation of the Miller Hill Corridor
Project status: **In progress**

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

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

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

Project URL: www.its.umn.edu/research /projects/2001043.html

Technologies for Modeling, Managing, and Operating Transportation Systems

Gary Davis, *Department of Civil Engineering*
A Case-Controlled Study of Driving Speed and Crash Risk
Project status: **In progress**

A fundamental problem in applied human factors and traffic safety concerns the relationship between the speed at which one chooses to drive and the likelihood of being involved in a traffic crash. The existing literature is less conclusive than one would desire, leading to beliefs that higher speeds do not necessarily increase crash risk, but that the presence of slower drivers does. In large part this confusion can be traced to methodological weaknesses in past research stemming from the failure to account for aggregation bias and/or measurement error. This project is conducting the most methodologically sound investigation to date into this issue by eliminating aggregation bias using a case-control study design, and accounting for measurement error by conducting a Bayesian analysis using recent advances in computationally intensive statistical tools.

Project URL: www.its.umn.edu/research /projects/2001032.html

Identification and Simulation of Common Freeway Accident Mechanisms
Project status: **In progress**

Arguably, the main cause of non-recurring traffic congestion on urban freeways is capacity-reducing crashes and incidents. Since large-scale increases in freeway capacity appear unlikely, reducing the occurrence of crashes should help freeway managers make the best use of the existing investment in freeway capacity, and this in turn should help minimize the delays experienced by the travelling public. The main principle underlying this proposal is that one is more likely to identify effective strategies for reducing traffic crashes if one understands the mechanisms by which they occur. This project will advance this understanding by first collecting a sample of video recordings of actual crash occurrences at one or more freeway sites. Data on vehicle speeds and positions and driver actions, both before and during the crashes, will then be extracted from the video recordings using standard video capture techniques. Using the video data, physical models of the crash will be constructed, and the models will be used to carry out

"what-if" analyses aimed at identifying causal factors, i.e., changes in conditions sufficient to prevent the crashes.

Project URL: www.its.umn.edu/research /projects/2003007.html

Identification of Causal Factors and Potential Countermeasures for Fatal and Severe Rural Crashes
Project status: **In progress**

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

Project URL: www.its.umn.edu/research /projects/2003014.html

Eil Kwon, *ITS Institute*
Signal Operations Research Lab for Development and Testing of Advanced Control Strategies (Phase II)
Project status: **Completed** (in FY03)

Corridor simulation with the capability of modeling various types of traffic control strategies as the external control modules is critical to developing and improving corridor management strategies. In this research, a microscopic network simulation model, VisSim, was used to develop such an environment. The new stratified Mn/DOT metering algorithm was simulated using U.S. Highway 169; its performance was compared with those of the fixed-metering method.

Based on the analysis results, an alternative approach to determine the minimum

metering rate for each entrance ramp was developed and coded. Further, an adaptive approach to automatically coordinate a freeway meter with the adjacent intersection signal was also developed and evaluated using the corridor simulation environment. The evaluation results show a clear advantage of the proposed method in reducing the overall delay at the ramp-intersection area. In addition, the method produced higher or compatible total vehicle-miles compared with the conventional intersection-control methods, i.e., pre-timed and actuated, without employing ramp metering. The corridor evaluation environment developed in this study can be used for future studies, including the continuous enhancement of the stratified metering algorithm to take advantage of the maximum allowable waiting time, automatic identification of the most effective metering strategy depending on prevailing traffic conditions, and extension of the adaptive coordination method to multiple intersections adjacent to a freeway entrance ramp.

Project URL: www.its.umn.edu/research /projects/2000036.html

Dynamic Estimation of Freeway Weaving Capacity for Traffic Management and Operations (Phase II)
Project status: **In progress**

Understanding the behavior of weaving flows and estimating the effects of time-variant traffic conditions on the capacity of weaving areas is critical for developing effective operational and design strategies for freeway systems that can maximize existing capacity for a given freeway system. The previous phase of this research identified and classified the major weaving areas in the Twin Cities metro freeway network. Further, the traffic behavior and the factors affecting capacity in a type A ramp-weave section—the most common type of weaving area in the Twin Cities metro freeway system—were analyzed and an online model was developed to estimate the time-variant capacity of type A ramp-weave sections. This research is expanding on the previous work by addressing the traffic behavior and capacity issues at multiple weaving areas, where more than two weaving sections are sequentially located. In particular, the flow process at multiple weaving sections, including lane-changing locations and behavioral patterns and the factors affecting flow breakdowns and capacity changes, will be analyzed using field data

to be collected from the selected weaving areas. Finally, the functional relationship between capacity changes and weaving patterns will be identified and modeled.

Project URL: www.its.umn.edu/research /projects/2001022.html

David Levinson, *Department of Civil Engineering and* **Kathleen Harder**, *College of Architecture and Landscape Architecture*
Ramp Meter Delays, Freeway Congestion, and Driver Acceptance
Project status: **In progress**

Minnesota's pre-shutdown ramp metering algorithms tried to maximize throughput, implicitly minimizing total delay. If time at the ramp is not weighted the same as time-in-motion by users, this time-minimizing strategy may not be utility-maximizing for travelers. This research attempts to quantify the value individuals associate with qualitatively different experiences of travel time: waiting at a ramp meter or freeway-to-freeway ramp meter versus traveling at varying freeway speeds requiring shifts in acceleration and deceleration. This information will enable the researchers to better time ramp meters in a way that responds to individual perceptions.

Project URL: www.its.umn.edu/research /projects/2002018.html

David Levinson, *Department of Civil Engineering*
Evaluation of Operating Strategies and Delay Analysis for Arterials
Project status: **Completed** (in FY03)

In most urban areas, traffic congestion is a serious and worsening problem. Freeways operate efficiently as long as the number of vehicles using the freeway remains at or below design capacity. While demand for

highways is growing quickly, highway capacity is growing much more slowly, leading to congestion. Due to congestion, road users suffer increased travel time and consume more fuel, increasing travel cost. This also disturbs the usual flow pattern on highways. Use of intelligent transportation system technology to manage freeways is gaining attention due to its advantages in reducing congestion, but there are still issues related to their best utilization.

Project URL: www.its.umn.edu/research /projects/2001035.html

Measuring the Equity and Efficiency of Ramp Meters
Project status: **Completed** (in FY03)

The Twin Cities ramp meter system, while successfully increasing the efficiency of freeway traffic flow, has been subject to increased political scrutiny. That scrutiny is due in part to perceptions of inequity in the system. This research tested alternative control strategies on both efficiency and equity criteria, and developed a new strategy designed explicitly to include equity measures. This new strategy was coded and tested in a simulation framework and compared to existing strategies.

Project URL: www.its.umn.edu/research /projects/2001010.html

Improving the Estimation of Travel Demand for Traffic Simulation
Project status: **In progress**

Traffic simulation is only as good as its input data. Unfortunately, it is impossible to inexpensively measure entry ramp to exit ramp flows, which would be particularly useful for testing ramp metering control strategies. In the past, research supported by Mn/DOT and CTS has produced a viable method for estimating freeway origin-destination (O-D) patterns from loop detector data. This research will further develop and apply those methods to estimate O-D demand for use in traffic simulation of freeway sections and corridors. The researchers require zone-to-zone traffic flows from a transportation planning model, and the flows entering and exiting on freeway ramps. The objective is to estimate the traffic from each on-ramp to each downstream off-ramp in short time intervals (e.g., 5 min.). This research will include development and implementation of software to enable the method to be used conveniently with easy-

to-collect data, and will test the method on Minnesota Trunk Highway 169.

