THE
INTELLIGENT
TRANSPORTATION
SYSTEMS
INSTITUTE

ANNUAL REPORT

CENTER FOR TRANSPORTATION STUDIES

1999/2000

**Intelligent Transportation Systems Institute**

# ITS INSTITUTE

INTELLIGENT TRANSPORTATION SYSTEMS INSTITUTE
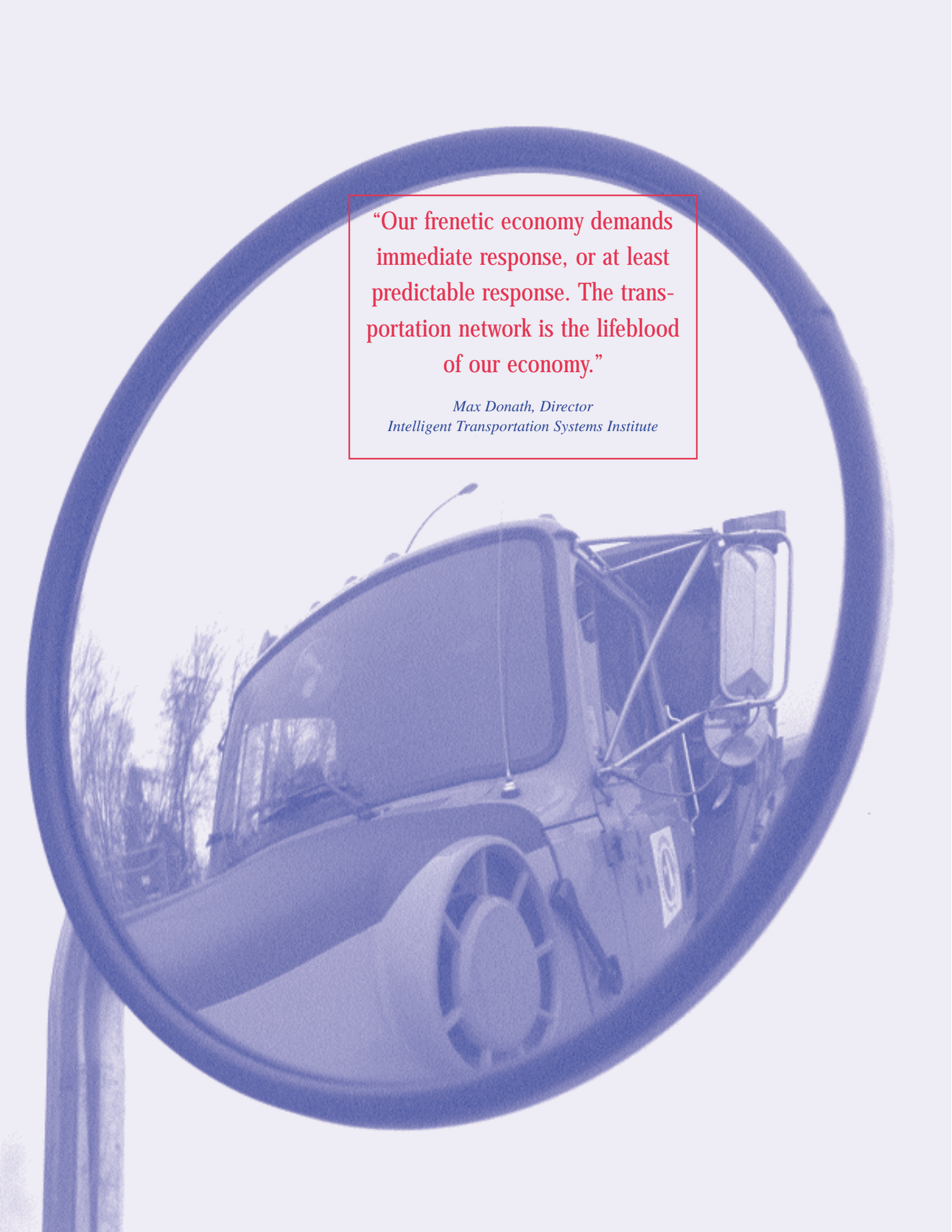
## ANNUAL REPORT 1999/2000

**This publication is a report of research, education, and technology transfer activities, fiscal year 1999/2000, of the Intelligent Transportation Systems Institute, University of Minnesota.**

## Contents

"Our frenetic economy demands immediate response, or at least predictable response. The transportation network is the lifeblood of our economy."

*Max Donath, Director*
*Intelligent Transportation Systems Institute*

# Message from the Director

We have all been there: traveling along a rural highway when traffic comes to a complete stop. Is there an incident ahead? Is there an alternate route? And should I bother to risk finding one in unfamiliar territory?

Congestion is no longer just an urban problem, nor is it just an inconvenience. Overnight delivery, just-in-time-production, fresh produce restocked daily on grocery shelves—all have become part of our natural expectations. Our frenetic economy demands immediate response, or at least predictable response. The transportation network is the lifeblood of our economy, and yet it must compete for taxpayers' attention against a myriad of other priorities. People tend to forget or ignore two key issues:

Mobility: Should it be viewed as a constitutional right? Are we moving toward needing a reservation in order to get onto our roads?

Safety: Over 43,000 mothers, fathers, sons, and daughters die in vehicle crashes every year in these United States. That's close to five fatalities an hour. Over 16,000 die due to lane departures, almost 6,000 due to inattentiveness or drowsiness, and 1,300 due to low visibility. Two thirds of fatalities occur on rural roads. We need to focus on some of the root causes of these fatalities and do something about them.

Technology sometimes gets the better of us, but I believe it can help us address these crucial concerns. For example, the PalmPilot has become popular because of its simple interface and focus on intuitive models for its design. Human-centeredness is the key to its remarkable success.

Our Intelligent Transportation Systems Institute is similarly focused on human-centered technology to enhance safety and mobility, merging technological advances in sensing, communications, computing, and control with human factors to solve problems.

This Annual Report describes many of the projects and people that are working to address this theme. Let me highlight some of those here:

Ramp metering has become a way of life on our freeways. But what strategies work best? What is fair? **Panos Michalopoulos**, **Eil Kwon**, and **David Levinson** are exploring different aspects of the ramp metering issue, including better traffic models and tools, using actual highways in the Twin Cities as their model.

Levinson, who joined us this year, will work with Michalopoulos and **Gary Davis** to improve estimation methods for travel demand. Their preliminary reports, due to the Minnesota legislature in the fall of 2000, will serve as important background for contentious ramp policy debates in the Twin Cities metro area.

How do we acquire data? **Nikolaos Papanikolopoulos** and Eil Kwon have joined forces to use digital image processing

strategies to track vehicles in free-way entry and exit areas. Gathering this data gives us a better understanding of human behavior in freeway weaving areas and can thus lead to improved design.

**Shashi Shekhar** has started to explore spatial visualization of traffic data so that ultimately, the traveling public will know what is happening along the freeways and on the ramps up ahead.

What about safety and traffic? Gary Davis will be addressing the role of vehicle speed as a risk factor in traffic crashes and **Eitan Naveh** is looking at the entire crash data situation.

And how do we move those data around? Our radio waves are overcrowded. **Vladimir Cherkassky** has been working on wavelet-based tools to compress images into fewer bytes that can be transmitted wirelessly and then decompressed at a later point for further processing or for display.

Wireless devices are proliferating, and packet-switched wireless data transfer is enabling major improvements in data communications and continuous wireless access to the Web. The impact of continuous wireless access on advanced traveler information services will be profound. With the recent approval of Dedicated Short Range Communications channels by the Federal Communications Commission, safety will also benefit.

That takes me to our Intelligent Vehicles Program. One new faculty member, **Rajesh Rajamani**, began his research agenda this year on fault diagnostic systems that can find problems in a vehicle's increasingly complex safety systems. Now he'll be working with Panos Michalopoulos and David Levinson on how adaptive cruise control can influence and optimize traffic flow, an area that was first explored at the ITS Institute by **Perry Li**.

Our Intelligent Vehicles (IV) Laboratory, led by **Craig Shankwitz,** was successful in attracting a field operational test funded by the Federal Highway Administration's Intelligent Vehicle Initiative. This project is integrating high-accuracy GPS, radar units, a head-up display, and magnetic lateral sensing to help snowplow operators do their job better, thus keeping roads open to the public. IV Lab members Shankwitz, new staff **Lee Alexander** and **Alec Gorjestani**, and **Pi-Ming Cheng** are also examining driver-assistive systems that combine visual, haptic, and audio feedback in ways that elicit intuitive responses when needed in order to compensate for human frailties.

Additionally, Human Factors Research Laboratory (HFRL) staff members **Peter Hancock**, **Kathleen Harder,** and our newest addition, **John Bloomfield**, are working with the IV Lab on the field operational test to develop systems that are adapted to the driver, rather than forcing the driver to adapt to the technology. Furthermore, **Taek Kwon** of the University of Minnesota-Duluth (UMD) is working on road visibility measurement techniques to be used along the 50-mile IVI highway test section, while **David Anderson** will examine the costs and benefits of these safety technologies.

Other work at the HFRL concerns how drivers react under a variety of situations, and what we can learn about human

behavior under stress. Peter Hancock is probing accident-likely situations and Kathleen Harder is investigating aggressive driving. **Herb Pick** is examining how people navigate and orient themselves during a trip. **Michael Wade** will be examining the effects of signage and vehicle velocity to try to eliminate driver blind spots at rural intersections. **Curt Olson**, who just joined the HFRL staff, and **Peter Easterlund** are planning a major upgrade of our driver simulation capabilities.

We have expanded our activities at UMD to build upon the work of Taek Kwon in sensors and road weather information systems. **Ed Fleege** has begun to work with faculty on developing research interests in transportation maintenance and operations and Eil Kwon, who joined the UMD campus as the McKnight Distinguished Professor for the spring semester, was able to identify other new areas for further development. He and Taek Kwon also worked together to advise a team of engineering undergraduates on the design issues surrounding traffic operations. A new project led by **Jiann-Shiou Yang** will be started this year to examine traffic issues in the Miller Hill area of Duluth.

Congestion has always been a friend of transit; nothing gets folks to look at transportation alternatives more than congested roads. Craig Shankwitz will lead a team to examine how technology can accelerate the introduction of Bus Rapid Transit (BRT), and Lee Alexander and Rajesh Rajamani will look at new technologies to facilitate the introduction of narrow but comfortable commuter vehicles that can be driven side by side in one lane. Since significant new roadway construction is unlikely, we must make better use of what we have.

Which leads me to the social sciences and related policy issues. **Lee Munnich** of the Humphrey Institute is investigating how telecommunications, a major aspect of ITS technologies, may affect the location of economic activity, the relationship between travel and access, community design, and transportation planning.

Of course, none of this could happen without all the assistance, long hours, and diligent efforts of our staff, whose support is very much appreciated, and of our students, who play such a vital role in every project that we undertake. You can find their names throughout this report.

We also want to thank the members of our research selection and review panels for their selfless efforts, and those at the Minnesota Department of Transportation who have made our partnership to explore and expand transportation horizons so successful.

Last but not least, we thank the taxpayers and their legislative representatives who have entrusted us to help solve the really tough problems.

**Max Donath, Director**
*Intelligent Transportation Systems Institute*

# Mission Statement and Overview

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

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

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 unites technologists and those who study human behavior to ensure that Institute-developed technologies become tools that optimize human capabilities. This human-centered approach means that new developments in the core ITS technologies of computing, sensing, communications, and control systems will be used to approach significant safety and mobility problems with a fresh perspective.

Additionally, the Institute addresses issues related to transportation in a northern climate and investigates technologies for improving the safety of travel in rural environments.

Our theme:
"To enhance the safety and mobility of road- and transit-based transportation through a focus on human-centered technology."

