

INTELLIGENT TRANSPORTATION SYSTEMS INSTITUTE



2000 / 2001

Intelligent Transportation Systems Institute

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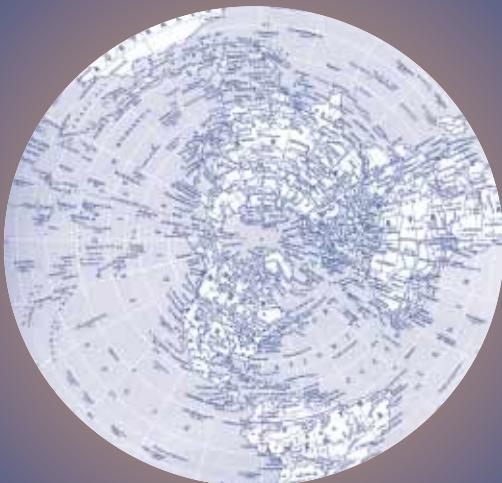
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ITS INSTITUTE

INTELLIGENT TRANSPORTATION SYSTEMS INSTITUTE

Annual Report 2000/2001



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This publication is a report of research, education, and technology transfer activities, fiscal year 2000/2001, of the Intelligent Transportation Systems Institute at the University of Minnesota.

MCLEOD
COUNTY

Message from the Director

Nearly every day the newspapers note how the Twin Cities have reached a milestone: fifteenth in the country as measured by most indices of congestion. We are ranked about the same in terms of population—fourteenth or fifteenth among the country's metropolitan areas. It would seem that our congestion is not too bad. However, while our population ranking has remained fairly constant over the past twenty years, our congestion ranking has risen from around fortieth in the country in 1980 to thirty-fourth in 1990 to fifteenth today. This trend does not bode well.

Our state legislature did take notice, and during the last year mandated the temporary shutdown of the 400-plus ramp meters in the Twin Cities in what was to become an eye-opening experiment for all of us. The results were clear. The ramp meters did serve an important function, but need to be carefully applied. Traffic is a complex phenomenon; its control clearly requires solutions based on an improved understanding of the underlying dynamics.

I am pleased that the ITS Institute and its researchers have been at the forefront of traffic engineering research and have developed models and tools that traffic managers can use today to better design the traffic management systems of tomorrow. We are

looking forward to installing some of these locally developed tools with the Minnesota Department of Transportation this coming year.

An unhappy corollary to congestion is road rage. Institute researchers are working to understand drivers and their roles in the vehicle and on the road. Our work on aggressive driving behaviors, older driver issues, and on driving fatigue covers the gamut of driving in varied situations. To aid work in these areas, we are investing in new



driving simulator facilities and have brought in new leadership to spearhead our human factors effort.

Our focus on traffic is not limited to the concerns of major urban areas; we are addressing also the problems of smaller communities and rural regions. Our new collaboration with the University of Minnesota Duluth in establishing the Northland Advanced Transportation Systems Research Laboratories, or NATSRL, will help immensely. When comparing the fatality statistics of rural environments to those of urban areas, the difference is appalling; almost twice as many fatalities occur in rural areas as in urban ones. Again, Institute researchers have begun to address the underlying issues and are working towards a better understanding of the problem in order to develop solutions. Poor visibility due to various weather conditions is one such rural

The ITS Institute and its researchers have been at the forefront of traffic engineering research and have developed models and tools that traffic managers can use today to better design the traffic management systems of tomorrow.

issue under investigation. We are installing new GPS-based head-up displays that enhance visibility for drivers of emergency response vehicles and snowplows. These driver-assistive technologies developed here under our Intelligent Vehicles Program have received worldwide attention.

Technology plays a vital role in making our transportation systems safer and more productive. Nevertheless, our lifestyles and communities are affected in so many ways. Our efforts in investigating the impacts of ITS technologies in building sustainable communities are part and parcel of our program. We are working on developing a better understanding of how transportation affects the way people live and work and how companies make decisions about where to locate.

None of this research, however, will achieve its potential to improve safety and mobility unless we get the message out. This past year, we demonstrated potential applications for our research to many segments of the public, from state patrol troopers to local and national lawmakers, from bus drivers to crowds attending the State Fair. And the media took notice. In addition, we sponsored more transportation seminars, increased the circulation of our Institute newsletter, and expanded the scope of our web site.

In order to ensure that ITS research will continue to address the above problems—and those of tomorrow—we need to be training researchers and practitioners for the future. To that end, we're using our educa-

tion activities to generate more interest in core ITS science and technologies. This past year, besides sponsoring many graduate research assistants, the Institute sponsored a team of students to compete in the international Intelligent Ground Vehicle Competition and sent others to national conferences.

Of course, our work at the Institute benefits from, and often relies on, our many relationships. Our work with counties and the Local Road Research Board, and our research sponsored by collaborating states, widen our horizons. Our partnership with Mn/DOT has continued to flourish with joint efforts in many areas.

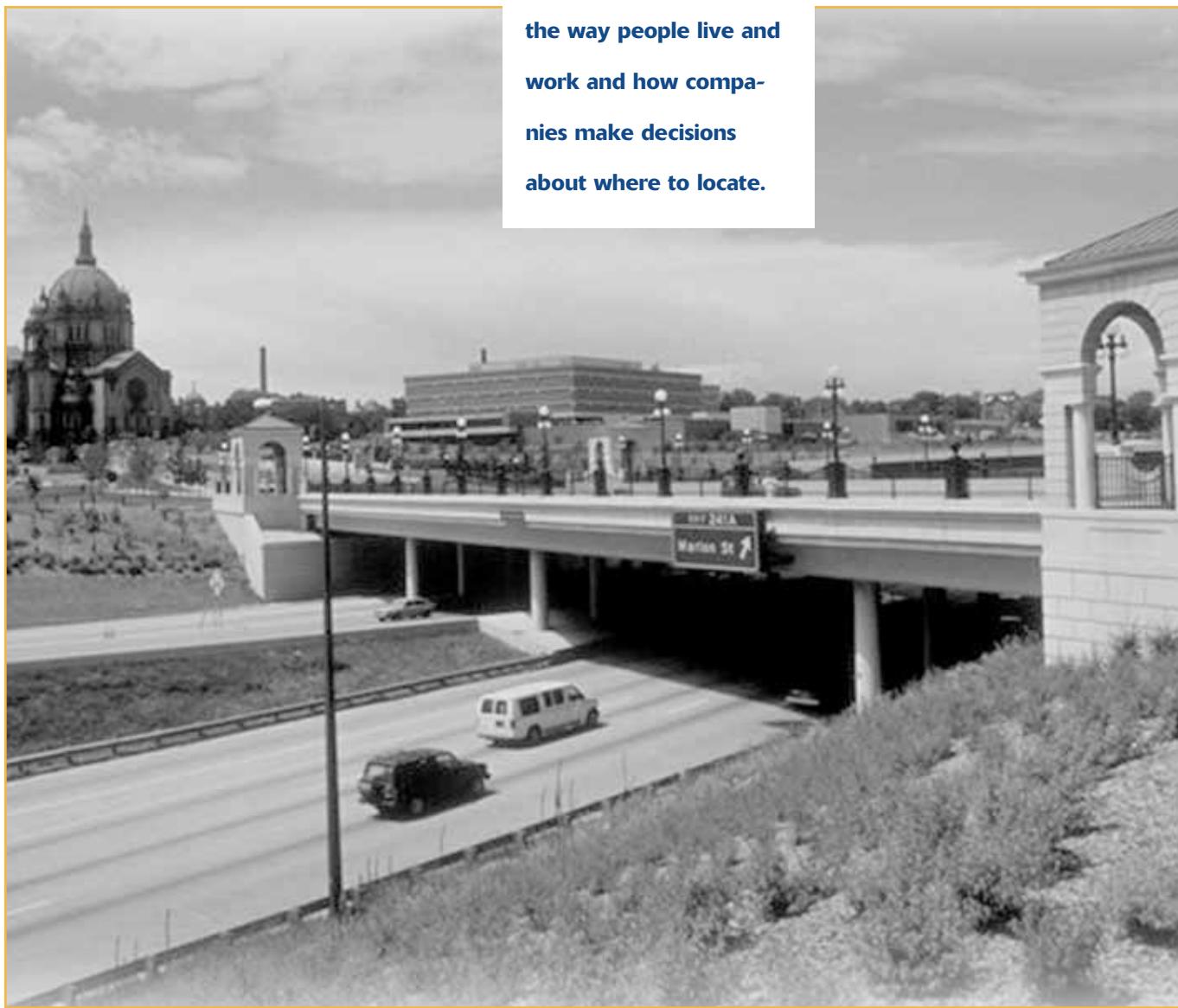
Our students and faculty also played a vital role in every project that we have undertaken. Finally, none of the progress that we have made over the last year would have occurred without the assistance, long hours, and diligent efforts of our staff members. Their support is very much appreciated.

Thank you.



Max Donath, Director
Intelligent Transportation Systems Institute

We are working on
developing a better
understanding of how
transportation affects
the way people live and
work and how compa-
nies make decisions
about where to locate.



Mission Statement and Overview

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

The Institute plans and conducts activities that further the mission of the UTC program of the United States Department of Transportation (USDOT). 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

Our theme:

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

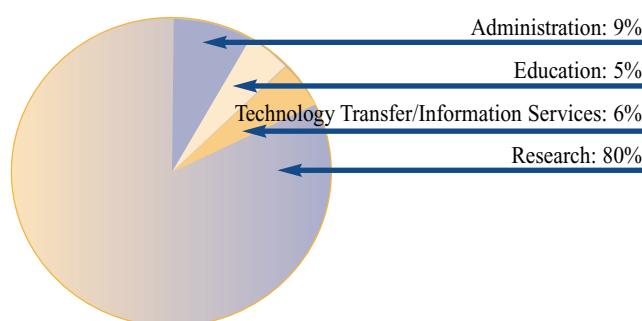
of road- and transit-based transportation through a focus on human-centered technology. To that end, the Institute brings together technologists and those who study human behavior to ensure that Institute-developed technologies become tools that optimize human capabilities. This human-centered approach 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, investigates technologies for improving the safety of travel in rural environments, and considers social and economic policy issues related to the deployment of the core ITS technologies.

Financial Report

Expenditures for Year Two

July 1, 2000 – June 30, 2001



Funding Sources

Total Annual Budget: \$4.0 million including matching funds from:

- Local Road Research Board
- Minnesota Department of Transportation
- University of Minnesota
- United Way

Management Structure

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

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

The Institute's board guides and oversees the implementation of the Institute's work. The board's responsibilities include working with the director to ensure that the USDOT's

Research and Special Programs

Administration (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 intelligent transportation systems 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 capabilities.

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ITS Institute Laboratories and Facilities

ITS Laboratory

The 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, Vissum, and ArcInfo/ArcView; wireless communication and control to remote traffic sensing devices; a real-time microwave video down-link from 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.



Electrical engineering student Kyle Wood (left) and Institute research fellow John Hourdakis work on creating a portable vehicle detection station based on Autoscope® cameras and wireless communications to collect real-time traffic data.

