From the Director

Our focus at the Roadway Safety Institute (RSI) is to explore the difficult road safety problems—those not amenable to easy solutions.

The period covered by this RSI summary report (2013–9) saw an increase in both total roadway fatalities and in fatalities per 100 million vehicle-miles traveled (VMT), highlighting the critical need for research to reduce the tragic number of lives lost on the road. RSI researchers are working diligently to meet this need, using varied approaches to improve safety for all types of roadway users.

The latest statistics from the National Highway Traffic Safety Administration indicate that crashes involving large trucks increased by 9 percent during the last decade. Researcher Steven Burks has been investigating the link between untreated obstructive sleep apnea and increased crash risk in truck drivers—and how to get those affected by the condition to treat it.

Bicyclist and pedestrian fatalities have increased during this period as well. Rajesh Rajamani has been leading a team working on sensors and other technologies to help bicyclists avoid collisions with nearby motorists. Greg Lindsey has been developing better methods for identifying high-risk locations for bicyclists so that appropriate countermeasures can be implemented. And researchers Nichole Morris and Ron Van Houten have been attacking the problem of pedestrian-vehicle crashes from a different angle, focusing on how to compel drivers to slow down on urban streets.

The past 10 years have also seen a 29 percent increase in drivers over age 65 involved in fatal crashes, mirroring a large increase in the percentage of licensed drivers in this age group. Given that this portion of the population will continue to grow, we need to consider all available means to keep older drivers safe on our roads. Nichole Morris has been working to better understand what these drivers need and want in order to remain mobile.

I often hear about the benefits of flashing yellow left-turn arrows and how they have made an incredible difference in reducing congestion and left-turn intersection crashes. Gary Davis played a key role in moving implementation of these signals forward and getting acceptance from the traffic engineering community.

Other RSI researchers are making great strides in understanding the scope of fatalities at rail grade crossings (Ray Benekohal), developing countermeasures for wrong-way driving (Albert Luo), improving emergency response at rail crossings (Dan Work), and exploring new methods for employing V2V wireless communications to reduce lane-departure crashes (Imran Hayee).

Of course, there is insufficient room here for me to adequately describe all of our researchers’ contributions to roadway safety, so I encourage you to read this report and learn more about their work. You can also read about our education and technology transfer initiatives, which are bringing results from our research to a wider audience.

Finally, I would like to thank our Institute staff, whose commitment and support on a daily basis make our successes possible. Together, we can make a positive impact on our region’s and nation’s roadways—now and for years to come.

Max Donath
The Roadway Safety Institute (RSI) is the Region 5 University Transportation Center (UTC) funded through the 2012 federal transportation bill. The region includes Minnesota, Illinois, Indiana, Michigan, Ohio, and Wisconsin.

The Institute conducts activities that further the mission of the UTC program of the USDOT—to advance U.S. technology and expertise in the many disciplines that make up transportation through education, research, and technology transfer activities at university-based centers of excellence.

Our objective is simple: improve safety for those who use the network, regardless of where they live or how they travel on it. To that end, we are working to develop and deploy human-centered transportation systems focused on specific users and on how systematic improvements can affect them and broader groups of travelers.

The consortium is led by the University of Minnesota. Other members are the University of Akron, the University of Illinois at Urbana-Champaign, Southern Illinois University Edwardsville, and Western Michigan University.
Research Overview: Topics at a Glance

Our research is driven by the goal of preventing crashes to reduce fatalities and life-changing injuries. Research concentrates on user-centered transportation safety, addressing both traffic safety system approaches and high-risk road users. More detailed information can be found at roadwaysafety.umn.edu. Specific projects in our research topic areas include:

**Driver-assist systems**
- Improving the eye-tracking tools used in a driving simulator
- Examining driver performance and distraction with the use of in-vehicle audio alerts
- Creating a digital highway high-accuracy map to improve safety and asset management
- Examining driver response to an in-vehicle lane-departure warning system
- Developing in-vehicle dynamic curve speed warnings
- Improving lateral position sensing for lane-keeping systems

**Pedestrian and bicycle safety**
- Evaluating pedestrian-activated crossing systems
- Developing a risk model for pedestrian and bicycle travel in urban areas
- Alerting drivers and bikers to potential collisions through a bicyclist warning system
- Creating methods for estimating bicycle and pedestrian traffic volume to assess risk and inform planning
- Exploring how crash risk and measures of equity can inform multimodal street improvements

