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?
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.

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 (PVT), 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

Kathleen Harder, College of Architecture and Landscape Architecture

The Effectiveness and Safety of Traffic- and Non-Traffic-Related Messages Presented on Changeable Message Signs
Status: Completed (in FY04)
Changeable message signs (CMSs) were originally 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 statewide 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. This research attempted to answer several key questions, 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? And what is the impact of CMS messages on traffic flow?

Using a driving simulator, the researchers 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.

Based on their findings, the researchers came up with a series of recommendations they believe will help increase the effectiveness of CMS messages, including Amber Alerts. These include making the public more aware of the Amber Alert system and 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. The radio station should then frequently repeat the full Amber Alert message, including the license plate number, which will greatly increase the likelihood that a driver encountering the vehicle mentioned will recognize it.

Project URL: www.its.umn.edu /research/projects/2003038.html

Reducing Crashes at Controlled Rural Intersections
Status: Completed (in FY04)
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 (e.g., innovative signage, improved sight lines for drivers) intended to increase the saliency of a problem intersection in Goodhue, Minn. One group of 24 participants drove with the intersection modeled as it is now, while a second group of 25 drove with 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 better 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
Status: Completed (FY04)
Because the snowplow operator’s tasks are 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 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 1.1 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

**Guidelines for Using Rumble Strips**

**Status:** In progress

This project is in response to a request by the Minnesota Local Road Research Board for research that focuses on the effect 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.

County engineers frequently find themselves in litigious situations because of the public’s perception that rumble strips are highly effective devices at problem rural controlled intersections. On the other hand, rumble strips can become a liability because once in place, they are often not properly maintained. This research is attempting to conduct a well-controlled empirical study that will establish guidelines for where to use and not use rumble strips in order to move toward standardization. Such guidelines would be helpful to county engineers, giving them more knowledge regarding whether or not in-lane rumble strips should be a tool they apply to problem intersections.

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

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

**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 current project is investigating the effect of in-lane rumble strips on the stopping performance of sleep-deprived drivers. The study is being 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.

**Project URL:** www.its.umn.edu/research/projects/2003001.html

**Psychological and Roadway Correlates of Aggressive Driving (Phase II)**

**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 are examining 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 Phase II of this research 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/2002034.html

**Tom Smith, School of Kinesiology**

**Reducing Risk Taking at Passive Railroad Crossings with Active Warnings**

**Status:** In progress

A disproportionate number of vehicle-train crashes in Minnesota occur at passively signed highway-rail intersections (HRIs). The high percentage of (mostly rural) passively signed HRIs is attributable to the high cost of conventional active warning technology. This study evaluates driver interaction with a low-cost active warning system being considered by Mn/DOT for potential installation at passive HRIs. The objective is to ascertain if, relative to HRIs with passive signage, drivers interact more cautiously with HRIs equipped with active warning system technology.

The study was conducted using a simulated driving environment consisting of various HRI scenarios and 25 subjects (15 females, 10 males). Major results show 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 advance warning signs, relative to active warning signs; with a train present and clear visibility, for all measurement intervals, active advance warning signs are associated with lower mean vehicle speeds, compared to mean speeds observed with passive advance warning signs; active advance and crossing warning signs were perceived by respondents as more usable and more perspicuous than passive advance and crossing warning signs; and finally, flashing words (e.g., a variable message sign) are perceived by respondents as more perspicuous than flashing lights on an active advance HRI warning sign.

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.

**Project URL:** www.its.umn.edu/research/projects/2000041.html

**Mike Wade, School of Kinesiology**

**Accident Analysis for Low-Volume Roads**

**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 select an 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 cluster 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 county engineers to better determine the impact of signage
Deer Avoidance Research: Use of Motion Detector Flashing Light

Status: In progress

This project is evaluating the potential impact of a new technology—motion detection information relative to the presence of deer in and around major highways—on driver behavior. Experiments will be performed that will record driver behavior as a function of the new deer motion detection system. Deer presence will be displayed as a warning light, which will flash in the area adjacent to the detection of the deer. Variables of interest will include the location and nature of the illuminated signal; the rate at which the warning light flashes; rural versus urban drivers; age of the operators (less than 40 years of age, older than 60 years of age), and possible gender effects. The variables will be generated in consultation with a Mn/DOT technical panel, and the research will be carried out at the University of Minnesota using a driving simulator.

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

Driving Performance During 511 Information Retrieval and Cell Phone Conversation Tasks, Combined Under Varying Levels of Traffic Density

Project Status: In progress

Currently, Minnesota has a 511 service that may be accessed by users while driving. There is considerable debate about cell phones as a risk factor in traffic crashes. Mn/DOT-funded research begun in 2003 will assess the “relative” risk of cell phone use to other common risk factors, including existing in-vehicle tasks and alcohol. As a logical and necessary extension of this research, this new project will assess cell phone use for 511 applications compared with other cell phone (conversation) interactions. These data will be used to evaluate the usability of 511 in traffic and to give design recommendations.

