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

- Human performance and behavior
- Technologies for modeling, managing, and operating transportation systems
- Computing, sensing, communications, and control systems
- Social and economic policy issues related to ITS technologies

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

The Institute’s geographic location gives it a unique advantage for developing research applicable to transportation in a northern climate and transportation in rural environments in addition to the metropolitan Twin Cities area. The ITS Institute research program includes research projects funded by various partners, including federal funds from the USDOT Research and Innovative Technology Administration’s University Transportation Center program, the Federal Highway Administration, the Federal Transit Administration, the National Highway Traffic Safety Administration, the National Park Service, and the National Science Foundation. Local funding partners include the Minnesota Department of Transportation (MnDOT) and the Minnesota Local Road Research Board. Additional funding and in-kind support are provided by the Metropolitan Council, Hennepin County, St. Louis County, Metro Transit, Minnesota Valley Transit Authority, City of Duluth, and other local governments, agencies, and private companies.

Activities undertaken by the Institute support all ITS-related research projects, regardless of funding source. All current ITS-related projects are listed in the appendix of this annual report, while a selection of research projects under way are highlighted in detail in the pages that follow.

Research fellow Arvind Menon installing components of the Safe Teen Car prototype
Safer cars for teen drivers

Novice teen drivers are overrepresented in vehicle crashes compared to more mature, experienced drivers, and research suggests this is in part because teens are more likely to engage in risk-taking behaviors while driving. In a project sponsored by the National Highway Traffic Safety Administration (NHTSA), the University of Minnesota and Maryland-based Westat Inc., a prominent research organization, are working to create and test a vehicle-based technology solution to reduce teen driver crashes. This team, which includes Institute researchers Mike Manser, Chris Edwards, Janet Creaser, Alec Gorjestani, Arvind Menon, and Craig Shankwitz, has developed a prototype driver support system called Safe Teen Car (STC) that provides feedback to drivers when risky driving behaviors are detected.

STC is a different concept than the Teen Driver Support System (TDSS) on which other Institute researchers are working (see page 6). While the TDSS is designed as an “after-market” device that can be used on any vehicle and has the capability to report unsafe behaviors to parents, the STC project is focused on what can be integrated into future vehicles during manufacturing to make them safer for teens. Specifically, the STC system monitors driving behavior and provides various combinations of auditory and visual feedback and adaptation strategies to the driver as opposed to recording, transmitting, summarizing, and reporting on driver performance.

Researchers recently conducted a four-week preliminary functional road test involving teen drivers and parents in Minnesota and Maryland to evaluate the individual driver feedback subsystems that currently make up the STC system. The subsystems address the most common risk factors associated with teen crashes and are grouped by the type of behavior the STC is trying to affect, including cell phone use, excessive maneuvering, and speeding. Each of these subgroups contains driver identification, passenger detection, seat belt detection, and driving context (external factors) capabilities that address these other known risk factors.

For this study, participants’ vehicles were instrumented with the STC system, and the teen drivers were assigned to one of the three STC subsystems so that researchers could evaluate each subgroup separately and identify effects specific to each.

The study began with a two-week baseline period in which the STC did not provide feedback or adapt vehicle functions. This was followed by a two-week treatment period in which the STC subsystems were activated and participants received feedback and vehicle adaptations based on which group they were in. Those in the excessive maneuver group, for example, received feedback in the form of a visual icon displayed on the driver-vehicle interface (DVI) synchronized with a 10-second tone,

The Safe Teen Car provides the driver with audio feedback, supported by an icon display, when it detects risky behavior.
When it comes to teen driving statistics, perhaps none is more shocking than this: 30 percent of all teen deaths in the United States are caused by motor vehicle crashes—the leading cause of death for teens. Combine inexperience behind the wheel with a propensity to engage in risky behaviors and the results are all too often fatal.

Although graduated driver’s licensing (GDL) programs have been effective at significantly reducing fatal crashes, they do not address all crash causes and are difficult to enforce because they rely heavily on parents to impose restrictions on their teen drivers. So researchers at the University of Minnesota are developing monitoring technologies to address the riskiest behaviors teen drivers engage in, some of which are also covered by GDL programs.