# Financial Report

## Funding Sources

Total Annual Budget: $3.66 million
including matching funds from:
- Minnesota Department of Transportation
- University of Minnesota
- International Truck and Engine
- United Way
- International Road Federation

## Expenditures for Year One

July 1, 1999 – June 30, 2000

Administration: 10%

Education: 6%

Technology Transfer/Information Services: 14%

Research: 70%
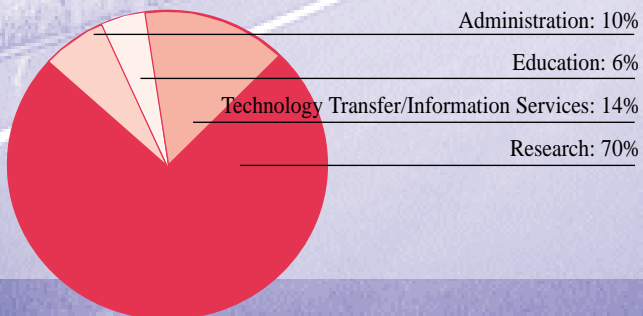
# Management Structure

The ITS Institute is part of and housed within the Center for Transportation Studies (CTS) at the University of Minnesota. Part of the Institute's successful reputation as a leader in the development and application of intelligent transportation systems and technologies is due to both its state and national partnerships, including those with CTS, the Minnesota Department of Transportation (Mn/DOT), private industry, and county and city engineers.

In addition, the Institute has established a satellite office at the University of Minnesota-Duluth (UMD). Institute staff is working with UMD faculty to identify transportation issues in northern Minnesota and to develop ITS-related research proposals that address those issues, including concerns unique to nonmetro areas.

The operation of the ITS Institute is overseen by its director, who implements its strategic plan and assumes overall responsibility for the Institute's success. In this role, he directs its pro-grams, 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 (RSPA) 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 the ITS Institute through research, education, and outreach activities. In addition, the leadership of CTS, through its group of directors, provides connections and access to an extensive transportation network. The Institute's location within the Center allows it to work seamlessly with CTS staff and benefit from its diverse outreach, administration, and communications skills.

"The ITS Institute, guided by a diverse board of transportation leaders, is significantly accelerating the research and development of technological innovations that will improve all modes of transportation."

*— Robert Johns,*
*ITS Institute Board chair and*
*Deputy Director, CTS*

# ITS Institute Board Members

**Robert Johns, Chair**
Deputy Director, Center for Transportation Studies

**Esam El-Fakahany**
Assistant Vice President for Research, University of Minnesota

**Art Leahy**
General Manager, Metro Transit

**Anne Beers**
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**Richard Graham**
President, Dakota Area Resources and Transportation for Seniors

**Al Steger**
Division Administrator, Federal Highway Administration

**Robert Benke**
Director, Office of Research and Strategic Services, Minnesota Department of Transportation

**Randy Halvorson**
Assistant Commissioner, Minnesota Department of Transportation

**Dick Stehr**
Division Engineer, Minnesota Department of Transportation

**Susan Coughlin**
Director and Chief Operating Officer, American Trucking Associations Foundation Inc.

**Pat Hughes**
Assistant Commissioner, Minnesota Department of Transportation

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John Hourdakis
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Jiann-Shiou Yang



*Panos Michalopoulos*



*Craig Shankwitz*



*Gary Davis*



*David Levinson*



*Nikolaos Papanikolopoulos*

## ITS Institute Laboratories and Facilities

The Institute works with over 30 faculty and staff from eleven University departments and uses the resources available to those faculty and departments, in addition to its own facilities that are described below.

### ITS LABORATORY

The Intelligent Transportation Systems (ITS) LABORATORY is used to test and evaluate new transportation management and operational strategies and traveler information technologies. The ITS LABORATORY serves a vital role in providing a safe environment for testing new strategies prior to implementation and supports the research, education, and training efforts of transportation faculty, students, and professionals.

The lab offers comprehensive simulation resources, such as AIMSUN2, KRONOS, and ArcInfo/ArcView; wireless communication and control to remote traffic sensing devices; a real-time microwave video downlink of the video traffic surveillance system located at the Minnesota Department of Transportation's Traffic Management Center; a direct fiber optic connection to the Institute's Human Factors Research Laboratory; video traffic and pedestrian sensing systems; a microsimulator integrated to programmable state-of-the-art intersection traffic signal controllers; and a real-time machine vision pedestrian, bicycle, and vehicular traffic sensing system.

The ITS LABORATORY also provides facilities to explore research areas such as advanced traffic management systems (ATMS), advanced traveler information systems (ATIS) integration, and incident detection methodology.

## Human Factors Research Laboratory

The Human Factors Research Laboratory (HFRL) provides facilities—including simulators and virtual reality equipment—and expertise to study the interaction between people and transportation systems.

Human factors researchers scientifically investigate human strengths and weaknesses to gain an understanding of the role of the individual in complex technological transportation systems. While discovering innovative ways to make existing technologies more user-friendly, they also use their findings to ensure that future products are designed with the human in mind.

HFRL research specializes in the simulation of real-world environments to study driver control and behavior. Specific research areas include driver reaction in accident-likely situations, driver aggression, collision-avoidance systems, traffic calming, and driver fatigue.

Researchers have access to a number of facilities, including a wrap-around driving simulator with a 360-degree immersive simulation environment housing a full-sized Acura; a single-screen, forward-view driving simulator using a Honda Accord; and virtual reality devices, including a head-mounted display, motion trackers, and data gloves.

## Intelligent Vehicles Laboratory

The focus of the Intelligent Vehicles (IV) Laboratory is to develop innovative human-centered technologies that improve the operational safety, mobility, and productivity of road-based vehicles. These human-centered technologies integrate sensors, actuators, computer processors, and specific human interfaces to provide drivers with needed information in difficult driving conditions such as low visibility, severe weather, and congested roadways.

Using the SAFETRUCK, an International 9400 tractor trailer, and the SAFEPLOW, an International snowplow, as experimental testbeds, research in the IV Laboratory focuses on driver-assistive technologies and human-centered design. A Metro Transit bus will soon be added to the vehicle fleet.

Driver-assistive system technologies under investigation include high-accuracy differential global positioning systems (DGPS); high-accuracy geospatial databases; radar and emerging range sensing technologies; collision-avoidance technologies; vehicle navigation, guidance, and control; and conformal, augmented head-up displays (HUDs).

Human interface components, designed based on human factors principles, work to integrate visual, haptic, and audible stimuli, project images that overlay the actual scene by using head-up technology, and integrate information from multiple sources in order to assist drivers in difficult situations as well as to accommodate older drivers.

## Other Facilities

### Signal Operations Research Laboratory

This laboratory consists of an advanced traffic signal controller, a microscopic intersection simulator, and an interface device that connects the controller and the simulator.

### Traffic Engineering Laboratory

The Traffic Engineering Laboratory contains simulation and traffic forecasting programs that researchers and practitioners use for traffic data analysis, demand forecasting, and transportation planning.

### Mn/ROAD High- and Low-Volume Road Test Facility

The Minnesota Road Research Project, Mn/ROAD, includes a freeway and a low-volume road pavement test track with 40 Portland cement concrete, asphaltic concrete, and unsurfaced test sections; 4,500 electronic sensors; a weigh-in-motion scale; a weather station; and DGPS correction signals. The ITS Institute uses the facility to test vehicles performing a range of experiments in areas such as collision avoidance, lane-keeping, warning systems, and augmented displays.

### Roadway Visibility Test Site

The Roadway Visibility Test Site (pictured, right) is located along Interstate 35 near Duluth, Minnesota. This site consists of fixed targets and video cameras used for automatic video-based visibility measurement and detection.

*Duluth, Minnesota*

Research

# Research

The Institute pursues research in 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, information, and communication (including sensing, measurement, and control systems)
- intelligent vehicles
- social and economic policy issues related to ITS technologies

The Institute's research program brings together 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 human capabilities to adapt to them.

Additionally, the Institute's geographical location gives it a unique advantage for developing research applicable to trans-portation in a northern climate with often hazardous winter conditions, and transportation in rural environments, which lie just beyond the Twin Cities metropolitan area.

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

The Institute's activities support all current ITS-related research projects, including those that began under the ISTEA-funded Institute. The first part of this research section of the Annual Report expands on a selection of projects under way, while the second part briefly describes all the other projects in progress. The third part reports on the projects selected to begin this coming year.

"I promote ITS because it aggressively moves new technology into transportation applications. Transportation was falling behind in utilizing new technology to provide better benefits to our customers. ITS falls into all my areas of responsibility for the planning, design, construction, operations, and management of state highways and for building advantages for transit into our roads."

*— Dick Stehr, ITS Institute Board member and Division Engineer, Mn/DOT*

# Highlighted Research in Progress

## Human Performance and Behavior

### Driver Performance in Accident-Likely Conditions

What happens to drivers in the last seconds before a crash—and if that's known, can something be done to prevent it?

These perplexing questions, and statistics showing that over 40,000 persons are killed each year in motor vehicle crashes, are driving the work of researchers at the Human Factors Research Laboratory (HFRL), a facility of the ITS Institute.

"That's the true value of ITS—improving safety," says Peter Hancock, professor of kinesiology/leisure studies and psychology and director of research for the HFRL.

With one of their latest projects, Hancock and research assistant Selma de Ridder are trying to discover how drivers react in the last vital seconds before a collision, and from this learn how general warnings could be communicated to drivers to promote avoidance behavior and prevent the collisions.

Since many crashes involve multiple vehicles, the researchers chose to study the interaction between two drivers in accident-likely situations. To do so, they created a unique simulation environment in which two individuals could each drive within the same virtual environment, seeing and reacting to each other's behavior in real time, by networking the lab's wrap-around simulator with its flat-screen simulator.

The researchers put a pair of drivers into a conflict situation requiring immediate mutual avoidance. To quantify the reactions of the drivers, the researchers used measures of collision-frequency, closest point of approach, swerve and brake behavior, and gas pedal usage. They calculated the closest point of approach and the point of first possible sight for the two cars, and, by examining the kinematic traces of steering and speed, determined at what point each of the cars responded to the imminent collision situation. Each driver's response was categorized as active, intermediate active, or passive based on brake and gas pedal usage between the point of first possible sight and the point of closest approach.

The results indicated that the crucial temporal window for interactive collisions in which the drivers' mutual actions



*HFRL researchers (left to right): Peter Hancock, Curt Olson, graduate student Ben Shihak, Peter Easterlund, graduate student Selma de Ridder, and Kathleen Harder.*

negate their avoidance intentions is between two and five seconds mutual viewing time. As a result, the researchers discovered that one of the situations they created afforded too little viewing time and so participants exhibited a random pattern of actions.

That suggested to the researchers that when drivers have too

little time to react, a collision-avoidance system should take over; if a driver has more reaction time, then perhaps the car's system can recommend a maneuver to avoid the crash.

In the next phase of this research, the HFRL team will examine a greater range of driving conditions, where drivers will be presented with extended viewing times to see at what point they can use information given to them in a systematic fashion to prevent collisions. They will also look at age-related differences in reactions of drivers, and ultimately hope the knowledge of how drivers naturally avoid collisions can be used to implement ITS technologies in vehicles that help, rather than distract, drivers.

## Orientation and Navigation in Elderly Drivers

As people continue living longer, those aged 65 and older are becoming a growing segment of the population. Unfortunately, drivers in this age group are already overly represented in the number of accidents per mile driven, and researchers want to know why. Many studies on elderly drivers have focused on vehicle control issues, including ways to improve roads and vehicles to accommodate elderly drivers. However, according to Professor Herb Pick of the Center for Cognitive Sciences, little research has been done on the main function of driving—that is, getting from place to place. While some recent research has centered on the use of in-vehicle navigation systems, there has been very little research on issues of spatial orientation and navigation while actually driving.

So Pick and graduate students Chryle Elieff and Selma de Ridder are studying the extent to which people have these problems as well as why the problems occur and how they may change with age. They recently surveyed a group of research participants, ages 25 to 65, about their travel route planning, their ability to stay on course and oriented to their surroundings during travel, and their methods of coping when lost or disoriented.

In the next phase of this research, Pick will use both actual on-the-road and simulated driving tests to study how quickly participants can learn an unfamiliar route as well as what



*Herb Pick in vehicle with graduate student Yen Nguyen and onlooker Mervyn Berggman of the Center for Cognitive Sciences.*

*Herb Pick (center) with students Yen Nguyen (left) and Hugo Bruggeman (right) on their "turntable."*

find that landmarks, for example, are particularly useful for younger drivers, that might suggest that elderly drivers should also focus on using landmarks to find their way," Pick explains. "We could then set up procedures to train older drivers on how to use landmarks to help them remain oriented while driving." Pick feels that the ability to train elderly drivers in this way will give them more confidence and help them retain a greater sense of self-reliance and mobility, all contributing to fewer driving accidents and a longer, better quality of life. Also, learning how humans use sensation and perception processes to navigate may lead to methods for maintaining or improving these processes as they degrade with age or to technologies for augmenting or replacing those human capabilities.

details, such as landmarks, they pay attention to along the route in order to learn it. Pick's goal is to find out if the drivers know anything more about the area surrounding the route than simply how to follow the route. With the simulator, Pick can vary the number and types of landmarks and study the impact of these, and other, variances as they relate to the driver's orientation and navigation abilities and age.

