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 people to adapt to technology.

The Institute’s geographic location gives it a unique advantage for developing research applicable to transportation in a northern climate and in rural environments, in addition to the metropolitan Twin Cities area.

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

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

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

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

Intelligent Driver Support Systems

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

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

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

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

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

The multidisciplinary research project with Nissan involves a consortium of universities in the United States, Canada, Japan, and Europe. Overall research is focusing on the exploration of new ways to better support drivers and design prototype systems that will primarily be evaluated by the HumanFIRST team. Thus far, the HumanFIRST team has analyzed the types of scenarios that are typical of the crash types the Nissan system is expected to benefit. These scenarios were then reproduced within the driving simulator under conditions of driver distraction to determine if the proposed system could increase driver awareness of traffic hazards to support driving. In the first study, the system did appear to reduce the number of distraction-related crashes.

Research planned for the upcoming year will focus on the comparison of this system to other longitudinal support systems such as adaptive cruise control and crash warning systems.

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

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

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

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

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

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

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

In the first experiment, more than half of the 120 participants followed the CMS instructions, which directed them to take an alternate exit due to a crash. But of those who did not follow...
ry, and 10 participants were in the Poor category.

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

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

Based on these, and other, findings, Harder and Bloomfield came up with a series of recommendations they believe will help increase the effectiveness of CMS messages, including Amber Alerts. First, the team suggests that the Minnesota Department of Public Safety increase its efforts to make the public more aware of the Amber Alert system. The researchers also recommend changing the Amber Alert messages themselves. Since the experiments show that it is particularly difficult for drivers to remember the license plate number flashed on a CMS, the Amber Alert messages should, instead, tell drivers to tune into an appropriate radio station, whose call sign will be easier to remember. Then, when drivers tune into that station, the full Amber Alert message, including the license plate number, should be repeated frequently.

According to Harder and Bloomfield, this will greatly increase the likelihood that if a driver encounters the vehicle mentioned on the Amber Alert he or she will be able to recognize it. This also will likely result in fewer slow-downs than occurred in the experiment.

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

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

**Development of Dynamic Route Clearance Strategies for Emergency Vehicle Operations**

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

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

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

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

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

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

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

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

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

To evaluate the route-based dynamic preemption system, Kwon and his team used VisSim™ microscopic traffic simulation software interfaced to an external virtual control center module, which was developed by the researchers using the C programming language. Key capabilities of VisSim for this application included its ability to model a set of detectors that can detect only emergency vehicles. A virtual intersection controller module was also developed to emulate different types of signal preemption strategies including the existing method with local detection. Because the current version of VisSim does not permit the route of an emergency vehicle to be specified during the simulation, testing the online route selection module was not performed in this study; this phase of testing focused purely on the effectiveness of dynamic signal preemption with a pre-specified route.

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

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

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

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

Simulating Snowplow Scheduling in District 1
For cities and counties in northern Minnesota, few maintenance operations are as critical—or as unpredictable—as snow removal. Differences in snow conditions, temperature, wind, and snowfall duration call for different snowplowing and deicing techniques, which makes keeping the roads open a challenge for plow drivers as well as for the managers who schedule and direct the plows. The fact that snowplows are owned and operated by entities in different geographic areas, including cities both large and small as well as counties, adds to the logistical puzzle. Snowplow schedulers must also worry about reloading plows with sand.
and deicing compounds, refueling, and minimizing “deadheading” that occurs when a plow is traveling over plowed roads from one area to another.

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

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

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

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

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

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

For next year, the team hopes to expand the model to include more cost features and to make it as flexible as possible so that it could be applied in other districts. This could be achieved by using Excel spreadsheets as an interface to the model, which may be modified by the user. In addition, the team would like to address the problems and operational issues associated with conditions of freezing rain.

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

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

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

In developing the model, Wilson says that Mn/DOT has had to examine how it manages, plans, and carries out its operations in order to help the research team model the process. “That, in itself, has sometimes been illuminating for both Mn/DOT and us,” Wilson says. “We’ve enjoyed the partnership that has developed.”
The Twin Cities area offers a variety of infrastructure elements already in place that will enable the use of lane-assist technologies as they emerge.

Computing, Sensing, Communications, and Control Systems

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

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

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

Researchers from the Intelligent Vehicles Laboratory are adapting lane-keeping and forward collision-avoidance technologies originally developed for snowplows. Significant enhancements to the snowplow-based system have been made to specifically address issues involved with guiding a wide bus on a narrow lane. One such enhancement is the provision of torque feedback through the steering wheel to help a driver maintain the proper position in the narrow shoulder. Should the bus stray from the center of the shoulder, a corrective torque is applied to the steering wheel to gently guide the driver back to the lane center.

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

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

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

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

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

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

Lateral Stability of a Narrow Commuter Vehicle

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

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

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

With the physical model constructed, the team conducted a set of experiments that progressed from dry to slippery pavement and from simple to more complex maneuvers. Because the prototype vehicle isn’t safe enough or strong enough to carry an actual driver, researchers used remote control to guide the vehicle around their testing grounds. The experiments yielded promising results and demonstrated that by using the automatic control system, the vehicle was able to tilt and balance itself while executing complex turns.

