Researchers’ ability to study the complex dynamics of traffic flow throughout the Twin Cities region took a big step forward with the opening of the Minnesota Traffic Observatory (MTO), a joint effort of the ITS Institute and the Department of Civil Engineering. The observatory combines real-time traffic data with state-of-the-art simulation systems, giving researchers and engineers the ability to analyze existing conditions and compare real-world observations with the results of simulated conditions.

“Instead of looking at just one or two locations, the observatory offers the ability to look at large systems where many different parts interact,” said director John Hourdos.

Video feeds flow into the observatory from an extensive network of traffic cameras. The observatory is connected by fiber-optic lines to the Minnesota Department of Transportation’s traffic operations center, allowing it to capture live feeds from up to 16 of the more than 300 cameras the agency uses to monitor the metropolitan freeway system. In addition, the observatory operates a dedicated system of cameras overlooking the I-94/35W Commons interchange—turning one of the most accident-prone intersection areas in the state into a real-world laboratory for the study of traffic flows and vehicle crashes.

The availability of a wealth of high-quality video data is ideal for the use of machine-vision systems to monitor and categorize vehicle movements. Computer image-processing algorithms developed by University of Minnesota researchers enable the observatory to track and analyze complex traffic patterns at intersections, on freeway interchanges, and in other areas that are difficult to study using other data sources.

Another key component of the MTO is a virtual traffic control center and simulation lab. Interfacing traffic signal control hardware with realistic traffic network models creates a powerful tool for examining system performance under a variety of conditions.

Given the complexity of the traffic issues that the observatory is designed to study, robust visualization tools are critical. In addition to a large projection wall, two innova-
interactive pieces of equipment provide researchers with powerful interactive visualization capabilities.

The GIS/MAP table, built by Hourdos and the observatory staff, combines the large horizontal working surface of a traditional drafting table with the interactive capabilities of geographic information systems technology. Two ceiling-mounted digital projectors create a seamless image covering the entire conference-table-sized surface, which can be manipulated using a tabletop pointing device to pan and zoom in on specific areas. In contrast to traditional ways of viewing digital maps and models on a desktop monitor, the table allows users to comfortably survey the entirety of a large traffic system and quickly focus on areas of interest.

The Digital Environment, or DEN, takes a different approach—putting viewers in the center of the action via 3-D immersive graphics. Three sides of the cubical structure are made up of large rear-projection screens made of a polarized material that actually transmits two slightly different images; a user wearing specially polarized glasses sees a different image with each eye, producing a realistic sense of three-dimensional space. A tracking system mounted in the DEN’s ceiling monitors the position of the user’s head and adjusts each projector to provide accurate perspective.

A single public road winds through the six million acres of unspoiled Alaskan wilderness that make up Denali National Park and Preserve, one of the crown jewels of the United States national park system. For thousands of visitors every year, this road offers their best chance to view and photograph the wildlife for which the park is famous.

Faced with an ever-increasing demand from visitors eager to come face to face with Denali’s wildlife, the National Park Service turned to the Minnesota Traffic Observatory and the ITS Institute to help balance the transportation demand from park visitors with the need to protect and preserve the natural habitat of the area’s wildlife.

Denali is a popular destination because it offers visitors the opportunity to see Alaskan wildlife up close in an unspoiled environment. In order to maintain this experience, traffic on the park road is limited to bus tours operated by designated tour operators. Adding more tours in response to increasing demand runs the risk of degrading the visitor experience by driving away the very wildlife that visitors have journeyed so far to encounter.

In order to gather accurate information on wildlife sightings, the researchers developed a prototype data-logging system to be used by bus drivers. With a touch-sensitive LCD panel and a customized graphical user interface, the system allows drivers to quickly input data on sightings as well as note any other reasons for stopping the vehicle along the roadway. Data will be incorporated into a digital map of animal sightings, allowing researchers to model the effects of the presence of wildlife on the movements of vehicles along the route.

The new traffic model being developed by the Minnesota researchers combines traffic demand modeling with data on wildlife movements and habitat requirements gathered by biologists, and information on visitor experience factors such as what types of wildlife have been encountered under various conditions. In its complete form, the model will give park managers and other researchers the ability to carry out scenario-based planning—evaluating the potential impacts of different use cases or road capacity levels in order to guide decisions about how to use the park’s natural resources.
Throughout the United States, the fatality rate from vehicle crashes in rural areas is considerably higher than in urban areas. HumanFIRST Program director Nicholas Ward and research fellow Mick Rakauskas are working to better understand the differences and similarities in attitudes and behaviors of drivers in these different geographic areas.

The researchers conducted a large-sample survey of urban and rural residents throughout Minnesota that focused on known risk factors—alcohol, speeding, and safety belt use—that may be related to the significantly higher crash rate on rural roads. The survey also examined crash and citation frequencies as well as attitudes toward current and proposed safety interventions suggested by the Minnesota Toward Zero Deaths (TZD) initiative.