Finally, to study participants' sensitivity to orientation-related sensory information, Pick will ask them to judge how far they have turned using different sources of information: visual, biomechanical, and vestibular (inner ear). These sources are manipulated using a large turntable-like apparatus. For example, in one condition the participants will stand still on a stationary turntable, while the visual surround (a curtain) rotates. Under these conditions most participants experience themselves turning and feel the surround is standing still.

Once the data from each of these tests have been collected, the information will be analyzed and used in future projects geared toward helping drivers with poor orientation skill and spatial knowledge improve their driving performance. "If we

## Technologies for Modeling, Managing, and Operating Transportation Systems

### Capacity Estimation in the Freeway Weaving Areas for Traffic Management and Operations

If you've traveled on any major metropolitan freeway lately, you've probably seen firsthand just how jam-packed these systems have become. Some of the worst congestion problems occur at "weaving sections," where an entrance ramp is closely followed by an exit ramp. Even the most basic weaving sections are difficult for traffic managers to monitor and control because these areas involve complex vehicle interactions: diverging and merging vehicles must cross each other within weaving sections and quickly complete their lane changing maneuvers.

As more and more motorists crowd onto already-congested freeway systems, traffic engineers must develop effective traffic management strategies that maximize the use of existing roadway capacity. One of the most critical elements is to

understand how drivers behave in weaving areas and how the capacity of a given weaving section can be estimated in real time. Historically, little research has been done to address that particular need. For the past two years, however, Eil Kwon, the Institute's program director of advanced traffic systems and an adjunct professor in Civil Engineering, has worked with graduate student Drexel Glasgow and a team of engineers that has included members of Mn/DOT to develop an improved procedure that can estimate time-variant capacity for weaving sections.

Kwon's team selected six weaving sites throughout the Minneapolis-St. Paul metropolitan area and developed a database using data collected from loop detectors at those sites. They also used a prototype video-detection system, developed by a team led by Professor Nikolaos Papanikolopoulos of the Department of Computer Science and Engineering, to measure the speed of each vehicle changing lanes in a weaving zone. To collect video data from weaving areas, Kwon worked with Mn/DOT engineers, who assembled a mobile video recording system consisting of a special trailer and a 44-foot mast on which a video recorder was mounted.

The analysis of all the data from different weaving sites resulted in interesting observations in terms of driver weaving behavior. For example, under medium to heavy traffic conditions, drivers tend to change lanes as early as possible regardless of the lengths of weaving areas. Based on the results, Kwon developed an adaptive procedure that can estimate with reasonable accuracy the

maximum possible weaving volume of a simple ramp-weave section through time. This model is now being extended to analyze several other, more complex, types of weaving areas in the Twin Cities area. With the ability to accurately estimate weaving section capacity, traffic managers are better equipped to control traffic flow in these areas, and in turn, improve congestion problems throughout the freeway network.



*Eil Kwon with graduate students Sreemannarayan Nanduri (left) and Sejun Song (right) in the ITS Laboratory.*

## Computer-Aided Testing and Evaluation of Adaptive Ramp Control Strategies

Freeway ramp metering is one traffic management strategy that is receiving considerable attention, as metropolitan areas struggle to find a way to deal with increasing traffic and the safety and congestion issues that accompany it.

Once new traffic management strategies, such as those for ramp metering, are developed, they must be evaluated and tested; testing in the field with real traffic, however, is not feasible. That means that researchers and professionals must rely on simulation models, but current models have limitations. So Professor Panos Michalopoulos, research fellow John Hourdakis, and research assistant Koka Muralidhar of the Department of Civil Engineering set out to improve those models. With input from Mn/DOT, the researchers developed a new computer-aided simulation method that can adapt to the unique characteristics of individual freeways and situations.

What makes this system unique is that the entire simulation, database, and control logic package can be used to estimate parameters and compare and evaluate ramp control strategies interactively. Experimenting with new control algorithms will now be easier and more practical.

This new system uses a versatile microscopic simulator that the team enhanced to include an interface that allows the integration of any user-specified ramp control scheme and that automatically collects and feeds demand patterns to the simulator. To minimize the extensive and time-consuming task of entering initial and boundary conditions, the researchers prepared software to store data from 3,000 detectors into a relational database that can produce those conditions for any modeled section.

The team tested the system using an application in which Mn/DOT's real-time ramp control strategy was compared with the no control alternative. The simulation was implemented on a 24-kilometer (14.9-mile) segment of freeway in Minneapolis that included 20 exit and 20 entrance ramps controlled during the afternoon peak hours, six weaving sections, a lane drop section, and three bottleneck locations.

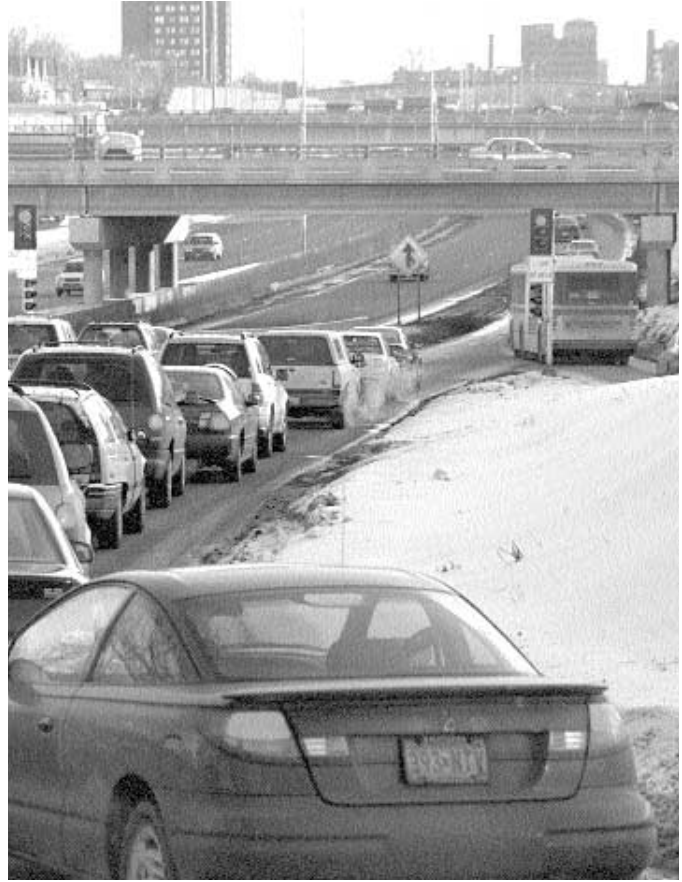The experiment consisted of two test cases, one involving



*(Clockwise from bottom left) Panos Michalopoulos, research fellow John Hourdakis, and graduate students Subramaniam Vijay Konduru and Koka Muralidhar.*

normal congestion, and the other with congestion increased by 20 percent. In each case, two simulations were performed with and without ramp control. The researchers collected and measured total travel time in vehicle-hours, total delay in vehicle-hours separately for the mainline and the ramps, and total travel in vehicle-kilometers for the whole network. Point specific statistics were collected for the three bottleneck sections, and each result was averaged over three simulations in order to minimize random fluctuations.

The results revealed that total travel time in the mainline decreased by 46 percent when control was introduced under normal congestion. Total ramp delays increased substantially as expected, but overall system total travel time was reduced by 35 percent and delays, by 62 percent. In heavy congestion, the total system travel time decreased by 24 percent and total delay by 39 percent. Similar improvements were also observed in the remaining measures of effectiveness. The researchers stress, however, that these results are preliminary and will need to be confirmed with other simulators, improved modeling, refinements in the assumptions, and calibration.

A more important outcome of the test application was that quantification of the results became a much easier task. The new method allows access to the quantitative results of continuously changing demand patterns without manual field measurements, and therefore should aid in the widespread use of simulation in practice as well as improvements in ramp control strategies and other traffic management methods.
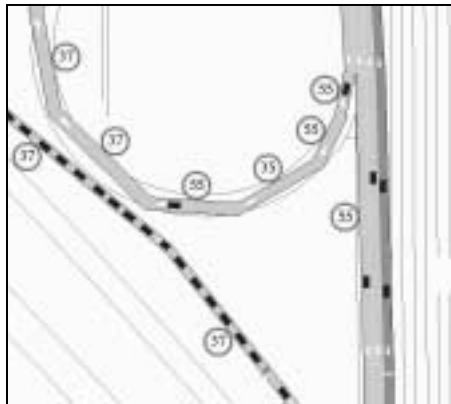


*The computer program shows simulated traffic moving through the highway system, including metered entrance ramps.*

## Computing, Information, and Communication

### Using ACC Vehicles to Control Traffic Flow on Semi-Automated Highways

New car buyers—get ready. The next generation of cruise control systems is on its way, taking standard cruise control systems to the next level. Rather than simply maintaining a set speed, the new Adaptive Cruise Control (ACC) systems automatically adjust a car's speed, as traffic situations change, to maintain an appropriate distance from the car ahead.

These systems were designed primarily for added safety and comfort; however, Perry Y. Li, Nelson Assistant Professor in the Department of Mechanical Engineering, is among the first researchers to investigate the use of ACC systems to improve traffic flow on highways. Li, along with graduate student Ankur Shrivastava, proposes that as ACC-equipped vehicle use increases, these systems may be effective in creating well-organized traffic patterns that will help reduce congestion without having to construct costly new highways.

The vision is that traffic managers could create certain traffic patterns using roadside structures that relay information to ACC-equipped cars regarding the type of pattern needed on the highway at that particular time. Each car's ACC system would respond accordingly by adjusting the speed and spacing from the car ahead.

"Right now we're using numerical simulations and mathematical theory to figure out how to design the ACC traffic control laws, or models, that tell us what the proper relationship should be between the speed and distance between cars," explains Li. "Next we'll need to determine exactly what information needs to be relayed to the vehicle's ACC system and how to relay it."



*Perry Li (right) with graduate student Ankur Shrivastava.*

When his current research wraps up next year, Li hopes to have developed the theoretical and modeling frameworks and the simulation tools he can use to analyze and evaluate how ACC systems impact traffic flow. In the next research phase, these tools will be used to design the information that will tell vehicles how to react in given traffic situations and establish a set of communication and computation requirements for the roadside infrastructure.

Li's concept is designed to work even if only a few vehicles on the highway are ACC-equipped, unlike previous "automated highway" research that focused on systems that required all vehicles on the road to be centrally controlled and equipped with ACC-type systems—an unlikely and costly scenario. Car manufacturers are beginning to introduce ACC-equipped vehicles, and Li's approach allows gradual and incremental introduction of the concept, making it more likely that the use of ACC systems as traffic control devices could become a reality within the next few years.

## Monitoring Weaving Sections

Freeway entrance and exit ramps are major contributors to traffic bottlenecks that are difficult for traffic engineers to solve. The biggest problem for engineers has been the inability to track vehicles that change lanes, cross paths with other vehicles, and merge with through traffic to enter or exit an expressway. Without this tracking ability, engineers cannot collect and accurately compute traffic data, and consequently, cannot accurately determine how to improve traffic flow in these "weaving areas."

Associate Professor Nikolaos Papanikolopoulos from the Department of Computer Science and Engineering, graduate students Osama Masoud and Surendra Gupte, and a team from Mn/DOT have now developed a portable, PC-based system designed to track vehicles and measure their direction (trajectories) and forward speed (velocities) as they change lanes in a weaving section.

Video cameras are used to capture images of vehicles moving through weaving sections. Engineers use recursive filtering techniques, which remove invalid measurements, and advanced segmentation techniques, which extract the vehicle images and take out unnecessary background objects, to accurately compute velocity and trajectory for as long as the vehicle is present in the image. Team members feed the videotaped images into the PC and key in a few geometric parameters, such as lane width, and the system produces the weaving data. To check the accuracy of the computation, engineers manually count and track vehicles as they change lanes within a specified time frame, and then compare that information with that of the computational algorithm.