Although General Motors first experimented with a difficult-to-drive, manual tilting vehicle back in the 1970s and 1980s, and several other automobile manufacturers are now working on some form of a narrow vehicle, the University of Minnesota team is the only group of university researchers working on such...
technology. And while the team has made excellent progress toward designing a vehicle that promises to make commuting easier, faster, and less expensive, according to Rajamani, there is much more work to be done. “We need to improve the crashworthiness of the vehicle, which is currently nonexistent.” He added that the control algorithms are far from completely reliable, and that continued testing and refinement are needed to improve the stability of the system before building a larger prototype.

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

Social and Economic Policy Issues Related to ITS Technologies

Sustainable Technologies Applied Research Initiative: Network Dynamics

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

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

Future work will include the study of human-machine interfaces, including drivability and comfort, and collision avoidance for such a machine.
illustrate the implications of current decisions on the future shape of the network.

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

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

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

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

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

**Sustainable Technologies Applied Research Initiative: Community Telecommunications Planning and Access**

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

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

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

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

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

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

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

Although these centers represent an advance in dispatching procedures for emergency personnel, obstacles such as incomplete cellular coverage—particularly in thinly populated northern Minnesota—and a constantly evolving wireless infrastructure still remain. This unique research will be an important component in Minnesota’s attempt to develop optimal solutions for residents of all areas of the state.
Human Performance and Behavior

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

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

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

Kathleen Harder, College of Architecture and Landscape Architecture

Guidelines for Using Rumble Strips

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

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

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

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

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

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

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

Project URL: www.its.umn.edu/research/projects/2003011.html

Psychological Roadway Correlates of Aggressive Driving (Phase II)

Project status: In progress
This project is an interdisciplinary effort to understand the extent to which pre-existing cognitions, emotions, roadway conditions, and attitudes toward driving contribute to aggressive driving. In Phase I of this project (already completed), a survey analysis revealed self-reported factors that can prompt aggressive driving behavior. In Phase II, researchers will examine these factors in a simulated driving environment of the Institute’s HumanFIRST Program.

Previous studies on aggressive driving have failed to address the factors that can precipitate aggressive driving as comprehensively as proposed in this study. Results from Phase I and the research proposed in Phase II will yield a rich resource of information for educational outreach throughout Minnesota and beyond, with the goal of reducing incidents of aggressive driving.

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

Reducing Crashes at Controlled Rural Intersections

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

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

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

User-Centered Auditory Warning Signals in Snowplows

Project status: In progress
Because the snowplow operator’s task is predominately visual, warnings presented visually may interfere with critical tasks. Auditory warnings could reduce visual load if they are meaningful, effectively signal danger, and are not annoying.

The researchers conducted a driving simulation experiment using a 210-degree forward field-of-view driving simulator and a field test to investigate using auditory icons as side and forward collision-avoidance warnings. Participants in the experiment drove on simulated snow-covered roads in 105-meter (344-foot) visibility conditions. Analysis of data from 28 participants showed the side collision-avoidance warnings were equally effective; lane change response times were approximately 11 seconds for both a single- and double-beep car horn warning (although participants said that the double-beep warning sounded more urgent). Analysis of the forward collision-avoidance warning data, obtained from 32 participants, showed that the mean response time with a warning consisting of two bursts of screeching-tire sounds was significantly faster than with a single-screech warning—with both warnings significantly faster than the mean time obtained when no warning was given. The poorest collision outcomes occurred with no warning; outcomes were better with the single-screech warning, and better still with the double-screech warning. In the field test, six of seven snowplow operators preferred the double-beep side-collision warning. As a result, the researchers recommend that an auditory icon sounding like the double-beep of a car horn be used as a side collision-avoidance warning, and an auditory icon sounding like two successive bursts of screeching tires be used as a forward collision-avoidance warning.

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

Auditory warnings could reduce visual load if they are meaningful, effectively signal danger, and are not annoying.
Herb Pick, Institute of Child Development
Older Drivers’ Influence of Wayfinding While Driving
Project status: In progress
This work builds on previous work done by the principal investigator on driving and navigating in which older drivers seem to be less oriented in a newly learned environment than younger drivers. This second project is looking at the consequences of this problem at the level of vehicle control. If driving while wayfinding causes problems for older drivers, it seems reasonable to see this problem as a so-called dual-task, or mental workload, problem.

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

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

Spatial Orientation and Navigation in Elderly Drivers
Project status: In progress
Most of the research on elderly drivers is understandably concerned with vehicle control. The elderly are an increasing proportion of the total population and they are already overly represented in the number of crashes occurring (per mile driven). However, because of this emphasis on control, research on the elderly and the main function of driving—i.e., getting from one place to another—has received little attention. A major facet of this topic involves, at a practical level, spatial orientation and navigation. Besides being of interest in its own right, difficulties maintaining orientation and finding one’s way may interact with vehicle control as a driver becomes distracted or even alarmed by losing his or her way, and as a result pays less attention to vehicle control or possibly makes erratic corrections en route.