**Safety on tribal lands**
- Collaborating with American Indian communities to learn about their travel risks
- Using GIS to improve traffic safety on tribal lands
- Improving emergency medical response to crashes in American Indian reservations

**Connected and automated vehicles**
- Alerting highway workers to potential hazards
- Creating a testbed for connected vehicles
- Developing a course on automated vehicle technologies for transportation professionals
- Developing a model for deploying automated vehicles in small towns and rural areas
- Improving vehicle merging through connected vehicle technology
- Developing a non-linear and network analysis for shared-road platooning

**Safety policy**
- Exploring how certain medical conditions may affect safety for truck drivers
- Analyzing the effectiveness of medical screening related to safety for commercial drivers
- Identifying attitudes for and against automated speed enforcement
- Examining the effect of exempting minor speed violations
- Making crash data more accurate and easier to collect
- Identifying where law enforcement should focus DWI efforts
- Uncovering why policymakers support—or oppose—traffic safety countermeasures
Rail crossing safety

- Predicting possible railroad crossing incidents through modeling
- Forecasting train arrival times for better emergency response
- Planning and coordinating emergency response to rail incidents

Driver distraction

- Investigating the effectiveness of in-vehicle safety messages in work zones
- Examining how in-vehicle alerts influence driver behavior

Intersection safety

- Improving left-turn safety at intersections
- Using high-resolution traffic signal data to estimate traffic conflicts
- Improving driver yielding behavior at crosswalks with gateway signage
- Improving intersection safety through variable speed limits for connected vehicles
- Assessing the effects of specific safety treatments at crosswalks
- Evaluating whether flashing LED stop signs reduce crashes at intersections

Safety for design and operations

- Assessing the safety of two-lane roundabouts
- Exploring sensing for high-occupancy vehicle and high-occupancy toll lane enforcement
- Evaluating the use of intelligent lane control signs for managing freeway incidents
- Investigating the effect of a variable speed limit system on a freeway high-crash area

Vulnerable users

- Developing smartphone technology to assist blind pedestrians with wayfinding
- Supporting older drivers with a system to help them drive safely
- Improving safety for novice teen drivers through real-time, in-vehicle feedback
- Ensuring the information provided to visually impaired pedestrians through a navigation app is accurate

Work-zone safety

- Studying how driver attention is affected by automated speed enforcement in work zones
- Improving work-zone safety with connected vehicle technology
- Testing Bluetooth-based in-vehicle messages to alert motorists in work zones
- Investigating the use of in-vehicle messages to reduce risky behavior

Wrong-way driving

- Preventing wrong-way-driving crashes with directional rumble strips
- Field testing and creating guidance for transportation agencies installing directional rumble strips
Selected Research Highlights

Collaborating to advance transportation safety on tribal lands

For American Indian communities, transportation safety is a high-stakes issue. Nationally, motor vehicle crashes are the leading cause of unintentional injury for American Indians aged 1 to 44, and their motor vehicle death rate is higher than for any other ethnic or racial group in the U.S. While most research into this issue examines sources of risk for the entire population, RSI researchers Kathryn Quick and Guillermo Narváez studied a previously unexplored aspect of the problem: roadway safety in American Indian reservations.

“Reservations are home to 22 percent of American Indians, so understanding this context is essential to improving their roadway safety,” says Quick, an associate professor with the University of Minnesota’s Humphrey School of Public Affairs. “We collaborated with people who have direct knowledge of and responsibility for reservation roadway safety: tribal governments, and the local and state governments who also work on safety issues in reservations. We wanted to determine what is distinctive about roadway safety in reservations, how the relationships among agencies with overlapping responsibility for roadway safety in reservations affect safety, and how roadway safety in reservations can be improved.”

The study generated extensive primary data through case studies of four reservations in Minnesota and national surveys. The case studies were conducted through partnerships with the tribal governments of the Red Lake Band of Chippewa, Fond du Lac Band of Lake Superior Chippewa, Leech Lake Band of Ojibwe, and Mille Lacs Band of Ojibwe. Data collection included 85 days of fieldwork observations, 102 interviews with key stakeholders, focus groups with expert drivers, and in-person surveys of 220 reservation residents. They then collaborated with the Federal Highway Administration to design and analyze results of the 2016 Tribal Transportation Safety Data Survey, a national online survey with responses from 151 representatives of tribal governments and 45 representatives of state governments.