Project URL: www.its.umn.edu /research/projects/2005024.html

Albert Yonas, Institute of Child Development

Improving the Ability of Drivers to Avoid Collision with Snowplows in Fog and Snow

Status: Newly funded

The researchers have created a laboratory test bed for investigating the effects of blowing snow, fog (luminance contrast), flashing warning lights, and color on the ability of drivers to perceive that they are approaching or withdrawing from a simulated vehicle. In doing so, they have found that lowering the luminance contrast between the image of a vehicle and the background significantly reduces the ability to perceive approach. In a low-contrast, equiluminant situation, the researchers required twice as much retinal motion as normal to begin to sense approach. Flashing lights, such as those mounted on snowplows to attract attention, also interfere with motion perception. Consequently, the researchers plan to completely characterize the chromatic contrast effect of blowing snow and fog on the color space by making systematic physical measurements on a selected number of carefully chosen color surfaces. In addition, they will use their computer-controlled laboratory task, and well-understood psychophysical methods, to investigate the impact of vehicle color and lighting enhancements. For example, they will investigate the effects of the number, location, color, and flashing of warning lights on the ability to perceive that a driver is approaching a vehicle. Results will enable them to make recommendations to increase the safety of Minnesota drivers.

Project URL: www.its.umn.edu /research/projects/P2005068.html

Human-Centered Interventions Toward Zero Deaths in Rural Minnesota: Psychological Factors, Driver Risk Taking, and Acceptable Interventions

Status: Newly funded

Motor vehicle crashes predominate as the cause of mortality in rural areas. Persons involved in a rural crash are three times more likely to die than persons involved in an urban crash. Since most rural crashes involve rural drivers, research must consider the pertinent human factors by examining the relationship between the personalities and attitudes of rural drivers toward safety and the higher rural crash rate, as well as driving style, relative to the urban context. This project will attempt to support the development of a human-centered intervention to reduce the carnage from the high rural crash rate in Minnesota by investigating these psychological and social factors that may predispose rural drivers to drive less safely.

Project URL: www.its.umn.edu /research/projects/P2005024.html

Nicholas Ward, Department of Mechanical Engineering

Design and Safety Implications for ATIS Use with Cell Phones

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. Now that many states are intending to introduce traveler information systems that may be accessed with cell phones while driving, there is an even greater need for relevant research to determine the risk of this secondary task. A risk can be assumed for any task that demands driver attention and distracts the driver from the primary driving task. Thus, the key question is not if cell phone use imposes a risk, but rather, if the amount of risk is unacceptable. An acceptable risk threshold can be assessed in relative terms by comparing cell phone use to other common risk factors. First, there is a range of common in-vehicle tasks that are routinely engaged in by the driving population. The risk imposed by this common task set may be considered a baseline that is based on the notion of consensual risk. Second, demonstrable limits have been set for other impairment factors such as alcohol (BAC 0.10). The risk imposed by these legislated limits can also be considered as a baseline that is based on the notion of sanctioned risk. This project will assess the “relative” risk of cellular phone use on driving impairment and driver mental effort compared with commonly accepted in-vehicle tasks as well as BAC 0.08.

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

Human-Centered Interventions Toward Zero Deaths in Rural Minnesota: Psychological Factors, Driver Risk Taking, and Acceptable Interventions

Status: Newly funded

Motor vehicle crashes predominate as the cause of mortality in rural areas. Persons involved in a rural crash are three times more likely to die than persons involved in an urban crash. Since most rural crashes involve rural drivers, research must consider the pertinent human factors by examining the relationship between...
prioritization of video data in packet-switching (IP) networks. These issues have been addressed using the prototype system developed and 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 used at Mn/DOT. This includes implementing the QoS prioritization software in the prototype system at the ITS Lab; analyzing existing network configurations and application settings that require QoS implementation; 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 when Mn/DOT networks are congested 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 QoS 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.htm](http://www.its.umn.edu/research/projects/2003010.htm)
evaluation efforts were undertaken by the University, with support and feedback provided by Mn/DOT.

**Project URL:** [www.its.umn.edu/research/projects/2000037.html](http://www.its.umn.edu/research/projects/2000037.html)

**Toward a Multi-State Consensus on Rural Intersection Decision Support**

**Status:** In progress

The National Safety Council estimates that 32 percent of all rural crashes occur at intersections. Although the average crash occurring at an intersection is not as severe as one occurring on the open road, 16 percent of all fatalities on rural highways are intersection-related.

Minnesota is partnered with California, Virginia, and the FHWA in a pooled-fund consortium (the Infrastructure Consortium) dedicated to improving intersection safety. Each member of the consortium is tasked with addressing an aspect of intersection safety; the Minnesota team’s objective is to develop a better understanding of the causes of crashes at rural intersections and then develop a toolbox of effective strategies to mitigate the high crash rate.

**Rural Intersection Decision Support (IDS)** focuses on enhancing a driver’s ability to successfully negotiate rural through-stop intersections. The system uses sensing and communication technology to determine the safe gaps and then communicate this information to the stopped driver so that he or she can make an informed decision about crossing the intersection or entering the traffic stream of a major road. The goal of the research is to reduce crashes and fatalities at such intersections without having to introduce traffic signals, which on high-speed rural roads often lead to an increase in rear-end crashes.

**Project URL:** [www.its.umn.edu/research/projects/2001048.html](http://www.its.umn.edu/research/projects/2001048.html)

**William Durfee, Department of Mechanical Engineering**

**Optimal Secondary Controls Using a Configurable Haptic Interface**

**Status:** In progress

Secondary controls are proliferating in automobiles as more and more electronic features are added for communication and navigation. The use of configurable, adaptable control knobs with haptic (touch) and aural feedback properties optimized to the driver and to the task may enable safe operation of a variety of secondary control functions with minimum distraction to the driver. In this project, the researchers are developing and testing new technology for configurable, manual controls with computer-controlled haptic and aural feedback properties. Controls will be tested in tabletop and driving-simulation experiments with human subjects to determine if optimal control properties can indeed benefit drivers. A future goal is to adapt this technology to drivers with motor, sensory, or cognitive disabilities.