Research was carried out to determine whether elderly drivers have more difficulty than young drivers in maintaining orientation when they learn routes in unfamiliar neighborhoods. Drivers learned an approximately three-mile irregular route through a novel neighborhood. After they could drive the route without errors or prompting, they were asked to indicate the direction of the route from the landmarks between the street intersections they used.

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

Initial crude observations indicated that when attention was on wayfinding, vehicle control was poorer. A more refined study of how vehicle control is affected is currently underway.

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

Tom Smith, School of Kinesiology
Reducing Risk Taking at Passive Railroad Crossings with Active Warnings
Project status: In progress
This simulated driving study involves a human factors evaluation of driver interaction with a low-cost active warning system (AWWS) being developed for potential installation at highway-rail intersections (HRIs) currently equipped with passive signage.

The objective of the study is to ascertain if, relative to HRIs with passive signage, drivers interact more cautiously with HRIs equipped with AWS technology. A disproportionate number of vehicle-train crashes in Minnesota occur at passively signed HRIs (about 100 in 1999). About 70 percent of HRI fatalities occur at passively signed HRIs, representing a $14 billion problem nationwide. Thus, use of AWS technology to abate driver risk taking at HRIs will yield safety benefits.

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

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

Project URL: www.its.umn.edu/research/projects/2000040.html

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

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

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

Deer Avoidance Research: Use of Motion Detector Flashing Light
Project status: In progress
This project is evaluating the potential impact of a new technology—motion detection information—to abate driver risk taking at highway-rail intersections. The high percentage of (mostly rural) passively signed HRIs is attributable to the high cost of conventional active warning technology. However, Mn/DOT is sponsoring a project to develop a low-cost AWS (projected at $10,000 to $15,000 per crossing) that makes use of solar-powered active warning signs that are respectively started and stopped via detection of start- and end-of-track radio signals from a train traversing the HRI. A distinctive feature of the system is that it features both grade and active advance warnings.

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

Project URL: www.its.umn.edu/research/projects/2000040.html

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

Nicholas Ward, Department of Mechanical Engineering
Driving Performance During Cell Phone Use and Common Secondary Tasks Combined Under Conditions of Driver Impairment
Project status: In progress
There is considerable debate (without sufficient research) about cell phones as a risk factor in traffic crashes and their relative risk compared to other existing secondary tasks drivers may perform in the vehicle. There is considerable debate (without consultation with a Mn/DOT technical panel, and the research will be carried out at the University of Minnesota using a driving simulator. The data will be analyzed to determine the impact of the deer avoidance technology on driver behavior.

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

Driving Performance During Cell Phone Use and Common Secondary Tasks Combined Under Conditions of Driver Impairment
Project status: In progress
There is considerable debate (without sufficient research) about cell phones as a risk factor in traffic crashes and their relative risk compared to other existing secondary tasks drivers may perform in the vehicle. There is considerable debate (without consultation with a Mn/DOT technical panel, and the research will be carried out at the University of Minnesota using a driving simulator. The data will be analyzed to determine the impact of the deer avoidance technology on driver behavior.

Project URL: www.its.umn.edu/research/projects/2002023.html
Automotive navigation systems do not have sufficient accuracy for road user charging applications. However, the GPS-determined GPS receivers that are commonly used by technical issues important for quality of service (QoS), such as video compression (using off-the-shelf commercial ... of video data in packet-switching (IP) networks. These issues have been addressed using the prototype system.

Environments—where roads of different jurisdictions and possibly different fee structures are located in close proximity ... road, for instance). In order for the system to be effective, it must be able to place the vehicle on the correct road.

Previous research (Phase I) focused on the development of system requirements for the GPS and the digital map components that makeup the core of an in-vehicle road user charging system. The focus was to evaluate both GPS and digital maps in the most difficult of width wireless channels, as well as transmission over fixed-link channels where the bandwidth requirements exceed available link capacity.

The main goal of this research was to transmittion of multiple video streams over limited-bandwidth communication channels. This includes transmission over limited-bandwidth wireless channels, as well as transmission over fixed-link channels where the bandwidth requirements exceed available link capacity.

Previous research (Phase II focused on the technical issues important for quality of service (QoS), such as video compression (using off-the-shelf commercial hardware/software) and prioritization of video data in packet-switching (IP) networks. These issues have been addressed using the prototype system developed/installed at the ITS Lab at the University of Minnesota. Phase I research helped to understand and quantify the trade-offs between the amount of compression, quality of video, available network bandwidth, and varying network traffic loads. Phase II research is concerned with practical design choices for implementing QOS under “typical” network configurations and simulating these network configurations in the prototype system in order to evaluate practical effectiveness of the QOS approach for different application settings.