“Our research methods created new data sources and facilitated in-depth analysis and problem-solving in particular reservations, while emphasizing the perspectives of people with the most direct, informed knowledge of reservation conditions,” Quick says. “Through our analysis, we identified five high-priority reservation roadway safety
concerns—pedestrians, road engineering and repair, reckless driving, seat belt and car seat use, and interjurisdictional coordination.”

Uncovering the importance of pedestrian safety on tribal lands was a novel and important finding of this study; there has been relatively little prior research indicating this is a particular concern. “We found unequivocal data that pedestrian safety is a critical, under-recognized priority on reservations,” Narváez says. “In reservation communities many people move around on foot, and we found that pedestrian safety is the single most outstanding feature of road safety in reservations compared to rural areas generally. This highlights the need for infrastructure investment, signage, enforcement, and education to protect pedestrians in reservations.”

Another key finding was that impaired driving must not be assumed to be “the” explanation for American Indian mortality rates. “Our research strongly confirmed that enforcement and education to reduce reckless driving behaviors—including speeding, impaired driving, and distracted driving—are high priorities. However, our findings challenge ‘conventional wisdom’ about drinking and driving or drug use as the sole explanation for high fatalities among American Indians or in reservations. We did not find that in the data,” Quick says.

In some communities, the research has already led to some practical safety improvements. Kade Ferris, transportation planner with the Red Lake Tribal Engineering Department, says that the researchers’ work allowed for “an unprecedented and useful integration of disparate types of data into a more comprehensive, robust picture,” which aided development of a comprehensive tribal transportation safety plan for the Red Lake Nation. The data have also helped the tribe identify and address specific safety concerns—for example, pedestrian safety concerns along Minnesota Highway 1, the main east-west highway through the reservation. The tribe then used the data to apply for and receive funding from the State of Minnesota to develop a new walking trail and street lighting to provide a safer walking environment for the reservation’s residents.

Going forward, the research team plans to continue its work on improving reservation roadway safety, particularly to evaluate roadway safety implementation with tribes, advance qualitative methods and expand qualitative data sources, and assess emergency response quality in reservations.

“Our findings challenge ‘conventional wisdom’ about drinking and driving or drug use as the sole explanation for high fatalities among American Indians or in reservations. We did not find that in the data.”

—Kathryn Quick
Selected Research Highlights

Improving mobility for visually impaired pedestrians

An estimated 25.5 million American adults have some type of visual impairment, from “trouble seeing” to complete blindness, according to a 2016 National Health Interview Survey. With the aging Baby Boomer generation, this population is expected to grow.

After receiving orientation and mobility training, people with vision impairment can usually travel independently to known places along familiar routes by relying on a white cane or a guide dog to avoid obstacles. However, neither of these provides spatial awareness along their path (such as the presence of a work zone, traffic intersection, bus stop, or subway entrance) or guidance information to a destination.

Understandably, traveling alone in an unfamiliar environment is often a challenge. “Every day it’s a new experience,” says Ken Rodgers, president of the American Council of the Blind in Minnesota. “I never know what I’m going to encounter exactly.”

For RSI researcher Chen-Fu Liao, technology offers the potential to revolutionize the way people with vision impairment navigate city streets.

“To improve mobility, access, and confidence in the transportation system, it’s important to remove not only the physical barriers, but also the information barriers that can impede mobility for people who are visually impaired,” says Liao, a senior research associate in the University of Minnesota’s Department of Mechanical Engineering who is leading research in this area.

In previous work, Liao developed the Mobile Accessible Pedestrian System, or MAPS, which uses smartphone technology to provide location and signal timing information to visually impaired pedestrians. Developed in collaboration with Minnesota’s Vision Loss Resources (a provider of services and support for people with vision loss), MAPS received positive feedback from testers. However, Liao discovered the GPS technology was not acceptably reliable in GPS-unfriendly environments. “Because we provide information to the visually impaired, we cannot afford to provide wrong information [even] one time,” Liao says.

This RSI-sponsored work is aiming to improve the app’s accuracy and reliability by developing a “self-aware” infrastructure—one that can monitor itself and ensure the information it’s providing is up to date, even in a GPS-unfriendly environment (such as indoors or in “urban canyons”). To that end, Liao and his team have developed a standalone Bluetooth Low Energy (BLE) smart system integrating commercial off-the-shelf BLE beacons.