Project URL: www.its.umn.edu/research /projects/2001034.html

The Value of Traveler Information for Motorists
Project status: **Newly funded**

A major strategy of the federal ITS initiatives and state departments of transportation is to provide traveler information to motorists. This is relatively uncontroversial, but its effectiveness is unknown. The benefits of traveler information can be in terms of time saved if travelers choose alternative routes.

However, there are other benefits to drivers—e.g., simply knowing that there will be a delay of a certain duration will reduce driver uncertainty. The economic value of information that reduces driver uncertainty is one of several variables the researchers aim to measure in the proposed research. They will assess user preferences for trips as a function of the presence and accuracy of information, travel time, number of stops, stopped delay, specific route, time of day, traffic conditions, individual and vehicle characteristics, and weather. In this way, the researchers can specify and estimate a more sophisticated route choice model accounting for those characteristics. To date, most route choice models embedded in transportation planning models simply assume that travelers choose the shortest (time) route. This research will ascertain the extent of this misspecification.

Project URL: www.its.umn.edu/research /projects/2004021.html

Panos Michalopoulos, *Department of Civil Engineering*
Employment of the Traffic Management Lab (TRAMLAB) for Evaluating Ramp Control Strategies in the Twin Cities
Project status: **Completed** (in FY03)

A desire to integrate the best possible combi-

nation of technology and architecture currently available into the next-generation Traffic Management Center revealed the need for a testing and evaluation facility. This project explored the development and implementation of a Traffic Management Laboratory (TRAMLAB). The basic idea behind TRAMLAB is to emulate a typical TMC traffic control room and implement, integrate, and evaluate existing or new concepts of its operations in a virtual environment prior to actual deployment. TRAMLAB effectively combines the power of simulation with the facility to easily gather, access, and manipulate data through a graphical user interface. In this project's final report, the final state of TRAMLAB, along with results from its first implementation in a section of the Twin Cities freeway network, are presented.

Project URL: www.its.umn.edu/research /projects/2001047.html

Accident Prevention Based on Automatic Detection of Accident-Prone Traffic Conditions
Project status: **In progress**

The goal of this research is to provide low-cost innovative solutions for identifying causes of crashes in crash-prone freeway locations and developing an accident avoidance/prevention system. This will be accomplished by simultaneously recording accidents and extracting raw traffic detector measurements that can be used for understanding crash dynamics as well as their causes. New traffic measurements such as traffic pressure, quality of flow, and others that can be derived from the raw data are defined, extracted, and analyzed in order to determine whether they are related to crashes and to identify crash-prone condition patterns.

Based on this, a proactive system for warning drivers and TMC operators is being developed in order to calm traffic flow and effectively prevent crashes. Most important, the system envisioned will be based on raw detector data (e.g., speed, occupancy, volume, time headway) that can be extracted from conventional sensors such as loops. Thus, the resulting system should be low cost and implementable in both urban and rural settings. This research capitalizes on earlier projects related to establishing feasibility, instrumenting a high crash area with newly developed wireless detection and surveillance stations, and a

recently completed traffic management laboratory facility.

Project URL: www.its.umn.edu/research /projects/2003031.html

Development of Portable Wireless Measurement and Observation Station
Project status: **In progress**

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

This project is continuing the work of John Hourdakis and Ted Morris in the ITS Laboratory, in which a prototype of such a station was developed, and tests it. Such an easily deployable, low-cost data collection and surveillance station could be used for planning and traffic management as well as for research purposes, such as simulation, modeling, and control. This "total" station capitalizes on recent advances in machine vision traffic sensors, digital video compression and transmission, and wireless communication networks. In essence, it is the first step toward the development of a highway laboratory for traffic studies and research.

Project URL: www.its.umn.edu/research/ projects/2002030.html

Evaluation and Improvement of the Stratified Ramp Metering Algorithm Through Microscopic Simulation
Project status: **Newly funded**

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

This project goes beyond evaluation and seeks to find a methodology for optimizing the new ramp-metering algorithm quickly and efficiently prior to field deployment. In the first year, the new stratified metering algorithm will be evaluated and compared with the old algorithm, a simple control plan (i.e., fixed-time metering), as well as with a no-control case. Detailed statistics will evaluate all aspects of the new algorithm's operation including queue formation and bottleneck operation, as well as long and short trip travel times. In addition, a sensitivity analysis will be conducted in order to understand the behavior of the new control algorithm with respect to changes in traffic demand, occurrence of traffic incidents, detector malfunctions, inclement weather conditions, and changes in the algorithm's own parameters. If successful, further plans include expansion of the sensitivity analysis to include the impacts of traveler information on the control strategy. Based on the knowledge acquired through the sensitivity analysis, fine-tuning of the algorithm parameters will take place through both manual search and optimization methods.

Finally, researchers will explore improvements to the algorithm structure in order to better take into account queue and other traffic pattern measurements.

Project URL: www.its.umn.edu/research /projects/2004050.html

Streamlining of the Traffic Modeling Process for Implementation in the Twin Cities Freeway Network
Project status: **Newly funded**

This research will attempt to streamline the traffic modeling process for practical implementation and to substantially improve Mn/DOT engineers' productivity in view of

the new federal requirements for roadway improvements, design, and planning. Streamlining will also improve decision-making and allow more widespread use of simulation internally for design, planning, operations, maintenance, and construction.

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

Although a great deal of effort has gone toward making simulation suitable for practical applications, engineers still regard it as a complex tool. In the previous phase of the proposed project, a number of rudimentary and crude tools for accelerating the simulation process were developed for improving the research team's effectiveness and productivity to meet tight deadlines. Subsequently, the technology was transferred to Mn/DOT through a series of training courses and continued technical assistance. During this collaboration, it became evident that in order for simulation to be effectively employed by Mn/DOT, more substantial automation and streamlining of the simulation process is needed for non-research-oriented engineers. As a result, the proposed continuation phase

aims to further improve the earlier simulation tools and methodologies and, in cooperation with Mn/DOT's modeling group, streamline the process to specifically address the needs and issues raised by practicing engineers within Mn/DOT and the research team. Special effort will be made to ensure that the methodologies developed are general—i.e., not tied to a particular simulation package.

Project URL: www.its.umn.edu/research /projects/2004049.html

Social and Economic Policy Issues Related to ITS Technologies

Frank Douma, *Humphrey Institute of Public Affairs*
Telecommunications and Sustainable Transportation
Project status: **In progress**

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

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

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

The second task is assessing operational benefits that may be gained by deploying GPS-based ITS applications in suburban areas among populations that do not have cars available as a primary mode of transportation. Focus groups of community members, users, and providers will be used to determine preferences and political barriers, and data from an operational deployment will be used to assess effectiveness.

The third task is building upon information gained from focus groups held in Rochester and Virginia, Minnesota, in August 2001. Using this information as a starting point, researchers will examine the institu-

tional and technical network requirements to deliver wireless services that enhance transportation safety.