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

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

This project in wireless communications is motivated by the demand of spectrally and power-efficient transmission systems of multimedia (not only voice but also images and video) traffic data over wireless links. The main objective of the research is to design and evaluate the performance of hierarchical constellation systems that have the advantage of offering different degrees of error protection and/or different rates for various bit streams. Research directions include development of adaptive M-FSK modulations for power-efficient transmission over wireless links; design and performance evaluation of hierarchical constellations; and design, analysis, and simulation of adaptive hierarchical and MFK modulation schemes for simultaneous multimedia transmission, in a bandwidth/power-efficient fashion, of ITS image and video data over wireless links.

Project URL: www.its.umn.edu/research/projects/20030317.html

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

Low-luminance contrast conditions, such as those created by blowing snow or fog, constitute some of the most hazardous conditions that drivers commonly experience. Recent experiments indicate that under fog-like conditions, people perceive themselves to be travelling significantly slower than they actually are. To compensate, they speed up. This low-luminance perceived slowing is comparable to the perceived slowing that occurs at equiluminance (no-luminance contrast), where motion information is carried by chromatic contrasts alone. In this project, the researchers will perform a series of experiments to test whether these two phenomena are governed by the same neural mechanism. They also propose to make controlled color–contrast measurements under real fog and blowing snow conditions. The combination of physical measurements and perceptual experiments will allow them to determine the impact of low-luminance contrast conditions and color on an individual’s perception of motion and space under real driving conditions. If such a relationship is demonstrated, this could lead to improvements in driving safety through the careful choice of color warning markings, chromatically controlled lighting, special fog tints, and better public education.

Project URL: www.its.umn.edu/research/projects/20030306.html

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

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

Previous research (Phase I focused on the technical issues important for quality of service (QoS), such as video compression (using off-the-shelf commercial hardware/software) and prioritization of video data in packet-switching (IP) networks. These issues have been addressed using the prototype system developed/installed at the ITS Lab at the University of Minnesota. Phase I research helped to understand and quantify the trade-offs between the amount of compression, quality of video, available network bandwidth, and varying network traffic loads. Phase II research is concerned with practical design choices for implementing QOS under “typical” network configurations and simulating these network configurations in the prototype system in order to evaluate practical effectiveness of the QOS approach for different application settings.

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

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

The main goal of this research was to develop the system requirements for the GPS and the digital map components that make up the core of an in-vehicle road user charging system. The focus was to evaluate both GPS and digital maps in the most difficult of width wireless channels, as well as transmission over fixed-link channels where the bandwidth requirements exceed available link capacity.

Previous research (Phase I focused on the technical issues important for quality of service (QoS), such as video compression (using off-the-shelf commercial hardware/software) and prioritization of video data in packet-switching (IP) networks. These issues have been addressed using the prototype system developed/installed at the ITS Lab at the University of Minnesota. Phase I research helped to understand and quantify the trade-offs between the amount of compression, quality of video, available network bandwidth, and varying network traffic loads. Phase II research is concerned with practical design choices for implementing QOS under “typical” network configurations and simulating these network configurations in the prototype system in order to evaluate practical effectiveness of the QOS approach for different application settings.

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

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

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

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

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

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

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

Previous research (Phase I focused on the technical issues important for quality of service (QoS), such as video compression (using off-the-shelf commercial hardware/software) and prioritization of video data in packet-switching (IP) networks. These issues have been addressed using the prototype system developed/installed at the ITS Lab at the University of Minnesota. Phase I research helped to understand and quantify the trade-offs between the amount of compression, quality of video, available network bandwidth, and varying network traffic loads. Phase II research is concerned with practical design choices for implementing QOS under “typical” network configurations and simulating these network configurations in the prototype system in order to evaluate practical effectiveness of the QOS approach for different application settings.

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

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

IVI Specialty Vehicle Field Operational Test
Project status: In progress

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

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

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

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

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

On Twin Cities metro freeways, loop detector stations have been installed at a half-mile spacing, forming sections. Each section thus comprises two sets of detector stations: one at the section entrance (upstream) and the other at the section exit (downstream). This research is studying a new way of measuring the average section travel time by tracing inductance signatures of the vehicles from two points, the section entrance and exit. This involves extracting the features of the inductance signatures generated by each vehicle passing through the upstream section and then re-identifying them at the downstream station by matching the features on both ends. For signal processing of vehicle inductance, several blind de-convolution approaches will be studied to develop an algorithm that leads to more clear discrimination of the inductance signatures. Another important issue in the feature-extraction process is normalization of the signatures such that each signature found is independent of the speed of the vehicles. An adaptive optimization approach will be developed for this normalization process. During the vehicle identification process, the features will be time-stamped with the arrival time and will be used to compute the travel time. Section travel-time has a significant advantage over other travel-time measurement approaches because once the travel time of all sections is known, travel time from any point to any other point can be computed by simply adding the section travel times along the route. Since this new section travel-time measurement works in real-time, if a network-wide system is installed, it would provide real-time route travel time.
Managing Suburban Intersections Through Sensing
Project status: Completed (FY03)
This project involved developing a dashboard-mounted camera to monitor the direction a driver is looking. This was done by using the Framework for Processing Video developed at the University of Minnesota by Osama Masoud. The monitoring software worked by first finding the lips on the driver’s face using color analysis. Then, the skin color of the driver can be sampled and a face region is generated. The largest holes in this region are the lips and eyes. Once the eyes are found, the software tracks the first three pixels in the eyes and marks these as the pupils. The software uses the relative positions of the eyes and pupils to make statements about the gaze direction and uses a multi-tiered tracking algorithm to keep track of the eyes once they are found.