Although both urban and rural drivers reported engaging in various unsafe driving behaviors, rural drivers coupled dangerous behavior with an attitude that such behavior was acceptable. For example, rural drivers chose to drive without safety belts more often than their urban counterparts while reporting that it was less dangerous to do so. Rural drivers also felt that proposed enforcement, education, and engineering safety interventions were less useful than did drivers in urban areas. Further, rural respondents considered driving while intoxicated less dangerous than did urban drivers, which seems to agree with the higher fatal crash risk prevalent in rural counties.

These findings suggest that although drivers from all geographic areas engage in risky behaviors, rural drivers may engage in more behaviors that lead to fatal crashes while believing that their behaviors are not risky. Rakauskas and Ward extended this work by studying driving behavior using simulator experiments in which participants from rural and urban areas “drive” in various simulated rural and urban settings. Results from these experiments suggest that the rural environment may encourage less safe driving, especially among high-risk groups such as teen drivers. The team identified potential interventions, such as education programs that focus on increasing awareness of the danger of driving without a seat belt, that might be accepted by target populations. The team also hopes the results from their work will give weight to suggestions for policy change where problems exist in both rural and urban areas.

Human Factors Interdisciplinary Research in Simulation and Transportation

The mission of the Human Factors Interdisciplinary Research in Simulation and Transportation (HumanFIRST) Program is to apply human factors principles in order to understand driver behavior and support the design and evaluation of usable intelligent transportation systems. As implied by its name, the program’s research strategy is based on a driver-centered approach, considering the “human first” within the transportation system.

The HumanFIRST Program has a core staff of transportation research specialists made up of psychologists and engineers who provide a consistently available base of expertise. This core group is linked to a broad interdisciplinary network of experts in basic and applied sciences throughout the University to provide a flexible and comprehensive research capacity. This network is supported by affiliations with additional University research units, which allows the program to create responsive interdisciplinary teams to investigate a range of complex human factors research issues in transportation safety. The program also has close relationships with the Minnesota Departments of Transportation and Public Safety, private industry, traffic engineering consultants, and other related entities. These connections provide support for implementing research that will influence transportation policy in response to real-world problems both regionally and nationally. In addition, to ensure that research takes into account developments on the world stage, the program’s work is supported by international collaborations with experts in relevant disciplines.

Research in the HumanFIRST Program seeks to propose, design, and evaluate innovative methods to improve transportation safety based on a scientific understanding of driver performance and the psychological processes associated with traffic crashes. This research considers how a driver will accept and use a proposed system while also considering the possibility of its producing undesirable driver responses and adaptation (e.g., distraction, complacency, fatigue, risk-taking) that could undermine the system goal of improved safety.
Recent research topics include:
- driver distraction from in-vehicle tasks and cell phones
- rural and urban driver attitudes and crash risk
- interventions for crash reduction at rural intersections
- intelligent driver-support systems such as vision-enhancement, collision-avoidance, hazard-awareness, and lane-keeping systems for passenger and specialty-purpose vehicles
- alcohol impairment including motorcycle safety
- intelligent driver-support systems for novice teen drivers
- in-vehicle use of advanced traveler information systems

The facility includes equipment for basic research on driver psychological functioning including a vision tester, DOT-certified alcohol Breathalyzer, mobile psychophysiology recording system, mobile eye-tracking system, video editing and behavior analysis suite, and a comprehensive psychometric test battery validated for traffic psychology.

Much of the research of the HumanFIRST Program uses a state-of-the-art driving simulator (supplied by AutoSIM and OKTAL) engineered specifically for human factors research in surface transportation. This Virtual Environment for Surface Transportation Research (VESTR) is a versatile and realistic simulation environment linked to a full-cab SC2 vehicle donated by Saturn using software that can create virtual environments that precisely reproduce any geospecific location. In addition, specialized visual-effect software can produce realistic weather and lighting—including light and shadow that correspond with season and time of day—as well as vehicle headlights with nighttime glare and water reflections.

The visual environment is generated with high-resolution images (1.97 arcmin per pixel) over a wide field of view (210-degree forward, 50-degree rear, 2 by 20-degree side mirror images). This immersive driving experience is enhanced by realistic motion generated by a three-axis motion base and both high- and low-frequency vibration units, including a surround-sound system. With multiple sound systems, configurable touch panel displays (including head-up displays), haptic feedback through the seat and accelerator pedal, and a head-free eye-tracker that can detect in real time what a driver is looking at, this simulator supports the investigation of a wide range of interface options for ITS development, design, and assessment. These features make VESTR one of the premier driving simulators in North America and Europe.