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

Project URL: www.its.umn.edu/research /projects/2002016.html

Kevin Krizek, *Humphrey Institute of Public Affairs*
Better Understanding the Potentional Market of Metro Transit's Ridership and Services
Project status: **Newly funded**

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

These data sources represent extremely rich surveys that could shed light on basic travel preferences that transit could better serve. The focus is to examine more closely the attitudes, preferences, and needs of both current and potential riders. The range of improvements possibly includes using technology to better track ridership behavior, modifying a frequent rider program, adjusting routes and times, and understanding and delineating different market segments of travelers. The analysis and findings of the research will be pursued jointly with staff

from Metro Transit and the Met Council to enhance its utility to each agency. The study will also provide recommendations on more specific data that could be collected to provide baseline information that would help monitor existing and future programs and traveler information.

Project URL: www.its.umn.edu/research /projects/P2004035.html

Lee Munnich, *Humphrey Institute of Public Affairs*

Sustainable Technologies Applied Research Initiative FY02

Project status: **Completed** (in FY03)

During FY02 of this multi-year research program, SLPP-led researchers conducted an integrated review of several key dimensions of the STAR research program. This has included activities in the following five project areas.

For Task 1, researchers continued the development of data needs and data sources. Researchers obtained a full set of TIGER files for the United States in the form of ArcView shapefiles that include census blocks, block groups, tracts, and traffic analysis zones (TAZ) for all metropolitan areas. Researchers completed data collection for a case study of General Mills Corporation and developed a detailed research design for replicating a study conducted in Japan and adapting this study to U.S. urban areas.

For Task 2, researchers refined the ITS EMS architecture outlined in the previous year based on field visits in Minnesota,

including a case analysis of the Virginia, Minnesota, System. The EMS model was also devised using a knowledge acquisition system called Protégé. A second case study will be conducted (in Brainerd, Minn.) to establish performance metrics for EMS; the

system will also be expanded to consider rural trauma transportation.

For Task 3, researchers selected two clusters to be pursued as in-depth case studies (recreational transport equipment and wood production). National rural cluster experts were convened for consultation. Researchers conducted a survey on supply chain relationships, examined the importance of the related transportation and information networks, and assessed the potential for ITS applications.

For Task 4, researchers collected empirical data that eventually will be used to complete a full-fledged database on which empirical and simulation models can be calibrated.

For Task 5, researchers conducted a roundtable disscusion to consider and possibly recommend research and educational/ training activities that recognize new concepts (e.g., complexity theory) and management challenges (e.g., dealing with technological change) in the transportation planning and management profession.

Project URL: www.its.umn.edu/research /projects/2002003.html

Sustainable Technologies Applied Research Initiative FY03

Project 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. As of July 2003, research activities have included the following:

For Task 1, researchers have completed the first phase of a study of the spatial location of information workers in four metropolitan areas—Atlanta, Denver, Phoenix, and Minneapolis-St. Paul. Working with 1990 data from the Census Transportation Planning Package (CTPP), the study found that the workplace locations of information workers were more spatially concentrated than other workers in all four metropolitan areas. Generally, their workplace locations tended to be focused on traditional central business districts and university centers, with mixed results in "edge city" centers. The residential locations of information workers were also more concentrated in three of the

four areas, but the difference tended to be less significant. Preliminary analysis of commuting effort indicates that information workers tend to spend more time commuting than other workers. The study will ultimately include an analysis of the 1990 CTPP data with that of the 2000 CTPP.

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

For Task 2, researchers completed the ontology development of version 1 of the EMS ontology, using Protégé software. This effort was summarized in a research-in-progress paper submitted to AMCIS. Researchers planned and conducted a second case study, which included interviews with Mn/DOT experts, State Patrol members, and PSAP representatives.

For Task 3, researchers conducted personal interviews in northern Minnesota with companies in the recreational transportation equipment and wood products clusters. These companies provided key information regarding the use and needs of ITS technologies as well as how these technologies affect supply and production relationships within the clusters.

For Task 4, researchers worked on enhancing the new node/link model by adding an equilibrium assignment and congestion effects. This is work in progress, which should be completed over the summer quarter. Researchers have also developed some qualitative evidence on network expansion decisions.

For Task 5, researchers have begun planning to invite past and current SLPP graduate research assistants for a day of discus-

sion around the topic of the "New Transportation Professional" and training needs as they relate to ITS. STAR researchers will also take an active role in organizing and participating in professional workshops and conferences related to the research themes noted above.

Project URL: www.its.umn.edu/research /projects/2003012.html

Telecommunications and Sustainable Transportation

Project status: **Newly funded**

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

For Task 1 (Spatial Impacts), researchers will complete their report on the General Mills case study; complete labor Demand Modeling: Location Patterns of Information Workers; develop and test their externalities/diffusion model; continue development of the location demand model; and launch, collect, analyze, and report on a study of how different elements of information and communication technology affect household travel behavior.

For Task 2 (Modeling of Wireless Rural EMS Performance), researchers will use the knowledge acquisition system to model and assess EMS performance. Once the model has been specified, a companion performance specification simulation will be conducted. Researchers will also explore the implications of this approach for the broader assessment of ITS systems.

For Task 3 (Industry Cluster), the researchers will use existing quantitative techniques to identify and compare new industry data with past industry data to understand how Minnesota industry clusters have changed, and how those changes may have affected ITS use. They will also analyze the data for changes in cluster size and distribution over time and conduct roundtable discussions to enhance the quantitative information.

For Task 4 (Networks and Productivity), the researchers will study and optimize existing codes, formulate the new-node/link

model, code the new model, run the model on a sample network and debug codes, integrate the model with the link expansion model, collect Twin Cities network data, and calibrate the integrated model for the Twin Cities.

For Task 5 (Roundtable Discussion: May2004), the researchers will develop a white paper on applications of technology-related impacts (and data) for local and rural planners as well as transportation managers. They will also organize roundtable discussions, conference presentations, and invited speakers and conduct outreach to local and national decision makers and educators.

Project URL: www.its.umn.edu/research /projects/2004099.html

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Burns, S. (2003, April). ILD Vehicle signature analysis. CTS 14th Annual Transportation Research Conference, St. Paul, Minnesota.

Cherkassky, V. (2002, August). Application of VC learning theory for signal and image demising. International Conference on Artificial Neural Networks, Madrid, Spain.

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Davis, G. (2003, January). A vehicle/pedestrian collision model for neighborhood traffic control. 82nd Annual Meeting of the Transportation Research Board, Washington, D.C.

Davis. G. (2003, June). Bayesian networks and traffic accident reconstruction. 9th International Conference on Artificial Intelligence and Law, Edinburgh, Scotland.

Davis, G. (2002, July). Towards a unified approach to causal analysis in traffic safety using structural causal models. 15th International Symposium on Transportation and Traffic Theory, Adelaide, Australia.

Davis, G. (2002, September). Vehicular homicide and speed: Accounting for uncertainty in traffic accident reconstruction using Bayesian networks. 5th International

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Digham, F.F., and Alouini, M.S. (2003, April). Adaptive M-FSK transmission for power limited systems. CTS 14th Annual Transportation Research Conference, St. Paul, Minnesota.