Human Factors Research Laboratory

The mission of the ITS Institute Human Factors Research Laboratory (HFRL) is to investigate human factors related to ITS applications in surface transportation. This involves multidisciplinary basic and applied research relevant to real-world issues in the area of surface transportation safety and mobility.

Research focuses on interfacing technology with the human factor within the transportation system using principles of human-centered design. Such designs are evaluated not only in terms of design objectives but also for the potential of technology to induce new forms of error within the transportation system, such as driver distraction, fatigue, behavioral adaptation, and risk compensation.

The research considers the driver to be at the center of the transportation system. From this vantage, the research strategy is to provide interventions to support driver performance, thereby reducing accident risk and increasing mobility for the overall traffic system. Research topics include orientation skills in elderly drivers, reducing crashes at rural intersections, psychological and roadway correlates of aggressive driving behavior, fatigue detection, and ramp meter delays.

The HFRL houses two fully interactive driving simulators on an SGI platform based on a full vehicle model. These offer a range of forward fields of view with rear channels and sound systems. At present, these simulators are networked so that drivers can interact within the same driving environment. Both simulators can also interface with head-up displays and in-vehicle GPS navigation systems.



Left: Walter Trach (right) describes to a lab visitor the driver-assistive technologies in a McLeod County plow.

Below: The Intelligent Ground Vehicles Competition team tests its vehicle on a practice course on campus. From left to right are Kevin Miller, Paul Zachman, Andy Pullis (kneeling), Jon Lenzen, project advisors Lee Alexander and Patrick Starr, and Josh Chambers.

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- and transit-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 SAFEPLLOW, an International snowplow, as experimental test-beds, 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 and driver-warning technologies; vehicle navigation, guidance, and control; and conformal, augmented head-up displays (HUDs).

**Research in
the IV Laboratory
focuses on
driver-assistive
technologies and
human-centered
design.**

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 help accommodate older drivers.





*The campus of the
University of Minnesota
Duluth*

The Northland Advanced Transportation Systems Research Laboratories program will study comprehensive winter transportation systems and the transportation needs of cities in small urban areas.

Northland Advanced Transportation Systems Research Laboratories

New this year is the Northland Advanced Transportation Systems Research Laboratories (NATSRL), a research program developed in a collaborative effort by CTS, ITS Institute, and University of Minnesota Duluth (UMD) staff. NATSRL will study comprehensive winter transportation systems and the transportation needs of cities in small urban areas.

Research will cover a wide range of topics, including visual and electronic traffic and road sensors, transportation data management, and inventory management of transportation infrastructure. NATSRL will collaborate with the Minnesota Department of Transportation District One, city and county engineers, and the university research community to address transportation-related needs, especially those that are specific to northern areas and climates.

NATSRL is led by James Riehl, dean of the College of Science and Engineering,

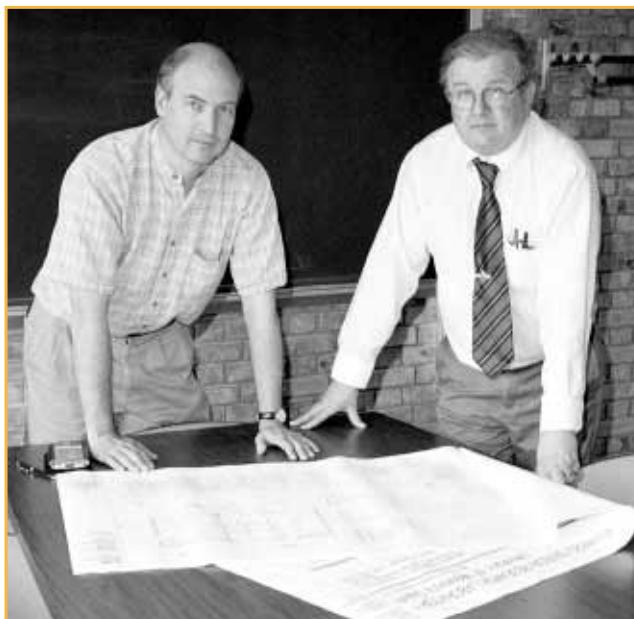
with support from Stanley Burns, professor and head, Department of Electrical and Computer Engineering (ECE); Donald Crouch, professor and head, Department of Computer Science; Taek Mu Kwon, associate professor, ECE; and David Wyrick, associate professor and head, Department of Industrial Engineering (IE).

NATSRL's initial laboratories are the Advanced Sensor Research Laboratory and the Transportation Data Research Laboratory.

The Advanced Sensor Research Laboratory will have facilities in UMD's ECE Department and will also include an off-campus field laboratory where newly developed or existing transportation sensors can be installed and evaluated. Goals of this laboratory include development and testing of advanced sensing technologies for pavement and road conditions (speed, slipperiness, and traffic density); development of new techniques to detect incidents and abnormal traffic conditions; and real-world analysis and real-time measurements of

road, weather, and traffic information using a test facility constructed along I-35 south of Duluth.

The Transportation Data Research Laboratory is housed in the ECE Department laboratory facilities, and will receive project support and laboratory space within the IE Department in the areas of human factors and operations management. This laboratory will work toward development of a statewide traffic data archival and analysis system, development of an automatic inventory management system for transportation infrastructure, and design of efficient management strate-



NATSR researchers David Wyrick (left) and Stanley Burns

gies for small urban and large-scale event traffic flow using modern visualization and management tools.

Other Facilities

Signal Operations Research Laboratory

This laboratory consists of an advanced traffic signal controller, a microscopic intersection simulator, and an interface 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—is located in Albertville, Minn., and includes a freeway and a low-volume road pavement test track with forty 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, Minn. This site consists of fixed targets and video cameras used for automatic video-based visibility measurement and detection.

Video cameras alongside I-35 are used for visibility measurement and detection.





Research

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

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

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

The Institute's geographic location gives it a unique advantage for developing research applicable to transportation in a northern climate and transportation in the rural environments that

lie beyond the Twin Cities metropolitan area.

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

Activities undertaken by the Institute support all current ITS-related research projects, including those that began under the ISTEA-funded Institute. The research section of this Annual Report comprises three parts. The first highlights a selection of proj-

ects underway, while the second briefly describes other projects in progress. The third part reports on the projects selected to begin this coming year.



Clockwise from bottom left: Osama Masoud, Professor Nikolaos Papanikolopoulos, Benjamin Maurin, Harini Veeraraghavan, and Robert Martin

The Institute's research program brings together technologists with those who study human behavior to ensure that new technologies adapt to human capabilities, rather than requiring human capabilities to adapt to technology.

Highlighted Research in Progress

Human Performance and Behavior

Psychological and Roadway Correlates of Aggressive Driving

Aggressive driving has received much attention in the popular press and from organizations such as AAA, which call it an increasing threat to the safety of future roadway environments.

So principal investigator Kathleen Harder of the Human Factors Research Laboratory (HFRL), Terry Kinney of the Department of Speech Communication, and Darcia Narvaez



Researcher Kathleen Harder in the HFRL's driving simulator.

of the Department of Psychology, University of Notre Dame (formerly of the Department of Educational Psychology, University of Minnesota), are seeking to identify and understand the psychological, emotional, and behavioral factors that contribute to aggressive driving (e.g., acceleration, braking, lane changes, speed, and tailgating) in order to reduce and prevent it.

In the first phase of the project, the team surveyed 300 University of Minnesota stu-

dents in order to investigate the relationship between personality, emotional, and behavioral variables and self-reported driving behavior. Students were targeted because their age range (16–35) demonstrates high levels of anger and hostility and a willingness to engage in riskier behaviors, relative to older adults.

In the survey, the researchers measured gender and age; personality characteristics such as hostility, anger expression, aggressiveness, competitiveness, and empathy; emotional states such as anger-provoking experiences, ability to “let go” of hostility, and negative thought patterns; and behavioral tendencies when driving, such as speeding, driving under the influence of alcohol, and risk taking.

According to the responses, participants who were more distrustful of others, suspicious, and prone to hostility were classified as “high hostiles.”

The results of a subsample (216 respondents) of the survey show that high hostiles reported more driving after drinking alcohol, more speeding, and more risk-taking than low hostiles. They also reported more anger in the presence of police, more anger toward slow drivers and discourteous drivers, and more anger from roadway obstacles than low hostiles reported.

Males reported more confrontational aggressiveness and more illegal and risky driving behavior than females did. Females reported greater anger by other drivers’ rude behavior.

In the second phase of the research, planned for winter 2002, the researchers will run a driving simulator experiment at the Institute’s HFRL to validate the self-reported driving



HFRL researchers Peter Easterlund, Kathleen Harder, Selma de Ridder, and Nicholas Ward

behaviors. Subjects will include both high hostiles and low hostiles who will be put into situations of either high emotional manipulation or low emotional manipulation before going into the simulator. When driving, subjects will navigate through several virtual traffic events and environments, including rural and urban settings, congestion, and road construction.

Results of the experiments should give the researchers the ability to link personality traits and styles to types and levels of driving behavior under various traffic events and environments, thereby allowing them to gain some understanding as to what type of person may be "at risk" for aggressive driving.

This may lead to strategies for preventing and reducing aggressive driving, they say. One example of such a strategy might be the use of persuasive messages (e.g., bumper stickers, billboards, radio ads) to target, then calm, high hostiles in their vehicles.

Reducing Crashes at Controlled Rural Intersections by Identifying Effective Countermeasures

Right-angle crashes at controlled (thru/STOP control) rural intersections in Minnesota account for nearly 71 percent of all fatalities

at this type of intersection. Further, right-angle crashes account for 62 percent of serious injury crashes and nearly half of property damage crashes at this type of intersection, say Institute researchers who are studying this issue.

Principal investigator Kathleen Harder of the Human Factors Research Laboratory (HFRL), along with Howard Preston, transportation engineer and senior project manager at Howard R. Green Company, want to find out why these crashes occur as well as what can be done to reduce their numbers.

According to Harder, some traffic engineers feel they have exhausted their "tool-box" of strategies for ways to improve safety at controlled rural intersections. Responding to a request from the Minnesota Department of Transportation and the Minnesota Local Road Research Board, researchers are studying the problem by assessing crash record databases, visiting sites to assess the physical

Males reported more confrontational aggressiveness and more illegal and risky driving behavior than females did. Females reported greater anger by other drivers' rude behavior.



Right-angle crashes at controlled rural intersections are a significant safety issue for traffic engineers.



Researchers will develop a method for studying the problem in the HFRL's driving simulator using a computer-generated virtual intersection and a number of alternative solutions.

limitations of the intersections, and running driver simulator tests to identify strategies to mitigate the problem, Harder says.

Right angle crashes occur either when drivers fail to stop, or do stop but then pull out into oncoming traffic. Of the 768 right-angle crashes examined, approximately 57 percent of the drivers stopped, then pulled out, and 26 percent of the drivers ran the stop sign (17 percent fall into the unknown/other category). “It was somewhat surprising to learn that running stop signs does not seem to be the major problem at rural controlled intersections in Minnesota,” Harder says.