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

Pedestrian Control Issues at Busy Intersections and Monitoring Large Crowds
Project status: Completed (FY03)
In this project, the researchers explored a vision-based method for monitoring crowded urban scenes involving vehicles, individual pedestrians, and crowds. Based on optical flow, the proposed method detects, tracks, and monitors moving objects. Many problems confront researchers who attempt to track moving objects, especially in an outdoor environment: background detection, visual noise from weather, objects that move in different directions, and conditions that change from day to evening. Several systems of visual detection have been proposed previously. This system captures speed and direction as well as position, velocity, acceleration, or deceleration, bounding box, and shape features. It measures movement of pixels within a scene and uses mathematical calculations to identify groups of points with similar movement characteristics. The system is not limited by assumptions about the shape or size of objects, but rather identifies objects based on similarity of pixel motion. Algorithms are used to determine direction of crowd movement, crowd density, and most-used areas. The speed of the software in calculating these variables depends on the quality of detection set in the first stage. Illustrations include video stills with measurement areas marked on day, evening, and indoor video sequences. The researchers foresee that this system could be used for intersection control, collection of traffic data, and crowd control.

Project URL: www.its.umn.edu/research /projects/1999020.html

Sensor-Based Ramp Monitoring
Project status: Completed (FY03)
This project covers the creation of a system for monitoring vehicles in highway ramp queues. The initial phase of the project attempted to use a blob-tracking algorithm to perform the ramp monitoring. The current system uses optical flow information to create virtual features based on trends in the optical flow. These features are clustered to form vehicle objects, and these objects update themselves based on their statistics and those of other features in the image. The system has difficulties tracking vehicles when they stop at ramp queues and when they significantly occlude each other. However, the system succeeds by detecting vehicles entering and leaving ramps and can record their motion statistics as they do so. Several experimental results from ramps in the Twin Cities are presented in the final report of this project.

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

Recognition of Human Activity in Metro Transit Spaces
Project status: In progress
Monitoring large public spaces with sensors is a challenging task with a variety of important applications. A camera system monitoring public spaces (such as airports, bridges, workzones, truck weight stations, tunnels, buses, planes, or trains) can be developed to detect all humans occupying those spaces and collect information about their activities. The proposed system is not limited to human detection, but rather can be extended to the detection of incidents that involve vehicles. Furthermore, certain types of incidents can be detected and alerts can be issued to human operators. The researchers propose the development and deployment of a system that will detect and classify human individual or group activities with the objective of notifying operators when pre-specified activities happen. They plan to evaluate the system’s robustness by its deployment in an actual public space. In particular, they plan to work with Metro Transit on applying this technology to monitor bus stops and thereby improve passenger safety on public transit.

Project URL: www.its.umn.edu/research /projects/2000303.0.html

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

Project URL: www.its.umn.edu/research /projects/2004040.html

Preventing Attacks to Critical Transportation Infrastructure
Project status: Newely funded
Preventing attacks to transportation infrastructure is a major concern for the Department of Homeland Security. Bridges, tunnels, seaport structures, airports, and rail and bus stations are vulnerable to attacks. Vehicular and pedestrian traffic is abundant at most of these sites. Recognizing events that may precede attacks is complex, since several of them blend in easily with the normal traffic activity at a particular site. This project will investigate using infrared sensors and cameras in the visible range in order to classify certain events as the pre-steps of an attack on critical transportation infrastructure. One example is a car stalled/stopped at a bridge. Currently, several states or federal agencies use human patrols to monitor events around a bridge. This project seeks the development of an automated system that notifies human operators about incidents in the general vicinity of critical infrastructure sites.

Project URL: www.its.umn.edu/research /projects/2004047.html
Abstracts of Research Projects

Rajesh Rajamani, Department of Mechanical Engineering
Adaptive Cruise Control System Design and its Impact on Traffic Flow
Project status: Completed (in FY03)
Adaptive cruise control (ACC) systems are currently being developed by automotive manufacturers for highway vehicle automation. An ACC system enhances regular cruise control by using on-board radar to maintain a desired spacing from a preceding vehicle that has been detected in the same lane on the highway. First-generation ACC systems are currently available in Japan and Europe and have just been introduced in the North American market.

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

This project concentrated on the following specific areas: 1) development of a unified evaluation framework for the evaluation of ACC algorithms, taking into account safety, comfort, and time-to-destination of individual vehicles as well as highway utilization and stability of traffic flow; 2) analysis of existing ACC control systems from the point of view with the necessary technology, but because of a lack of snow during the winter of 2002–2003, no operational testing was done under this project. The systems will be released for operational testing when training is complete.