In one project, a multidisciplinary team of researchers developed a prototype Teen Driver Support System (TDSS) that uses a GPS-enabled smartphone mounted on a vehicle’s dashboard to provide the driver with real-time warnings about speeding, excessive maneuvers, and stop sign violations. If an unsafe behavior continues, the device automatically sends a text message to notify parents. The prototype also monitors seat belt use and detects the

Support system uses teen’s phone to monitor driving

A GPS-enabled smartphone mounted on the dashboard provides real-time warnings.

warning drivers when a vehicle maneuver exceeded a critical threshold. Drivers in the speed group received system feedback when the vehicle speed was greater than a set of criteria. When speed exceeded the limit by 2 miles per hour (mph), a mild speed warning consisting of a one-second auditory tone was presented. Speeds 2 to 15 mph above the speed limit set off a second strong speed warning including the phrase “speeding violation” followed by a one-second buzz; the visual icon changed from white to red on the DVI. For the cell phone group, when a cell phone call was detected a warning was presented consisting of a one-second beep followed by the phrase “cell phone detected,” then a second one-second beep. All participants received seat belt-related feedback, which included a warning that paired an auditory voice with a visual icon and text displayed on the DVI when the driver’s or occupant’s seat belt was not fastened.

Driving behavior data were collected throughout the study and allowed researchers to make comparisons between the stages that would identify the extent to which the STC contributed to changes in driver behavior. One significant finding involved the speed management subsystem, which showed a reduction in the levels of speeding. For example, drivers who drove 10 to 15 mph over the limit prior to STC subsystem activation drove only 5 to 10 mph over the limit once the system was activated.

At the end of the study, each teen driver, accompanied by one parent, participated in unstructured discussions intended to help researchers understand the participants’ specific experiences and impressions of the STC subsystems to which they were exposed. Results from these discussions suggest the STC concept appeals to teens and their parents and that overall, the majority of teens agreed or somewhat agreed that the STC improved their safety.

Observations of driver behavior and system acceptance were used to refine the systems and methods prior to the start of a full system evaluation that began in July. This current study combines subsystems (except cell phone) for a longer time period and is exploring the carryover effects—that is, the extent to which each STC subsystem influences drivers to select safe behaviors even after the system is switched off. Upon completing this study and in relation to other tasks, the team will outline the final specifications for a safe teen vehicle and document the methods, findings, and recommendations of the entire project for NHTSA and other stakeholders.

For more information, see An Evaluation of a Prototype Safe Teen Car at www.its.umn.edu/Research/ProjectDetail.html?id=2010077.
A prototype system uses a GPS-enabled smartphone to provide the driver with real-time warnings about speeding, excessive maneuvers, and stop sign violations.

In an effort to provide transportation decision makers with more information on nonmotorized transportation facilities, a team of researchers from the Humphrey School of Public Affairs is conducting a study on the use of bicycle and pedestrian trails in Minneapolis. Using infrared counters, the team is collecting data on when and how often these trails are used.

The project, funded by the Institute’s TechPlan program at the Humphrey School of Public Affairs, is led by Greg Lindsey, a professor with the school. Lindsey and his team are using the data they collect to develop more sophisticated models for estimating nonmotorized traffic on Minneapolis streets, sidewalks, and trails. Their models are helping policymakers and planners make better decisions about how, when, and where to invest in nonmotorized infrastructure.

From June through December 2010, the team installed seven infrared devices in Minneapolis: three on the Midtown Greenway, two at Lake Calhoun, two at Lake Nokomis, and one at Wirth Park. When a passing cyclist or pedestrian breaks the infrared beam spanning the trail, the event is registered on an electronic counter. According to Lindsey, this is an unobtrusive way to measure how many people are using a given trail and at what

Infrared sensors count bicyclists, pedestrians on Minneapolis trails to aid planning
times of the day traffic levels are highest.

The three infrared sensors on the Midtown Greenway are positioned near Minneapolis Department of Public Works bike counters, which are magnetic devices in the trail that register an event when a bike travels over them. Placing both types of counters at the same locations has allowed the research team to test and compare the two measurement technologies.

Each type of counter has limitations, according to Lindsey. Magnetic devices will not register pedestrians because they are not designed to detect the small amount of metal typically on a person, and infrared sensors systematically undercount because they cannot detect if two or more people are traveling side by side. To account for the infrared sensor error, the research team used field observations to develop models that adjust the data.