Although the six-month project is in the beginning stages, the results so far are promising. The system tracks vehicles moving at high speeds and computes their trajectories with 70 to 80 percent accuracy. The system also groups vehicles by

class; since trucks are more dangerous than cars at weaving sections, it is useful for engineers to collect vehicle class data. All this information can be used to improve traffic control measures at weaving sections as well as to create real-time traffic simulations and traffic predictions, which traffic managers can use to better manage system-wide traffic flow.



*Nikolaos Papanikolopoulos*

Eil Kwon, an ITS Institute researcher and program director of advanced traffic systems, is using the system in his work to develop more accurate procedures for estimating maximum weaving section capacity. Use of vehicle-tracking systems will result in better designed, less congested, and safer roads. In addition, these systems can be used to monitor vehicle and pedestrian interactions at complicated urban intersections and possibly to predict situations that may evolve into accidents. Since every accident costs the economy real dollars and cents, vehicle-tracking systems have far-reaching financial implications and will be a factor in reducing the number of accidents as well as the resulting personal suffering.

## Development of a Next-Generation R/WIS

Minnesota's Road/Weather Information System (R/WIS) helps the state maintain safe travel conditions on roads in inclement winter weather. R/WIS is a customized computer network that collects, processes, and disseminates information related to current and forecasted road and weather conditions to users, typically maintenance engineers and traffic managers, to assist with snowplowing and deicing operations.

Mn/DOT's original R/WIS (consisting of 17 stations), however, suffered from several limitations that Associate Professor Taek Mu Kwon of the Electrical and Computer Engineering Department at the University of Minnesota-Duluth, students Scott Findley, Mark Sholund, and Erik VanGuilder, and Mn/DOT set out to resolve.

One problem with the original R/WIS was that it used equipment from different manufacturers, so communication to different R/WIS field stations was restricted by the proprietary structure of each manufacturer's network. And, since each manufactur-
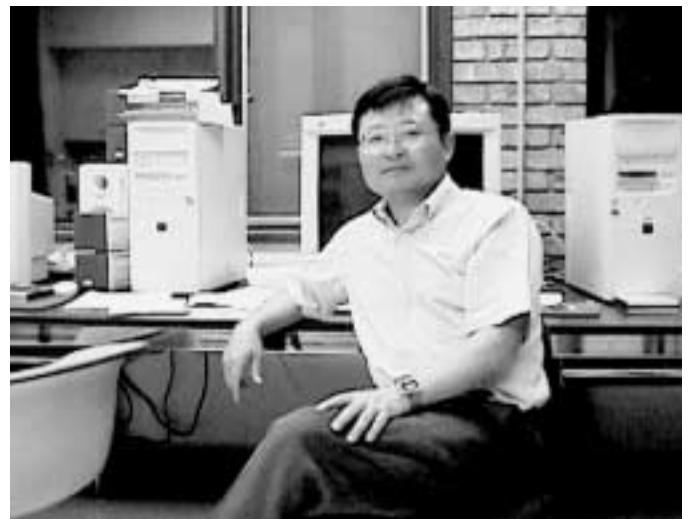


*Taek Kwon*

er's closed system was incompatible with the other systems, integrating newly developed sensors or improved technologies was extremely difficult.

The system was also based mainly on weather sensor-related information such as road surface temperature and wind speed, while one vital component—real-time video images of road scenes—was lacking.

Kwon's goal was to develop a "next generation" R/WIS (NG R/WIS) that could integrate the existing heterogeneous systems and grow with new technologies. He also wanted to make the resulting data available on the Internet and through an automated voice answering system so that many users could simultaneously access it through any networked PC or a telephone touch-tone key pad. The result was a working prototype system for Mn/DOT's District 1 in Duluth, which will serve as a testbed for the statewide model.

The NG R/WIS consists of four interacting hierarchical layers. The sensor layer gathers all the sensor data from the existing R/WIS system and passes them to the data integration layer, which unifies different formats. The database layer receives unified data formats from the data integration layer and stores them while networking together the servers in the layers to allow computer communication between them and the application layer. The user interface occurs in the application layer, which delivers data through three methods: Web service, automated voice-answering service (for those without Web access), and live video-stream service.

By accessing the Web, users can view a real-time data table and a graphic display; a 24-hour graph showing the trend of the



*Video cameras along the highway provide data on weather conditions for the Next Generation Road/ Weather Information System.*

pavement, air, and dew point temperatures; a 12-hour table that includes the types of data that cannot be expressed in the 24-hour graph; and live video images.

The added video component allows for verification of the data received from the weather sensors and provides information on traffic conditions, visible incidents, and other weather conditions that are unavailable from sensors alone. In addition, the visibility of an area can be computed by using a video camera-based visibility measurement system that Kwon has developed.

While Mn/DOT is currently incorporating these concepts into the statewide system, Kwon notes that, with additional work, the NG R/WIS could be further developed to include new technologies to deliver traffic information, snowplow information, pavement condition forecasts, and customized data (perhaps through e-mail) to specific groups or individuals.

## Intelligent Vehicles

## A GPS-Based Failure Identification System for Automated Vehicles

Imagine driving an intuitive automobile that warns you when you're about to collide with another object, alerts you when you inadvertently leave your lane, and helps you maintain an adequate distance from the vehicle in front of you.

While this may sound like a car from a science fiction tale, these, and other, automated driver-assistive systems are beginning to be used today in some passenger vehicles and in indus-

*Researchers are designing and testing a "failure warning" system on the Institute's SAFETRUCK.*

trial vehicles such as snowplows to increase driving safety and reduce freeway congestion. Since driver-assistive systems essentially relieve the driver of certain driving tasks, they require built-in diagnostic tools that can automatically identify and handle malfunctions in the system.



*Rajesh Rajamani*

Nelson Assistant Professor Rajesh Rajamani, from the Department of Mechanical Engineering, is heading up a team that is developing one such diagnostic tool. Since beginning this yearlong project in late September 1999, Rajamani and graduate students Jin-Oh Hahn, Chunyu Zhu, Kumar Santhanakrishnan, and Ankur Shrivastava have been designing and testing their "failure warning" system on the ITS Institute's SAFETRUCK, a semi-tractor test-rig (an International 9400) equipped with various automated driver-assistive technologies. The team's focus is to develop software that detects and identifies malfunctions in the automation system hardware; future research will be conducted to develop the system's response to a malfunction once it is detected.

So far, the team has developed mathematical vehicle models based on data collected from SAFETRUCK driving and road tests. They are using these models to develop the diagnostic software installed on the truck. The software continuously reads the signals from the system hardware, which consists of various sensors and actuators on the truck, to monitor the condition of the hardware. Rajamani says they have found it diffi-

cult to develop a reliable system to monitor the radar sensors, which measure the truck's distance to other vehicles on the highway. Since this measurement involves other independent vehicles with which SAFETRUCK has no communication, assessing the accuracy of the measurement is a significant challenge. Monitoring the hardware related to the SAFETRUCK's own operations will be easier, he says.

The team is designing their failure warning system around the SAFETRUCK's existing hardware, rather than adding more—or redundant—hardware. While this approach is more difficult, it will ultimately result in a less costly, more reliable product. "It would be much easier to build a diagnostic tool for a system with three radars, for example," Rajamani explains. "We could simply compare the radars to each other to determine how well, or not so well, they are working. Without that redundancy, we have to rely on mathematical models."

And while most fault diagnostic systems are based on linear mathematical models, the vehicle systems Rajamani is working with require complex, but more reliable, non-linear models, making their system one of the very few non-linear fault diagnostic systems ever developed.

Having recently received the National Science Foundation Career Award, which will provide four years of additional funding, Rajamani will continue to work on advancing viable vehicle automation systems that improve safety and solve traffic flow problems.

*IV team members from left to right: (top row) Heon Min Lim and Mike Sergi, (second row) Pi-Ming Cheng, Lee Alexander, and Craig Shankwitz, (third row) Bryan Newstrom, Max Donath, and Walter Trach, (bottom row) Sameer Pardhy.*

## IVI Specialty Vehicle Field Operational Test

Operating a snowplow is a difficult and dangerous task because the driver must often navigate on icy roads and in conditions of poor visibility caused by blowing and drifting snow. While clearing roads under these conditions, snowplow operators must also try to avoid obstacles such as moving and parked cars, bridge end treatments, signs, and guardrails. And drivers of other specialty vehicles, such as police cars and ambulances, are often required to operate in similar conditions.

To increase safety for these drivers, researchers at the ITS Institute's Intelligent Vehicles Laboratory have been developing and integrating vehicle-guidance and collision-avoidance technologies into a comprehensive system for the SAFEPLOW, an International 2000 snowplow that serves as an experimental testbed.

The IV lab team is working with other University researchers, including those from the Human Factors Research Laboratory, the Center for Transportation Studies, and the University of Minnesota-Duluth's Electrical and Computer Engineering Department, to optimize the human-machine interface and to document economic and societal benefits of wide-scale deployment of these systems.

And now those systems are being put to the test. The University was notified in October 1999 that it would receive $2.65 million from the Federal Highway Administration to conduct an Intelligent Vehicle Initiative (IVI) field operational test of the technologies over three years on a 46-mile (74-km) stretch of Minnesota Trunk Highway 7 between Hutchinson, Minn., and the Twin Cities. Mn/DOT, McLeod County, the city of Hutchinson, the Minnesota State Patrol, and private industry partners are providing additional resources and funding for this $6.5 million project.

This project is focusing both on reducing the risk of driving snowplows or emergency vehicles in low-visibility situations and on increasing public safety through improved emergency response and more efficiently plowed roads. Four snowplows, one state patrol vehicle, and one ambulance will be equipped with the driver-assistive technologies. The first two years of the study will be devoted to installing, testing, and refining the systems and training drivers. Actual field tests are planned for the third year.

The University team is providing the technical leadership for the development, testing, and integration of several vehicle navigation and control technologies. These include a centime-

*The SAFEPLOW*

ter-level differential global positioning system (DGPS), 3M's magnetic lateral-position sensing technology deployed along parts of the roadway, high-accuracy digital road maps, several types of radar, a "virtual" rumble strip, and a windshield head-up display (HUD). The positional technologies are used to determine snowplow location, speed, and heading, which together with the geospatial database, project a virtual view of the roadway directly into the driver's field of view. Moreover, the position and database information is fused with radar information to provide the range, range rate, and azimuth angle to obstacles blocking the path of the snowplow and to the other vehicles around the plow. This information is represented in the HUD, which serves as the primary human-machine interface.

The HUD, developed by University researchers, allows drivers to "see" the road via a projected image of lane boundaries, fixed roadside features, and obstacles detected by radar. Haptic feedback is provided using a virtual rumble strip. This technology, also developed at the University, simulates a physical rumble strip by oscillating the steering wheel, thus replicating the feel and sound of a vehicle driving on a physical rumble strip embedded in the road or shoulder, in the event of an unwanted lane departure.

## Social and Economic Policy Issues Related to ITS Technologies

### Telework, Telecommunications, and Community Design

The increasing use of telecommunications services by companies and communities can have both a direct and indirect impact on travel behavior and ultimately, the design of communities. However, research into how intelligent transportation systems and related telecommunication systems can be woven into the design and redesign of communities to enhance livability is relatively uncharted territory. Beginning in late 1999, the State and Local Policy Program (SLPP) at the Humphrey Institute of Public Affairs began a yearlong project to examine and propose community planning tools, methods, and activities to help incorporate ITS and telecommunications into community design and development practices.

This project builds upon previous SLPP research by developing more in-depth data on behavioral impacts of telecommuting activities used in public and private employer programs. As their primary research tool, the team of Humphrey Institute researchers, led by Lee Munnich, senior fellow and director of SLPP, and Frank Douma, SLPP research fellow, will use employer case studies that include structured interviews and an Internet-based survey conducted with management-level employees regarding the organizational and behav-

ioral impacts of telecommuting. The results of the project will be used to develop practical information about the community impacts of telecommunications services and will assist Mn/DOT, as well as private and other public employers, in developing telecommuting programs and in understanding the trends affecting transportation demand. The information produced is important, since telecommuting may help reduce the need for travel and also serve to substitute one type of trip for another, for example, work or commuting trips for shopping.