In St. Louis County, a conventional RTK system will be used for GPS corrections. However, the topology in St. Louis County is quite hilly, and so will provide an opportunity to determine first-hand the robustness of conventional RTK to a terrain that is more difficult to cover. The Polk County plow has been equipped with the necessary technology, but because of a lack of snow during the winter of 2002–2003, no operational testing was undertaken. St. Louis County took delivery of the plow onto which the technology will be installed in February of 2003. Lack of snow in St. Louis County also delayed testing. The project received a no-cost extension until June 2004, with the hope that heavy snows in 2003–2004 will allow for thorough operational testing. Twenty-two lane miles of roads will be mapped in each county. Drivers will be trained prior to the first snow of the winter of 2003, and the systems will be released for operational testing when training is complete.

Project URL: www.its.umn.edu/research/projects/2002039.html

Infrared Sensors for Driver-Assistive Systems for Specialty Vehicles, Including Snowplows
Project status: In progress
The University of Minnesota driver-assistive system has been proven in tests with snowplows on Highway 101 between Elk River and Rogers, with snowplows in field tests at the Rosemount Research Station, and on patrol cars during high-speed tests at Brainerd International Raceway. The system has worked well, allowing drivers to drive

Craig Shankwitz, Department of Mechanical Engineering
Advanced BRT: Innovative Technologies for Dedicated Roadways
Project status: In progress
This project is working to develop safe, economical methods to implement fault-tolerant, robust active lane-keeping and collision-warning systems for heavy vehicles. As a result, the robustness and reliability (and therefore, safety) of the driver-assistive systems under development will be significantly increased.

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

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

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

A complement to the image processing task will be that of using paint striping machines to collect geospatial data. The image-based system will be modified so that the global location of the paint nozzle can be determined from a sensor suite and a DGPS receiver located on the paint striping machine. Converting the collected raw data into actionable information becomes the next task. From that data, smoothing, feature extraction, and formatting software will be developed that will allow for the automated creation of the digital map.

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

In St. Louis County, a conventional RTK system will be used for GPS corrections. However, the topology in St. Louis County is quite hilly, and so will provide an opportunity to determine first-hand the robustness of conventional RTK to a terrain that is more difficult to cover. The Polk County plow has been equipped with the necessary technology, but because of a lack of snow during the winter of 2002–2003, no operational testing was undertaken. St. Louis County took delivery of the plow onto which the technology will be installed in February of 2003. Lack of snow in St. Louis County also delayed testing. The project received a no-cost extension until June 2004, with the hope that heavy snows in 2003–2004 will allow for thorough operational testing. Twenty-two lane miles of roads will be mapped in each county. Drivers will be trained prior to the first snow of the winter of 2003, and the systems will be released for operational testing when training is complete.

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

Gang Plowing Using DGPS
Project status: In progress
Gang plowing is one method used by Mn/DOT to increase the productivity of snowplow operations. However, these gains in productivity often come at the expense of increased driver stress. These higher stress levels are the result of the low visibility caused by the snow clouds created by the lead snowplow and by buses drivers trying to pass between the slower moving plows. To improve the gang-plowing process, researchers are working on an enhancement to an existing driver-assistive system. The proposed system would combine active and passive technological solutions to improve driver comfort and driving safety. The enhanced driver-assistive package would provide for improved safety on two fronts. First, driver stress and therefore driver fatigue will be reduced; alert drivers are in better control of their vehicles. Second, the driver-assistive system will allow a “tighter” formation for the plows, reducing the opportunity for a rogue motorist to violate the gang formation. The enhanced driver-assistive package would provide for improved safety on two fronts. First, driver stress and therefore driver fatigue will be reduced; alert drivers are in better control of their vehicles. Second, the driver-assistive system will allow a “tighter” formation for the plows, reducing the opportunity for a rogue motorist to violate the gang formation.

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

Project URL: www.its.umn.edu/research/projects/2002039.html
Technologies for Modeling, Managing, and Operating Transportation Systems

Gary Davis, Department of Civil Engineering
A Case-Controlled Study of Driving Speed and Crash Risk
Project status: In progress
A fundamental problem in applied human factors and traffic safety concerns the relationship between the speed at which one chooses to drive and the likelihood of being involved in a traffic crash. The existing literature is less conclusive than one would desire, leading to beliefs that higher speeds do not necessarily increase crash risk, but that the presence of slower drivers does. In large part this confusion can be traced to methodological weaknesses in past research stemming from the failure to account for aggregation bias and/or measurement error. This project is conducting the most methodologically sound investigation to date into this issue by eliminating aggregation bias using a case-control study design, and accounting for measurement error by conducting a Bayesian analysis using recent advances in computationally intensive statistical tools.
Project URL: www.its.umn.edu/research/projects/P2003007.html

Identification of Causal Factors and Potential Countermeasures for Fatal and Severe Rural Crashes
Project status: In progress
Developing effective strategies for achieving a zero-fatality goal requires understanding the exact causes of traffic crashes. This project will address this issue by first conducting a detailed reconstruction and causal analysis of a core sample of fatal Minnesota crashes, and second by conducting an expert assessment of the presence of specified causal factors, and susceptibility to countermeasures, for a larger sample of fatal and/or severe rural crashes.
Project URL: www.its.umn.edu/research/projects/P2003014.html