Since BLE beacons are primarily designed to be detected and not communicate with each other, the researchers integrated them with the necessary interface elements to...
sense other BLE devices within their range, Liao explains. The BLE beacons can be placed in locations such as on light posts, traffic barrels, or barricades. Then, using a positioning and mapping algorithm, the system can estimate a user’s location based on nearby Bluetooth signals, share information among nearby devices, and inform the system administrator if any beacon location has changed. A database containing the location and message of each device is then integrated with the smartphone app to provide navigation information.

“This mapping methodology will ensure that correct audio information is provided to app users at the right location,” Liao says. “It could be used anywhere—at traffic intersections, skyways, or underground tunnels—to provide directions for travelers.”

Results of testing in a variety of environments indicate that the system can successfully detect if the location of one or multiple BLE beacons in a network has changed and detect when any of its beacons are not functioning—resulting from a loss of power or vandalism, for example.

Liao has received additional funding from the Minnesota Department of Transportation to deploy the system at six intersections in Stillwater, MN, in the summer of 2019. Researchers will integrate the Bluetooth system with the smartphone app and then conduct real-world tests of the new technology. The University of Minnesota has also filed a provisional patent on the technology.

“The benefit of our approach is that the visually impaired need nothing more than a smartphone with a text-to-speech capability to receive traffic and location information,” Liao says.

“The intent of our assistive system is not to undermine the skills and strategies that people with vision impairment have learned for navigation and wayfinding,” Liao adds. “Instead, the system aims to support their wayfinding capability, extend mobility and accessibility, and improve safety.”
Reductioning wrong-way freeway driving with directional rumble strips

Far too often, news headlines report the catastrophic results of high-speed, head-on crashes resulting from wrong-way freeway driving. Preventing these deadly crashes is a high priority for transportation departments, and Roadway Safety Institute researchers are developing a new tool to help them accomplish this goal: directional rumble strips (DRS) designed to deter wrong-way freeway entries.

“The ultimate goal of our study was developing a low-cost safety countermeasure that can capture a driver’s attention through elevated in-vehicle sound and vibration for wrong-way driving while providing normal sound and vibration levels for right-way driving,” says Albert Luo, an RSI researcher at Southern Illinois University Edwardsville. This approach is particularly important for locations with limited access to power.

Researchers began by conducting a national survey of transportation professionals and knowledgeable vendors to collect comments on different directional rumble strip designs. The national survey indicated broad support for the idea of directional rumble strips, finding that 85 percent of participants believed directional rumble strips could act as a warning system on off-ramps to mitigate wrong-way driving. Based on the survey and literature review results, a total of five patterns and eight configurations were developed for field tests.

The initial field tests to collect sound and vibration data were conducted at the National Center for Asphalt Technology of Auburn University, generating multiple measurements at six different speed levels in both the right-way and wrong-way direction for each pattern and configuration. “The results indicated that all the tested patterns can generate an adequate sound increase in the wrong-way direction to alert drivers to slow down,” Luo says.

Based on results from the initial field tests, three designs were selected for field verification. Once further tests indicated that all three patterns could generate recognizable interior sound and a moderate amount of vibration to alert wrong-way drivers, researchers considered the characteristics of each pattern and recommended specific segments of off-ramps for further implementation.

“We found that these three patterns work in different ways,” Luo says. “One is ideal for the straight, long segment of an off-ramp, a second works well close to the stop bar at an off-ramp terminal, and the third pattern is suitable for installation before the sharp curve of off-ramps to provide visual cues about the curve ahead in addition to providing recognizable sound and vibration to wrong-way drivers.”

In the future, researchers hope to conduct real-world tests to evaluate the effectiveness of directional rumble strips in deterring wrong-way freeway entries and further assess the practical impacts of this promising safety countermeasure. Three example locations have been identified by the research team for implementation, where three months of before-and-after data can be collected to quantify operational and safety effects on both wrong-way and right-way traffic.
Selected Research Highlights

Designing an app to improve older driver safety

Teenagers are generally known for being riskier drivers, and past RSI research has turned to app systems to address this problem. Right behind young drivers in terms of riskiness, however, are older drivers, and Institute researchers are hoping to modify an existing smartphone app in the search for a solution. “My research is focused on reducing serious-injury and fatal crashes,” says Nichole Morris, director of the University of Minnesota’s HumanFIRST Laboratory and principal investigator of the study. “Older drivers represent the second-highest age group of fatal crashes per licensed drivers and are the first for per-mile driven, so attempting to come up with solutions to reduce these crashes was an important research goal.”