**Project URL:** [www.its.umn.edu/research/projects/2003054.html](http://www.its.umn.edu/research/projects/2003054.html)

**Ravi Janardan, Department of Computer Science and Engineering**

**Real-Time Collision Warning and Avoidance at Intersections**

**Status:** In progress

Collisions between vehicles at urban and rural intersections account for nearly one-third of all reported crashes in the United States. This has led to considerable interest at the federal level in developing an intelligent, low-cost system that can detect and prevent potential collisions in real time.

This project is motivated by the need for methods that address problems raised by the Intelligent Vehicle Initiative Federal Infrastructure Consortium. The researchers are developing a system that uses video cameras to continuously gather traffic data (e.g., vehicle speeds, positions, trajectories, vehicle sizes) at intersections and then applies efficient algorithmic techniques to detect potential collisions and near misses in real time.

The goal is to establish the feasibility of this approach using both computer simulations and field tests at actual intersections.

The current status of the project includes the development of a comprehensive video processing module for video acquisition and frame-by-frame analysis and tracking of vehicles, as well as the design and implementation of a variety of collision detection algorithms.

**Project URL:** [www.its.umn.edu/research/projects/2002025.html](http://www.its.umn.edu/research/projects/2002025.html)

**Taek Mu Kwon, Department of Electrical and Computer Engineering (Duluth)**

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

**Status:** In progress

Poor-visibility conditions often lead to large-scale chain vehicle crashes that take lives and damage property. Such visibility-related crashes might be prevented if motorists were warned ahead of time to reduce speed and drive cautiously before entering a poor-visibility zone.

The challenge is to accurately measure visibility in real time in order to determine the optimal speed limit and then notify drivers in real time. The objective of this research was to advance visibility measurement technologies that process images captured through video cameras.

There are two fundamental problems in converting atmospheric parameters into visibility, which is the case in most of today’s visibility meters. The first is that visibility is a complex multivariable function of many atmospheric parameters so that measurements of one or two parameters, as is currently done for most visibility meters, cannot accurately estimate the true human-perceived visibility. On the other hand, any attempt to measure every possible atmospheric parameter is simply too complex and costly. The second source of difficulty results from an attempt to express the spatially variant nature of atmospheric visibility using a single representative value: distance. This works only if the atmosphere is uniform, which it rarely is.

A solution offered by this research is to measure visibility using visual properties of video images (perceived information) instead of indirectly measuring physical properties of atmosphere and then converting them into visibility. The spatial variance problem in visibility was solved by introducing a new concept of relative measurement of visual information referred to as the Relative Visibility (RV).

The research also extended the first phase of the video-based visibility study in which fixed multiple targets were used. The main finding was that the accuracy of visibility measurements increases as more targets in varying distances are used. For night visibility, measurements of air-opacity using a reflective near infrared (NIR) source from a specific type of surface property provided the most accurate representation.

**Project URL:** [www.its.umn.edu/research/projects/2000024.html](http://www.its.umn.edu/research/projects/2000024.html)

**Section Travel-Time Measurement Using Inductance Signatures of Loop Detectors**

**Status:** In progress

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 station 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.

Project URL: [www.its.umn.edu](http://www.its.umn.edu/research/projects/2003027.html)

**TMC Traffic Data Automation for Mn/DOT’s Traffic Monitoring Program**

**Status:** In progress

The Minnesota Department of Transportation (Mn/DOT) has been responsible for collecting, analyzing, and publishing traffic count data from the various roadway systems throughout the state. The traffic reporting system mainly developed by the Traffic Forecasting and Analysis Section (TFAS) of Mn/DOT has been used in several federal programs, for internal Mn/DOT applications, and by many private-sector firms. This project is continuing the TFAS automation efforts by computerized integration of the current manual effort to import, filter, and analyze the TMC portion of traffic data contributed to Mn/DOT’s Traffic Monitoring System. The resulting system will allow users to specify the conditions for acceptance tests required by TFAS for both continuous and short-duration count volume data. Once the filtering procedures and parameters are set by an operator, the raw data can be automatically processed by the system without human intervention.

Project URL: [www.its.umn.edu](http://www.its.umn.edu/research/projects/2001033.html)

**Nikolaos Papanikolopoulos, Department of Computer Science and Engineering**

**Development of a Tracking-Based Monitoring and Data-Collection System**

**Status:** In progress

This project is working toward the development and deployment of a flexible, portable, and reliable intersection-monitoring and data-collection system. The proposed system will be based on vehicle-tracking methodologies implemented on a single or multiple camera(s). Researchers will compute a variety of traffic and behavior data such as turning vehicle counts, vehicle trajectories, vehicle classes, delays, lane changes, gap acceptance behavior by turning vehicles, speed variations, safety-related data, and other types of intersection data as needed by traffic engineers. The proposed system could be used for accessing the effectiveness of existing signal timing plans and operational methods and the level of intersection safety. The researchers’ approach will include the development of a user-friendly interface and will chiefly employ existing camera hardware. The researchers also envision the proposed system to be used as the main tool for before/after study of the effectiveness of intersection and local area improvement treatments.