Using these case studies and surveys as starting points, an interdisciplinary team representing transportation policy and urban planning, law, and design will select several communities that are all working to develop a master plan for their communities. The team will conduct a "design studio" on commu-

nity deployment of information technology. The primary goal is to build a practical set of information technology planning and evaluation guidelines and tools for community design. Building upon the guidelines developed in the design studio, the research team will meet with several communities interested in adopting ITS and telecommunications services as part of their community design and development strategies. The meetings will serve as a forum for drafting community action and funding plans. The information gathered from both the design studio and community meetings will be used to develop an evaluation framework to gauge the success of community information technology strategies as a sustainable development strategy.

The results from this research project will be used to develop practical guidelines for implementing ITS and related telecommunications services to improve the livability of Minnesota communities. As such, this project will provide communities with planning tools and approaches that will help them realize the possibilities of new digital technologies. This research will also produce better data to guide planners and policymakers in land use, community design, transportation planning, and service delivery.



*Humphrey Institute staff includes (clockwise from bottom left): Andy Mielke, Frank Douma, Lee Munnich, Hannes Loimer, Marit Enerson, Mike Rentz, Cynthia Pansing, Jennifer Ward, Janice Young.*

## Specialized Transit and Elderly, Disabled, and Families in Poverty Populations

Dakota Area Resources and Transportation for Seniors (DARTS) and ITS Institute staff, led by Dawn Spanhake, recently completed the first of two phases in a project on specialized transit.

The first phase included identifying transportation accessibility issues for a target group of users. Three separate listening sessions were held in March and April with a focus on specialized transit and the elderly, specialized transit and the disabled, and specialized transit and families in poverty. The listening sessions provided a forum for discussing needs, issues, and future plans for specialized transit and revealed that the populations experience three common barriers: the need for coordinated resources among all service providers; a lack of flexible transportation options; and the need for transportation-oriented developments and better community planning.

The most prevalent issue—the need for coordinated resources among the various service providers—goes beyond shared funds to also include the use of shared information, shared drivers, and even shared facilities.

Each population identified the lack of transportation options and lack of flexibility as a major issue. For the elderly, the majority of transit users are those who are no longer able to drive. Since they are accustomed to the freedom and flexibility of car ownership, their expectations for transit are high. Many will stay at home rather than ask for help or use transit. In addition, the elderly are typically reluctant to use transit due to its perceived safety risk and their own increasing frailty, and because the services provided do not meet their needs.

For the disabled, it is not a matter of loss of freedom, but rather, a lack of available transportation options that accommodate their disability. The trend for community-based living is compounding the transportation problem for the disabled. Much of the affordable and available housing for the disabled is located in the suburbs, where transportation options are limited. Additionally, the developmentally disabled may require supervision, which often limits transportation choices.

Families in poverty require perhaps the most flexible transportation options. For those poor who have jobs but no access to cars, they may work second or third shifts when transit service is unavailable. Many families in poverty also struggle with cultural and language barriers.

Transit-oriented developments and smarter community planning should be a priority for planners and policymakers. New developments should consider access to jobs, education and training, transportation, and human service facilities.

The second phase of the project is currently under way. In this second phase, DARTS will use the listening session information to develop a logistics support service, and the ITS Institute will work with University researchers to develop a specialized transit research agenda to include the application of ITS technologies. Final report publication is anticipated for late fall 2000.



## Abstracts of Other Selected Research Projects in Progress

*Projects listed in alphabetical order by principal investigator.*

### Image Compression for Storage and Transmission of Digitized Images

*Principal Investigator: Vladimir Cherkassky, Department of Electrical and Computer Engineering*

The Mn/DOT Office of Land Management is responsible for providing digital mapping products for maintaining the state's transportation system. Due to the current trend toward digitization of the image/map data and Web-based delivery of services, there is a need for compressing large image data sets, such as aerial photographs and maps. Such a compression is needed for efficient storage and retrieval of the hang data, as well as for data transmission over (low-capacity) Internet connections. This research will investigate applicability of several commercial and research methods for image compression to the needs of the Office of Land Management. Benefits of this research—a recommendation on image compression method or products—will have a long-term effect on the digitization and transmission of image data by the Office of Land Management.

## Psychological and Roadway Correlates of Aggressive Driving

*Principal Investigator: Kathleen Harder, College of Architecture and Landscape Architecture*

The AAA Foundation for Traffic Safety, the National Highway Traffic Safety Administration, and the Federal Highway Administration have identified road rage/driver aggression as one of the major threats to safety in future roadway environments. This research is an interdisciplinary effort to understand the extent to which pre-existing cognitions, emotions, roadway conditions, and attitudes toward driving contribute to aggressive driving. The general goal is to identify factors that prompt aggressive driving behavior and to examine them in a simulated driving environment at the Human Factors Research Laboratory. Previous studies on aggressive driving have failed to address factors that can precipitate aggressive driving as comprehensively as proposed in this study. Results obtained from the survey and subsequent experimental analysis will yield a rich resource of information for educational outreach throughout Minnesota and beyond, with the goal of reducing incidents of aggressive driving.

## User-Centered Auditory Warning Signals in Snowplows

*Principal Investigator: Kathleen Harder, College of Architecture and Landscape Architecture*

Given the visually demanding work environment of snowplow drivers, the Mn/DOT Office of Advanced Transportation Systems has identified a need for human factors research into the type of auditory warning signal that most effectively communicates the intended message. This project will develop a virtual snowplow environment at the Human Factors Research Laboratory (HFRL) to investigate the effect of in-vehicle auditory warning signals on driver behavior with the goal of improving safety for snowplow drivers and other drivers on the roadway. The capability to visualize and test the effectiveness of various auditory warning signals in a virtual snowplow environment provides the opportunity to identify the optimal system before substantial resources are devoted to final implementation. The study addresses the following objectives: replicate a snowy roadway in Minnesota in a virtual environment at the HFRL, use the wrap-around driving simulator at the HFRL to determine the optimal acoustic features of various warning signals and their placement in the vehicle, and analyze the ways in which auditory cues affect the behavior of snowplow drivers. The chief benefit will be the information gained from identifying which auditory warning signals most completely and effectively convey the intended message in snowplow environments.

## Signal Operations Research Laboratory for Development and Testing of Advanced Control Strategies: Phase II

*Principal Investigator: Eil Kwon, ITS Institute*

A virtual network environment where new advanced control concepts can be refined and tested prior to field implementation is critical for developing an efficient network control strategy that has real-time operational capability. The previous phase of this research developed a pseudo real-time testing environment for a single intersection by integrating an advanced traffic controller and the newly developed microscopic traffic simulator through the signal converter that was also developed in the previous phase. The resulting virtual

intersection environment is being used to improve traffic models and refine and test a new adaptive control strategy for an intersection. Phase II will expand the current research effort by developing a pseudo real-time testing environment for a network of intersections and freeway ramps. Further, alternative concepts for optimal management of corridors will be formulated based on the capabilities of state-of-the-art control hardware and sensor technologies. The new control method will be based on adaptive system identification and will make control decisions using sectionwide system performance directly quantified with detector measurements. The evaluation of new corridor control strategies under the virtual network environment will be performed in the subsequent phase of this research. The ultimate goal of this research is to develop a next-generation, adaptive management strategy that can be implemented in real time for a network of intersections and freeway ramps. The final product, a virtual network laboratory, will also be used as an education and training tool for undergraduate and graduate students and practicing engineers.

## An Automatic Visibility Measurement System Based on Video Cameras: Phase II

*Principal Investigator: Taek Mu Kwon, Department of Electrical and Computer Engineering, UMD*

The objective of this research is to continue to develop and refine an automatic visibility measurement method based on video cameras to meet the requirements of Mn/DOT's statewide Road/Weather Information Service (R/WIS). The Mn/DOT statewide system includes many pieces of real-time video equipment that provide live video streams to users.

Video images can vary drastically depending on the type of cameras and digitizers used, lighting conditions, bit resolutions, etc. In order to cope with the requirements of accepting different types of video equipment, the algorithms developed must now include an automated calibration system to allow the visibility evaluation to be consistent. The goal of this research is to develop the calibration algorithms or methods and integrate them into a single unified system, which could function as a sensor module for the statewide R/WIS. In addition, the main algorithms developed in the last study will be further refined. The benefits of this research would go directly to the travelers of Minnesota highways and Mn/DOT decision makers.

## Reassessment of Road Accident Data Analysis Policy in Minnesota: Do We Use the Data We Have? What More Can Be Learned?

*Principal Investigator: Eitan Naveh, Center for the Development of Technological Leadership*

While airplane crashes are studied and scrutinized from all angles to determine how such disasters can be prevented, much more systematic data analysis of road accidents is needed for the same reasons. This research will address two questions: What more can be learned from Minnesota's existing road accident data? (It seems that accident data are not being used as an improvement initiator when they could be.) And, what data are missing for the purpose of reducing Minnesota's accident rates, and how can this information be collected? The research objectives, which will concentrate on Minnesota road accident statistics, are to assess current statistical data analysis policy of road accidents, such as data collection, data quality assurance, and analytical methods, in order to gain a better

understanding of the causes of road accidents based on existing data. The researchers will identify independent, control, mediator, and moderator variables and develop new methods and criteria for data collection and analysis of road accidents.

### Detecting Driver Fatigue Through the Use of Advanced Face-Monitoring Techniques

*Principal Investigator: Nikolaos Papanikolopoulos, Department of Computer Science and Engineering*

By monitoring several fatigue-related indicators (e.g., eye movements, steering patterns, heart rate), the symptoms of driver fatigue can be detected early enough to avoid several types of accidents. The research during this project consists of face detection; monitoring through the use of skin color information; use of low-light cameras, infrared sensors, and automatic pan-tilt-zoom mechanisms; real-time computation of the "PERCLOS" Measure; and experiments at a driving simulator.

### Driver-Assistive Systems for Snowplows

*Principal Investigator: Craig Shankwitz, Department of Mechanical Engineering*

Operating a snowplow is a difficult and dangerous task. The snowplow driver faces problems due to environmental conditions and low-visibility. In addition, snowplow drivers are stressed because of long hours and the tasks (avoiding obstacles and determining and setting the application rates of deicing agents) required to successfully clear streets and highways. Since many of the problems faced by snowplows also affect heavy trucks, buses, ambulances, police cars, and other specialty vehicles that are required to operate in all weather conditions, the results from this work can be applied to these vehicles as well.

The emphasis of this project is on human-centered technology, which is the development of technology designed to work with humans to increase their productivity, safety, and well being. The work is aimed at snowplows, which typically operate under difficult environmental conditions. The technologies addressed here include vision enhancement, forward collision and rear impact warning and avoidance, obstacle warning and avoidance, and driver assistance in task performance (steering, throttling, and braking). The researchers will focus on the integration of radar with high-accuracy geospatial databases and DGPS, modeling of snowplow dynamics in icy conditions, and applications of the virtual bumper. Methods of evaluation will also be developed.

### High Performance Spatial Visualization of Traffic Data

*Principal Investigator: Shashi Shekhar, Department of Computer Science and Engineering*

The objective of this project is to develop high performance spatial tools and techniques to generate critical visualizations of loop-detector traffic data collected at Mn/DOT's Traffic Management Center. High-performance visualization techniques are becoming crucial as the wealth of traffic data collected by an ever-increasing network of sensors is growing much faster than can possibly be analyzed manually. For example, producing a three-dimensional visualization of speed as a function of time and highway network space for a single day's traffic data can take up to a week using the current tools. The performance bottleneck forces visualizations to be limited to a very small sample of traffic data out of the data set collected by the sensors. This bottleneck makes it hard for traffic

researchers to perform interactive visualization when asking "what if" questions. Interactively changing the variables selected for visualization and drilling down to smaller subsets (e.g., a traffic zone, a corridor, a lane) for further details is difficult due to the performance bottlenecks caused by the large volume of traffic data.