Although the research is not far enough along to allow for causal analysis, Harder says that the right-angle crashes do seem to be more prevalent in drivers who are 19

years of age and under and those who are 85 and older. Whether the problem is perceptual, or whether it involves not looking, delayed reaction times, or some combination of these factors is not yet known.

Researchers are conducting on-site field analyses this summer to look at the physical characteristics at these intersections and consider how those features might contribute to safety problems. Once field inspections and a subsequent focus group session are completed, researchers will develop a method for studying the problem in the HFRL's driving simulator using a computer-generated virtual intersection and a number of alternative solutions.

“We hope that our results will allow us to develop strategies that will result in safer rural controlled intersections,” Harder says.

Computing, Sensing, Communications, and Control Systems

IVI Specialty Vehicle Field Operational Test

For snowplow operators and drivers of other specialty vehicles, such as police cars and ambulances, winter driving is difficult and dangerous. During the winter, these drivers routinely navigate in poor driving conditions while trying to avoid moving and parked cars,

bridge end treatments, signs, guardrails, and any number of other obstacles.

To increase safety for these drivers, researchers at the ITS Institute's Intelligent Vehicles (IV) Laboratory—in cooperation with other University researchers, including those from the Human Factors Research Laboratory (HFRL) and the University of Minnesota Duluth's Electrical and Computer Engineering Department—have been developing and testing a variety of vehicle-guidance and collision-avoidance technologies.

From November 2000 through January 2001, HFRL researchers field-tested some of these technologies, including a head-up display (HUD) system that allows drivers to “see” the road via images projected onto a combiner mounted close to the windshield. Lane-departure warnings are provided by a “virtual rumble strip,” the result of a combina-



Bill Gardner of Mn/DOT's Office of Advanced Transportation Systems drives the plow while opaque curtains obscure the front and side windows. This test required drivers to rely on the head-up display to “see” the roadway.

tion of haptic and auditory signals that simulates a physical rumble strip with a vibration in the driver's seat and an auditory signal.

Tests were conducted at the University's Rosemount research facility with the Mn/DOT "SAFEPLLOW," which was equipped with a vehicle data acquisition unit to collect data representative of drivers' responses. During the study period, 16 Mn/DOT snowplow operators drove the vehicle with opaque curtains completely obscuring the front and side windows. "They weren't able to see the actual roadway but could drive anyway because of the virtual roadway displayed on the HUD," says Kathleen Harder, HFRL research associate. She and John Bloomfield, another HFRL researcher, ran the study, which is one of several HFRL research projects exploring driver-assistive technologies and their effects on drivers. Results will be incorporated into the final version that will be deployed for testing next winter.

Researchers are now preparing for operational testing by outfitting four snowplows, one state patrol car, and one ambulance with driver-assistive systems. The team hopes to have all the vehicles ready by the end of the summer of 2001. Once installed on the vehicles, the systems and subsystems will be tested to make sure they work as intended, and drivers will be trained to use the technology. The operational testing is scheduled to begin in October 2001 and will run for six months.

A prerequisite for the operations test is the completion of infrastructure requirements for the project. The team is in the process of installing six weather stations along Highway 7 between Hutchinson, Minn., and I-494 in

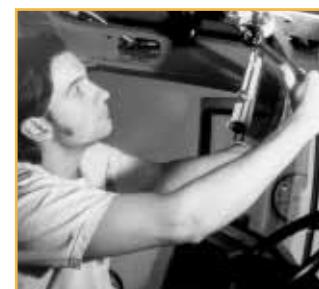
**Researchers are
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the Twin Cities metropolitan area. Team members are also preparing to install three GPS correction base stations. Once the GPS base stations are operational, the team will begin mapping Highway 7, creating a map from which all DGPS-based vehicle guidance will operate.

This research is part of the Intelligent Vehicle Initiative (IVI) Field Operational Test Program, funded by the Federal Highway Administration, Mn/DOT, and industry partners. The ITS Institute is leading the research effort for the program, under which the University is receiving \$2.65 million over three years. 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.

With additional funds from the Minnesota Local Road Research Board, the team is now working towards having this new technology used and evaluated at the county level. Researchers also hope to explore how these systems can be applied to transit vehicles, particularly to help drivers navigate on narrow bus-only shoulders.



Top: IVI team members (back row) Craig Shankwitz and Heonmin Lim; (front row) Walter Trach, Bryan Newstrom, Rick Odgers, and Mike Sergi

Bottom: Alec Gorjestani adjusts the plow's head-up display.



Associate Professor Vladimir Cherkassky

Wireless Transmission of Image and Video Data

The trend toward wireless transmission of traffic information poses difficult problems for transmission systems that operate over low-speed wireless channels like CDPD (Cellular Digital Packet Data). This project, led by Associate Professor Vladimir Cherkassky of Computer Science, is part of an overall ITS Lab strategic focus on spatially meaningful presentation of traffic information. A prototype wireless network housed in the Institute's ITS Laboratory serves as the testing environment and will also be used for future research in this area.

Cherkassky's work focuses on technical and system-integration issues related to the practical implementation of wireless video/image transmission. The Minnesota Department of Transportation (Mn/DOT) is currently investigating wireless traffic data transmission, and the results of the current research project will assist Mn/DOT in implementing an effective wireless data system.

This project encompasses two areas of research: 1) compression and denoising of digital video/image signals, and 2) dynamic allocation of network resources in a wireless video/image transmission system.

In the area of compression and denoising, Cherkassky's research team will assess the performance of a typical "commercial off-the-shelf" (COTS) video/image compression product based on wavelet-thresholding algorithms, giving particular attention to the tradeoff between the amount of signal compression and the visual quality of the decompressed image.

In addition, the project incorporates research on a new compression and denoising methodology developed by Cherkassky during 2000. Comparison to existing commercial systems will uncover potential improvements that can be achieved with more research.

The second research area, allocation of network resources, presents major challenges in the implementation of a wireless image-transmission system; efficient resource allocation can significantly increase system performance. Here Cherkassky will build on a separate research project in which he is currently involved with FireSummit, a Minnesota company developing software for dynamic alloca-

tion of priorities in different types of computer networks.

**This project
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Because computer networks and the wireless networks under study make use of the same Internet Protocol (IP) methodology for transmitting data, the resource-allocation system under development can be utilized for both. By using this software in combination with router/switching hardware, the researchers are able to model different levels of wireless service with varying bandwidth and latency. The prototype wireless system will be tested under varying loads of compressed image/video traffic to quantify the effects of video/image compression and dynamic allocation of network priorities.

Based on Cherkassky's results, the researchers will make recommendations on commercial compression products for use by Mn/DOT and will provide an assessment of the usefulness of network prioritization software for practical implementation of wireless transmission within Mn/DOT.

Technologies for Modeling, Managing, and Operating Transportation Systems

Comparative Analysis of Operational Algorithms for Traffic Responsive Coordinated Metering

Methodology for Evaluating Ramp Control and Implementation in Two Twin Cities Freeways

Measuring the Equity and Efficiency of Ramp Meters

Although the use of ramp metering as part of an overall traffic management strategy has been a subject of long-term study by

University researchers, over the last year it was in the spotlight due to the Twin Cities' "ramp meter shutoff" mandated by the state legislature. During that time, the Minnesota Department of Transportation (Mn/DOT) turned off the metro area's 430 ramp meters for nearly two months in order to observe the results.

Simultaneously, three Institute projects examined Mn/DOT's use of ramp metering from three different perspectives.

Dr. Eil Kwon, program director of the ITS Institute's Advanced Traffic Systems Program, led a project comparing the performance of the

Mn/DOT ramp metering algorithm with alternative algorithms used elsewhere around the country.

Kwon's key findings were:

- Among 24 cities with ramp meters, five have on-line coordinated methods to maximize system-wide flow while minimizing delay. Washington, D.C., and Minnesota



have control designed to maximize bottleneck flows with section-wide explicit coordination.

- Simulation analysis showed that the Minnesota approach distributed traffic flows more evenly on the mainline, but had more ramps with higher waiting times than the other approaches.
- Most metering systems, except Minnesota and San Diego, implement a "ramp queue override" method to reduce ramp waiting time even if it results in increased delay on the mainline.

The implications, Kwon says, are that system-wide efficiency needs to be balanced with ramp queue delay, and a new algorithm for Minnesota should target corridor-wide traffic management by explicitly reflecting conditions at the mainline, ramp queues, and adjacent intersections.

Assistant Professor David Levinson of the



Eil Kwon, program director of the ITS Institute's Advanced Traffic Systems Program



*Professor Panos
Michalopoulos*

Department of Civil Engineering (CE) led an effort to identify and develop performance measures that evaluate the equity as well as the efficiency of the metering strategy to determine overall effectiveness.

Levinson's key findings were:

- Freeway speeds and flows are consistently higher with ramp metering than without.
- Overall trip speeds (including both the freeway and the ramp) are not uniformly higher with ramp metering than without. Long trips benefit from metering at the expense of short trips.
- If people value their time differently (e.g., waiting on a ramp versus waiting on the mainline), a ramp metering system that satisfies users must consider ramp delay in addition to freeway throughput.

This leads to two key implications, Levinson says: equity and efficiency performance measures (e.g., mobility, accessibility, productivity) can and should be used when testing new algorithms, and a limit on individual delay, even at the expense of overall freeway efficiency, may be necessary for the ramp metering system to

satisfy equity considerations.

The goal of the project led by Professor Panos Michalopoulos, also of CE, was to enhance and validate a simulation model that allows new or modified metering strategies to be tested and evaluated before being deployed on the road network.

Michalopoulos's key findings were:

- Simulation results are consistent with the findings from Mn/DOT's Twin Cities Ramp Meter Evaluation Study.
- The implementation of ramp metering should be site and time specific.
- The simulation demonstrated that Mn/DOT's metering strategy was beneficial overall on the mainline system, but adversely affected the ramps themselves by creating queues and delays.

- Simulation will allow new strategies to be tested and existing ones to be fine-tuned before deployment.

The implications, he says, are twofold: First, the Mn/DOT metering strategy should be modified to take ramp conditions into account. And second, because ramp metering affects



Assistant Professor David Levinson (in back) with students Atif Sheikh, Shantanu Das, and Lei Zhang

more than the freeway, it should be approached from a corridor-wide perspective so that diversion onto arterials is taken into account.

Next steps and further research include development of a modified algorithm for use by Mn/DOT that incorporates ramp-queue man-

agement; development of performance measures and tools that allow evaluation of efficiency and equity; and use of the simulation lab to test alternative metering strategies for potential deployment on Twin Cities freeways.

Social and Economic Policy Issues Related to ITS Technologies

Sustainable Technologies Applied Research

Researchers at the Humphrey Institute of Public Affairs' State and Local Policy Program (SLPP) are investigating sustainable transportation technologies by systematically examining the impacts of ITS and telecommunications along five dimensions: spatial location, community design, accessibility, network performance, and productivity.

The major theme for SLPP's work is the relationship between technological networks and places. This theme is being explored in an interdisciplinary fashion with perspectives ranging from urban development to network analysis. Over the next several years, Sustainable Technologies Applied Research (STAR) will explore the community and regional impacts of advanced transportation technologies such as ITS and telecommunications, placing special emphasis on their transportation and environmental impacts.