Additionally, to support the validity of HumanFIRST research, the program has access to a variety of closed test tracks and road network field sites for on-road studies with instrumented vehicles.
Intelligent Vehicles Laboratory

The Institute’s Intelligent Vehicles (IV) Laboratory develops and tests innovative, human-centered technologies that improve the operational safety, mobility, and productivity of the transportation network in general, and highway vehicles in particular. These human-centered technologies integrate sensors, actuators, computer processors, and custom human interfaces to provide drivers with needed information under difficult driving conditions such as low visibility, severe weather, and narrow and congested roadways.

Although the IV Lab is focused primarily on vehicles, it also considers the roadway, supporting infrastructure, and electronic wireless communication as part of the transportation network and uses all of these elements in generating solutions to today’s transportation problems.

Driver-assistive systems developed by the IV Lab have been tested on specialty vehicles, including snowplows, patrol cars, ambulances, heavy vehicles, and transit vehicles. Ultimately, these systems will also be used on passenger vehicles, providing drivers with warnings and assistance with collision-avoidance and lane-keeping tasks. Numerous vehicles utilizing IV Lab driver-assist technologies have been deployed in both Minnesota and Alaska.

The University of Minnesota is recognized as a leader in developing and testing driver-assistive systems and is one of a small number of universities nationwide conducting this work. The IV Laboratory’s core staff consists of engineering professionals who work closely with an interdisciplinary team of specialists, including cognitive psychologists specializing in human factors from the ITS Institute’s HumanFIRST Program. The staff has developed expertise in wireless communications, embedded computing, visibility measurement and quantification, geospatial databases, virtual environments, image processing, driver-assistive technologies, control systems, and sensors.

IV Laboratory research seeks to increase driver safety in difficult driving conditions through the use of vehicle-guidance and collision-avoidance technologies. Several vehicles serve as experimental testbeds, including the SAFETRUCK (an International 9400 tractor-trailer), the SAFEPLLOW (an International 2540 crew-cab snowplow), a state highway patrol car, and a Minnesota Valley Transit Authority (MVTA) bus. Using these vehicles, IV Laboratory researchers are developing, testing, and integrating advanced technologies including centimeter-level differential global positioning systems (DGPS); high-accuracy digital-mapping systems; range sensors, including radar and laser-based sensors; a windshield head-up display (HUD), a virtual mirror, and other graphical displays; and haptic and tactile feedback.

The IV Laboratory’s lane-assist technology is unique in that it uses DGPS and does not require hardware in the roadway surface. The technology is transferable between various transportation modes and works in all low-visibility-
ity situations, including snow, fog, smoke, heavy rain, and darkness. In addition, these systems use human-centered technologies to enhance driving ability and reduce driver error due to distractions, fatigue, and other factors related to difficult driving situations.

Other difficult driving conditions are encountered by drivers on a daily basis. For instance, the vast majority of vehicle crashes occurring at rural, unsignalized intersections are the result of drivers incorrectly gauging the size of a gap between oncoming vehicles—not running stop signs. The IV Lab has developed a sophisticated rural intersection data-collection system used to study how drivers waiting at a low-volume minor road enter or cross a high-speed, high-volume expressway. This test intersection is located in Minnesota at the junction of U.S. 52 and Goodhue County Road 9 approximately eight miles south of Cannon Falls.

Minnesota. The data collected at the intersection are being used to model driver behavior to determine where the gap-acceptance decision process fails and leads to a crash, and to then design countermeasures to reduce the number of these crashes.

Because safety systems can produce improvements only if they are deployed, the IV Lab works with a variety of states to collect data and evaluate system performance. For instance, three vehicles (and a fourth planned) with driver-assist technology have been deployed in Alaska, where high snowfall rates and dry, blowing snow routinely cause whiteout conditions and zero visibility. By March 2008, the Minnesota Mobile Intersection Surveillance System (MMISS) will have collected driver behavior at rural expressway through-stop intersections in Wisconsin, Iowa, Michigan, North Carolina, Georgia, New Hampshire, Mn/DOT and local transit authorities operate more than 200 miles of bus-only shoulders throughout the Twin Cities Metro area. Allowing transit vehicles to use shoulders during periods of traffic congestion provides passengers reliable, on-time service regardless of congestion levels in the normal traffic lanes. Bus drivers, however, face a serious challenge: keeping a bus that is 9.5 feet wide from mirror to mirror on shoulders that are generally no more than 10 feet wide. This is difficult under good conditions and becomes extremely challenging in bad weather.

That’s where the Institute’s Intelligent Vehicles (IV) Lab is hoping to help. In an earlier pilot project funded by the Federal Transit Administration (FTA), IV Lab researchers successfully tested lane-keeping and collision-avoidance technologies on a Metro Transit bus—dubbed the TechnoBus. FTA funding for that project has expired, so to keep the work moving, the Minnesota Valley Transit Authority (MVTA) offered to support deployment of a test fleet of instrumented vehicles—the first such fleet in the country. Since then, the IV Lab team has transplanted technology from the TechnoBus to an MVTA bus, mapped a section of the Cedar Avenue “test” corridor, and conducted test runs and demonstrations for the FTA, the MVTA board, and MVTA drivers and driving trainers.