Douma, F. (2003, May). Does higher speed mean fewer trips? Impact of telecommunications on residential travel. CTS 14th Annual Transportation Research Conference, St. Paul, Minnesota.

Douma, F. (2003, January). Stranded but connected? Case study of wireless ITS systems for emergency medical services in small town and rural environments. 82nd Annual Meeting of the Transportation Research Board, Washington, D.C.

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Horan, T. (2003, March). Rural Transportation and Technology Academic Seminar, University of Vermont.

Horan, T. (2003, January). Stranded but connected: Findings from wireless EMS case studies. 82nd Annual Meeting of the Transportation Research Board, Washington, D.C.

Kwon, T. (2003, January). Data service through internet access. 82nd Annual Meeting of the Transportation Research Board, Washington, D.C.

Levinson, D. (2002, November). Transportation network dynamics. Institute for Operations Research and the Management Services Conference, San Jose, California.

Levinson, D and Chen, W. (2003, January). Traffic management system performance. 82nd Annual Meeting of the Transportation Research Board, Washington, D.C.

Levinson, D and Huo, H. (2003, January). Effectiveness of VMS using empirical loop detector data. 82nd Annual Meeting of the Transportation Research Board, Washington, D.C.

Levinson, D., Parthasarathi, P., and Gillen, D. (2003, January). Insurance value of freeway service patrols. 82nd Annual Meeting of the Transportation Research Board, Washington, D.C.

Michalopoulous, P.G. (2002, September). Advances and needs in traffic flow modeling. FHWA workshop on next generation of models for traffic analysis, monitoring, and management, Tucson, Arizona.

Munnich, L. (2003, May). Exploring the connection between intelligent transportation systems and rural industrial clusters. ITS America 2003 Annual Meeting, Minneapolis, Minnesota.

Papanikolopoulos, N. (2003, May). Camera-based monitoring of urban intersections. CTS 14th Annual Transportation Research Conference, St. Paul, Minnesota.

Papanikolopoulos, N. (2003, May). Vision-based pedestrian tracking and motion recognition for homeland security. CTS 14th Annual Transportation Research Conference, St. Paul, Minnesota.

Pick, H.L. (2002, June). Age differences in drivers' spatial orientation. Regional meeting of "55 Alive" organization, St Paul, Minnesota.

Shankwitz, C. (2003, March). Bus rapid transit: lane assist systems for narrow lanes. ITS Minnesota Annual Meeting.

Shankwitz, C. (2003, March). DGPS and intelligent vehicles. Minnesota Surveyors' Conference.

Shekhar, S., Lu, C.T., and Zhang, P. (2002, November). Cube view: A system for traffic data visualization. 14th Annual IEEE International Conference on Tools with Artificial Intelligence, Washington, D.C.

Shekhar, S., Lu, C.T., Zhang, P., and Liu, R. (2002, November). Data mining for selective visualization of large spatial datasets. 14th Annual IEEE International Conference on Tools with Artificial Intelligence, Washington, D.C.

Stachowicz, M., Krishnamoorthy, D., and Sosonkina, M. (2003, February). Parallelization of fuzzy relational equations. International Conference on Artificial Intelligence and Applications, Innsbruck, Austria.

Smith, T.J. (2003, April). Reducing risk taking at passive railroad cross-

ings with active warnings. CTS 14th Annual Transportation Research Conference, St. Paul, Minnesota.

Stubbs, K., Arumugam, H., Masoud, O., McMillen, C., Veeraraghavan, H., Janardan, R., and Papanikolopoulos, N. P. (2003, May). A real-time collision warning system for intersections. ITS America 2003 Annual Meeting, Minneapolis, Minnesota.

Swaminathan, S., and Li, P. (2003, June). Traffic flow stability induced by arbitrary adaptive cruise control policies. 2003 American Control Conference, Denver, Colorado.

Vitthaladevuni, P.K., Hossain, M.J., Alouini, M.S., and Bhargava, V.K. (2003, April). Hierarchical constellations for multimedia transmission over fading channels. CTS 14th Annual Transportation Research Conference, St Paul, Minnesota.

Michael Wade and student

Wade, M.G., and Hammond, C. (2003, May). Traffic engineering issues. Minnesota Leadership Conference Driver Safety Program, Bloomington, Minnesota.

Wechsler, H., Duric Z., Li, F. and Cherkassky, V. (2002, August). Motion prediction using VC-gener-

alization bounds. International Conference on Pattern Recognition, Quebec City, Quebec.

Wilson, M. (2002, July). Simulating snowplow operations in northeastern Minnesota. Promodel Users Conference, Park City, Utah.

Wilson, M. (2003, April). Snowplow operations and resource management. CTS 14th Annual Transportation Research Conference, St. Paul, Minnesota.

Wilson, M. (2003, June). Snowplow operations and resource management. Federal Maintenance Decision Support System, Des Moines, Iowa.

Wyrick, D. (2002, October). Benchmarking fleet management. National Conference for the American Society for Engineering Management, Tampa, Fla.

Wyrick, D. (2003, April). Benchmarking fleet management benchmarking assessment (poster session). CTS 14th Annual Transportation Research Conference, St. Paul, Minnesota.

Yang, J.S. (2003, April). Traffic flow modeling on the Miller Hill Corridor. CTS 14th Annual Transportation Research Conference, St. Paul, Minnesota.

Yang, J.S. (2003, May). Traffic simulation study based on calibrated traffic flow models. International Conference on Circuits, Signals, and Systems, Cancun, Mexico.

Yerra, B. (2003, February). The emergence of hierarchy in transportation networks. 42nd Annual Meeting of the Western Regional Science Association, Rio Rico, Arizona.

Jiann-Shiou Yang

Zhang, L., and Levinson, D. (2003, January). Balancing efficiency and equity of ramp meters. 82nd Annual Meeting of the Transportation Research Board, Washington, D.C.

Zhang, L., and Levinson, D. (2003, January). Optimal freeway ramp control without origin-destination information. 82nd Annual Meeting of the Transportation Research Board, Washington, D.C.

Zou, X., and Levinson, D. (2003, January). Evaluation of adaptive cruise control in mixed traffic. 82nd Annual Meeting of the Transportation Research Board, Washington, D.C.

Zou, X., and Levinson, D. (2003, January). Predicting breakdown of traffic. 82nd Annual Meeting of the Transportation Research Board, Washington, D.C.

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

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

Transportation seminars highlight diverse ITS research

During the 2002–2003 academic year, the Institute continued its multidisciplinary seminar series at the University. These Advanced Transportation Technologies Seminars included a diverse set of presentations by local and national researchers addressing different areas of ITS research, such as traffic management and modeling, human factors, sensing, and intelligent vehicles as they relate to road- and transit-based transportation.

From the seminars, students learned about ITS technologies in areas outside their current field of study, researchers learned about other research projects in progress, and practitioners learned about the technologies of the future.

New this year, the seminar series was offered during the fall semester and was available as a one-credit graduate-level course. It was also a required course in the new Graduate Certificate Program in Transportation Studies at the University of Minnesota.