The first year's research activities range from theoretical reviews to applied analysis of local systems in Minnesota. Leading the theoretical work is Professor Emeritus Richard Bolan, who has conducted a review of network theory and application. Based on advances in complexity theory, there is a new body of research to help understand how networks such as ITS perform and change. In a related vein, visiting scholar Tom Horan is



*Top: Humphrey planning faculty Karen Chapple (left) and Richard Bolan
Bottom: Research assistant Ramachandra Karamalaputi (left) and Assistant Professor David Levinson*



Research assistants Marcus Martin and Greg Schrock examine data on home-based businesses.

systems, including locally-based ITS systems. SLPP Director Lee Munnich is conducting industry cluster analyses on how economic networks drive and benefit from transportation and related networks.

Professor Ken Keller is serving as an advisor and reviewer of these research elements.

Assistant Professors Karen Chapple, Humphrey Institute, and David Levinson, Civil Engineering, are leading the way in creating robust databases to examine the intersection of people and networks.

As part of the spatial location research, Chapple is investigating the issues of employment, transit use, and technology for the North Metro I-35W Corridor Coalition, a joint powers organization uniting seven communities along I-35W north of St. Paul and Minneapolis. For this project, SLPP is teaming with the Minnesota Center for Survey Research and Demographic Technologies, Inc., a consulting firm specializing in demographic applications of geographic information systems (GIS) technology.

In year two, researchers will conduct a

conducting a review of information design theory and how it can guide review and analysis of community information

labor force assessment to determine the extent of underemployment in the I-35W corridor, as well as the potential for deploying high technology infrastructure (including ITS) to assist both employers and workers in the Twin Cities and in greater Minnesota.

The data collection process began in May 2001 and includes a mail survey to 11,000 area households, follow-up focus groups with area residents, and interviews with local employers. Information collected from the surveys and interviews will allow researchers to examine the extent to which resident workers are underemployed or dis-

Researchers at the Humphrey Institute are investigating sustainable transportation technologies by systematically examining the impacts of intelligent transportation systems and telecommunications along five dimensions.

satisfied with their employment and the problems employers experience in recruiting and retaining a qualified workforce. In addition, the team will use survey and interview data to examine the potential use of transit, ITS, and telecommunications technologies to improve the labor force situation.

Survey analysis will take place in late 2001, the results of which will be used to design workforce development programs to help underemployed persons seek more appropriate employment; to support the efforts of local businesses at attracting a trained workforce; and to develop strategic transit improvements in the corridor communities. The survey findings will be maintained and refreshed as additional data, such as the 2000 Census results, become available.



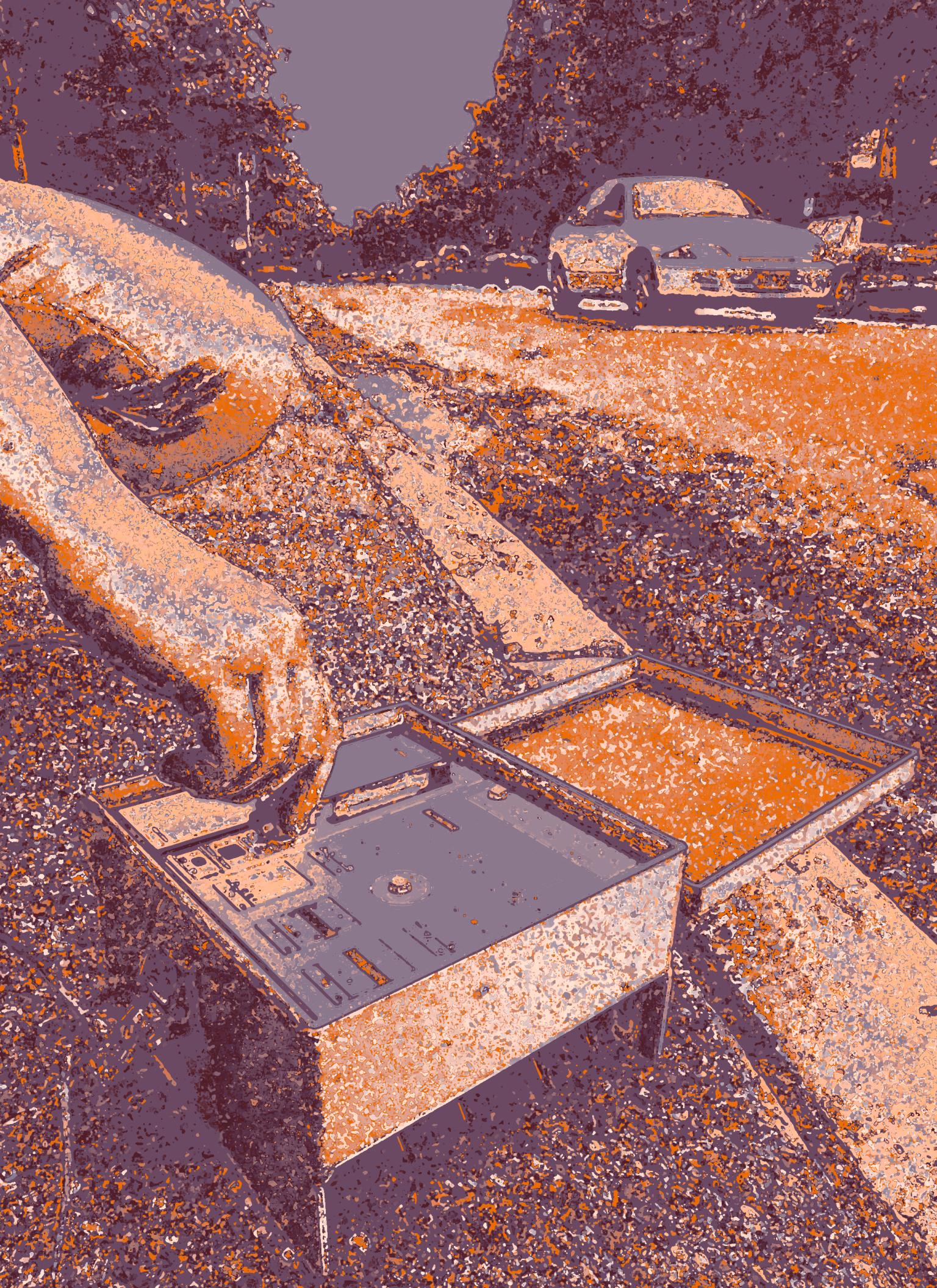
Humphrey Institute visiting scholar Tom Horan (left) describes focus group findings to State and Local Policy Program colleagues.

Another dimension of the STAR research involves examining ITS in relation to transportation network performance. A team of University of Minnesota researchers led by Levinson is conducting an empirical investigation of transportation network characteristics and is exploring the impact of intelligent transportation systems, such as ramp meters and changeable message signs, on those networks. Currently the team is working to develop specific measures to evaluate the effects that transportation investments, including ITS, have had on transportation productivity in the Twin Cities. In the subsequent phases, Levinson will explore new

models of how to accurately predict traffic demand and public supply responses and will develop a more theoretical network simulation framework.

In the ensuing five years of the research program, the entire SLPP research team will extend their research to encompass a range of urban and rural settings, as well as several distinct technological platforms. The research promises to substantially increase the field knowledge about how ITS and other technologies impact social, economic, and environmental dimensions of communities.

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Abstracts of Other Selected Research Projects in Progress

Human Performance and Behavior

Effectiveness of In-lane Rumble Strips

Principal Investigator: Kathleen Harder, Human Factors Research Laboratory

This work stems from a request by SRF Consulting Inc. for human factors experiments investigating the effect of rumble strips on stopping behavior at rural controlled intersections. The experiment, which will be conducted in the wrap-around driving simulator, will involve rural controlled intersections both with and without rumble strips.

User-Centered Auditory Warning Signals in Snowplows

Principal Investigator: Kathleen Harder, Human Factors Research Laboratory

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 is developing a virtual snowplow environment 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 study addresses the following objectives: replicate a snowy roadway in Minnesota in a virtual environment, use the wrap-around driving simulator 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.

Orientation and Navigation in Elderly Drivers

Principal Investigator: Herb Pick, Institute of Child Development

This research seeks to determine how elderly drivers—in comparison to young and middle-aged drivers—navigate and spatially orient themselves while driving, and explores difficulties faced by elderly drivers operating their vehicles in different driving environments. By identifying specific issues that impact elderly drivers, such as way finding, this research may help reduce the accident rate among them.

To evaluate young and elderly drivers' ability to learn and integrate spatial information when driving, testing has been carried out both on the road and in a virtual-reality driving simulator. Comparison of data from the real and simulated driving tasks has confirmed that drivers exhibit similar performance patterns in both environments. Thus from this point on, the simulator can be used to perform more detailed experiments on



how drivers' ability to orient themselves is affected by the nature of the driving task.

A survey questionnaire has also been administered to considerable numbers of young, middle-aged, and elderly drivers. The results of the questionnaire are still being analyzed and the results will be correlated with performance on the two driving tasks described above. However, preliminary analysis of survey data suggests that elderly persons drive differently than younger persons; they make shorter trips, drive less at night and in heavy traffic, and report more distress after losing their way, rather than the frustration typical of younger drivers. The results of the actual and simulated driving tasks also support the original hypothesis that acquiring and maintaining spatial orientation is more problematic for elderly than young drivers and hence could be a distracting factor.



Researchers set up an automatic traffic recorder to collect data on individual vehicle speeds and headways.

The Effects of Vision Enhancement Systems (VES) on Older Drivers' Ability to Drive Safely at Night and in Inclement Weather

Principal Investigator: Tom Smith, School of Kinesiology and Leisure Studies

This project is examining the efficacy of vision enhancement systems (VES) that are being developed to help the driver "see" by using sensors in the ultra-violet and infrared spectra and displaying the information as visible light in a head-up display that is overlaid on the traffic environment. The purpose of VES displays are to assist the driver at night, dusk, and in inclement weather.

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 impact of signage and vehicle velocity on collisions or near collisions as a function of blind spots generated by the width of the front doorpost of an automobile. Traffic engineers have reported this problem, especially at rural intersections where the signage



employed is often 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 signage, and the failure by 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, this research seeks to determine the frequency of accident-likely events caused by such blind spots. The research 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.

Computing, Sensing, Communications, and Control Systems

Lateral Stability of Narrow Commuter Vehicles

Principal Investigators: Lee Alexander and Rajesh Rajamani, 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 practical narrow vehicle of this type will have to be stable at all speeds and on all surfaces (including snow and ice), be tem-

perature-controlled 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. The researchers propose to extend the work of earlier researchers in this field by testing modern sensors, actuators, and control design methodologies on a large-scale model of this type of vehicle, and then design and build a full-sized vehicle to be used for continuing research.

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.

A New Approach to Assessing Road User Charges

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

This research is evaluating a design for a road user charge system that avoids the problems and shortcomings of current mechanisms while having the following 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 at different 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.

Technologies that are being investigated are differential GPS integrated with digital maps. To carry out the study objective, the researchers, together with the University of Iowa, are addressing 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 data privacy.