Eli Kwon, ITS Institute
Signal Operations Research Lab for Development and Testing of Advanced Control Strategies (Phase II)
Project status: Completed (in FY03)
Corridor simulation with the capability of modeling various types of traffic control strategies as the external control modules is critical to developing and improving corridor management strategies. In this research, a microscopic network simulation model, VisSim, was used to develop such an environment. The new stratified Mn/DOT metering algorithm was simulated using U.S. Highway 169; its performance was compared with those of the fixed-metering method.
Based on the analysis results, an alternative approach to determine the minimum...
A serious and worsening problem. Freeways operate efficiently as long as the number of vehicles using the freeway remains at or below design capacity. While demand for highways is growing quickly, highway capacity is growing much more slowly, leading to congestion. Due to congestion, road users suffer increased travel time and consume more fuel, increasing travel cost. This also disturbs the usual flow pattern on highways. Use of intelligent transportation system technology to manage freeways is gaining attention due to its advantages in reducing congestion, but there are still issues related to their best utilization.

**Project URL:** [www.its.umn.edu/research/projects/2001022.html](http://www.its.umn.edu/research/projects/2001022.html)

**David Levinson, Department of Civil Engineering and Kathleen Harder, College of Architecture and Landscape Architecture**

**Ramp Meter Delays, Freeway Congestion, and Driver Acceptance**

Project status: Completed (in FY03)

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

**Project URL:** [www.its.umn.edu/research/projects/2001035.html](http://www.its.umn.edu/research/projects/2001035.html)

**Measuring the Equity and Efficiency of Ramp Flow**

Project status: Completed (in FY03)

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

**Project URL:** [www.its.umn.edu/research/projects/2001010.html](http://www.its.umn.edu/research/projects/2001010.html)

**Improving the Estimation of Travel Demand for Traffic Simulation**

Project status: In progress

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

**Project URL:** [www.its.umn.edu/research/projects/2000104.html](http://www.its.umn.edu/research/projects/2000104.html)

**Panos Michalopoulos, Department of Civil Engineering**

**Evaluation of Operating Strategies and Delay Analysis for Artterials**

Project status: Completed (in FY03)

In most urban areas, traffic congestion is a serious and worsening problem. Freeways operate efficiently as long as the number of vehicles using the freeway remains at or below design capacity. While demand for to be collected data, and will test the method on Minnesota Trunk Highway 169.

**Project URL:** [www.its.umn.edu/research/projects/2000134.html](http://www.its.umn.edu/research/projects/2000134.html)

**The Value of Traveler Information for Motorists**

Project status: Newly funded

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

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

**Panos Michalopoulos, Department of Civil Engineering**

**Employment of the Traffic Management Lab (TRAMLAB) for Evaluating Ramp Control Strategies in the Twin Cities**

Project status: Completed (in FY03)

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

**Project URL:** [www.its.umn.edu/research/projects/2000147.html](http://www.its.umn.edu/research/projects/2000147.html)

**Accident Prevention Based on Automatic Detection of Accident-Prone Traffic Conditions**

Project status: In progress

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

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

Project status: Newly funded

This research is in response to a request for low-cost innovative solutions for evaluating and improving the current and future ramp-metering strategies in the Twin Cities. This is a continuation of a recently concluded project in which the previous Mn/DOT ramp control algorithm was successfully implemented for two Twin Cities freeways. In this previous project, it was demonstrated that evaluation results through simulation are similar if not superior in content and accuracy to the ones reached by before-and-after studies. This project goes beyond evaluation and seeks to find a methodology for optimizing the new ramp-metering algorithm quickly and efficiently prior to field deployment. In the first year, the new stratified metering algorithm will be evaluated and compared with the old algorithm, a simple control plan (i.e., fixed-time metering), as well as with a no-control case. Detailed statistics will evaluate all aspects of the new algorithm’s operation including queue formation and bottleneck operation, as well as long and short travel times. In addition, a sensitivity analysis will be conducted in order to understand the behavior of the new control algorithm with respect to changes in traffic demand, occurrence of traffic incidents, detector malfunction, inclement weather conditions, and changes in the algorithm’s own parameters. If successful, further plans include expansion of the sensitivity analysis to include the impacts of traveler information on the control strategy. Based on the knowledge acquired through the sensitivity analysis, fine-tuning of the algorithm parameters will take place through both manual search and optimization methods. Finally, researchers will explore improvements to the algorithm structure in order to better take into account queue and other traffic pattern measurements.

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

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

Project status: Newly funded

This research will attempt to streamline the traffic modeling process for practical implementation and to substantially improve Mn/DOT engineers’ productivity in view of the new federal requirements for roadway improvements, design, and planning. Streamlining will also improve decision-making and allow more widespread use of simulation internally for design, planning, operations, maintenance, and construction. The key element in improving traffic operations and infrastructure is the ability to assess the effectiveness of various alternatives prior to implementation. Simulation methods have long been recognized as the most effective tool for such analysis, and various simulators have been developed by different agencies for analyzing freeway and/or arterial networks.