Older drivers are at greater risk for a number of reasons. Researchers noted, for example, that older drivers tend to process information slower, especially in unfamiliar or complex situations. Their vision and hearing also can be less acute, and collisions tend to be more serious because of their overall fragility.

The HumanFIRST Lab had previously developed the prototype RoadCoach app, which warned teenagers if they were driving dangerously and sent text message alerts to their parents. In the hopes of also mitigating risky driving among older populations, the HumanFIRST Lab began modifying RoadCoach to fit this new demographic.

The RSI-funded study examined how well the app worked and what modifications needed to be made for older drivers. Working with Morris were HumanFIRST researchers Jacob Achtemeir and Curtis Craig.

“We went into this research with some assumptions that the design and features of the previously built prototype for teen drivers would need to be modified to accommodate the wants and needs of older drivers,” Morris says.

What they found, however, was that the app is sufficiently universal to appeal to both demographics. The app includes visual and audio alerts for events such as upcoming speed changes and curves, and it warns drivers when they are going too fast, braking too hard, or taking turns too quickly. Based on initial interviews and focus groups, the research team worked to add more contextual features to the app—adding the current speed limit to complement the upcoming speed limit, for example. After showing these modifications to drivers in an immersive driving simulation, however, they found that these additions were considered too much and unnecessary.

“More than anything, older drivers wanted to use an app that was designed for all drivers, not made or marketed for their age group,” Morris says.

Researchers conducted a field operational test (FOT) in early 2018 of 30 older drivers to determine if risky behaviors could be reduced over a longer time period and if acceptance of the system remains high after prolonged use. The researchers are analyzing the data from the FOT; if the results show promise, they’ll apply for additional grants to test this on a larger group of drivers.

If the app proves effective, Morris says her team will seek a partner organization to license the technology and put it in the hands of as many drivers as possible.

“(Older drivers) want to drive safely and maintain their independence,” Morris says. “I think they will be eager to purchase and use technology to assist them under challenging or unfamiliar driving conditions and into their later years of driving.”

“Older drivers represent the second-highest age group of fatal crashes per licensed drivers...so attempting to come up with solutions to reduce these crashes was an important research goal.”

—Nichole Morris
The University of Minnesota’s HumanFIRST Laboratory recently completed a significant upgrade of its driving simulators, resulting in one of the most advanced driving environment simulation systems at any academic institution in the United States.

The improvements were possible thanks to a 2017 Research Infrastructure Investment Program award of just over $186,000 from the University’s Office of the Vice President for Research. One-to-one match funding was provided by the laboratory’s own accumulated funds gathered through usage fees.

The HumanFIRST Laboratory is a facility of the UMN’s Department of Mechanical Engineering and is affiliated with the Roadway Safety Institute. It conducts research to collect, analyze, and understand driver behavior data generated during driving simulation studies and field tests of enhanced human-machine interfaces designed to reduce risky driving behaviors.

The HumanFIRST Lab houses two advanced driving simulators, which together host most of its research experiments. Funding from the award was used to overhaul components of both simulators. The laboratory’s immersive simulator replaced the 2002 Saturn full-vehicle cab with a modern sedan and an upgraded three-axis motion system. The previous discrete, five-panel projector system was replaced with five high-resolution projectors onto a smooth, cylindrical display and LCD-embedded side mirrors. The new vehicle cab facilitates research into human-computer interaction with its glass dash and large touchscreen display. Finally, the computer systems operating the immersive simulator and its companion portable simulator used for off-site and interdepartmental collaborations were replaced with the latest-generation computing hardware and graphical software for creating the simulated driving worlds.

RSI director Max Donath says that when the immersive simulator was originally installed, it was state-of-the-art and among the best in the country, but the primary components of both simulators were nearing the end of their lives.

This upgrade is expected to re-engage Minnesota as a national leader in driving behavior research. “As automated vehicle technology continues to advance, it will be critical to test machine-driver handoff between automated and manual driving modes in simulated settings,” Donath says. Demand for research in automated vehicles is only expected to grow, he adds.