An Automatic Visibility Measurement System Based on Video Cameras (Phase 2)

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

This research will continue to develop and refine the automatic visibility measurement



methods developed based on image processing of video images in Phase I. Study of basic measurement principles is being expanded to include a single target (multiple-target approaches were used in Phase I) for easier implementation. Video image characteristics can vary drastically depending on the types of cameras, digitizers, lighting conditions, bit resolutions, etc. A new image calibration approach will be developed to cope with the differences in imaging characteristics. In addition, night visibility will be further studied in the visible and near infrared spectrum regions through design of different types of light sources and targets. The main benefit of this research is that video images produced by many surveillance video cameras will be further utilized to determine visibility conditions.

Algorithms of Vehicle Classification (Phase 2)

Principal Investigator: Nikolaos Papanikopoulos, Department of Computer Science and Engineering

This research will continue the work of Phase 1 and show more strongly the potential of laser scanners, CCD cameras, and infrared sensors as vehicle classification devices. The ultimate goal is to develop an inexpensive multi-sensory portable unit that can classify vehicles quickly, safely, and accurately. The researchers plan, based on the work of Phase 1, to improve the vision-based vehicle classification algorithms and adapt them to infrared images and images

that are the output of laser scanners. The final step is to implement these algorithms in real-time computing hardware. The research during Phase 2 consists of the following tasks: dynamical statistical pressure snakes for vehicle classification, neural-network based classification, comparison of the results of Phase 1 with other vehicle classification sensors and techniques, evaluation of laser scanners for vehicle classification, and development of a small prototype unit.

Handling Pedestrian Control Issues at Busy Intersections and Monitoring

Large Crowds

Principal Investigator: Nikolaos Papanikopoulos, Department of Computer Science and Engineering

This project provides a new way of looking at pedestrian control issues at busy intersections. Furthermore, the proposed techniques can be used to monitor large crowds. The researchers are using their experience in handling scenes with a small number of pedestrians to handle cluttered scenes at busy intersections. Instead of focusing on the detection or tracking of single pedestrians, they are focusing on the detection and tracking of crowds. They plan to illustrate their approach to busy (with respect to the number of pedestrians) intersections; the development will be on a PC-based system with a C80 board. Finally, they will illustrate their approach in video sequences of large crowds (athletic events, schools, underground scenes, etc.).

Managing Suburban Intersections Through Sensing

Principal Investigator: Nikolaos Papanikopoulos, 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. Traffic lights should discourage behaviors that do not follow rules.

With this project, the researchers are developing 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 Papanikopoulos, 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 are adapting 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 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.

GPS-Based Failure Identification System for Intelligent Vehicles

Principal Investigator: Rajesh Rajamani, Department of Mechanical Engineering

This project is working to develop and implement a fault diagnostic system for intelligent vehicles that can monitor the health of the sensors and actuators on a vehicle and identify the source of a malfunction as soon as a malfunction occurs.

Two key technical challenges need to be addressed in the design of the fault diagnostic system: 1) vehicle dynamic models are nonlinear, but fault diagnostic methods based on analytical redundancy exist in literature primarily for linear time-invariant systems; and 2) automated vehicles utilize sensors that measure inter-vehicle and vehicle-

road variables. The first of these challenges is being addressed through the development of a systematic fault diagnostics methodology for nonlinear systems. The second technical challenge is addressed through the formulation of solutions specific to the automated vehicle application domain.

Thus far, the project has developed and implemented a fault diagnostic system on the SAFETRUCK that can effectively monitor the health of the GPS system, the lateral accelerometer, and the yaw-rate gyroscope which constitute the set of lateral dynamic sensors and the forward-looking radar that measures distance, relative velocity, and azimuth angle to other vehicles and objects on the highway.

The immediate benefit of this project is that the fault diagnostic system will enhance the safety of the SAFETRUCK and also help improve its control system performance. The longer term benefits arise from the fundamental need for fault tolerance in both partially and fully automated vehicles.

Model-Based Intelligent Vehicle Control System

Principal Investigator: Rajesh Rajamani, Department of Mechanical Engineering

This project will develop and implement an intelligent cruise control (ICC) system on a Volvo truck that is being donated to the University of Minnesota (U of M). The ICC system would automatically monitor vehicles on the same and adjacent lanes on the highway, detect vehicles that "cut in" from adjacent lanes, switch from speed control to spacing control when necessary, and provide safe and comfortable driving in the presence of moderately dense traffic. The work is being done in collaboration with Volvo, which will provide detailed engine maps, vehicle parameters, and access to existing sensors and actuators on the truck. The project is being cost-shared by using funds from a U of M Grants-in-Aid research grant and indirectly through engineering person-hours contributed by the U of M Center for Diesel Research and by Volvo. The immediate benefit of the ICC system would be to enable a

Mobile Emissions Laboratory on the Volvo truck to safely and accurately follow vehicles on the highway and make reliable exhaust plume measurements. The long-term benefits of the research include the improvement of safety in highway driving, the development of a test-bed for future research related to vehicle automation, the potential use of the vehicle monitoring system for driver assistance in poor visibility, and the reduction of fuel consumption by 25 percent in the case of trucks operating as a fleet by the use of ICC.

Automated Vehicle Control Algorithms and Their Influence on Traffic Flow

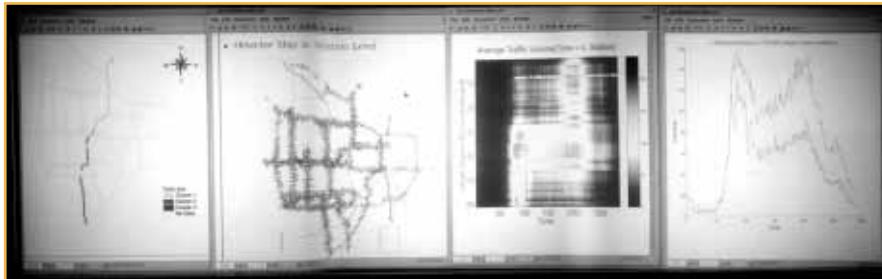
Principal Investigators: Rajesh Rajamani, Department of Mechanical Engineering, and David Levinson, Department of Civil Engineering

This project will concentrate on development of new vehicle-following algorithms and on a rigorous analysis of such algorithms in a unified framework. The researchers will 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.

High-Performance Spatial Visualization of Traffic Data

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

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 multi-dimensional visualization of occupancy as a function of multi-dimension time (year, season, day of the week, hour of the day) and multi-dimensional space (highway, distance from city centers, etc.) for traffic data from the last five years can take a long time using the current tools. This performance bottleneck forces visualizations to be limited to a very small sample of traffic data from the data set collected by the sensors, and makes it difficult for traffic researchers to perform interactive visualization when asking "what if" questions. Also, 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

large volume of traffic data.

This project seeks 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 by developing new ways to address existing performance bottlenecks.

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

*Principal Investigators: Craig Shankwitz and Max Donath,
Department of Mechanical Engineering*

Metro Transit and Mn/DOT currently are cooperatively operating a BRT-like capability throughout the Twin Cities metro area.

Buses operate in HOV lanes and on specially designated bus-only road shoulders, albeit at speeds significantly lower than limits posted for the adjacent highway. By enhancing bus-only shoulders, they become a more viable component to be integrated in future BRT systems.

Although the bus-only shoulder policy continues to be a very successful program, emerging driver-assistive technology developed at the University of Minnesota can be used to solve problems associated with driving on bus-only shoulders. For instance, most of the shoulders on which transit buses operate require that a driver maintain a lateral error of less than one-half foot to avoid collisions. This is a difficult task under the best conditions, and degrades to impossible during conditions of bad weather, low visibility, high traffic congestion, etc.

This work is the first phase of a plan to adapt and develop driver-assistive technology optimized for bus operations, focusing primarily on lane keeping and forward collision-avoidance driver-assistive technologies originally developed for snowplows. The secondary (and long term) focus is on collision avoidance for the rear and sides of transit vehicles.

Technologies for Modeling, Managing, and Operating Transportation Systems

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. At present the researchers have obtained crash records on 60 fatal crashes from Mn/DOT and have developed a modeling structure for run-off-

road and pedestrian crashes. They are currently working on the modeling structure for two-vehicle crashes.



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 bot-

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. Detailed algorithms with 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 2)

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 weaving areas in the Twin Cities' metro freeway network. Further, the traffic behavior and the factors affecting capacity in a Type A ramp-weave section, the most common type of weaving area in the Twin Cities metro freeway system, were analyzed. An online model was developed to estimate the time-variant capacity of Type A ramp-weave sections. This research is expanding 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.

Signal Operations Research Laboratory for Development and Testing of Advanced Control Strategies (Phase 2)

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 2 is expanding 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 section-



tory, will also be used as an education and training tool for undergraduate and graduate students and practicing engineers.

Improving the Estimation of Travel Demand for Traffic Simulation

Principal Investigators: David Levinson, Gary Davis, and Panos Michalopoulos, 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 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.



wide system performance directly quantified with detector measurements. 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 labora-

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 being 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 microsimulation through a recently developed tool called the Traffic Management Laboratory (TRAMLAB) for assessing the effectiveness of Mn/DOT's control strategy in two Twin Cities freeway sections totaling approximately 35 miles (56 km). To take into account diversion through adjacent arterials, the feasibility of simulating a whole corridor section will be assessed. 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 explored 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.

Future TMC Operations System Prototype and Testing Facility (Phase 2)

Principal Investigator: Panos Michalopoulos, Department of Civil Engineering

This phase of the research is to develop an innovative and unique "Future TMC operations system prototype and testing facility." The work has two major objectives. The first



is to analyze and understand Mn/DOT's current Traffic Management Center (TMC) control room operations. Based on the results of the analysis, the researchers will propose and develop alternative concepts for future control room operations. These concepts will be presented to the TMC for feedback and prioritization, with detailed design of the selected concepts and a user interface for their implementation to follow. The second objective is to expand the current TRAMLAB system by adding new components, such as ramp metering Variable Message Sign (VMS) control and simulation. The expanded TRAMLAB system will serve as a Traffic Management Laboratory able to evaluate operational control policies and objectives, new ramp metering control algorithms, and data/control parameter derivation rules. In short, in this phase a new incremental and component-independent facility will be developed for rapid development, testing, and deployment of the next generation TMC.

Traffic Flow Modeling and Simulation of the Miller Hill Corridor

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

This project is studying the traffic flow modeling, simulation, and signal timing plans evaluation of the Miller Hill corridor along 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 area. Along this 2.3-mile (3.7-km) corridor, eight signalized intersections and seven road segments will be investigated. A real-time, non-intrusive data collection system will be used to collect traffic data on the corridor and provide useful data in some locations not currently covered by the existing loop detectors. Researchers will then model traffic flow using a macroscopic approach and, using the collected traffic data, will identify and properly tune the 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 be analyzed and used to evaluate alternative traffic signal timing 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.