Data collection is planned to continue indefinitely at all seven locations, Lindsey said. As more data are collected, the researchers hope to gain a clearer understanding of how variables like weather and time of day affect trail use. Additional data will also help researchers examine how the use of trails and bike lanes varies depending on the presence of nearby employment opportunities or the land-use mix in a given area. This information could help decision makers invest in infrastructure where it will be most heavily used.

The data collected by the sensors may also affect trail management in the short term, Lindsey said, citing traffic control changes on the Midtown Greenway as one example. When the trail was developed, there were stop signs on the trail, and vehicles on the streets intersecting the trail had the right-of-way. When traffic counts revealed that nonmotorized traffic on the trail exceeded vehicle traffic on the cross streets, some of the stop signs were reversed. Trail users were given the right-of-way at certain intersections, and vehicles on the cross streets had to stop.

Ultimately, the new models of nonmotorized traffic will provide transportation planners with tools to make more informed choices about investing in new bicycle and pedestrian facilities and reduce the amount of customized work needed for individual projects. “Traffic counts are a basic building block for decision making,” Lindsey said. “They provide evidence to make transportation decisions rationally.”

For more information, see Understanding Use of Nonmotorized Transportation Facilities at www.its.umn.edu/Research/ProjectDetail.html?id=2010058.
Improving emergency medical response for rural crashes

Over the past five years, researchers with the University of Minnesota's ITS Institute and the Center for Excellence in Rural Safety (CERS) have investigated the role that information technology plays in improving emergency medical response to victims of rural automobile crashes. The goal of this work is to reduce the adverse health impacts of traffic crash trauma, especially those in rural areas, where crashes account for a high percentage of trauma injury and death.

“One key aspect of reducing these adverse medical effects...is to decrease the amount of time it takes emergency services to respond, provide care, and take a patient to the right [trauma level] hospital,” explains Tom Horan, a researcher with the ITS Institute and research director of CERS.

Within the first hour after trauma occurs, a patient’s medical fate is usually sealed. Thus, with regard to emergency trauma care, a few minutes can mean the difference between life and death. Working with his colleague Ben Schooley, Horan and his research team assessed the potential value of a web application that would facilitate a more seamless transfer of patient and incident information from emergency medical services (EMS) pre-hospital practitioners to hospital emergency room/trauma center providers as a way to improve patient care during that “golden hour” following a traffic crash. The researchers conducted case studies of EMS systems in San Mateo County, California, and Rochester, Minnesota, to validate the model and study best practices of these rural trauma systems. The case studies included analysis of EMS response data, interviews, and focus group discussions with EMS and emergency room practitioners.

Through these efforts, the team found that information collection and handoff from ambulance providers to hospitals is fragmented. “Evidence from literature suggests that more timely patient information could significantly impact patient care,” Schooley notes. The case studies also confirmed that new and emerging mobile- and map-based technologies could be used to address this information-handoff challenge, and the group moved from concept to development of a prototype system called CrashHelp.

With CrashHelp, emergency responders use a mobile smartphone on-scene to collect multimedia data about crash victims—including digital pictures, audio recordings, and videos—as well as other basic patient and incident information. These data are sent directly into the emergency/trauma department to a web-based interface.
Today’s drivers tune in to traffic updates on their car radios. But tomorrow’s drivers are likely to rely on a very different kind of radio system to help them avoid congestion. Under the U.S. Department of Transportation’s Connected Vehicles research initiative, researchers are developing a range of applications that transmit data between moving vehicles, and between vehicles and the transportation infrastructure.

Professor M. Imran Hayee of the University of Minnesota Duluth’s Department of Electrical and Computer Engineering, along with his team of students, is developing a system that transmits congestion data to motorists near work zones, where traffic jams are common and collisions with maintenance workers are a safety hazard. The research is affiliated with the Northland Advanced Transportation Systems Research Laboratories (NATSRL), part of the ITS Institute.

The new system is one of many applications now being developed based on the dedicated short-range communications (DSRC) standard, which was allocated specifically for ITS applications by the USDOT in 1999. DSRC is designed for short-range use—typically less than 1,000 meters. It offers high data transmission rates with low latency (i.e., a minimal time delay between input processing and corresponding output) and is largely unaffected by weather disturbances, both of which are critical characteristics for ITS applications with rapidly moving vehicles.