Project URL: [www.its.umn.edu](http://www.its.umn.edu/research/projects/2003042.html)

**Finding What the Driver Does**

**Status:** Newly funded

This project will work toward 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, behavioral 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.

A potential benefit of the proposed work is a decrease in the number of vehicle crash-related deaths, in accordance with the Toward Zero Deaths initiative.

Project URL: [www.its.umn.edu](http://www.its.umn.edu/research/projects/P2004010.html)

**Rajesh Rajamani and Lee Alexander, Department of Mechanical Engineering**

**Lateral Stability of a Narrow Commuter Vehicle**

**Status:** In progress

In an effort to explore technological solutions for increasing the carrying capacity of urban highways, this research is developing a prototype of a one- or two-passenger narrow vehicle, the width of which (about one meter or 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.

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, researchers designed the rear-wheel-drive vehicle, which has two wheels in the front and one in back, then built a working prototype of the vehicle.

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. 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.

Next, the researchers 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 meant to stimulate the development of future transportation technologies that reduce congestion on freeways in Minnesota and across the country.

**Project URL:** [www.its.umn.edu/research/projects/2001030.html](http://www.its.umn.edu/research/projects/2001030.html)

**Rajesh Rajamani, Department of Mechanical Engineering**

**GPS-Based Real-Time Identification of Tire-Road Friction Coefficient**

**Status:** In progress

This project is developing a new GPS-based friction identification system for winter maintenance vehicles that will measure the road friction coefficient at the tires and this real-time information available to the maintenance vehicle operator. This work will enable the operator to adjust the amount and kind of deicing material to be applied to the roadway.

In work completed so far, a vehicle-based system for friction measurement has been developed and evaluated on a winter maintenance vehicle, the SAFEPLow. The vehicle-based system utilizes real-time measurements of the longitudinal and lateral motion of the vehicle together with a knowledge of vehicle dynamics in order to calculate the value of the friction coefficient at the tires.

The advantage of the system developed in this project is that it is applicable during both vehicle acceleration and braking and works reliably for a wide range of slip ratios, including high-slip conditions. The system can be used on front/rear-wheel-drive as well as all-wheel-drive vehicles. Experimental results show that the system performs reliably and quickly in estimating friction coefficient on different road surfaces during various vehicle maneuvers.

As part of the project, a wheel-based friction measurement system is also being developed. This system uses a redundant wheel on the vehicle similar to that used by commercial friction measurement systems such as the Norsemeter. Unlike the Norsemeter, however, the advantage of the system being developed is that it requires no forced skidding of the external wheel and is likely to be a more reliable system due to the presence of very few moving parts. The wheel-based system is currently being evaluated on the SAFEPLow.

Besides winter maintenance, real-time identification of the friction coefficient should also be valuable for other vehicle systems, including ABS, skid control, collision avoidance, and adaptive cruise control systems.

**Project URL:** [www.its.umn.edu/research/projects/2002026.htm](http://www.its.umn.edu/research/projects/2002026.htm)

**Automated Winter Road Maintenance Using Road Surface Condition Measurements**

**Status:** Newly funded

This project aims to develop an automated sander control system for a snowplow using the friction coefficient of the road surface and pavement temperature as key measurements for feedback.

The project consists of two major technical activities: 1) Improvement of an existing tire-road friction measurement system on the SAFEPLow by using additional piezo sensors mounted on the insides of the tires of the snowplow. These additional sensors will help improve the accuracy and reliability of the friction measurement system; and 2) Automation of the snowplow sander using real-time measurements from the friction measurement system and a pavement temperature measurement sensor, and experimental evaluation of the performance of the automated system on the SAFEPLow.

The project should lead to the development of valuable winter maintenance technology in which knowledge of pavement conditions is used to keep roads in good condition. The technology will help reduce material costs, help better utilize maintenance crews, and lead to safer roads in winter.

**Project URL:** [www.its.umn.edu/research/projects/P2005035.html](http://www.its.umn.edu/research/projects/P2005035.html)

**Craig Shankwitz, Department of Mechanical Engineering**

**Advanced BRT: Innovative Technologies for Dedicated Roadways**

**Status:** In progress

In the United States, a number of transit agencies are either operating Bus Rapid Transit (BRT) systems or are in the process of initiating this service. For example, Twin Cities Metro Transit operates a BRT system using a network of 200 miles of road shoulders to allow bus passage during periods of high traffic congestion. Lane Transit in Eugene, Oregon, and the Cleveland Regional Transit Authority are considering a BRT system, both of which are likely to use lane-assist technology on dedicated, narrow lanes.

The present Intelligent Vehicles Lab (IV Lab) lane-assist system is based on precise vehicle-positioning technology and a high-accuracy digital road map. This system requires a reasonably clear view of the sky overhead in order to receive GPS satellite information. Without a clear view of the sky, GPS information is unavailable, disabling the lane-assist system. Urban canyons, roads with tall trees located close to the roadway, bridges, and underpasses all represent areas where the GPS receiver cannot receive satellite signals, and therefore cannot operate.

This project proposes augmenting the present IV Lab lane-assist system with ranging and positioning technology that will allow it to operate in the difficult environmental conditions listed above. Alternative ranging and positioning sensors will be analyzed, modeled, and eventually incorporated into the IV Lab lane-assist system. Successful augmentation will result in a system that meets the operational and robustness needs of transit agencies as well as the cost-effectiveness and reliability needs of the bus manufacturer and its OEM supplier.