The past year's presentations were:

- "Ramp Meters on Trial." David Levinson, Department of Civil Engineering
- "Is the Sequential Travel Forecasting Paradigm Counterproductive?" David Boyce, Department of Civil and Materials Engineering, University of Illinois at Chicago
- "Wireless EMS Services: Opportunities and Challenges to Bringing Safety and Travel Services to Rural Minnesota." Tom Horan and Frank Douma, Humphrey Institute of Public Affairs

- "Ecological Validity in Applied Perception Research in Simulation Environments: Past, Present, and Future." Michael Manser, HumanFIRST Program
- "Simulating Snowplow Scheduling in District 1." Martha Wilson, Department of Industrial Engineering, University of Minnesota Duluth (videocast from Duluth)
- "Dynamics and Control of Tilting Vehicles." Lee Alexander, Department of Mechanical Engineering
- "Mn/DOT ITS Projects." Farideh Amiri, Mn/DOT Office of Traffic, Security and Operations

Seminar addresses homeland security issues

On June 2, the Institute sponsored a special ITS seminar, "Advanced Technology for Homeland Security Applications." Vassilios Morellas, senior principal research scientist at the Situation Assessment Technologies Laboratory in Honeywell Laboratories' Automation and Control Systems business unit, discussed new video and imaging systems the company developed for three security applications. About 30 people attended, including many University faculty and researchers, Mn/DOT staff, and a representative from Rep. Jim Ramstad's office.

At the Minneapolis-St. Paul International Airport, Honeywell is testing DIVAS (Digital Integration of Video for Airport Security), a networked video camera system that not only tracks selected people by using

body and clothing colors and facial particle filtering, but also detects entry- and exit-point bolting. Morellas said the company is also designing a face recognition technology system called S-Gate for naval bases that uses a new tri-band light imaging system to detect faces, discriminating between human and dummy skin as well as identifying disguises. S-Gate secures authorized access to a base by matching the mug shot on an RF-ID tag to the driver, automatically diverting questionable vehicles to a checkpoint.

To continue security technology improvements, Morellas encouraged U of M faculty to pursue work in this area. "We need to work collaboratively and exchange information," he said. Additional video data-mining work is needed and local agencies should develop the technology for the benefit of all, he added.

Students hear advice at Career Expo

In March, the Institute partnered with the CTS Education/Outreach Council, the Women's Transportation Seminar, the Minnesota Local Road Research Board, and Minnesota LTAP to hold the eighth annual Transportation Career Expo in Minneapolis.

Mn/DOT Seeds program intern Alia Abdel-al, a graduating University of Minnesota senior, came to the expo with an intention similar to that of many other students: to get a job.

With tightening budgets, openings for entry-level civil engineers have become scarce, even for a student with internship experience. "The

Vassilios Morellas discussed technology for homeland security operations at an Institute-sponsored seminar.

The eighth annual Transportation Career Expo brought together students and potential employers.

From the seminars, students learned about ITS technologies in areas outside their current field of study, researchers learned about other research in progress, and practitioners learned about the technologies of the future.

job market is tight," said Abdel-al. "It's the toughest part of a person's life—graduating and looking for an entry-level position."

About 75 students, from Minnesota and Wisconsin, and 18 exhibitors attended the expo, which provided job seekers advice for pursuing a variety of careers in transportation. Employers promoted their organizations through booths, and several company representatives led informational sessions.

The event offered a general session on career preparation and four concurrent sessions on specific areas of transportation: engineering/technical careers, transportation planning and policy careers, transportation logistics careers, and careers in intelligent transportation systems.

Student of the Year awarded to Robert F. K. Martin

Graduate research assistant Robert F. K. Martin received the ITS Institute's 2002 Outstanding Student of the Year Award. He was recommended for the award by Nikolaos Papanikolopoulos, professor of computer science and engineering.

Martin, who earned his bachelor's degree in electrical engineering from the University of Minnesota, is seeking his master's in computer and information science. His current work is focused on the detection, tracking, and classification of vehicles using computer vision techniques. He was chosen for the award based on his contributions to addressing the problem of shadow removal for vehicle detection and classification.

Martin has held previous positions as a principal software engineer for Lockheed Martin–Technical Defense Systems and as a software engineer for MicroDynamics Corporation. This experience provided him with the programming background that has been invaluable to his current research for the ITS Institute.

Martin says he appreciates being recognized for the work he's accomplished thus far, since as a graduate student, "there is your ultimate goal of getting a degree, but in between the beginning and the end, it feels like a lot of work goes unnoticed. Receiving this award was a large pat on the back."

Martin plans to pursue a Ph.D. and then teach and conduct research in the area of computer science, specializing in computer vision and the cognitive workings of human vision. He received the award in January at the Transportation Research Board 82nd Annual Meeting in Washington, D.C. It was presented by Ellen Engleman, administrator, USDOT Research and Special Projects Administration, and J. Richard Capka, deputy administrator, Federal Highway Administration.

Institute student receives awards from CTS, FHWA

An ITS Institute student was one of two recipients of the 2003 Matthew J. Huber Award for Excellence in Transportation Research and Education. Lei Zhang is a doctoral candidate in the Department of Civil Engineering, concentrating in transportation engineering. He is advised

Martin says he appreciates being recognized for the work he's accomplished thus far, since as a graduate student, "...it feels like a lot of work goes unnoticed."

Student of the Year Robert Martin (center), receives the award from J. Richard Capka (left) and Ellen Engleman (right).

Award recipient Lei Zhang (center), with Cheri Marti (left) and advisor David Levinson (right)

by Assistant Professor David Levinson.

The award was presented by Cheri Marti, CTS assistant director, at the center's annual meeting and awards ceremony held in April in Minneapolis. Zhang thanked CTS and Levinson, adding that the award makes him feel he is doing something worthwhile for this area of transportation and encourages him to contribute more to this area of study.

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.

Zhang also received the Milton Pikarsky Award–Science and Technology during the annual Transportation Research Board meeting in Washington, D.C., in January. Christine Johnson of the Federal Highway Administration presented the award to Zhang at the Council of University Transportation Centers Sixth Annual Awards Banquet.

In Zhang's thesis, Developing Efficient and Equitable Freeway Ramp Control Strategies, measures of efficiency and equity for ramp meters are defined and applied to data collected in the Twin Cities ramp metering shut-off experiment of fall 2000. Zhang also developed an analytical framework for ramp metering under which future ramp metering studies can be conducted.

Institute sponsorships help students attend national conferences

The Institute grants travel awards to students so they can attend various conferences to report on their research to a larger audience. This past year, the Institute sponsored 11 students to attend the national meeting of the Transportation Research Board (TRB) in January. The students were Wei Chen, Wenling Chen, Joseph Keith Fortowsky, Andy Johnson, Robert Martin, Jonathan Osmond, Tait Swenson, Haifeng Xiao, Wuping Xin, Lei Zhang, and Xi Zou.

High school students experience ITS America annual meeting

The University of Minnesota's ITS Institute, 3M, and ITS America partnered to sponsor a high school student competition held in conjunction with the 2003 ITS America Annual Meeting.

The winning student teams, from Twin Cities-area Eastview and Harding High Schools, joined the usual ITSA exhibitors to share what they learned from the competition about the effectiveness of ramp meters, having completed a Web-based curriculum on the topic. The curriculum, which was created by the Institute, is aimed at introducing students to ITS while having them practice their research, data synthesis, and presentation skills.