DSRC is intended to support both vehicle-to-vehicle applications, such as cooperative forward-collision warning, and vehicle-to-infrastructure applications, such as communication between the traffic signal and vehicle. In both cases, vehicles and infrastructure practitioners can view on demand. This instant messaging of sorts gives hospitals advance notification of crash severity and related information that can be used to best prepare for a patient’s arrival. EMS agencies responsible for oversight can view aggregate information over time and conduct spatial (map-based) analyses of EMS response trends across the region and state.

According to Schooley, special attention was paid in the design phase to make a user-friendly, electronically secure tool. “We knew we had to make it simple and secure or it wouldn’t be used,” he says. “CrashHelp is as easy to use as a flip phone… it does not require hospitals to install new systems or even to manually download the information sent from EMS personnel.” Additionally, the team has put an important emphasis on system security so that CrashHelp will comply with the Health Insurance Portability and Accountability Act (HIPAA) of 1996 and other electronic healthcare data security requirements.

The research team is now pilot testing CrashHelp with EMS agencies and hospitals in the Boise, Idaho, area and is set to go live with the system by fall 2011. During this three-month pilot study, researchers will evaluate any improvements made in information collected by on-scene EMS personnel, communication between pre-hospital transport and hospitals, care decision making by hospital personnel (for some incidents), and resource use by hospital personnel. Preliminary results from the pilot will be available in late 2011.

Discussions are currently under way to conduct further testing as part of Minnesota’s Toward Zero Deaths program. For more information on this study, visit www.ruralsafety.umn.edu/.

For more information, see ITS and Transportation Safety: EMS System Data Integration to Improve Traffic Crash Emergency Response and Treatment (Phases II thru IV) at www.its.umn.edu/Research/Researcher.html?id=25125.

Benjamin Schooley
components become nodes on a wireless network. Each vehicle’s onboard DSRC system constantly updates the topology of its local network as vehicles and infrastructure nodes enter and leave the system’s coverage area.

Hayee designed a system consisting of a portable roadside unit (RSU) that can be installed easily in work zones and onboard units (OBUs) to be installed in vehicles. Both types of units are commercially available. The RSU gathers data on the location and speed of nearby vehicles by engaging their OBUs. With these data, the RSU determines average travel time in the vicinity of the work zone and locates the start of congestion—the point where traffic changes from a free-flowing state to a congested state. This information is then broadcast back to the OBUs. Each OBU calculates the distance to the start of congestion and displays the information to the driver via a separate user interface, enabling the driver to decide whether to take an alternate route and warning him or her of a sudden speed reduction.

Because data from private vehicles are transmitted automatically in an uncontrolled environment, protecting the privacy of users is a key concern. The DSRC communication protocols underlying Hayee’s prototype system include built-in security measures that protect DSRC applications from eavesdropping, falsification of data, and other attacks.

The system can be adapted to any road by changing the input parameters of the RSU; the OBU does not require any data about the road being monitored.

The use of a consumer smartphone as the driver interface is one of the innovative aspects of the prototype system, and one that allows significant cost savings, especially for those vehicles that lack a built-in dedicated interface. Rather than a dedicated driver interface, which is expected in future vehicles, each OBU is equipped with a communication interface device that can connect to a smartphone via the Bluetooth wireless networking protocol. An application installed on the smartphone connects to the OBU automatically and presents information to the driver. The researchers note that the system architecture supports the use of various user interfaces as needed to avoid driver distraction.

Hayee tested the prototype extensively in a variety of congestion scenarios in both urban and rural areas. The field tests showed that the system can accurately determine travel time and the location of the start of congestion in real time under changing traffic conditions.

One limitation of the current system is that optimal performance requires a clear line of sight between the RSU and OBUs. However, the researchers plan to address this issue in their future development of the system by enabling vehicle-to-vehicle data networking.