As a means to this end, the IV Lab intends to work with transit agencies and bus manufacturer(s) to deploy an augmented DGPS digital map lane-assist system for a BRT narrow-lane application in the United States.

**Project URL:** [www.its.umn.edu/research/projects/2002041.html](http://www.its.umn.edu/research/projects/2002041.html)

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

**Status:** In progress

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, this research is developing driver-assistive technologies to solve these challenges.

Researchers 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. A second enhancement is the incorporation of side and rear sensors used for collision avoidance.

To aid system development and facilitate testing, the team has outfitted an experimental vehicle—a Metro Transit bus—with a system that provides haptic feedback to the driver. The TechnoBus is fitted with a steering actuator, which
Driver-Assistive Systems for Rural Applications: A Path to Deployment

Status: In progress

This project has two components. The first is to develop and implement an automated means 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 or digital “map.”

A complement to the image-processing task will be to use 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 geospatial 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 county engineers 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 forges the need to provide a local, ground-based GPS base station and the wireless communication equipment needed to get the correction to the roving vehicle, thereby offering 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 real-time kinematic (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 systems in a difficult environment.

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, but 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 would allow for thorough operational testing.

Gang Plowing Using DGPS

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 anxious 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 tactile steering feedback with throttle and brake actuators to help the driver of the following vehicle maintain the proper following distance and lane position behind the lead vehicle. 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 try to squeeze in between the ganged snowplows. A side-scanning laser sensor and a “virtual mirror” will also be used to detect the rogue motorist trying 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 will have been performed at Mn/ROAD to verify the concept. This approach to gang plowing will be demonstrated on an actual road, Minnesota Trunk Highway 101 between Rogers and Elk River, Minn.
Multi-Use, High-Accuracy, High-Density Geospatial Database
Status: Newly funded
High-accuracy (2-8 cm) DGPS and high-accuracy (5-20 cm) geospatial databases are the primary components of the IV Lab driver-assistive systems. In addition to vehicle-based systems, the IV Lab geospatial database has been used in other applications—for instance, for a new intersection decision support (IDS) project in which radar sensors are used to determine the state of an intersection as a first step in warning drivers when it is unsafe to enter an unsignalized intersection. For this application, the geospatial database is used to improve the ability of the radar system to determine whether a target represents a legitimate threat at the intersection.

The IV Lab geospatial database was designed and optimized for vehicle applications, and as such it provides real-time access to an extremely accurate, dense geospatial data. Because of this optimization, however, its functionality in other applications is somewhat limited. As new applications arise (e.g., the need to integrate high-accuracy geospatial data into a driving simulator), a more “global” approach to the geospatial database is required. This project proposes a redesign of the geospatial database and database manager and the development of a new front end to serve a wide application base.

Project URL: [www.its.umn.edu/research/projects/P2005043.html](http://www.its.umn.edu/research/projects/P2005043.html)

Shashi Shekhar, Department of Computer Science and Engineering
Evacuation Route-Schedule Planning for Disasters Damaging Automatic Traffic Control Systems
Status: In progress
Evacuation route-schedule planning identifies paths to move populations out to safe areas in the event of catastrophes, natural disasters, and terrorist attacks. Current approaches are based on assignment-simulation tools (e.g., DYNASMART). However, the quality of solutions from these tools depends on the logical configuration of the transportation network. Currently, engineering judgment is used to select logical network configuration. This project is working to develop algorithms and software tools to determine effective logical network configuration given physical transportation network and evacuation traffic demand. Developing efficient and effective algorithms for logical network design is a challenging research problem due to the exponential combinatorial search space of possible solutions. The new algorithms will be also be integrated with assignment simulation tools such as DYNASMART. Researchers will also evaluate the new algorithms under certain given scenarios. This research will provide new tools to help Mn/DOT find optimal logical network configurations to supply to assignment simulation models toward effective evacuation route-schedule planning.

Project URL: [www.its.umn.edu/research/projects/2004051.html](http://www.its.umn.edu/research/projects/2004051.html)

Jiann-Shiou Yang, Department of Electrical and Computer Engineering (Duluth)
Traffic Flow Modeling Simulation and Signal Timing Plans Evaluation of the Miller Hill Corridor
Status: Completed (in FY04)
This research presents a study of the traffic flow modeling, simulation, and signal timing plans evaluation of the Miller Hill corridor. The corridor on Highway 194 between Arlington Avenue and Haines Road is recognized as one of the most heavily traveled and congested roadways in the Duluth area. The ability to better understand traffic in that area will provide for better traffic management and better traveler information.

The traffic data along the corridor was collected over a 10-month period using a non-intrusive side-fire mounted RTMS traffic detector. A modified Papageorgiou’s macroscopic model was then developed to model the traffic flow on the corridor. Using the data collected, the model parameters were identified by solving a least-squares optimization problem. From the dynamic model developed, a traffic flow simulation system was then further developed and implemented to perform the real-time traffic simulation along the corridor during the afternoon rush hours.

Finally, based on the traffic flow modeling and simulation results, the traffic signal timing optimization along the corridor was conducted. The ultimate goal of this research is to provide a better signal-timing plan to improve the efficiency of traffic movement in that area.

Project URL: [www.its.umn.edu/research/projects/2001043.html](http://www.its.umn.edu/research/projects/2001043.html)

A Nonlinear-State Space Approach to Arterial Travel Time Prediction
Status: Newly funded
Travel time information is a good operational measure of the effectiveness of transportation systems and can be used to detect incidents and quantify congestion. Travel time prediction refers to predicting and calculating travel time before a vehicle has traversed the arterial freeway or route of interest. The ability to accurately predict freeway and arterial travel times in transportation networks is a critical component for many ITS applications (e.g., advanced traffic management systems, in-vehicle route guidance systems).