Social and Economic Policy Issues Related to ITS Technologies

Transportation Technologies for Sustainable Communities

Principal Investigator: Lee Munnich, Humphrey Institute of Public Affairs

Developing a sustainable transportation system is a key goal of Mn/DOT. While sustainability has many definitions, reducing negative environmental impacts, increasing multi-modalism, and improving safety are all elements of a sustainable system. The State and Local Policy

Program (SLPP) at the Humphrey Institute of Public Affairs has examined many aspects of ITS and smart growth, including institutional and political issues related to telecommuting and development of indicators of sustainable transportation. Key technologies now in late stages of development and early stages of deployment include Global



Positioning Systems (GPS), telecommunication, and wireless technologies. Given the potential widespread impact, this study will

examine the political, legal, and institutional issues raised by the application of GPS, wireless, and telecommunications technolo-

gies to transportation and will begin to investigate the question of what additional effects may result.

Abstracts of Newly Funded Research Projects

Human Performance and Behavior

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

Principal Investigator: John Bloomfield, Human Factors Research Laboratory

Driver fatigue is a contributing factor in highway crashes, and commercial motor vehicle (CMV) drivers are particularly vulnerable. The effects of fatigue on driving could be mitigated in a number of ways, such as by the use of testing instruments by law enforcement officers to determine when drivers are fatigued, by the use of monitoring systems that would warn a driver so that he or she could take corrective action, and through the dissemination of information both to CMV drivers and to the general public to make both groups more aware of the effects of fatigue on drivers. This proposal focuses on the first of these approaches by exploring the relationship between sleep deprivation, driving performance, and measurements obtained from a candidate-testing instrument.

Between 20 and 40 subjects will be kept awake and tested throughout a 20-hour period. Driving performance data will be collected while the subjects drive in a wrap-around driving simulator. Impairment will be assessed with various measurement instruments—including EyeCheck™, the psychomotor vigilance test (PVT), and the digit symbol substitutions test (DSST)—before

and after each driving session. If it appears there is a reliable relationship between driving performance impairment and the output of the EyeCheck™ once the data are analyzed, then these data will be formulated in a way that facilitates use by law enforcement officers.

Accident Analysis for Low-volume Roads

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

This study seeks to determine, via meta-analysis of extant accident data for greater Minnesota township roads, whether or not design of low-volume roads, and/or existing standards relating to signage on them, are driven by decisions based on accident data. The researchers will analyze accident data in a typical out-state county to determine accident rates on low-volume township roads and discover if signage, seasonal variations, and other factors influence accident rates.

Deer Avoidance Research: Use of Motion Detector Flashing Light

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

Each year in Minnesota there are approximately 20,000 reported, and as many as 10,000 unreported, deer-vehicle collisions. These collisions result in personal injuries, costly vehicle damage, loss of wildlife, and two to three human deaths per year.

Various methods of deer control have been



implemented in regions with high deer concentrations. All have had mixed results, and most have proven ineffective.

This study seeks a driver-centered approach. Rather than attempt to manipulate fauna, which are unpredictable and quickly habituate to most control methods, this research seeks an effective method of manipulating driver behavior.

New technologies have been developed using infrared motion detectors coupled with standard warning signage with the hope of improving both driver awareness in deer crossing zones and the ability to precisely indicate the location of the deer. For example, General Motors's infrared detection system is mounted on a vehicle's grill and detects long-range infrared signals, which are converted into a video signal and projected to the driver via a head-up display on the lower portion of the driver's windshield. The effectiveness of this system has not been evaluated.

The researchers propose building a simulator model of a typical Minnesota road and incorporating existing signage and the proposed infrared deer warning systems to assess driver responses prior to real-world implementation.



Computing, Sensing, Communications, and Control Systems

GPS-based Real-time Identification of Tire-road Friction Coefficient

Principal Investigator: Rajesh Rajamani, Department of Mechanical Engineering

This project aims to develop a GPS-based system that can provide accurate real-time estimates of tire-road friction coefficients for a vehicle. The proposed system combines knowledge of vehicle dynamics with real-time measurements of the longitudinal and lateral motions of a vehicle in order to calculate the value of the friction coefficient at the tires.

The friction identification system would be useful to snowplows, since real-time knowledge of the friction coefficient could aid in snowplowing and salt-addition operations. Real-time identification of the friction coefficient would also be immensely valuable for driver-assistive safety systems, including ABS, skid control, collision avoidance, and adaptive cruise control.

Automated BRT: Innovative Technologies for Dedicated Roadways

Principal Investigator: Craig Shankwitz, Department of Mechanical Engineering

This research will develop safe, economical methods to implement fault-tolerant, robust driver-assistive systems that perform vehicle guidance and collision-avoidance tasks for heavy vehicles. At the conclusion of this work, the robustness and reliability (and therefore, safety) of the driver-assistive sys-

tems presently under development will be significantly increased.

The primary applications for this technology in Minnesota are for buses operating on bus-only shoulders and on dedicated bus ways. The main thrust of this research will use the Institute's SAFETRUCK as a test bed to develop these robust, redundant vehicle guidance and collision-avoidance technologies. Once proven on the SAFETRUCK, the technology will be applied to transit buses and exhaustively tested, ideally in a field operational test scenario.



Driver-assistive Systems for Rural Applications

Principal Investigator: Craig Shankwitz, Department of Mechanical Engineering

This research is aimed at developing a deployment path for the driver-assistive system developed for snowplows over the next five years. This driver-assistive system uses high-accuracy DGPS, digital maps, radar, and a head-up display (HUD)-based graphical user interface to create a virtual view out the windshield when the normal view is obscured by snow, sleet, ice, rain, or darkness.

The research is separated into two components. The first aims at developing a technology to quickly and efficiently create digital

maps using data collected during paint striping operations. Currently, the digital maps used for driver-assistive systems are created from photogrammetry, or vehicle "drive-over" data, which is then manually reduced, formatted, and placed in a geospatial database. These techniques are time consuming, labor intensive, and expensive. To automate the process, data acquisition equipment will be located on paint striping equipment and configured to measure precisely where the lane boundaries are placed. From that data, smoothing, feature extraction, and formatting software will be developed to automate the creation of the digital map.

The second component of this deployment path will give county engineers the opportunity to evaluate driver-assistive technology, provide feedback, and help improve the technology. The intent is to partner with a number of counties across Minnesota in order to get feedback on the deployment of these technologies in a variety of landscapes.

Technologies for Modeling, Managing, and Operating Transportation Systems

Gap Acceptance Model/Conflicts and Accidents at Merging and Turn Lanes

Principal Investigators: Gary Davis and David Levinson, Department of Civil Engineering

A recurring problem in intersection and interchange design involves assessing the tradeoffs between the geometric characteristics of ramps, turn lanes, or merge lanes and

the potential for accidents during merging. This project will conduct an empirical investigation of merging behavior on selected Minnesota roads with the aim of developing a gap acceptance model that adequately describes driver behavior during merging. The gap acceptance model will then be used to predict the likelihood of "near misses" during merging as a function of 1) geometric characteristics such as design speeds and

lengths of merging lanes, and 2) speed and gap distributions of oncoming traffic. Finally, the near-miss model will be coupled with a model of braking, acceleration, and reaction time to predict the number and severity of rear-end collisions in the merge area. This will provide a tool for comparing the differences in expected merging accidents for different merging/turning lane designs.



Development of a Dynamic Route-Clearance Strategy

Principal Investigator: Eil Kwon, ITS Institute

Providing a safe and fast driving environment for emergency vehicles so they can reach their destinations in the least amount of time possible is vital for saving lives and reducing property loss. Although various types of signal preemption technologies have been developed to provide a green light for an emergency vehicle approaching an intersection, current state-of-the-art signal preemption in the United States has not reached the point where route-based signal clearance strategies can be automatically generated and implemented in real time.

This research will develop dynamic route-based signal preemption strategies by com-

bining emerging technologies in wireless network communication and automatic vehicle location. The first phase of the research will formulate alternative strategies and conduct preliminary evaluation under the simulated environment. Further, a framework for an interface with the Traffic Operations Center of the city of Minneapolis, which operates the intersection signals for the University campus network, will also be developed with the participation of city traffic engineers. The results from the first phase of this research will be used to develop a prototype dynamic route-clearance system in the subsequent phase.

TMC Traffic Data Automation for Mn/DOT's Traffic Monitoring Program

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

Mn/DOT has been responsible for collecting, analyzing, and publishing traffic count data from the various road systems throughout the state. The traffic reporting system developed chiefly by the Traffic Forecasting and Analysis Section (TFAS) of Mn/DOT has been used in several federal programs, internal Mn/DOT applications, and the private

sector. The objective of this project is to continue the TFAS's automation efforts by computerized integration of the current manual effort to import, filter, and analyze the Traffic Management Center's portion of traffic data contributed to Mn/DOT's Traffic Monitoring System. The resulting system will allow users to specify the conditions for acceptance tests required by TFAS for both continuous- and short-duration-count volume data. Once the filtering procedures and parameters are set by an operator, the raw data can then be automatically processed by the system without human intervention.

Ramp Meter Delays, Freeway Congestion, and Driver Annoyance

Principal Investigators: David Levinson, Department of Civil Engineering, and Kathleen Harder, Human Factors Research Laboratory

Current ramp metering algorithms try to maximize capacity, implicitly minimizing total delay. If travelers value time at the ramp differently than time-in-motion, this time-minimizing strategy may not maximize utility for travelers. This research will attempt to quantify the importance travelers give to qualitatively different experiences of travel time: waiting at a ramp meter versus trav-

eling at different freeway speeds requiring varying numbers of acceleration and deceleration shifts. This information will enable ramp meters to be better timed in a way that responds to individual perceptions.



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Urban
Cities in the Telecommunications Age

Planning
Planning for the Long Range

Capello

Spatial Economic Analysis of Telecommunications
Regional Concentrations

Planning
Planning for the Long Range

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 policy, among others.

The Institute sponsors and supports many edu-

cational 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 attend national conferences, awards that recognize outstanding students, and research assistantships to help attract more students to the study of

transportation. Through these initiatives, the Institute is increasing awareness of and interest in its core ITS science and technologies.



Through education initiatives, the Institute is increasing awareness of and interest in its core ITS science and technologies.



Students viewed exhibits from organizations involved in transportation at the sixth annual Transportation Career Expo.

Over 70 participants—from institutions including the University of Minnesota, St. Cloud State University, and North Dakota State University—attended sessions and viewed exhibits from 18 organizations involved in transportation.

Students hear advice at Career Expo

In March, the Institute partnered with the Center for Transportation Studies, the Women's Transportation Seminar, the Minnesota Local Road Research Board, and the Minnesota T²/LTAP Program to hold the sixth annual Transportation Career Expo in Minneapolis. Over 70 participants—from institutions including the University of Minnesota, St. Cloud State University, and North Dakota State University—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: engineering/technical careers, transportation/policy careers, intelligent transportation systems (ITS), and transportation logistics careers. The ITS session was moderated by Dawn Spanhake, the Institute's manager of research development and contract management, and featured panelists from private

industry and the Minnesota Department of Transportation.

Institute helps prepare student for career in driver behavior

Selma de Ridder, graduate research assistant at the Institute's Human Factors Research Laboratory, credits the Institute with helping her work toward a profession in which "I might really be able to make a difference," she says. That difference may take the form of vehicle safety improvements that reduce crashes, as well as improvements in comfort and convenience.