For more information, see Development of a Portable Work Zone Traffic Information System with DSRC-Based V2I or V2V Communication and BT Cell Phones at www.its.umn.edu/Research/ProjectDetail.html?id=2010005.
Research

Using transit data, tools for better planning and scheduling

A common mantra in government now is “do more with less.” For transit agencies specifically, the challenge is to reduce costs while continuing to provide secure, reliable, and convenient services. To address this challenge, more and more transit agencies across the United States are installing automatic data-collection systems (ADCS) on their transit vehicles to monitor vehicle location and gather system performance information to improve their services.

Despite the increasing use of these systems—which collect large volumes of potentially useful transit data—these data are largely underutilized because of limited resources and the tremendous effort required to transform them into usable information. ADCS data are often queried only “as needed” or used only for basic applications such as bus schedule planning. But the detailed data available from ADCS, if more easily processed, could be used for more thorough system evaluation, planning, and decision making.

During a six-month sabbatical at the University of Minnesota, Nigel Wilson, professor of civil and environmental engineering at the Massachusetts Institute of Technology (MIT) and a leading researcher in public transportation policy and technology, provided guidance and expertise on transit data analysis and modeling to researchers at the Institute’s Minnesota Traffic Observatory. He also worked with Twin Cities Metro

Computer vision system for truck stop parking receives FHWA grant

The Federal Highway Administration (FHWA) recently selected the Minnesota Department of Transportation (MnDOT) to receive $2 million for a University of Minnesota research project designed to use intelligent transportation systems (ITS) technology to deliver real-time information on parking availability at highway truck stops to truck drivers.

Although only 53 percent of parking spaces at truck stops are occupied on any given night, 90 percent of truck drivers perceive a shortage of parking. Drivers unable to locate empty spaces may become fatigued or stop to rest in unsafe locations, such as on roadway shoulders or ramps.

The University research team includes lead investigator Nikolaos Papanikolopoulos, professor in the Department of Computer Science and Engineering (CSE); Vassilios Morellas, program director with CSE; Max Donath, director of the ITS Institute; Panos Michalopoulos, professor in the Department of Civil Engineering; and Ted Morris, lab manager of the Institute’s Minnesota Traffic Observatory.

Another project partner is the American Transportation Research Institute (ATRI), part of the American Trucking Associations Federation. Dan Murray, ATRI vice president, will be the liaison to the research team. The results of the study are expected to be of interest to the public and private sectors.

The funding is provided through the FHWA’s Truck Parking Facilities Discretionary Grants Program. The program helps improve safety on the nation’s interstates by promoting projects that allow trucks to park safely and securely in areas away from moving traffic, instead of alongside the road itself or on ramps. Drivers unable to locate empty spaces may become fatigued, which is thought to be a contributing factor in a number of crashes.

The new project will implement and deploy findings from ITS Institute-funded research recently completed by Papanikolopoulos and Morellas. In that work, the researchers developed an automated parking space identification system that can compute occupancy at stops. This information could then be used to notify drivers about the availability of parking spots using variable message displays miles ahead of stops.

Variable message sign notifying truck drivers about parking availability
Transit, the primary transit agency in the Minneapolis–St. Paul metropolitan area, on fare policy, fare collection technology, and data analysis.

Through this work funded by the ITS Institute, Wilson and senior systems engineer Chen-Fu Liao with the Minnesota Traffic Observatory developed a methodological data analysis framework able to process an extensive amount of ADCS transit data including vehicle location, passenger count, and electronic fare transaction information. The team recently fine-tuned this framework to produce a route-based trip simulation tool that enables users to apply and analyze various transit scheduling strategies.

For this piece of the project, the researchers obtained one month of automatic vehicle location and automatic passenger counter system data from Metro Transit, specifically for bus route 10 along Central Avenue between downtown Minneapolis and the Northtown Mall in Blaine, a Minneapolis suburb. They then analyzed the time point (TP) time and inter-TP link travel time to describe the relationship between trip travel time and primary independent variables such as number of passengers boarding and alighting. Regression models were calibrated and validated by comparing simulation results with the existing schedule using adjusted travel time derived from data analyses. In addition, three separate months of transit data were used to verify the transit route model.

Other TP time models are based on general parameters such as number of passengers boarding and alighting and bus crowding. However, this new transit route model also considers fare payment type, bus type, stop location, intersection geometry, signal timing, and traffic volume—factors that affect bus travel time. The resulting simulation tool enables transit planners to predict and evaluate the potential impact of different transit strategies such as schedule changes and stop consolidation, prior to deployment.