This project will focus on arterial travel time prediction by developing a recursive, nonlinear-state space model to predict short-term travel time on arterials. Prediction of travel time is potentially more challenging for arterials than for freeways because vehicles traveling on arterials are not only subject to queuing delay but also to traffic signal delay. Kalman filtering/time series analysis techniques will be incorporated with the prediction model due to their ability to update travel time information continuously to reflect the traffic fluctuation in real time. Unlike many offline algorithms that use only historical data for prediction, both real-time and historical data will be used in the process of travel time prediction. Real-time data will be collected using the Global Positioning Systems (GPS) probe vehicle technique. In addition, information on traffic conditions on upstream and downstream links via video detectors will be used to improve the quality and robustness of the data.

Project URL: [www.its.umn.edu/research/projects/P2005034.html](http://www.its.umn.edu/research/projects/P2005034.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
Status: In progress
In crash reconstruction, individual vehicle crashes are treated as essentially deterministic events, although incomplete information can leave one uncertain about how exactly a crash happened. In statistical studies, on the other hand, crashes are treated as individually random, although the parameters governing their probability distributions may be modeled deterministically. Selection of one or the other of these approaches affects how data are interpreted. In this research, a simple deterministic model of a vehicle/pedestrian encounter is used to illustrate how naively applying statistical methods to aggregated data could lead to an ecological fallacy and to Simpson’s paradox. This research suggests that these problems occur because the statistical regularities observed in crash data have no independent status but are simply the result of aggregating particular types and frequencies of mechanisms.
Project URL: www.its.umn.edu/research/ projects/2001032.html

Identification and Simulation of Common Freeway Accident Mechanisms
Status: In progress
Determining whether or not an event caused a vehicle crash often involves determining the truth of a counterfactual conditional, for which “what happened” is compared to “what would have happened” had the alleged cause been absent. Previous research by others has developed a rigorous method for posing and answering causal questions—an approach that is especially well suited to the reconstruction and analysis of crashes. In this project, researchers applied these methods to freeway rear-end collisions. Starting with video recordings of crashes, trajectory information on a platoon of vehicles involved in a crash was extracted from the video record. These trajectories were used to estimate each driver’s initial speed, following distance, reaction time, and braking rate. Using a model of rear-end crashes, it was then possible to simulate what would have happened had, other things equal, certain driver reactions been other than they were. In each of three crashes the researchers found evidence that: 1) short following headways by the colliding drivers were probably causal factors for the collisions; 2) for each collision, at least one driver ahead of the colliding vehicles probably had a reaction time that was longer than his or her following headway; and 3) had this driver’s reaction time been equal to his or her following headway, the rear-end collision probably would not have happened.
Project URL: www.its.umn.edu/research/ projects/2003007.html

Identification of Causal Factors and Potential Countermeasures for Fatal and Severe Rural Crashes
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/2003014.html

Bus Signal Priority based on GPS and Wireless Communications
Status: Newly funded
With the recent installation of GPS systems, Metro Transit is monitoring bus locations and schedules in order to provide more reliable transit services. Many applications are enabled by such vehicle-location systems. Using this type of information and other on-board systems, transit vehicles could potentially be used as probes for determining traffic speeds and travel times along freeways and major arterials.

Transit Signal Priority (TSP) for transit has been proposed as an efficient way to improve transit travel and operation. Bus signal priority has been implemented in several U.S. cities to provide more reliable travel and improve customer ride quality. Current signal priority strategies mostly utilize sensors to detect buses at a fixed or at a preset distance away from the intersection. Signal priority is usually granted after a reprogrammed time offset after detection. This study will take advantage of the GPS system on the buses and knowledge about bus stop locations to develop a signal priority strategy that could consider the bus’s timeliness with respect to its schedule, number of passengers, location, and speed.
Project URL: www.its.umn.edu/research/ projects/2005030.html

Cross-Median Crashes
Status: Newly funded
A cross-median crash occurs when a vehicle leaves its current path of travel, completely crosses the median dividing the highway’s directional lanes, and collides with a vehicle traveling in the opposite direction. AASHTO’s Roadside Design Guide suggests two countermeasures for preventing cross-median crashes: 1) the use of medians wide enough to provide adequate “clear zones” where a driver can stop or regain control of a vehicle before crossing into the opposing traffic stream, and 2) for areas where medians are less than 10 meters wide and annual daily traffic is greater than 20,000 vehicles/day, installation of median barriers.
As with any safety countermeasure, installation should begin with those locations showing the greatest expected benefits. This project will first review the state of the art in median crash protection through a literature review and a survey of current practices. This will be followed by statistical modeling of the frequency of median-crossing crashes in Minnesota, with the objective of identifying those locations where countermeasure installation is most likely to pay off.
Project URL: www.its.umn.edu/research/ projects/2005019.html

Eil Kwon, formerly with the ITS Institute
Development of Dynamic Route Clearance Strategies for Emergency Vehicle Operations (Phase II)
Status: Completed (in FY04)
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.
Traffic Signal Preemption systems consist of some form of vehicle-mounted signal emitter combined with sensors mounted on or near traffic signals. When triggered by an 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: a vehicle-mounted signal transmitter must have a clear “line of sight” to the traffic signal in order to trigger the preemption routine, and it is possible to needlessly preempt intersection signals that are not on the emergency route if they happen to be located in the line of sight.