The 3M Foundation provided stipends to the participating high schools to offset their cost of attendance, plus an additional $1,000

The winning student teams joined the usual ITSA exhibitors to share what they learned about the effectiveness of ramp meters.

Student teams from Harding High School (above, left) and Eastview High School (above, right) were among the exhibitors at ITS America's annual meeting.

grant for each school. ITS America donated the exhibit hall space for the students.

While at the annual meeting, the students took time to visit the exhibits and meet with some of the ITS professionals in attendance, later commenting that the experience taught them more about intelligent transportation systems and its far-reaching effects.

The student competition is just one way the Institute is working to interest more of the best and brightest students in a career in intelligent transportation systems.

Web modules provide learning opportunity for high school students

A ramp meter module designed by the ITS Institute's K-12 coordinator, Mark Tollefson, has been distributed to all Twin Cities metropolitan-area high schools and is being used by many teachers.

Students in physics, algebra, and statistics classes are using the computer-based curriculum that covers ramp metering theories and intelligent transportation systems concepts.

"It brings students the opportunity to learn about a subject most people know very little about," said Tollefson. "I think informed students today will make informed taxpayers in the future."

The youth, who also learn about ITS careers through the module, "could become the ITS workers of tomorrow," he said.

By reaching students with engaging, hands-on activities, the Institute

hopes to spark an early interest in transportation.

"I like this unit because I get to use the computer, get to learn about cars, and I can work at my pace," said a student who explored the module in a test group.

Additionally, Tollefson has designed a Web-quest curriculum on global positioning systems that is currently at the review stage. Along with listing various Web sites about GPS, the curriculum includes quizzes that check students' learning progress. The unit can be used in the same courses as the ramp meter module as well as in earth science and physical science courses. The GPS module will be distributed and available on the Institute's Web site during the first quarter of FY04 (check www.its.umn.edu/education for updates).

The ramp meter module can be accessed at www.its.umn.edu /education/rampmodule/index.html.

Lab opens door to ITS career

When recent graduate Kyle Wood began his internship with the Center for Transportation Studies his sophomore year, he had no interest in transportation. Although the electrical engineering student was hired for administrative-related duties, his background and a budding interest led him more and more into helping out in the ITS Lab across the hall. Soon he was "adopted" by the lab.

Two and a half years later, Wood is pursuing a full-time engineering job in ITS technology with a resume stacked full of skills and original

By reaching students with engaging, hands-on activities, the Institute hopes to spark an early interest in transportation.

Eastview High School students use the Web module designed by teacher Mark Tollefson (center back).

Student Kyle Wood works in the ITS Lab's Digital Immersive Environment.

project work he's developed at the Institute. His experience in assisting research fellow John Hourdakis on the Beholder project has been so extensive that Wood is only halfway through writing an over 50-page how-to manual on what he does.

Kyle Wood

"I'm really the only one that knows the 'ins and outs' of how the entire system is working," he said. Wood helped design Beholder's wireless infrastructure, using an 802.16 protocol, for traffic data transmission from Autoscope® vehicle detection systems—a challenge because he had to deal with conversions using different protocols. His other major accomplishment for the project was building four dedicated, fully automated video encoders to capture and broadcast the video over a 20Mbit wireless network back to the lab.

The Beholder experience became instrumental to Wood's senior project, titled Video Compression over Limited Bandwidth Channels, which couldn't have covered a more related subject. For the project, Wood and his four group members spent a lot of time using the ITS Lab—a valuable resource available to any undergraduate student working on a transportation-related assignment.

Other work experiences also spilled over into Wood's classroom learning, including the PCB (printed circuit board) he built for Beholder's initial communications equipment, and the use of stereo imaging and ultrasonic motion tracking when helping Ted Morris design and construct the lab's Digital Immersive Environment (DEN) for investigating novel human interfaces.

"We are always learning and doing new things here," Wood said, adding that he couldn't have chosen a better place to work. "The experience I've gotten has been phenomenal." Together with the contacts he's made, Wood said he's on excellent footing for his career. "I owe it all to the ITS Institute."

Interactive simulations enhance ITS education, outreach

At the ITS Laboratory, work is underway to make traffic simulation tools more widely available. Senior Systems Engineer Chen-Fu Liao is working to give researchers, students, and eventually the public access to advanced computer-generated traffic simulation systems that would allow users to experiment with traffic flow on the streets of Minneapolis, for example.

Traffic simulators are important tools in ITS research because they enable researchers to study the effects of ITS technologies in the laborato-

ry and optimize them prior to implementation. However, their use is often restricted to advanced researchers with access to special facilities.

By introducing students in diverse engineering disciplines to traffic simulation, Liao's simulation modules will help the ITS Institute expand the understanding and application of intelligent transportation systems.

After joining the ITS Laboratory in 2002, Liao began supporting simulator use and developing simulation-based modules for several transportation-related courses in the Civil Engineering department. His first task was to support the simulation module used in a transportation engineering course focusing on freeway ramp metering and capacity expansion. In this case, students were able to analyze and compare different traffic management strategies on an important metro commuter route.

Liao is also working on an ambitious project to develop a virtual reality traffic simulation environment for use over the Web. This module will allow users to control parameters such as traffic volume and signal timing, then watch the results play out in a realistic artificial world. Users of the advanced simulation module will be able to observe traffic behavior from any vantage point—from overhead to street level, or even from the driver's seat of a vehicle on the road. The new module will be targeted at undergraduate and high school students, traffic engineers, and distance-learning students at the University.

Using Virtual Reality Modeling Language (VRML), Liao is currently constructing a detailed electronic model of the streets and buildings along a section of Washington Avenue near the East Bank campus. These streets will be populated with virtual vehicles, generated by a traffic simulation application in the ITS Lab. An added benefit of the virtual reality environment is that it can be used in other simulation projects, such as the HumanFIRST Program's advanced driving simulator and the ITS Laboratory's Digital Immersive Environment (DEN).

Chen-Fu Liao

Traffic simulators are important because they enable researchers to study the effects of ITS technologies in the laboratory and optimize them prior to implementation.

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 designed 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 redesigned 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.

NATSRL Research Day showcases Duluth projects

The Northland Advanced Transportation Systems Research Laboratories at the University of Minnesota Duluth, in partnership with Mn/DOT District One, held its first annual Research Day in November 2002 to showcase ongoing work by UMD researchers. The event, which was open to the public, was held at the Mn/DOT District One Headquarters in Duluth.

The presentations highlighted the ongoing research activities of UMD faculty and students in the Electrical and Computer Engineering, Mechanical and Industrial Engineering, and Computer Science departments. Dr. Taek Mu Kwon presented a summary of his projects with Mn/DOT in computing traffic statistics and large-scale data archiving. Dr. Jiann-Shiou Yang, who specializes in traffic flow modeling and simulation, presented updates on his analysis of the Miller Hill Corridor traffic flow and his initial modeling efforts for Duluth Entertainment Convention Center special events. Dr. Stanley Burns is researching the effects on inductive loop detectors and the various vehicle signatures impacting data compilation.