## Reducing Risk-Taking at Highway At-Rail Grade Crossings with Supplemental Visual Warnings

*Principal Investigator: Thomas Smith, School of Kinesiology and Leisure Studies*

There is a widespread belief among rail safety professionals that drivers who ignore highway rail grade crossing warnings, and proceed through crossings despite the warnings, are responsible for the majority of rail crossing accidents. Some rail safety experts believe that the best solution to the problem is to eliminate highway rail grade crossings altogether. Unless or until this occurs, however, it can be argued that reduction of risk-taking behavior by drivers at rail crossings will tend to reduce the magnitude of the rail crossing safety problem. The premise of this research is that provision of a supplemental visual warning of the oncoming train at rail crossings will be effective in reducing risk-taking behavior of drivers, and therefore will benefit rail-crossing safety. Although this project proposes to document this benefit in the Human Factors Research Laboratory driving simulator, the laboratory findings could readily be validated under field conditions by appropriately configuring an actual crossing and using the Mn/DOT grade crossing camera monitoring technique.

## Abstracts of Newly Funded Research Projects

*Projects listed in alphabetical order by principal investigator.*
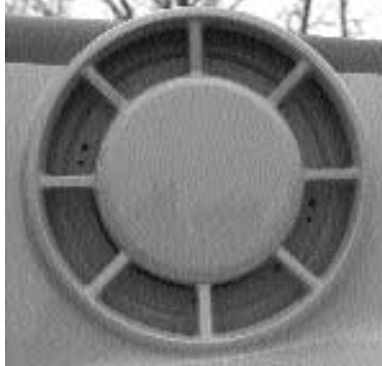
### Lateral Stability of Narrow Commuter Vehicles

*Principal Investigator: Lee Alexander, Department of Mechanical Engineering*

The inevitable increase in metropolitan traffic congestion creates a need for commuter vehicles that take up less space on the road than the standard automobile. Since the majority of the cars on the road during rush hour have only one or two occupants, one approach is to design a narrow vehicle that can carry one passenger in a seat directly behind the driver. The width of this vehicle, about 1 meter (3.3 feet), would be such that two vehicles would be able 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 that the lane can handle. A motorcycle is one example of a narrow vehicle, but one with obvious disadvantages in Minnesota winters. A practical narrow vehicle of this type will have to be stable at all speeds and on all surfaces (including snow and ice), be warm on the inside, and be easy to get into and out of. The roll stability of this vehicle when cornering will depend on an active suspension control system that will allow it to react to lateral forces by leaning like a motorcycle even though it has more than two wheels. In this effort researchers propose to extend the work of earlier researchers in this field by implementing modern sensors, actuators, and control design methodologies on a one-third scale model of this type of vehicle.

The researchers will explore control strategies that will allow such a vehicle to operate on slippery roads without

requiring undue skill from the driver. Future work should include the study of human-machine interfaces (including drivability and comfort), the safety envelopes, and collision avoidance for such a machine.

**Compression of Real-Time Traffic Data**

*Principal Investigator: Vladimir Cherkassky, Department of Electrical and Computer Engineering*

Currently, traffic data (i.e., the highway volume and occupancy data) are collected over 30-second intervals. The sheer volume of these data poses two major problems preventing its efficient utilization: expensive storage requirements and slow database access of pertinent information for future use. For these reasons, the 30-second data are being kept only for a short time. The goal of this project is to apply data compression algorithms to the 30-second traffic data in order to reduce the storage costs and enable fast database retrieval without degrading its representation accuracy for congestion periods. The researchers will also investigate the possibility of compressing 5-minute traffic data currently stored on CD-ROMs in order to reduce storage requirements and to speed up database access.

**A Case-Control Study of Driving Speed and Crash Risk**

*Principal Investigator: Gary Davis, Department of Civil Engineering*

This study will investigate the role of vehicle speed as a risk factor in traffic crashes. A case-control study design will be used in which the estimated speeds of vehicles involved in crashes will be compared with the speeds of appropriately selected control vehicles. Accident reconstruction methods will be used to estimate the speeds of the vehicles involved in the crash, and methods for assessing uncertainty in accident reconstructions, recently developed by the principal investigator, will be employed. A functional relationship between speed and the relative risk of crash involvement will be developed.

**A New Approach to Assessing Road User Charges**

*Principal Investigators: Max Donath and Pi-Ming Cheng, Department of Mechanical Engineering*

This research proposes to design a road user charge system that avoids the problems and shortcomings of current mechanisms while having the following desirable attributes: low collection costs for both agency and user; a stable revenue stream; higher user charges for users who impose higher costs (e.g., road damage by heavy vehicles and contributions to congestion delays by autos); a low evasion rate; incentives for users to travel on appropriate roads and across time periods; the ability to remain unaffected by the method of vehicle propulsion; and a sufficiently fine-grained structure to allow segment-specific pricing. The approach should not be burdensome to road users and should be tamperproof, highly reliable, and flexible enough to be a useful tool for achieving a variety of policy objectives through road pricing. The objective is to weave a host of desirable attributes into a relatively simple approach for charging road users. Technologies that will be investigated are differential GPS integrated with digital maps. To carry out the study objective, the researchers must address a series of institutional and technological issues, ranging from the accuracy of vehicle-positioning technologies to public policy considerations such as phase-in measures and protection from inappropriate use of travel records.

**Driver Behavioral Response in Incipient Accident Conditions: Phase II**

*Principal Investigator: Peter Hancock,*
*School of Kinesiology and Leisure Studies*

This project is the second phase of a sequence of investigations into driver behavior in accident-likely conditions. In Phase I, the researchers created and researched situations in which drivers had to avoid each other in a shared simulation world. Viewing time conditions in these experiments allowed only for a single avoidance maneuver, typically a unidirectional swerve. These results confirmed that warning technologies are not likely to be useful with under two seconds of viewing time, and so more automated systems are required. The present work seeks to extend viewing times out to six seconds and to evaluate mutual avoidance behaviors in light of the proposed characteristics of ITS warning and crash avoidance aids.

**Reducing Crashes at Controlled Rural Intersections by Identifying Effective Countermeasures**

*Principal Investigator: Kathleen Harder, College of Architecture and Landscape Architecture*

Right-angle crashes at controlled rural intersections are of significant concern. It is currently believed that there are two types of problems at these intersections: 1) drivers do not stop, or 2) drivers stop and then pull out into oncoming traffic. The objective of Phase I of this project is to generate innovative ways in which to address and diminish these two sets of behaviors with the overall goal of improving safety in these problem areas. The researchers do not anticipate solving the problem in Phase I, but do expect to make substantive progress toward facilitating creative resolutions to safety-related issues now present at rural intersections.

**Capacity Analysis for Dynamic Bottlenecks and Alternative Concepts for Coordinated Ramp Metering Operations**

*Principal Investigator: Eil Kwon, ITS Institute*

Freeway bottlenecks are, in general, caused by physical geometry changes and/or by conflicting flow patterns, such as merging or weaving flows, which reduce the maximum amount of flow that can pass a given location. While the capacity of conflict-based bottlenecks is heavily dependent upon the time-variant traffic patterns within bottleneck areas, a geometry-based bottleneck, e.g., a lane-drop or a bridge with narrow shoulder, can also be wiped out by a downstream queue that grows past the bottleneck location. The capacities of both types of bottlenecks are further affected by continuously changing weather conditions. This project will address the above issues by developing a dynamic procedure to update capacity values for given bottlenecks. Further, as a first step toward developing a next-generation metering algorithm incorporating ITS technologies, alternative concepts for coordinated ramp metering will be formulated. The detailed algorithms that have real-time operational capability will be developed in the subsequent phase of this research.

**Dynamic Estimation of Freeway Weaving Capacity for Traffic Management and Operations: Phase II**

*Principal Investigator: Eil Kwon, ITS Institute*

Understanding the behavior of weaving flows and estimating the effects of time-variant traffic conditions on the capacity of weaving areas is important for developing effective operational strategies, which can achieve the maximum utilization of existing capacity for a given freeway system. The previous phase of this research identified and classified the major weav-

ing 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 (119 out of 226), were analyzed. An online model was developed to estimate the time-variant capacity of Type A ramp-weave sections. This research will expand the previous work by testing and refining the online estimation model with an expanded data set. The variation of Effective Weaving Zone, identified in the previous phase, will also be modeled and tested with real data. In addition, the incorporation of the online capacity model into the current ramp metering algorithm will be studied. Finally, the traffic behavior of multi-lane ramp-weave sections will be analyzed and the variation of capacity in those areas will be modeled with data from selected weaving sites.

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

Traffic simulation is only as good as its input data. Unfortunately, it is impossible to directly 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 the Center for Transportation Studies has produced a viable method for estimating freeway Origin-Destination (O-D) patterns from loop detector data. This research will further develop and apply this method to estimate O-D demand for use in traffic simulation of freeway sections and corridors. The researchers require zone-to-zone traf-

fic flows from a transportation planning model and the flows entering (and ideally exiting) on freeway ramps. The objective is to estimate the traffic from each on-ramp to each downstream off-ramp in short time intervals. This research will include development and implementation of software to enable the method to be used conveniently with easy-to-collect data. It will then apply the method to selected corridors, including I-35W and I-94, being analyzed in the Laboratory Environment for Traffic Analysis (LETRAN).

**Measuring the Equity and Efficiency of Ramp Meters**
*Principal Investigator: David Levinson, Department of Civil Engineering*

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 aims to test alternative control strategies on both efficiency and equity criteria and to develop a new strategy designed explicitly to include equity measures. This new strategy will be coded, tested, and compared with available alternatives.

**Evaluation of Ramp Control Strategies in the Twin Cities**
*Principal Investigator: Panos Michalopoulos, Department of Civil Engineering*

As freeway traffic congestion spreads, ramp metering is implemented to address the problem. However, recently there is increasing opposition to freeway ramp control because of excessive ramp delays. The objective of this research is to

employ a recently developed tool called the Traffic Management Laboratory (TRAM-LAB) for assessing the effectiveness of Mn/DOT's control strategy in two Twin Cities freeway sections totaling approximately 45 miles (72 km). Two additional control strategies developed and deployed elsewhere in the United States will also be implemented in TRAMLAB and tested on the same freeway sections for comparison purposes. As a result of this testing, TRAMLAB will evolve into an effective tool for developing control strategies that could reduce ramp delays without excessively increasing freeway congestion. Finally, a new traffic management concept for early detection of incident-prone traffic conditions will be developed and integrated for traffic management through ramp metering and variable message signs in order to smooth flow and prevent (to the extent possible) incident occurrence, thereby further reducing delays and improving safety.

**Integrated Planning and Financial Strategies for Sustainable Transportation Alternatives in Minnesota**
*Principal Investigator: Lee Munnich, Hubert H. Humphrey Institute of Public Affairs*

This research project will build upon past State and Local Policy Program research on the role of advanced transportation technologies (ITS and telecommunications) in fostering sustainable development. More specifically, this project will explore the institutional characteristics of current rural and urban Minnesota transportation planning and financing approaches that impede the planning, implementation, maintenance, and evaluation of multimodal transportation alternatives, especially advanced technologies such as ITS and telecommunications. In part, an integrated approach to trans-

portation planning and financing would help overcome these barriers and foster sustainable development and smart growth in Minnesota. Current planning and financing efforts under way by state, regional, and local agencies could be better coordinated, possibly restructured, and integrated to promote sustainable development and smart growth. Public/private partnerships also may play a viable role. In addition, integrated planning and financing tools and methods need to be made available to such agencies in order to promote multimodal transportation options and sustainable development.

**Managing Suburban Intersections Through Sensing**
*Principal Investigator: Nikolaos Papanikolopoulos, Department of Computer Science and Engineering*

Since traffic lights guide but do not monitor the traffic situation at an intersection, they do not offer the users much protection against aberrant behaviors such as red light violations by cars or by pedestrians. Neither do they take into consideration the special needs of users such as older pedestrians, parents with small children or infants, and large trucks, all of which may require a longer time to cross the street or make a turn. The traffic lights need to be programmed according to federal mandates and should discourage behaviors that do not follow rules.

With this project, the researchers will develop an intelligent monitoring system for suburban intersections equipped with vision modules to monitor the traffic conditions and use such information to dynamically adjust the duration of the signal periods. The objectives are to improve the safety of crossings for pedestrians as well as for cars and to reduce unnecessary traffic holding time.