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 this data to a route selection subsystem, which then calculates an optimal route based on current conditions.

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.

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. A virtual intersection controller module was also developed to emulate different types of signal preemption strategies including the existing method with local detection.

The streets around the University of Minnesota’s Minneapolis campus were selected as the sample network for this evaluation. 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. 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.

Dynamic Estimation of Freeway Weaving Capacity for Traffic Management and Operations (Phase II)

Status: Completed (in FY04)

Understanding the behavior of weaving flows and estimating the effects of time-variant traffic conditions on the capacity of weaving areas is critical for developing effective operational and design strategies for freeway systems that can maximize existing capacity for a given freeway system. The previous phase of this research identified and classified the major weaving areas in the Twin Cities metro freeway network. Further, the traffic behavior and the factors affecting capacity in a type A ramp-weave section—the most common type of weaving area in the Twin Cities metro freeway system—were analyzed and an online model was developed to estimate the time-variant capacity of type A ramp-weave sections.

This research expanded on the previous work by addressing the traffic behavior and capacity issues at multiple weaving areas, where more than two weaving sections are sequentially located. In particular, the flow process at multiple weaving sections, including lane-changing locations and behavioral patterns and the factors affecting flow breakdowns and capacity changes, was analyzed using field data collected from the selected weaving areas. Finally, the functional relationship between capacity changes and weaving patterns was identified and modeled.

David Levinson, Department of Civil Engineering

Improving the Estimation of Travel Demand for Traffic Simulation

Status: In progress

Many current traffic management schemes are tested and implemented using traffic simulation. An Origin-Destination (OD) matrix is an ideal input for such simulations. The underlying travel demand pattern produces observed link counts, and these counts could be used to reconstruct the OD matrix. This research developed an offline approach for estimating a static OD matrix over the peak period for freeway sections using these counts.

Almost all existing offline methods use linear models to approximate the relationship between the on-ramp and off-ramp counts. Previous work indicates that the use of a traffic flow model embedded in a search routine performs better than these linear models. In this research, that approach is enhanced using a microscopic traffic simulator, AIMSUN, and a gradient-based optimization routine, MINOS, interfaced to estimate an OD matrix. The problem is highly non-linear and non-smooth, and the optimization routine finds multiple local minima but cannot guarantee a global minima. However, with a number of starting “seed” matrices, an OD matrix with a good fit in terms of reproducing traffic counts can be estimated. The dominance of the mainline counts in the OD estimation and an identifiability issue is indicated from the experiments. The quality of the estimates improves as the specification error, introduced due to the discrepancy between AIMSUN and the real-world process that generates the on-ramp and off-ramp counts, decreases.

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

Ramp Meter Delays, Freeway Congestion, and Driver Acceptance

Status: In progress

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 maximize utility 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/2002018.html

The Value of Traveler Information for Motorists

Status: In progress

A major strategy of federal ITS initiatives and state departments of transportation is to provide traveler information to motorists. This is relatively uncontroversial, but its effectiveness is unknown.

Traveler information can save travelers time if they choose alternative routes based on the information they receive. However, there are other benefits to drivers. For example, simply knowing of 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 this 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 these 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.

Project URL: www.its.umn.edu/research/projects/2001034.html

The Value of Traffic Simulation

Status: In progress

Many current traffic management schemes are tested and implemented using traffic simulation. An Origin-Destination (OD) matrix is an ideal input for such simulations. The underlying travel demand pattern produces observed link counts, and these counts could be used to reconstruct the OD matrix. This research developed an offline approach for estimating a static OD matrix over the peak period for freeway sections using these counts.

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Project URL: www.its.umn.edu/research/projects/2004021.html
Panos Michalopoulos, 
Department of Civil Engineering

Development of a Portable Wireless Measurement and Observation Station

Status: In progress

In spite of progress made in ITS technology over the past decade, road instrumentation for data collection purposes continues to be somewhat inadequate. Furthermore, the majority of data-collection devices depend on outdated technologies to take very limited measurements, such as volume and occupancy. This was recently experienced in a study for evaluating ramp metering in which even actual ramp demands had to be measured manually. Because of the extent of the roadway system, however, it is impossible to deploy sufficient instrumentation for all planning, traffic, and research needs. For this reason, there is a need for developing and testing an easily deployable, low-cost data collection and surveillance station that can be used for measuring detailed traffic data such as individual speeds, density, and other factors.

This project continues the work of John Hourdakis and Ted Morris in the ITS Laboratory, in which a prototype of such a station was developed, and tests it. Such an easily deployable, low-cost data collection and surveillance station could be used for planning and traffic management as well as research purposes, such as simulation, modeling, and control. This “total” station capitalizes on recent advances in machine vision traffic sensors, digital video compression and transmission, and wireless communication networks. In essence, it is the first step toward the development of a highway laboratory for traffic studies and research.