Dr. Martha Wilson and Dr. David Wyrick are both working closely with Mn/DOT fleet operations. Wilson and her graduate students are modeling snowplow operations in northeastern Minnesota with a goal of improving efficiency and effectiveness of winter road maintenance activities (see related article, pages 18–19). Wyrick and his students are analyzing all aspects of managing and maintaining fleet operations and benchmarking the best practices.

Other sessions included a variety of new research endeavors initiated

University of Minnesota Duluth researchers participated in NATSRL's first Research Day.

From left: Robert Johns, Rep. John Kline, Max Donath, and Michael Manser view the HumanFIRST Program's driving simulator.

IV Lab researcher Pi-Ming Cheng, left, greets Rep. Martin Sabo during a tour of the TechnoBus.

this year, from advanced timber bridge inspection techniques to the utilization of satellite images for detecting and counting vehicles.

NATSRL is a cooperative program of UMD and the ITS Institute. It provides an education and outreach program to acquaint students with transportation-related problems and offers opportunities for students to actively participate in research areas.

Congressional staff, visitors view Institute labs and research

During the past year, the Institute has opened its door for tours and demonstrations of its laboratories and research projects. Visitors have included local and national government officials, legislators, and the general public, among others. These efforts give visitors a first-hand look at the work underway at the Institute, which in turn increases the Institute's visibility and support for its activities.

In December 2002, U.S. Congressman John Kline heard an update by ITS Institute director Max Donath about research being performed in the Institute's Intelligent Vehicles (IV) Laboratory during a visit to the Center for Transportation Studies. Kline then viewed a demonstration at the HumanFIRST lab by research associate Mike Manser.

In November, Donath presented an Institute briefing to Dick Larson (Congressman Gil Gutknecht's office), Katie Delmore (Congresswoman Betty McCollum's office), Louis Moore (Congressman Martin Sabo's office), Mark Matuska (Congressman Mark Kennedy's office), and Deven Nelson (Congressman James Oberstar's office), who were

attending a Congressional staff day hosted by CTS. In addition, the staff saw demonstrations of the HumanFIRST Program by program director Nicholas Ward; the IV Lab and the TechnoBus intelligent vehicle by program manager Craig Shankwitz; and the ITS Institute Lab by lab manager Ted Morris of CTS and John Hourdakis of the Department of Civil Engineering.

Members of the Minnesota House of Representatives Transportation Policy and Transportation Finance Committees experienced transportation research in progress at the University during a visit in March. The TechnoBus, demonstrating the latest in high-tech navigational equipment, transported the legislators to and from the University, with a demonstration on the intercampus busway. The group also toured the HumanFIRST Program's facilities, which include a driving simulator that allows researchers to test driver response to various situations. University hosts included Max Donath, Nicholas Ward, and Lee Alexander, research fellow with the Intelligent Vehicles Lab.

In April, U.S. Congressman Martin Sabo toured the TechnoBus and HumanFIRST lab in conjunction with speaking at the CTS Annual meeting. Sabo recently left the House Transportation Appropriations Subcommittee to become the ranking member of the new Homeland Security Subcommittee.

Institute research, facilities showcased at ITSA

About 75 attendees of the 2003 ITS America national conference, held in Minneapolis in May, took part in tours and demonstrations of

Tours and demos give visitors a first-hand look at the work underway at the Institute, which in turn increases the Institute's visibility and support for its activities.
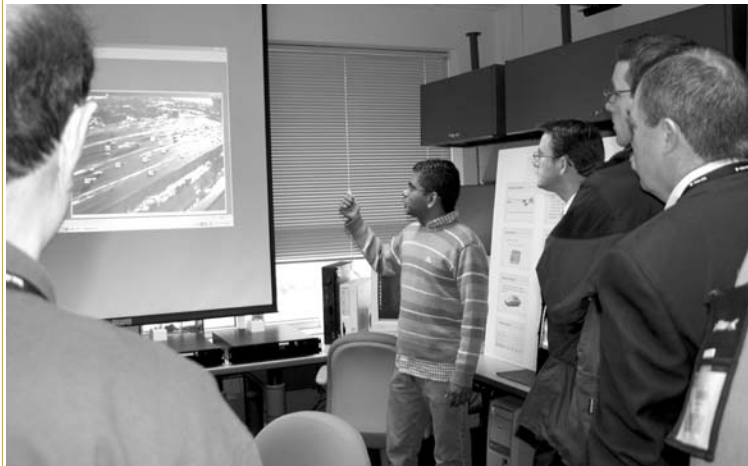
ITSA attendees toured the ITS Lab (above) and the HumanFIRST Program's facilities (below).

The Intelligent Vehicle Initiative's work with global positioning systems was part of a feature on the cable History Channel.

the ITS Laboratory, the HumanFIRST Program, and the Intelligent Vehicles Laboratory.

During the ITS Lab tour, participants viewed the lab's comprehensive simulation resources, wireless access to traffic imaging systems located along the I-94/I-35W commons area, and large-screen displays, including the Digital Immersive Environment, which uses the illusion of 3-D to allow users to step into a research digital-world environment.

While touring the HumanFIRST Program, participants observed its state-of-the-art driving simulator in action. This Virtual Environment for Surface Transportation Research, or VESTR, wraps around an

instrumented Saturn vehicle. The simulator plays an important role in HumanFIRST research, which investigates driver acceptance and use of proposed new systems, as well as how those systems might produce undesirable driver responses and adaptation.

Another technical tour was given of the Institute's Intelligent Vehicles Lab, during which participants rode the TechnoBus, the latest addition to the program's research vehicle fleet. Along the route to the Minnesota State Fairgrounds, the bus traveled on the University's BRT-like intercampus transitway while the driver demonstrated the TechnoBus's haptic steering and virtual rumble strip technologies. At the demo area, participants could view the head-up display and feel the tactile feedback systems. The technologies were demonstrated in both a snowplow and a State Patrol vehicle. Among the tour participants was FTA Associate Administrator Barbara Sisson, who drove both the bus and the snowplow.

In addition to the tours and demos, at this year's conference the Institute once again joined with the Minnesota Guidestar program to create and manage an informational exhibit. Institute staff members were on hand to answer ITS-related questions and distribute Institute publications to the many visitors who stopped by.

IV Lab appears on History Channel

The Intelligent Vehicle Laboratory's work on global positioning systems (GPS) was part of a feature on the cable History Channel. Segments with BMW and General Motor's OnStar were also part of the show.

The segment featured the IV Lab's Intelligent Vehicle Initiative and BRT lane-assist projects. These projects increase safety for the drivers of specialty vehicles through the use of vehicle-guidance and collision-avoidance technologies. Led by ITS Institute director Max Donath and IV Lab director Craig Shankwitz, University researchers are developing and testing a variety of these technologies, including high-accuracy differential GPS.

The projects are funded by the Federal Highway Administration, Federal Transit Administration, Minnesota Department of Transportation, Metro Transit, and industry partners.

A History Channel crew worked with Mn/DOT, State Patrol, University of Minnesota, and Metro Transit staff to film a squad car, a snowplow, and the TechnoBus, all of which are equipped with centimeter-level GPS technology.

For the filming of the TechnoBus along state highway 252, the camera crew traveled alongside the bus to show it in traffic. On state highway 7 near Hutchinson, the crew filmed a re-enactment of a car chase

Television crews filmed IVI project vehicles for a feature on GPS.