**Sensor-Based Ramp Monitoring**
*Principal Investigator: Nikolaos Papanikolopoulos, Department of Computer Science and Engineering*

This work describes a methodology for integrating sensing (in this case, a vision sensor or a laser scanner) with discrete control. Moreover, the proposed approach can accommodate a moving sensor in order to improve the accuracy of the measurements. The researchers plan to adapt the algorithms developed for work zone monitoring and pedestrian detection in order to analyze the ramp queue. Their philosophy is to treat traffic objects as entities with specific but diverse characteristics. After the detection and tracking, the relevant information can then be fed to the controller. Their "true" tracking approach can detect and track vehicles (vehicle classification is even possible) and monitor their status (e.g., velocity, changes in lanes). The proposed system can also monitor traffic speed on the freeway. As the freeway becomes less congested, the ramp meter rate can be adjusted in order to address the new situation. Thus, adaptive ramp control can use a combination of traffic data from the freeway as well as the ramps by using a simple and flexible PC-based approach. Furthermore, an adaptation mechanism may be used to compute the appropriate action of the traffic controller. Finally, the camera model and the noise characteristics of the vision measurements can be included in the design of the traffic controller.

**On Automated Vehicle Control Algorithms and Their Influence on Traffic Flow**
*Principal Investigator: Rajesh Rajamani, Department of Mechanical Engineering*

This project is a new strategic initiative for the study of automated vehicle control algorithms (such as those used in adaptive cruise control) and their influence on highway traffic flow. A team of researchers with unique skills in vehicle control, traffic modeling, and traffic flow simulation has been established to lead the project. The team proposes to analyze vehicle-following algorithms from the perspectives of 1) the individual vehicle, wherein safety, comfort, and time-to-destination resulting from the algorithm are of importance, and 2) highway utilization, wherein higher traffic flow and stable traffic patterns are of importance. An evaluation of standard adaptive cruise control algorithms demonstrates how individual vehicle benefits are often obtained at the cost of highway traffic flow. Preliminary results on new vehicle-following algorithms indicate that better traffic flow patterns can be promoted without any deterioration in individual vehicle safety or comfort. This project will concentrate on development of new vehicle-following algorithms and on a rigorous analysis of such algorithms in a unified framework. Theoretical analysis and microsimulation traffic tools will both be used extensively in the analysis.

## Eliminating Driver Blind Spots at Rural Intersections: Effects of Signage and Vehicle Velocity

*Principal Investigator: Michael Wade,*
*School of Kinesiology and Leisure Studies*

This study seeks to determine the influence both of signage and approach speed in determining the occurrence of driver blind spots at rural intersections. Collisions and near collisions may be a function of blind spots generated by the width of the front doorpost of the vehicle. When subtended at a distance of 500 feet (152.4 m), a 4-inch (10.2-cm) doorpost can produce a blind spot as wide as 4 feet (1.2 m) in the driver's field of view. This problem has been reported by traffic engineers, especially at rural intersections where the signage employed is a yield sign on the minor road intersecting the major road. In many instances, collisions or near collisions occur and drivers report "failure to see the other vehicle." The speed of the vehicle, the use of yield signage, and the failure of drivers to orient about the sight line on either side of the blind spot generated by the doorpost may all be candidates for investigation. Via simulation, the researchers will determine the bandwidth fidelity dilemma of this blind spot as a function of vehicle approach speed. They will also evaluate strategies that drivers may use to check for approaching vehicles coming at right angles to their trajectory path in such a way as to avoid potentially fatal accidents. The researchers will create a rural intersection scenario using the simulator in the Human Factors Research Laboratory. The subject driver will respond to a random distribution of simulated vehicles approaching at various but realistic speeds. Velocities of the two vehicles would be both different and at times the same. First principles suggest that coincident deceleration may maintain the blind spot. This can be trigonometrically determined, but has yet to be verified in simulation.

## Traffic Flow Modeling and Simulation of the Miller Hill Corridor

*Principal Investigator: Jiann-Shiou Yang,*
*Department of Electrical and Computer*
*Engineering, UMD*

This project will study the traffic flow modeling, simulation, and signal timing plan evaluation for the Miller Hill Corridor along Highway I-94 (Central Entrance-Miller Trunk Highway) between Haines Road and Arlington Avenue, one of the most heavily traveled and congested roadways in the Duluth, Minn., area. Along this 2.3-mile (3.7-km) corridor, eight signalized intersections and seven road segments will be investigated. The researchers will develop a real-time traffic data collection system so that it can improve data accuracy and provide useful data in some locations on the corridor not currently covered by the existing loop detectors. Traffic flow modeling using a "hybrid" approach will be conducted, then identified and properly tuned by using collected data model parameters. Based on the dynamic models developed, a traffic-flow simulation system will be integrated and implemented to perform the traffic flow simulation study, and the results will further be analyzed and used to evaluate alternative traffic signal timing plans on the corridor. The ultimate goal of this research is to provide a better signal timing plan to improve the efficiency of traffic movement in that area.

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Education
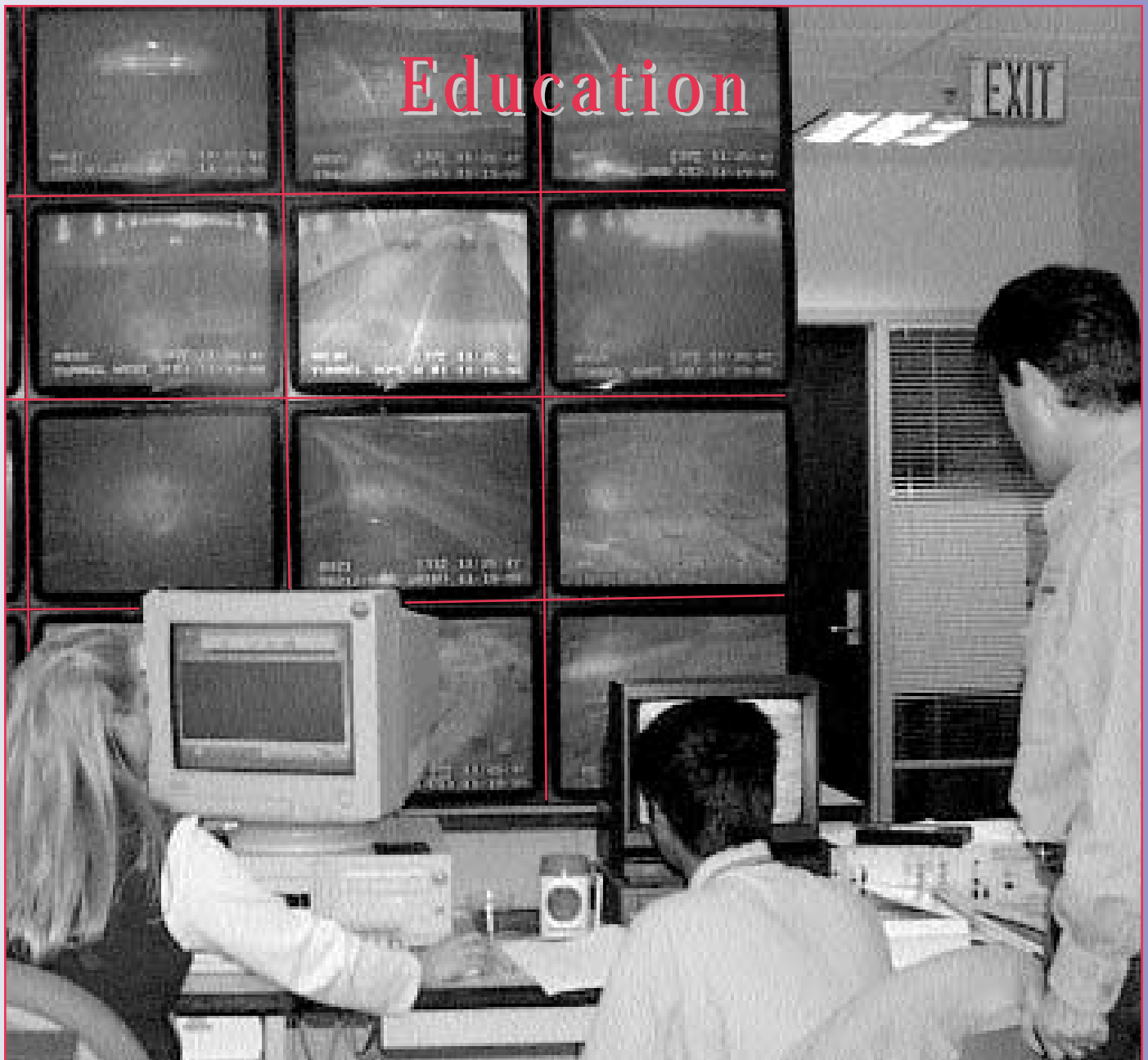
# Education

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

The Institute sponsors and supports numerous educational initiatives for students, including the development of new curriculum and courses, the involvement of undergraduate and graduate students in research projects, travel awards that allow students to interact with professionals and researchers nationwide, awards that recognize outstanding students, and research assistantships to help attract more transportation students. Through these initiatives, the Institute is increasing awareness of and interest in its core ITS science and technologies.

"ITS is viewed as a critical program area in achieving the FHWA's goals of improved mobility, system productivity, safety, and environmental compatibility."

*— Alan Steger, ITS Institute Board member and Division Administrator, Federal Highway Administration*

## Career Expo

In February 2000, the ITS Institute partnered with the Center for Transportation Studies (CTS), the Women's Transportation Seminar, the Minnesota Local Road Research Board, and the Minnesota T$^2$/LTAP Program to hold the fifth annual Trans-



*Career Expo panelists Tom Peters, Mn/DOT, Linda Dolan, ADDCO, and Craig Shankwitz, Intelligent Vehicles Lab, with moderator Dawn Spanhake of the ITS Institute.*

portation Career Expo in Minneapolis. Over 70 participants attended sessions and viewed exhibits from 18 organizations involved in transportation. The event offered a general session on career preparation and four concurrent sessions on specific areas of transportation. The ITS session was moderated by the Institute's research development engineer, Dawn Spanhake, and featured panelists from private industry, the Minnesota Department of Transportation (Mn/DOT), and the Institute's Intelligent Vehicles Laboratory.

## Student of the Year Award

Curtis Hammond, a Ph.D. candidate in Kinesiology and Human Factors, received the 1999 Outstanding Student of the Year Award at the Transportation Research Board (TRB) 79th Annual Meeting, held in January in Washington, D.C. For the past eight years the USDOT has honored the most outstanding student from each University Transportation Center at a special ceremony during the TRB meeting. Hammond was selected for his research on evaluating and measuring the relationship between driving performance in real-world conditions and laboratory simulation.

## Transportation Research and Education Awards

CTS presents the Matthew J. Huber Award for Excellence in Transportation Research and Education annually to graduate stu-

dents demonstrating an outstanding contribution in research, writing, and educational activities in the field of transportation. The award is named in honor of the late Professor Matthew J. Huber, in recognition of his long and valuable contribution to the teaching and study of transportation at the University of Minnesota.

This year's award was given to two ITS Institute students, Selma de Ridder and Heon Min Lim. de Ridder is a doctoral candidate and graduate research assistant at the Human Factors Research Laboratory (HFRL). She was nominated by Professor Peter Hancock, research director of the HFRL, for her research on human response to accident-likely situations. Lim, a doctoral candidate and graduate research assistant in the Department of Mechanical Engineering, was nominated by Professor Max Donath, ITS Institute director, for his research



*Presenting the award to Curtis Hammond (second from right) were USDOT Deputy Secretary Mortimer Downey, Secretary of Transportation Rodney Slater, and RSPA Administrator Kelley Coyner.*

*Award recipient Heon Min Lim (center) with Robert Johns (left) and Max Donath (right).*



*Award recipient Selma de Ridder (center) with Robert Johns (left) and Peter Hancock (right).*

on GPS-based head-up displays for use in low-visibility conditions. The awards were presented at the Center for Transportation Studies's annual meeting and awards ceremony held in April in Minneapolis.

## Student Sponsorships

The Institute sponsors ITS students to attend various conferences so that they can report on their research to larger audiences. This past year, the Institute sponsored a total of 15 students to attend national meetings of the Transportation Research Board (TRB) in January and ITS America in May.