Metro Transit is currently testing this tool and using it in a study of 11 local bus routes to upgrade current operation to bus rapid transit or equivalent services as another way to improve ridership and service quality.

“This work has already provided important insight into our existing transit service,” says John Levin, director of service development with Metro Transit. “We are excited to continue our partnership with the University to support research that will allow us to provide better, more efficient service.”

In their next phase of study, the researchers hope to investigate the transferability of the TP model to other urban local routes, study the impact of wheelchair lift events, and investigate transit riders’ Origin to Destination patterns as well as travel behavior.

For more information, see System Analysis for Public Transit: Developing Data-Driven Support Tools for Transit Planning and Scheduling at www.its.umn.edu/Research/ProjectDetail.html?id=2010064.
Researchers at the Minnesota Traffic Observatory (MTO) are using newly developed traffic monitoring tools to investigate safety and accessibility issues affecting pedestrians and bicyclists at traffic roundabouts.

Once rare in the United States, roundabouts are becoming more common in Minnesota and across the country. Municipalities are increasingly interested in roundabouts in light of recent research showing they provide a variety of benefits over traditional signalized intersections, including reducing the number of automobile crashes and allowing traffic to flow in all directions with virtually no interruptions. The impact of roundabouts on the safety and mobility of pedestrians and bicyclists, however, remains poorly understood. Roundabout safety is a particularly important issue for pedestrians who are elderly or visually impaired.

MTO director John Hourdos, lab manager Ted Morris, civil engineering professor Gary Davis, and a group of nine undergraduate students worked with the Minnesota Department of Transportation (MnDOT), which is funding this research, to identify a pair of roundabouts for study—one in suburban Richfield and another in a residential area of Minneapolis. The two sites differ in terms of road geometry, traffic control features, and traffic characteristics, allowing the researchers to compare and contrast different roundabout situations.

The suburban site is a complex design, typical of recent roundabout designs, with two lanes at each entrance and exit; it is illuminated at night and features traffic control signs and markings, as well as bus stops on two approaches. The Minneapolis roundabout represents an older, less complicated design, with a single traffic lane at each entrance and exit; it is not lighted and does not have many of the traffic control features present at the Richfield site.

Getting accurate data on vehicle-pedestrian interactions at roundabouts was one of the first challenges faced by the researchers. To gather the large number of observations necessary for a thorough analysis, the researchers developed a video-based data gathering system to continually observe the entire roundabout. The heart of the system is a cluster of eight cameras atop a telescoping mast mounted on a trailer that can be positioned at the center of the roundabout. A camera is trained on each of the four marked crosswalks on the roads connected to the roundabout, while the other four cameras (equipped with wide-angle lenses) provide a full 360-degree view...
of roundabout traffic. The camera trailer houses batteries and control software that enable the system to record traffic for up to two weeks without human intervention.

At the suburban site, the video system recorded more than 400 hours of data over nearly a month of operation. An initial analysis of a 12-day period revealed that roughly 25 pedestrian or bicycle crossing events involving an interaction with motor vehicles occurred at each approach to the roundabout each day. These observations have been classified and coded to create a data set suitable for logistic regression analysis.

Drivers’ failure to yield to pedestrians and cyclists is one of the key issues being examined in this research. Although Minnesota law requires drivers to yield to any pedestrian in a crossing, observations at the research sites confirm that drivers often fail to do so, creating a significant safety risk. A preliminary analysis showed that drivers were less likely to yield at roundabout exits, and more likely to yield to pedestrians in the center of the roundabout than to those on the sidewalk. As the project continues, the researchers will examine how other factors—including traffic volume, number of lanes, and general roundabout design—affect yielding behavior.

For more information, see Investigation of Pedestrian/Bicyclist Risk in Minnesota Roundabout Crossings at www.its.umn.edu/Research/ProjectDetail.html?id=2010099.

Preliminary results indicate that drivers are less likely to yield at roundabout exits and more likely to yield to pedestrians in the center of a roundabout than to those on the sidewalk.

To obtain accurate data about vehicle-pedestrian interactions, researchers developed a video-based data-gathering system to continually observe an entire roundabout.