HumanFIRST director Nicholas Ward (left) with visiting scientist Nobuyuki Kuge

The IDSS research is evaluating prototypes in a comprehensive manner in relation to safety enhancement, usability, ease of driving, and possible system-induced problems.

and repeated runs of the state patrol vehicle in operation.

John Scharffbillig of Mn/DOT, Jeff Goldsmith of the Department of Public Safety State Patrol, and Shankwitz were all interviewed for the segment.

Institute director presents seminars on DGPS and human-centered technologies

Institute director Max Donath presented the seminar, "DGPS-based Augmented Reality: 'Seeing' the Roads and Staying in the Lane," at the University of Washington last summer. About 30 students, faculty, and transportation professionals gathered to hear Donath discuss vehicle collision statistics, a head-up display of the local geospatial landscape, and prevention of lane-departure accidents. DGPS-based technology can greatly improve the safety of vehicles operating during a whiteout or in other low-visibility conditions. He described the USDOT's Specialty Vehicle Intelligent Vehicle Initiative, a field operational test being conducted to evaluate the system on snowplows and emergency response vehicles.

Donath also challenged participants to consider new human-centered technologies for reducing road fatalities at the CEO Forum on Safety, held at the Annual Meeting of the American Association of State Highway and Transportation Officials (AASHTO) held in Anchorage, Alaska, in October.

Visiting researchers help promote exchange of ideas

Visiting researchers often create a win-win situation by bringing unique skills and experience to a research program, then taking new knowledge back to the organizations they return to. The ITS Institute, therefore, does what it can to promote these mutually beneficial relationships.

Since October of 2002, visiting research fellow Nobuyuki Kuge of the Nissan Research Center in Yokosuka, Japan, has been working with the Institute's HumanFIRST Program on its intelligent driver-support system (IDSS) research with Nissan. Such a system would give drivers multi-sensory information in order to help them better control their vehicles and manage distractions that might lead to crashes.

The IDSS research is evaluating prototypes in a comprehensive manner in relation to safety enhancement, usability, ease of driving, and possible system-induced problems. During his year-long assignment with the HumanFIRST Program, Kuge hopes to help establish methodology in terms of the driver support-system evaluation, working with driving simulator experiments and data analysis.

"With ITS research becoming more and more active, how to measure driver cognitive aspects while using systems…[involving] work load, distraction, and adaptation remain hot issues," Kuge says. "I believe that my experience at the University can help improve my knowledge regarding these issues."

Kuge has been with the Nissan Research Center for the past 10 years, where he's involved with the research and development of ITS and telematics products. Examples of past projects he's worked on include

Coverage described in detail the lane-assist technology intended to help bus drivers safely navigate the freeway shoulders designated for bus use during rush hours.

an emergency braking advanced advisory system for the Japanese government and driver behavior analysis for adaptive cruise control.

Other collaborations with visiting researchers include those with Dick de Waard from the University of Groningen (the Netherlands), Jeff Caird from the University of Calgary, and Erwin Boer of the University of California, all of whom are working with the Institute's HumanFIRST Program. Associate Professor Thomas Horan of Claremont Graduate University serves as a visiting scholar at the Humphrey Institute of Public Affairs, where he is working with the Sustainable Technologies Applied Research initiative. In addition, Eil Kwon, the Institute's advanced traffic systems program director, helped facilitate research between Mn/DOT's Office of Traffic, Security and Operations and the University as he conducted work on urban traffic dynamics.

TechnoBus research covered in media

Articles on the Institute's TechnoBus appeared in both the Minneapolis *Star Tribune* and *St. Paul Pioneer Press*, as well as in the University's newspaper, the *Daily*, last fall. Coverage described in detail the lane-assist technology intended to help bus drivers safely navigate the freeway shoulders designated for bus use during rush hours. The prototype lane-assist system on the TechnoBus features laser and radar-based collision avoidance devices as well as a head-up display, a virtual mirror, and assisted steering to help keep the bus centered in its lane despite weather and road conditions.

Several other publications, including the *Fresno Bee* and the *Urban Transportation Monitor*, ran coverage of the technologies developed

for the bus as well as for the IVI Lab's SAFEPLOW. Two international publications—*Traffic Technology International* and *ITS International*—ran articles featuring the Institute's research into intelligent vehicles, ramp metering, and simulation technology.

Web, publications promote Institute work

The Institute continued to improve its Web site (www.its.umn.edu) over the last year. A restructuring and graphic redesign made the site easier to use and more attractive. The research section of the site was given a high priority, and the options available to users searching for research project information were expanded. Information on projects carried out prior to 1999 was also added to the site, increasing the amount of searchable information available online. Development of topical Web pages to pull together multiple related research projects was also initiated.

A new Web project was initiated during FY03, with the goal of presenting information directly from the Institute's research and administrative database directly on the Web. This will speed up the information posting process and bring new types of information to users. The project is slated for completion within 2004.

News articles on the ITS Institute Web site were also included in the Center for Transportation Studies' *Research E-News*, an electronic mail newsletter in HTML format, widely circulated within the transportation research community.

Other communications this past year continued to further the Institute's mission by raising awareness among academic and professional communities and by disseminating the results of Institute research as well. Publications included the Institute's quarterly *Sensor* newsletter, a source of detailed information on specific research projects; promotional brochures describing the Institute's Intelligent Vehicles program and ITS Laboratory; a semiannual and annual report; and research reports. All communications can be found on the Institute's Web site (www.its.umn.edu).
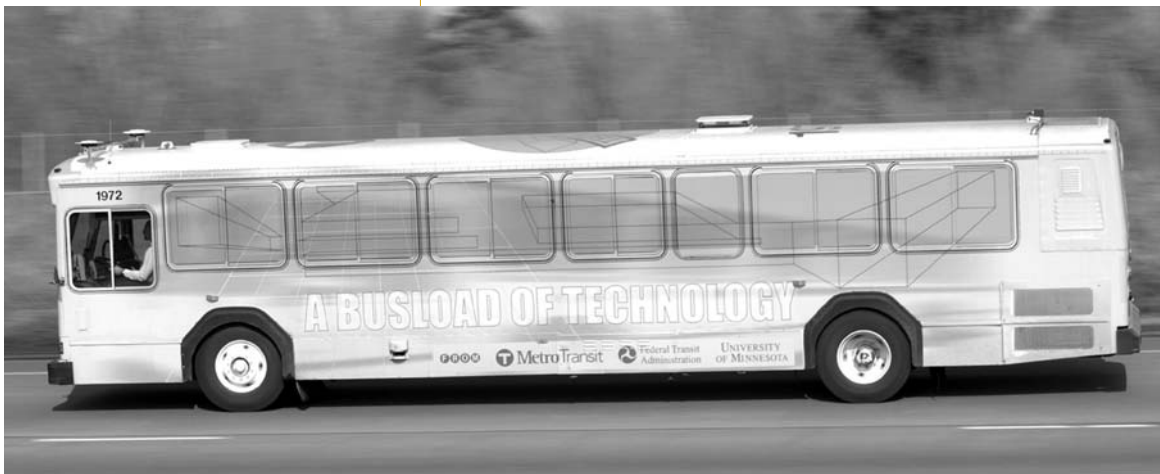
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