Student attendees at the TRB Annual Meeting included Seshasai Kanchi, Heather O'Connell, David Timm, Sarah Schmidt, Matthew Oman, Diego Arabbo, Christopher Gardner, Matt Ricker, Eric Corwin, and Mark Mutziger, all of Civil Engineering, and Selma de Ridder and Curtis Hammond, both of Kinesiology and Leisure Studies. Student attendees of the

ITS America Annual Meeting were Seshasai Kanchi, Subramaniam Vijay-Konduru, and Sreemannarayan V. Nanduri, all of Civil Engineering.

The Institute also awards fellowships to help students pursue ITS-related studies. In cooperation with 3M, the Institute awarded the International Road Federation Fellowship to graduate student Atif Sheikh of the Department of Civil Engineering. His research interests include GIS and infrastructure management.



*UMD students gave their final class presentations for the course "Design of Distributed Systems for Intelligent Transportation Systems" to Mn/DOT engineers in May. Professor Eil Kwon (second from left) of the ITS Institute, who was a visiting McKnight professor at the Duluth campus during spring semester, taught the course. Professor Taek Kwon of UMD is in the front row, far right.*

*Assistant Professor David Levinson, Department of Civil Engineering, with graduate students Pavithra Kandadai-Parthasarathi (left) and Seshasai Kanchi (right).*

hands-on experience in designing and implementing intelligent transportation systems to solve real-life multidisciplinary transportation problems.

The interdisciplinary laboratory course is being developed through several phases. In Phase I, a prototype laboratory format was developed and evaluated. The instructors of ME 5286/Robotics, Professor Max Donath and Associate Professor Brad Nelson, both of Mechanical Engineering, adopted this prototype in ME 5286 during the spring semester of 2000 as a trial for the first laboratory experience, a vehicle guidance project. The project consisted of four modules—a GIS database, a steering controller, a guidance controller, and a cruise controller—that the students used to drive a virtual truck along a specified path, the Mn/ROAD low-volume test road.

Based on feedback from the students who took the
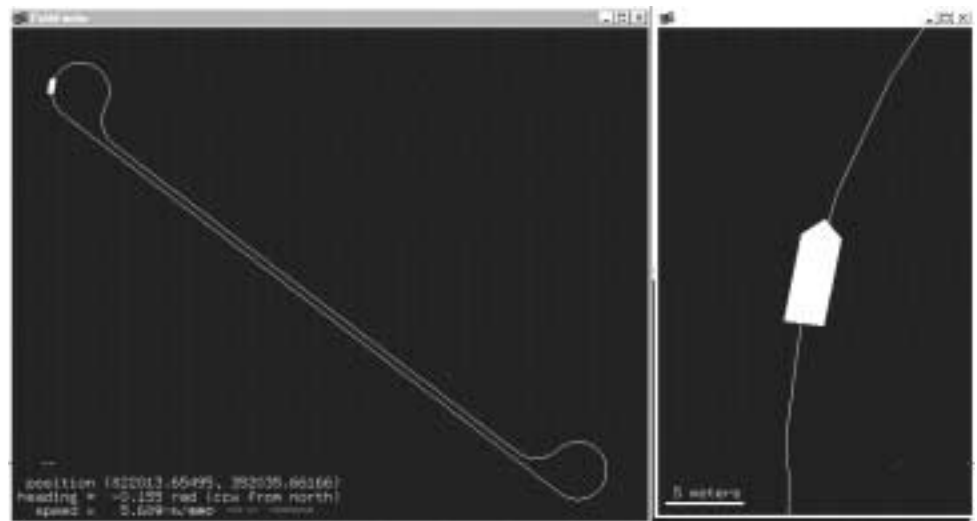
## Interdisciplinary Lab Course

In order to expand the educational experience of both undergraduate and graduate students in ITS technologies, the Institute is creating a senior/graduate level interdisciplinary laboratory course.

The course is designed to introduce students to intelligent transportation systems and encourage them to pursue a graduate program in ITS while giving them a sufficient background for more in-depth study. The course will also give students



*Screen snapshots of the vehicle guidance simulation: a truck on the Mn/ROAD test track (left) and a zoom-in view depicting the offset of the truck to the center of a lane (right). Students wrote the embedded control software to guide the truck along the test road in real time.*

*Research fellow John Hourdakis (left) demonstrates a traffic simulation to visitor Dr. Jaime Barcelo of the University of Catalonia.*

course, the test of the vehicle guidance project was successful. In addition, most students reported that having class notes, handouts, and tutorials available online was helpful.

This experience will be used as a model for a variety of other laboratory projects in different disciplines and will be merged into the interdisciplinary laboratory course. Faculty from different departments will work together to coordinate the effort. In FY01 the second, traffic-related module will be developed.



*Associate Professor Vladimir Cherkassky, Department of Electrical and Computer Engineering, with graduate students Jie Shao (left) and Xuhao He (right).*

Technology Transfer

# Technology Transfer

Technology transfer is an inherent component of the ITS Institute, since it ensures that the Institute's research results are disseminated to a local, national, and international audience in ways that will foster implementation for real-world applications. Technology transfer is also a way to increase the visibility of the Institute and to educate students, policy-makers, and the general public about ITS issues and solutions.

Although graduating students joining the workforce represent the most direct means

of technology transfer, the Institute also uses various technology transfer approaches to reach a wide and diverse audience. For example, the Institute's informational booths and demonstrations raise awareness and generate interest with the general public; Institute-sponsored seminars serve researchers and students; and Institute publications, the Web site, and conference exhibits share information with practitioners, students, and others. This section of the Annual Report highlights some of the past year's outreach efforts.

*"The FHWA's mission ... is to apply advanced ITS technologies in innovative ways to maximize safety, improve mobility, and increase productivity through improved transportation operations. We are also conducting research to support the advancement of the Intelligent Vehicle Initiative, a cooperative program with industry to accelerate the deployment of in-vehicle systems that address the problem areas that are the major causes of crashes."*

*— Toni Wilbur, ITS Institute Board member and Technical Director, Federal Highway Administration*

*Gina Baas (left) of CTS and Dawn Spanhake (right) of the ITS Institute handed out materials and answered questions at the Institute's State Fair exhibit.*

## Minnesota State Fair Exhibit

The ITS Institute was represented at the Minnesota State Fair with the Center for Transportation Studies (CTS) booth in the University of Minnesota building. Using a working traffic signal, Osama Masoud, Surendra Gupte, Doug Perrin, Fotis Bazakos, Rotherick Tan, and Paul Rybski, students of Associate Professor Nikolaos Papanikolopoulos, demonstrated their work on pedestrian tracking at intersections.

## Faculty Seminars

During the last year, the Institute and CTS held faculty research seminars as a way for researchers to share their work with students, faculty, and other interested practitioners. The researchers who presented at these seminars were:

- Nelson Assistant Professor Rajesh Rajamani, Mechanical Engineering, discussing "Control Systems for Highway Vehicle Automation" in October.
- Professor Panos Michalopoulos, Civil Engineering, presenting "Application of Machine Vision in Traffic Surveillance, Management, and Control" in November.
- Nelson Assistant Professor Perry Y. Li, Mechanical Engineering, presenting "Highway Traffic Flow Control and Adaptive Cruise Control Vehicles" in April.

Beginning in the 2000–2001 academic year, the Institute will host these seminars biweekly. Presenters will include University of Minnesota graduate students and researchers as well as researchers from throughout the United States.
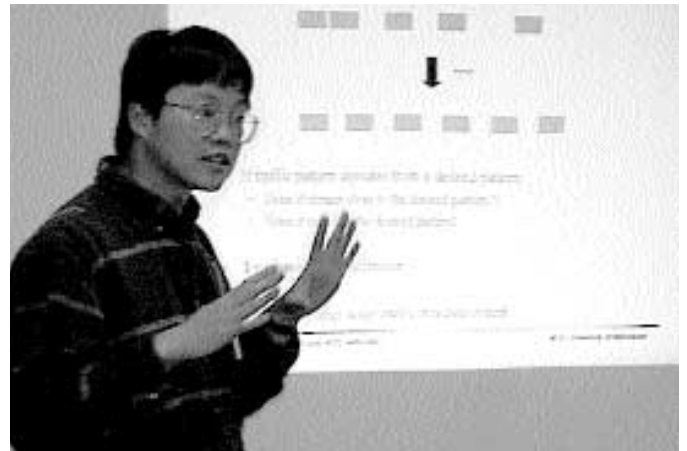


*Perry Li discussed his current work on using adaptive cruise control vehicles for traffic flow regulation at an ITS faculty research seminar.*

*The Institute's booth at ITS America explained its Intelligent Vehicles program and allowed visitors to "drive" a replica of the Institute's SAFEPLOW.*

## ITS America Booth

The Institute joined with the Minnesota Department of Transportation to create and staff a booth at this year's ITS America conference held in Boston May 1–4. The Institute sent staff members and students to manage the booth and answer ITS-related questions for visitors.

The highlight of the booth was a replica of the Institute's SAFEPLOW, a specially-instrumented snowplow. The replica was equipped with various driver-assistive technologies that demonstrated a head-up display and an electronic rumble strip that was triggered when a "driver" steered too far to the right or left (imitating the effects of a real rumble strip). Visitors to the booth also received Institute literature, including folders, information sheets, and other publications.

## Web Site

The Institute's Web site (www.umn.edu/itsinst) was redesigned in the last year for easier use and navigation, and content con-tinues to be added as the Institute's research, education, and outreach activities expand. Some of the information site visitors can access includes current research abstracts, the Institute's strategic plan, descriptions of Institute facilities and laboratories, contact information, ITS-related University courses, a listing of upcoming events, the Institute's quarterly newsletter, and links to related sites of interest.

## Publications

In December, the Institute published the first issue of its newsletter, the *Sensor*. The quarterly publication, mailed to over 1,300 individuals nationwide, shares research results with faculty, practitioners, researchers, and others. The newsletter can also be downloaded from the Institute Web site.

Other new publications include several marketing-type pieces created to help publicize the Institute and its work to a wide audience. These brochures, folders, and fact sheets, which describe Institute laboratories and research projects, are distributed at ITS-related exhibits, informational booths, conferences, and to visitors or to those wanting to learn more about the Institute.

*A local news crew filmed research by Professor Panos Michalopoulos (center) and research fellow John Hourdakis (far right).*

## Patents

Patenting the work of faculty, staff, and students is a technology transfer method that leads to real-world application of academic research. One outcome is that private industry gains novel methods of meeting specific needs and reaps subsequent benefits that were previously not available.

Two Institute faculty who have patents filed and pending for their ITS-related work are:

- Associate Professor Nikolaos Papanikolopoulos, Computer Science and Engineering, for "Counting Vehicle Occupants Using Infrared"
- Associate Professor Taek Kwon, Electrical and Computer Engineering (Duluth), for "Video Camera-Based Visibility Measurement"

## Media Coverage

Over the last year, the Institute caught the attention of both local and national news organizations, which resulted in many opportunities for publicizing Institute research to a far-reaching audience. Some highlights:

- Twin Cities station KARE-11 TV filmed Professor Panos Michalopoulos's simulation research in the ITS LABORATORY for a story on local freeway ramp metering. Michalopoulos's research was also cited in a ramp metering article in the Minneapolis *Star Tribune.*
- *NBC Nightly News* filmed the Institute's SAFEPLOW and its head-up display to create a news segment on winter travel, tied in with a major snowstorm in the

*The Institute's SAFEPLOW team was filmed for a segment on NBC Nightly News.*

eastern states. Local television stations KARE-11, WCCO, and KMSP also covered the SAFEPLOW in winter weather-related stories.

- A St. Paul *Pioneer Press* article featured Associate Professor Nikolaos Papanikolopoulos's research on tracking pedestrians for traffic control at intersections.
- A Minneapolis *Star Tribune* article, "Intelligent Transportation Systems Given Radio Spectrum Spot by FCC," featured Associate Professor Shashi Shekhar.
- Professor Max Donath served as a guest columnist discussing the future of transportation in the St. Paul *Pioneer Press.*
- Several media sources, including *Inside ITS* and *ITS International,* covered the selection of the Institute's Intelligent Vehicles Laboratory as one of the teams that received funding under the USDOT's Intelligent Vehicle Initiative.

*Saint Paul, Minnesota*

*Minneapolis, Minnesota*

# ITS INSTITUTE

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