Project URL: [www.its.umn.edu /research/projects/2002630.html](http://www.its.umn.edu/research/projects/2002630.html)

Evaluation and Improvement of the Stratified Ramp Metering Algorithm Through Microscopic Simulation

Status: In progress

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 evaluated 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 trip 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 malfunctions, 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](http://www.its.umn.edu/research/projects/2004050.html)

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

Status: In progress

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 for simulation to be effectively employed by Mn/DOT, more substantial automation and streamlining of the simulation process are needed for non-research-oriented engineers. As a result, the 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](http://www.its.umn.edu/research/projects/2004049.html)

Development of Real-Time Traffic Adaptive Accident-Reduction Measures for the I-94/35W Commons Section

Status: Newly funded

According to Mn/DOT statistics, the westbound section of I-94 at the 94/35W commons south of downtown Minneapolis is the location of more crashes than any other location in the Twin Cities. In an ongoing project related to crash prevention and the detection of crash-prone conditions, this location was heavily instrumented, and data were collected and analyzed. Between September 2002 and October 2003 more than 150 crashes occurred on this stretch of highway (95 of them captured on video), ranging from simple rear-end collisions to multi-vehicle crashes with injuries. In addition, 215 near misses have also been recorded at the same location. These data show that crashes occur under certain traffic conditions that can be detected prior to a crash occurring.

This project will capitalize on the results by using techniques for early detection of crash-prone conditions to develop a traffic calming/driver warning system for reducing crashes. The system will be specifically tuned for maximum effectiveness on the aforementioned I-94 section. The goal of this first phase will be to design, evaluate, refine, and finalize such a system. In the next phase, researchers will estimate cost and time requirements and recommend necessary steps for field deployment and evaluation.

Project URL: [www.its.umn.edu /research/projects/P2005071.html](http://www.its.umn.edu/research/projects/P2005071.html)

Employment of Traffic Management Laboratory for the Evaluation and Improvement of Stratified Metering Algorithm: Phase III

Status: Newly funded

This project is in response to a Mn/DOT request for a robust and computationally
feasible solution for enhancing and improving its new stratified ramp control strategy. The research is a continuation of the ongoing project related to testing and evaluating the effectiveness of this strategy through rigorous microscopic simulation. As suggested from a one-year field operation and a recently concluded preliminary assessment, this strategy is generally effective in achieving a balance between freeway performance and ramp delays. However, the strategy can be further improved to address some inherent limitations and enhance its performance.

This research will enhance the strategy by providing more reliable ramp demand prediction, improving the trade-offs between freeway performance and ramp delays, and developing a more accurate and computationally feasible on-line ramp-queue size estimator. In addition, a methodology for determining location-dependent bottleneck capacity will be established to make the strategy more adaptive to freeway geometric characteristics. All the enhancements and improvements to the stratified ramp control strategy will be computationally feasible, and their effectiveness will be assessed by comparison with the current prototype version using microscopic simulation. Finally, the sensitivity analysis of the stratified ramp control strategy commenced in the current phase will be continued to cover adverse weather conditions based on the measurements being collected.

**SOCIAL AND ECONOMIC POLICY ISSUES RELATED TO ITS TECHNOLOGIES**

**Frank Douma, Humphrey Institute of Public Affairs**

**Telecommunications and Sustainable Transportation**

Status: Completed (in FY04)

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 multimodal. 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 attempted 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 improving operations by applying wireless telecommunications technologies to suburban transit and to rural emergency services.

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

The second task assessed operational benefits that might 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 were used to determine preferences and political barriers, and data from an operational deployment was used to assess effectiveness.

The third task built upon information gained from focus groups held in Rochester and Virginia, Minnesota, in August 2001. Using this information as a starting point, researchers examined the institutional and technical network requirements to deliver wireless services that enhance transportation safety.

The fourth task involved a series of educational and 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/P2000570.html](http://www.its.umn.edu/research/projects/P2000570.html)

**Lee Munnich, Humphrey Institute of Public Affairs**

**Sustainable Technologies Applied Research Initiative FY03**

Status: Completed (in FY04)

This research aims to better understand the potential market of Metro Transit’s Ridership and Services

**Kevin Krizek, Humphrey Institute of Public Affairs**

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

Status: In progress

This research assesses the market potential 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 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 their utility to each agency. The study will also provide recommendations on more specific data that could be collected to provide baseline information to help monitor existing and future programs and traveler information.

**Project URL:** [www.its.umn.edu/research/projects/P2004035.html](http://www.its.umn.edu/research/projects/P2004035.html)

**Modeling of Wireless Rural EMS Performance (Task 2): Tom Horan**

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.
development of version 1 of the emergency management systems (EMS) ontology, using Protégé software. This effort was summarized in a research-in-progress paper submitted to the Association for Information Systems Americas Conference. Researchers planned and conducted a second case study, which included interviews with MnDOT experts, State Patrol members, and Public Service Answering Points (PSAP) representatives.

**Industry Clusters (Task 3)**
Researchers conducted personal interviews in northern Minnesota with companies in the recreational transportation equipment and wood products industry 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.

**Networks and Productivity (Task 4)**
Researchers worked on enhancing the new node/link model by adding an equilibrium assignment and congestion effects. Researchers have also developed some qualitative evidence on network expansion decisions.

**Roundtable Discussion (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.

**Sustainable Technologies Applied Research Initiative FY04**

**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. Year three activities have led to the following focus areas for Year Four.

**Spatial Impacts (Task 1)**
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.

**Modeling of Wireless Rural EMS Performance (Task 2)**
Researchers will use the knowledge acquisition system to model and assess emergency management systems (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.

**Industry Clusters (Task 3)**
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.

**Networks and Productivity (Task 4)**
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.

**Roundtable Discussion: May 2004 (Task 5)**
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](http://www.its.umn.edu/research/projects/2004099.html)