Although she first considered a career as an artist, de Ridder says she is happy to have found her current niche in driver behavior research.

de Ridder recently accepted a job at TNO-Human Factors in Soesterberg, the Netherlands, and will begin work there in November 2001. At TNO, de Ridder will be coordinating and conducting research for industry and government on a variety of projects related to driver and traffic behavior.

ITS Institute funds allowed de Ridder to attend the TRB 2000 Annual Meeting, where, she says, "I realized most clearly that I was very interested in this particular work and



Graduate research assistant Selma de Ridder in the Institute's Human Factors Research Laboratory

have been even more excited since." She also met a researcher whom she'll be working with at TNO. "So in many ways that conference was a great opportunity," she says.

Receiving the 2000 Matthew J. Huber Award (for excellence in transportation research and writing) from CTS was another good opportunity for her, she says, in that it allowed her to meet people and provided additional research funding. Preparing research grants through the Institute "taught me the ropes of practical implications related to grant writing and funding possibilities," she adds.

de Ridder is a doctoral candidate in kinesiology at the University of Minnesota and holds a doctorandus [master's degree equivalent] in theoretical psychology from the University of Leiden, the Netherlands.

Mentoring program gives student experience in ITS research

The President's Distinguished Faculty Mentor Program at the University of Minnesota gives freshmen and sophomores who are just beginning their academic careers an opportunity to learn and gain practical experience from faculty. This program, which pairs participating students with a faculty mentor, helps students maximize their scholastic and professional development opportunities and provides a solid foundation for graduate school.

The program has been an invaluable tool for mechanical engineering student Jennifer Wagner. Her mentor, professor and Institute director Max Donath, has given her advice, motivation, and best of all, connections, Wagner says. Following Donath's advice, she obtained a drafting position with the Narrow Commuter Vehicle project that is designing and building a half-lane-wide tilting vehicle. "The mentoring experience has been very helpful. Besides the expanded network, it has



helped me learn about the [University] and all it has to offer," Wagner says.

Faculty learn from the mentoring program, too. "It was my pleasure to have [Wagner] participate on our team," says Donath. "I learned as much from her as she did from us. Her enthusiasm is not the kind that you typically experience in the classroom. Her work with Lee Alexander made a real difference."

Institute sponsorships help students attend national conferences

The Institute sponsors ITS students to attend various conferences so that they can report on their research to larger audiences.

Students also help staff Institute exhibit areas, giving them a chance to interact with conference participants. This past year, the Institute sponsored 14 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 were Seshasai Kanchi, Atif Sheikh, Subramaniam Vijay-Konduru, Satyanarayana Muthuswamy, Sreemannarayanan Nanduri,

In the Data Acquisition Laboratory at UMD's ECE Department, student David Olsen and Dr. Rocio Alba connect and test a microcontroller that will be used to read information from sensors, process the information, and generate control signals for actuators.



Duluth-area high school students toured the campus as part of the FHWA's National Summer Transportation Institute.



University team members Paul Zachman, Kevin Miller, Andy Pullis, Josh Chambers, and Patrick Starr at the Ninth Annual Intelligent Ground Vehicle Competition in Rochester, Mich.

Ravi-Praveen Ambadipudi, Kate Sanderson, and Wing Lau.

Students attending ITS America were Xi Zou, Pavithra Kandadai-Parthasarathi, Atif Sheikh, Prasoon Sinha, Adarsh Sekhar, and Jiji Kottomannil.

Institute partners with Fond du Lac Tribal and Community College

The ITS Institute was a partner in the Summer Transportation Institute hosted by the Fond du Lac Tribal and Community College. The summer institute ran for four weeks between July 17 and August 18 of 2000.

The National Summer Transportation Institute (NSTI) is funded by the U.S. Federal Highway Administration (FHWA). The NSTI provides career orientation and educational experiences to motivate secondary school students toward college education and professions in the field of transportation by exposing them to a variety of academic experiences.

During the ITS Institute-sponsored tour, the

students viewed a presentation describing intelligent transportation systems that put them into the context of day-to-day living experi-

enced by the students. The explanation of research projects currently underway at the Institute helped the students understand the future of transportation and the role technology will play. The students were also given a tour of Mn/DOT's Traffic Management Center, where they were able to see first-hand how vital technology is to the transportation system.

On August 18, ITS Institute director Max Donath participated in the closing "graduation" ceremonies together with the Fond du Lac Tribal and Community College president Lester "Jack" Briggs in Cloquet, Minn.

Students create "intelligent ground vehicle" for competition

A team of mechanical engineering students built a vehicle for and competed in the Ninth

Annual Intelligent Ground Vehicle Competition (IGVC), hosted by Oakland University in Rochester, Mich., June 2–4. It was the first time in many years that a University of Minnesota team competed in the annual event.

The IGVC project, which was funded by the Institute, prepares students for working with “intelligent machines” and helps them understand vehicle guidance technology. “The real benefit of these vehicles is that they let students know the potential of the technology available today,” says student Josh Chambers, a team member responsible for the vehicle’s programming and maintenance.

With two semesters to complete the project, the students faced the task of building a fully autonomous ground vehicle that, during the obstacle course competition, needed to stay within a five-mile-per-hour speed limit, avoid obstacles on the track, and complete the course within ten minutes.

To create the vehicle, students designed and built a manually controllable robot platform and then designed, built, and tested a sensing and control system to direct the robot. The vehicle uses a differential system for maneuverability and sensory devices to gather course data, which are then converted into control signals by the vehicle’s central computer.

Although the vehicle didn’t fare as well at the competition as it did in testing (motion control and algorithm problems prevented it from qualifying), building it was an invaluable learning experience for the students, Chambers says. Although many of the technical skills gained from the experience were useful, what he learned about group dynamics was more valuable because that could not be learned from a textbook. In addition, Chambers says, “I



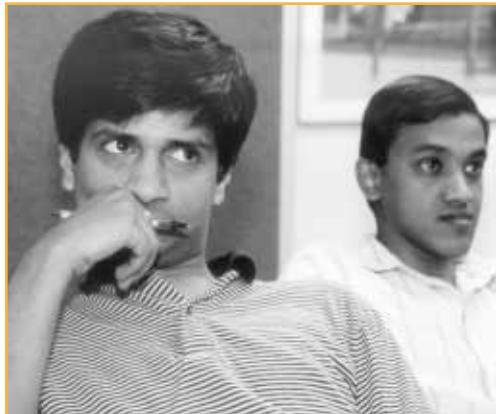
learned that I have to confront problems the first time I see them, and not push them off to the side where they will come back at the worst time possible.”

New program expands research opportunities for UMD students

With the creation this past year of the Northland Advanced Transportation Systems Research Laboratories, University of Minnesota Duluth undergraduate and graduate students will have an important new resource for conducting transportation-related research and a place for developing and testing new traffic information systems. In addition, students from the Fond du Lac Tribal and Community College, Iron Range community colleges, and UMD will work on NATSRL research projects under funding obtained from a National Science Foundation Computer Science, Engineering, and Mathematics Scholarships grant awarded to the UMD Department of Computer Science.

UMD students and faculty involved in NATSRL projects include (left to right): Victoria Harp, Dale Gehrke, Dr. Richard Maclin, Chad Pruden, Dr. Donald Crouch, Josh Westerlund, Dr. Carolyn Crouch, Bridget Thomson, and Anthony Uttley

Receiving the Student of the Year Award was gratifying, Sergi says, because "it made me feel that I contributed something worthwhile to the field [of ITS]."



Seshasai Kanchi, a graduate research assistant in the Department of Civil Engineering, received the 2001 Matthew J. Huber Award.



Michael Sergi received the 2000 Outstanding Student of the Year Award at the TRB 80th Annual Meeting.

Students receive TRB, CTS awards

Michael Sergi received the 2000 Outstanding Student of the Year Award at the Transportation Research Board (TRB) 80th Annual Meeting, held in January in Washington, D.C. For the past nine years the USDOT has honored the most outstanding student from each University Transportation Center at a special ceremony during the TRB meeting.

Sergi, a research assistant at the ITS Institute's Intelligent Vehicles Laboratory, was recognized for his work on developing the web-based laboratory used as a baseline for the ITS Interdisciplinary Laboratory. The laboratory, used in the mechanical engineering robotics course, required students to write and test their own software to automate the steering and guidance systems of a truck so that it could drive on a test road digitized in a geospatial database.

As the teaching assistant for the class, Sergi wrote the technical material that was used for the project and developed and tested the software that the students used. (The project details are described on the Web at www.me.umn.edu/courses/me5268/project.html.)

According to Professor Max Donath, instructor for the course, the Institute hopes to use the system as a model for training future transportation professionals in the component technologies of ITS.

Receiving the Student of the Year Award was gratifying, Sergi says, because "it made me feel that I contributed something worthwhile to the field [of ITS]." Sergi is pursuing his master's degree in mechanical engineering at the University of Minnesota.

Seshasai Kanchi is the 2001 recipient of the Matthew J. Huber Award for Excellence in Transportation Research and Education. CTS presents this award annually to graduate students 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 contribution to the teaching and study of trans-

portation at the University of Minnesota.

Kanchi, a graduate research assistant in the Department of Civil Engineering, was nominated by Assistant Professor David Levinson.

The awards were presented at the CTS annual meeting and awards ceremony held in April in Minneapolis.



Students from the Fond du Lac Tribal and Community College, Iron Range community colleges, and UMD will work on NATSRL research projects under funding obtained from a National Science Foundation Computer Science, Engineering, and Mathematics Scholarships grant awarded to the UMD Department of Computer Science.



Technology Transfer

Technology transfer plays a vital role in accomplishing the Institute's goals. Through technology transfer, Institute research results reach local, national, and international audiences 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, policymakers, and the general public about ITS issues and solutions.

Graduating students



joining the workforce represent the most direct, but not the only, means of technology transfer. By creating and staffing informational exhibits, sponsoring seminars, producing publications, and maintaining a web site, the Institute is able to communicate to a broad and diverse audience of researchers, students, practitioners, policymakers, and others among the general public.

This section of the Annual Report highlights the Institute's outreach efforts over the past year.

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Assistant Professor Mats Heimdahl (center) with students Yunja Choi (left) and Sanjai Rayadurgam

Transportation seminars highlight diverse ITS research

During the 2000–2001 academic year, the Institute initiated a new multidisciplinary seminar series at the University. These Advanced Transportation Technologies seminars included a diverse set of presentations that covered many areas of ITS research and featured local and national researchers.