The four-year goal is to equip four or five buses with lane-assist systems and operate them along the Cedar Avenue corridor. In the first phase, researchers will enhance existing Global Positioning System (GPS) technology to provide seamless coverage when signals are lost under bridges. In the second phase, MVTA drivers will use the lane-assist system on a small number of training vehicles, ideally ranging from smaller buses to motor coaches. The third phase will extend use to in-service routes carrying actual passengers.

This research will provide tangible evidence of how technologies developed by the ITS Institute can help bus drivers navigate freeway shoulders used as part of a Bus Rapid Transit (BRT) system and improve system operations. Moreover, the baseline data collected in phase one will provide the economic foundation for a benefit/cost analysis, which could be used by other transit agencies considering lane-assist technologies for BRT operations.

The ITS Institute, MVTA, and Hennepin County have committed funds for phase one and are now establishing the necessary contracts. Local funding should be in place by September 2007. The hope is that by successfully demonstrating the system’s robustness in phase one, the FTA will provide funding support for phases two and three.
The Northland Advanced Transportation Systems Research Laboratories (NATSRL), founded in 2000, is an advanced research program located at the University of Minnesota Duluth. Its mission is to develop innovative ITS technologies that can make surface transportation systems in northern areas safe, efficient, reliable, and environmentally sound.

NATSRL has been strongly supported by its key stakeholders, including the Minnesota Department of Transportation, St. Louis County, Washington County, and the city of Duluth.

Current research focus areas in NATSRL include advanced traffic/pavement sensor technologies; vehicle safety technologies; transportation data archival and analysis methods; renewable power for ITS operations in rural areas; and traffic safety and management strategies for rural and urban areas.

Specific NATSRL research projects in these focus areas
Each year, Mn/DOT-operated snowplow trucks suffer collisions in which the dump box on the back of the truck hits a bridge while in the raised position. These collisions, which can shear off the dump box from the truck frame, typically incur $30,000 to $40,000 in repair costs per incident and result in potentially dangerous traffic conditions and delays in clearing snow along the affected plowing route.

NATSRL researchers Richard Lindeke and David Wyrick, professors in the Department of Mechanical and Industrial Engineering at the University of Minnesota Duluth, are working to develop both off-vehicle and on-vehicle control software solutions that may prevent these collisions.

Specifically, the researchers are investigating the frequency, location, and severity of snowplow-bridge collisions and are assessing the current “box-up” driver warning system in order to identify possible improvements.

Through this effort, the team is working to link onboard GPS technology used for automatic vehicle location with Mn/DOT’s bridge information database to create route-by-route collision maps. These maps could then be used to develop a warning system that takes input from the plow’s GPS system, along with readings from its speedometer and odometer and from transponders mounted along the roadway, to alert plow drivers when they are approaching a bridge with the dump box at a dangerous height. This information will be integrated into an onboard position sensor that interfaces with an automated box controller to lower the box temporarily in the event of an unsafe situation. The controller will automatically re-elevate the box after the obstacle is cleared so the truck can continue sanding and applying chemicals.

So far, the researchers have developed the offline program for extracting obstacles and generating plow route files along each route. The files contain bridge identification data that note the underpass height, deck width, and location using longitude and latitude values. These files—specific to Mn/DOT District 1—are being used along with a recently purchased microprocessor unit and GPS hardware to build the onboard controller.

Lindeke and Wyrick also examined the effectiveness of different types of warnings—visual, auditory, or tactile—to be used during plow operation. They have determined that using a brief audio alert and flashing lamp provides an effective warning to the driver that the box is being lowered automatically and helps reduce driver stress.

The team plans to conduct live on-board tests of the total system in 2007 in selected District 1 routes.

New system aims to prevent snowplow collisions with overhead bridges

Richard Lindeke with graduate students Benjamin Wiegers and Ted Pelzer

In addition, NATSRL partners with Mn/DOT District 1 each year to provide a daylong formal presentation of ongoing research efforts.

Richard Lindeke with graduate students Benjamin Wiegers and Ted Pelzer

include a wireless detection network to measure spatial traffic data; a video-based vehicle tracking system designed to process a vehicle motion-detection algorithm in real time; an early detection and warning system for driver drowsiness; realistic snow modeling within a driving simulator environment to assess the effects of alternative snowplow truck color and lighting options on the perceived safety distance of following drivers; and development of a freeway travel time database and Mn/DOT weigh-in-motion data archive design.

In addition, NATSRL partners with Mn/DOT District 1 each year to provide a daylong formal presentation of ongoing research efforts.