Although a great deal of effort has gone toward making simulation suitable for practical applications, engineers still regard it as a complex tool. In the previous phase of the proposed project, a number of rudimentary and crude tools for accelerating the simulation process were developed for improving the research team’s effectiveness and productivity to meet tight deadlines. Subsequently, the technology was transferred to Mn/DOT through a series of training courses and continued technical assistance. During this collaboration, it became evident that in order to simulation to be effectively employed by Mn/DOT, more substantial automation and streamlining of the simulation process is needed for non-research-oriented engineers. As a result, the proposed continuation phase aims to further improve the earlier simulation tools and methodologies and, in cooperation with Mn/DOT’s modeling group, streamline the process to specifically address the needs and issues raised by practicing engineers within Mn/DOT and the research team. Special effort will be made to ensure that the methodologies developed are general—i.e., not tied to a particular simulation package.

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

Social and Economic Policy Issues Related to ITS Technologies

Frank Douma, Humphrey Institute of Public Affairs

Telecommunications and Sustainable Transportation

Project status: In progress

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

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

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

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

The third task is building upon information gained from focus groups held in Rochester and Virginia, Minnesota, in August 2001. Using this information as a starting point, researchers will examine the institutional and technical network requirements to deliver wireless services that enhance transportation services. The fourth task involves a series of educational outreach activities related to work in the preceding three tasks, such as work reviews, seminars, and presentations at University and community forums, led by Humphrey Institute faculty.

Project URL: www.its.umn.edu/research/projects/2002096.html

Kevin Krizek, Humphrey Institute of Public Affairs

Better Understanding the Potential Market of Metro Transit’s Ridership and Services

Project status: Newly funded

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

These data sources represent extremely rich surveys that could shed light on basic travel preferences that transit could better serve. The focus is to examine more closely the attitudes, preferences, and needs of both current and potential riders. The range of improvements possibly includes using technology to better track ridership behavior, modifying a frequent rider program, adjusting routes and times, and understanding and delineating different market segments of travelers. The analysis and findings of the research will be pursued jointly with staff...
from Metro Transit and the Met Council to enhance its utility to each agency. The study will also provide recommendations on more specific data that could be collected to provide baseline information that would help monitor existing and future programs and traveler information.

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

Lee Munnich, Humphrey Institute of Public Affairs Sustainable Technologies Applied Research Initiative FY02

Project status: Completed (in FY02)

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

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

For Task 2, researchers refined the ITS EMS architecture outlined in the previous year based on field visits in Minnesota, including a case analysis of the Virginia, Minnesota, System. The EMS model was also devised using a knowledge acquisition system called Protégé. A second case study will be conducted (in Brainerd, Minn.) to establish performance metrics for EMS; the system will also be expanded to consider rural trauma transportation.

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

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

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

Project URL: www.its.umn.edu/research/projects/2001003.html

Sustainable Technologies Applied Research Initiative FY03

Project status: In progress

The STAR project is investigating the intersection of various networks—including ITS-infused transportation networks—and how they interact with physical places, as well as the changes that are occurring among and between networks and the dimensions (e.g., access, activity) that concern the STAR researchers. As of July 2003, research activities have included the following:

For Task 1, researchers have completed the first phase of a study of the spatial location of information workers in four metropolitan areas—Atlanta, Denver, Phoenix, and Minneapolis-St. Paul. Working with 1990 data from the Census Transportation Planning Package (CTPP), the study found that the workplace locations of information workers were more spatially concentrated than other workers in all four metropolitan areas. Generally, their workplace locations tended to be focused on traditional central business districts and university centers, with mixed results in “edge city” centers. The residential locations of information workers were also more concentrated in three of the four areas, but the difference tended to be less significant. Preliminary analysis of commuting effort indicates that information workers tend to spend more time commuting than other workers. The study will ultimately include an analysis of the 1990 CTPP data with that of the 2000 CTPP.

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

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

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

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

For Task 5, researchers have begun planning to invite past and current SLPP graduate research assistants for a day of discussion around the topic of the “New Transportation Professional” and training needs as they relate to ITS. STAR researchers will also take an active role in organizing and participating in professional workshops and conferences related to the research themes noted above.

Project URL: www.its.umn.edu/research/projects/20030312.html

Telecommunications and Sustainable Transportation

Project status: Newly funded

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

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

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

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

For Task 4 (Networks and Productivity), the researchers will study and optimize existing codes, formulate the new-node/link model, code the new model, run the model on a sample network and debug codes, integrate the model with the link expansion model, collect Twin Cities network data, and calibrate the integrated model for the Twin Cities.

For Task 5 (Roundtable Discussion: May 2004), the researchers will develop a white paper on applications of technology-related impacts (and data) for local and rural planners as well as transportation managers. They will also organize roundtable discussions, conference presentations, and invited speakers and conduct outreach to local and national decision makers and educators.

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