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

The past year's presentations were:

- “Driver-Assistive Systems” by Craig Shankwitz, Mechanical Engineering
- “Evaluation of Ramp Metering in Twin Cities Freeways” by John Hourdakis, Civil Engineering
- “Image Compression for Storage and Transmission of Digitized Images” by Vladimir Cherkassky, Electrical and Computer Engineering
- “Traffic-Responsive Ramp Metering: Current Status and

Future Directions” by Eil Kwon, ITS Institute

- “Advancements in Transit-Related Research” by Walter Kulyk, Director, Federal Transit Administration Office of Mobility Innovation
- “Monitoring Weaving Sections Using Computer Vision Techniques” by Nikolaos Papanikopoulos, Computer Science and Engineering
- “Reassessment of Road Accident Data Analysis Policy in Minnesota” by Eitan Naveh, [formerly of the] Center for Technological Leadership, and Alfred Marcus, Carlson School of Management
- “An Automatic Visibility Measurement System Based on Video Cameras” by Taek Kwon, Electrical and Computer Engineering (UMD)
- “The Influence of First- and Second-Generation Antihistamines and Alcohol on Driving Performance” by John Bloomfield, Human Factors Research Laboratory
- “Narrow Tilting Vehicles for Future Individual Transportation” by Dean Karnopp, Mechanical and Aeronautical Engineering, University of California at Davis
- “Software Issues in Critical Transportation Systems” by Mats Heimdahl, Computer Science and Engineering
- “Psychological and Roadway Correlates of Aggressive Driving” by Kathleen Harder, Human Factors Research Laboratory, and Terry Kinney, Department of Speech Communication

Institute holds first research program review

In August of 2000, the ITS Institute hosted its first Research Program Review. Faculty

and students presented information on ITS-related projects currently underway at the University of Minnesota. Tours of the Human Factors Research Laboratory, ITS Laboratory, and the SAFEPLOW were offered during the two-day event.

Review committee members included representatives from the USDOT, local government, academia, and the private sector. Members met with the Institute director following the review sessions and had the opportunity to provide suggestions for improving both individual projects and the ITS Institute research program as a whole. Overall, the comments were very favorable for the Institute's research program and its peer review process.

The peer review presentations were open to anyone interested in hearing about the Institute's research—a benefit to practitioners and others who wanted to learn more about ITS technologies.

Institute exhibits attract crowds, media coverage

The ITS Institute was represented at the Minnesota State Fair as part of the University's Institute of Technology exhibit



KARE-11 local TV news filmed the “mini” snowplow on display at the State Fair booth, while the Institute’s Dawn Spanhake (center) explained the driver-assistive technologies.

in the “Wonders of Technology” building. A highlight of the exhibit was a “mini” snowplow on loan from Mn/DOT’s Office of Advanced Transportation Systems that was instrumented with some of the same advanced technologies being tested by ITS Institute researchers. Those technologies included a head-up display and an electronic rumble strip that was triggered when a “driver” steered too far to the right or left (the seat vibrated, imitating the effects of a real rumble strip).

“We had what seemed like a nonstop stream of visitors, especially kids, who wanted to ‘drive’ the plow,” says Gina Baas, CTS manager of communications and conference services. “A surprising number of adults had seen TV coverage of our plow research and recognized it. We even had several city and county workers and snowplow drivers who had heard about the research at the state maintenance expos or from their co-workers.” KARE 11, NBC’s local

The highlight of the booth was a “mini” snowplow instrumented with some of the same advanced technologies being tested by ITS Institute researchers.



A tour of the ITS Laboratory was part of the Institute’s annual review meeting.



(Left to right) Officers Dick Theis, Matthew Hodapp, and Stan Gruis with Craig Shankwitz and Heonmin Lim of the University's Intelligent Vehicles Lab

TV affiliate, also covered the exhibit on its morning news show.

In addition, the Institute joined Mn/DOT's booth at this year's ITS America conference held in Miami June 4–7. The Institute sent staff members and students to manage the booth, run a slide presentation highlighting Institute research, education, and outreach efforts, and answer ITS-related questions. Visitors to the booth also received Institute folders, information sheets, and other publications.

Plow demo draws federal and state officials

An array of officials—including U.S. Senator Rod Grams and Minnesota State Senator Carol Molnau—attended a demonstration of the SAFEPLOW at the McLeod County Fair in August 2000. The demo was part of a news conference to give elected officials a local perspective on intelligent transportation systems and an update on the Intelligent Vehicle Initiative (IVI) Field Operational Test along Highway 7 between Hutchinson, Minn., and the Twin Cities. Other officials attending the press confer-

ence included five McLeod County commissioners, the mayor of Hutchinson, and members of Hutchinson's city council.

Intelligent vehicles team takes troopers for a test drive

Members of the Institute's Intelligent Vehicles Lab hosted a demo of the SAFEPLOW February 14 for Minnesota State Patrol officers at the University's Rosemount, Minn., test facility. A white opaque curtain covering the plow's windshield allowed district commander Stan Gruis, fleet manager Dick Theis, and Minnesota State Patrol Troopers Association president Matthew Hodapp to experience something akin to the white-out conditions for which the plow's technologies were designed. Those technologies include a DGPS, magnetic lateral-position sensing, high-accuracy digital road maps, a "virtual" rumble strip, and a head-up display (HUD). The result is a projected virtual view of the roadway—with lane boundaries, fixed roadside features, and obstacles—shown on a screen in front of the vehicle's windshield where the driver can easily view it without taking his or her eyes off the road.

"It's impressive," said Hodapp after taking a test drive and seeing the technology at work. Since State Patrol officers as well as snowplow operators must often drive in low-visibility conditions, the University team is installing and testing the driver-assistive technologies in a car provided by the Minnesota State Patrol. High-speed tests with the equipped patrol car are planned for September at Brainerd (Minn.) International Raceway. This research is part of the three-year IVI Field Operational Test, funded by the FHWA, Mn/DOT, and industry partners.

Visiting researchers help build Institute partnerships

During the last year, two visiting researchers worked with Institute staff on various transportation projects.

Joel Katz, traffic management coordina-



Dr. Young-Tae Oh, associate director of the Transportation Research Institute at Ajou University in South Korea

tion engineer with Mn/DOT's Traffic Management Center (TMC), spent a six-month mobility assignment with CTS last spring and summer learning and helping to create new traffic management tools useful to Mn/DOT. He also evaluated how the visiting fellow program could improve collaboration between researchers and professionals in the future. In addition, Katz worked with Professor Panos Michalopoulos of Civil Engineering on simulation research for ramp meters.

Dr. Young-Tae Oh, associate director of the Transportation Research Institute at Ajou University in South Korea, worked with Dr. Eil Kwon, director of the ITS Institute's Advanced Traffic Systems Program, from May to July. Oh came to learn about Mn/DOT's TMC and to help develop an algorithm for traffic management for South

Korea by the end of 2002.

Although Seoul has a subway system, it suffers from severe traffic congestion. Oh was interested in studying Minnesota's ramp metering system and learned a great deal from the recent ramp meter shutoff.

"Transportation has to be sensitive to public opinion," he observed. He also said he enjoyed the opportunity for connection between the universities and looks forward to future cooperation.



A snowplow outfitted with a head-up display

Media cover snowplow research

Last winter, both Twin Cities newspapers ran articles on the Institute's snowplow research, which is part of the Intelligent Vehicle Initiative (IVI) program. The *Pioneer Press*'s article, "High-tech snowplows hit the roads," and the Minneapolis *Star Tribune*'s article, "New snowplow can find its way in a blizzard," highlighted the project's driver-assistive technology for operating in low-visibility conditions and its potential safety benefits. (The *Star Tribune* article can be read at www.its.umn.edu/news/strib-superplow.html.)

In addition, local television station KMSP-TV covered an event in which Metro Transit bus drivers operated the test plow at the Rosemount course in January. As part of the IVI program, Institute researchers are exploring how the plow's driver-assistive systems could be applied to transit vehicles, particularly to help drivers navigate narrow bus-only shoulders.

Institute research efforts receive attention, support from local lawmakers

Officials from the University and Mn/DOT gathered in St. Paul in February to honor U.S. Representative Martin Sabo for his sup-

Funding

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related education.**



Duluth, Minnesota

port and leadership of transportation in Minnesota, including investing in transportation technology and research.

Funding secured by Sabo has meant that more graduate students could receive a transportation-related education, said Lee Munnich, director of the Humphrey Institute's State and Local Policy Program. Many have chosen careers in transportation policy—another big impact of Sabo's efforts.

Sabo then expressed his appreciation for the recognition. Legislators don't question ITS expenditures in Minnesota, he said, because of "our record of success—the money is spent well and the products are good." A key to this success is the connection between researchers and practitioners. He also called the Minnesota model, in which transportation funds are designated for university research and deployment, the "right way to structure a program like this."

In March, U.S. Representative Jim Oberstar joined officials from the Twin



U.S. Rep. Martin Sabo noted the success of ITS efforts in Minnesota.

Cities and Duluth campuses of the University of Minnesota, CTS and its ITS Institute, and Mn/DOT to sign a Memorandum of Understanding creating a new transportation research program at the University of Minnesota Duluth: the Northland Advanced Transportation Systems Research Laboratories (NATSRL).

NATSRL will receive \$3.7 million over four years from federal transportation funds, Mn/DOT, and the University of Minnesota.

Mn/DOT Commissioner Elwyn Tinklenberg

Tinklenberg said that the event formalized work that has been going on for a while and that NATSRL will play an important role in continuing the innovative work of the ITS Institute.

Oberstar congratulated all those who worked to develop the new program, which is partially funded by TEA-21 legislation funds. According to Oberstar, TEA-21 (the Transportation Equity Act for the 21st Century) expanded funding from its predecessor, ISTEA, to advance safety and expand mobility without the need to pour more concrete. "NATSRL will move us further down that road," Oberstar said. "I look forward to seeing really great ideas coming from this initiative."

Institute continues to expand web site, publications

Development, updates, and expansion of the Institute's Web site (www.its.umn.edu) continued over the last year.

Hosting of the site was transferred to a new dedicated server in-house, and work began on converting portions of the site from static HTML to dynamic content from the research database. The transition to a database-driven publishing system will give users access to more information and allow for more timely updates.

Information that 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



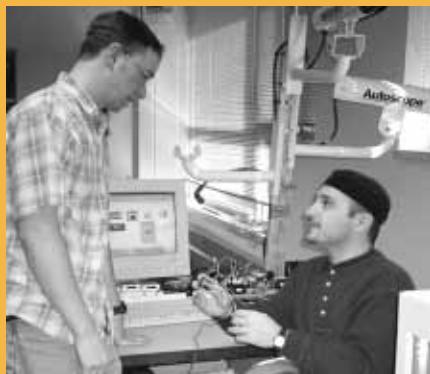
UMD Chancellor Kathryn Martin, Mn/DOT Commissioner Elwyn Tinklenberg, U.S. Rep. Jim Oberstar, and Graduate School Dean Christine Maziar sign the Memorandum of Understanding creating the NATSRL program.

listing of upcoming events, the Institute's quarterly newsletter, the Institute's annual report (as a PDF file available for download), and links to related sites of interest.

Circulation of the Institute's newsletter, the *Sensor*, increased to approximately 1,800. The *Sensor* is one of the primary vehicles for increasing visibility of the Institute, and the increased circulation represents a wider knowledge of and interest in ITS research activities among academic and professional audiences.

Other publications that the Institute produced include a semiannual and annual report, research reports, fact sheets describing Institute laboratories and research projects, and posters publicizing the Institute's advanced transportation technologies seminars.

The increased circulation represents a wider knowledge of and interest in ITS research activities among academic and professional audiences.



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