HumanFIRST Lab director Nichole Morris says the lab’s simulators will also allow her research team to safely test impaired driving performance to better understand and deal with drivers who may be fatigued, under the influence of drugs or alcohol, or have mild cognitive impairment. “Impaired driving continues to account for at least one third of fatal crashes on our roadways, and little progress in this area has been made in recent years,” she says.

An open house of the facility, offering demonstrations of the simulator and discussions with research staff, was held December 18, 2018.

Lab’s simulator upgrade raises the bar for behavioral driving research
Finding a link between sleep apnea treatment and crash risk for truckers

Drowsy driving on U.S. roadways poses an alarming risk to safety—often with serious traffic results. The National Highway Traffic Safety Administration estimates that drowsy driving was responsible for 90,000 crashes, 41,000 injuries, and more than 800 deaths in 2015—numbers that are likely underestimated, it notes.

Because commercial truck drivers and drivers with untreated sleep disorders are especially vulnerable to the dangers of drowsy driving, RSI researchers have been investigating this issue in a study that carries implications for both trucking companies and policymakers.

“It’s well established that left untreated, obstructive sleep apnea is associated with higher crash risk in the general driving population, but relevant data about commercial drivers has been scarce,” says Stephen Burks, a professor of economics and management at the University of Minnesota Morris and a researcher with the Institute. “Our study examined the first-ever employer-mandated program for diagnosing and treating this dangerous disease among drivers and found a large and statistically significant association between non-adherence with treatment and serious preventable tractor-trailer crashes.”

Obstructive sleep apnea (OSA) is a disease in which the patient’s airway closes repeatedly during sleep, causing repeated awakenings that prevent normal, restorative sleep. To help prevent crashes associated with OSA, major motor carrier Schneider became the first trucking company to institute a mandatory program to screen, diagnose, and treat this disease among its drivers in 2006; drivers diagnosed with sleep apnea are provided with an auto-adjusting positive airway pressure treatment, at no out-of-pocket cost for those enrolled in the firm’s employee medical insurance program. Treatment adherence is required for continued employment.

Using the data collected through this employer-mandated program, Burks and his research team set out to identify exactly how risky truckers with untreated OSA are on the road. By comparing the relative crash rates for drivers who followed their OSA treatment plan with drivers who did not, researchers found that the non-adherent group had a risk about five times higher than the control group.

“In short, we found that if we followed 1,000 drivers of each type driving for one year, the control and treatment-adherent groups would both have 14 preventable, serious (i.e., DOT-reportable) crashes while the non-adherent group would have 70 such crashes,” Burks says.

An employer-mandated OSA program that includes required adherence to treatment could improve safety because it effectively sorts the workforce—retaining those drivers who are adherent and safer while filtering out those who are not adherent and much riskier, thereby improving the preventable crash performance of the entire fleet, Burks says. All commercial drivers have a screening exam at least every two years to determine their medical fitness to drive. Sleep apnea can only be diagnosed with an overnight test administered outside the screening exam. Currently, medical examiners are not required to use any specific standards in order to decide who should be given such a test, and truck drivers know not to say anything about conditions that might jeopardize their driving careers, Burks explains. “As a result, drivers that have been diagnosed with OSA and who are not adherent with treatment can go to work for another company and be back out on the highway with you,” he says.

The USDOT began an exploratory rulemaking on OSA screening for truck drivers in 2016, but it was withdrawn by the new administration in 2017, Burks notes. “Our study suggests that mandating screening in the commercial vehicle drivers’ biennial medical exam is worth revisiting.”

In additional work with the data obtained from the primary study, the research team is completing an analysis of the savings in medical insurance claims costs associated with the program. “Credible evidence of the savings in medical and crash costs accruing to a firm employing an OSA program will make investment in such programs by individual motor carriers more likely, even in the absence of regulations,” Burks says. Additionally, he adds, this information may help reduce opposition to new regulations requiring OSA screening.

Ultimately, the results have the potential to influence more motor carriers to unilaterally institute the screening of their employee drivers for OSA, Burks adds.
Getting more people to bike or walk to their destinations has been a high priority for transportation planners in recent years. However, as the number of pedestrians and bicyclists using the transportation system increases, so does the potential for serious—even deadly—crashes involving these high-risk road users.

“To best prevent bicycle and pedestrian crashes, transportation planners need a better idea of how many people are using nonmotorized transportation and what their exposure to risk is,” says Greg Lindsey, an RSI researcher and professor in the University of Minnesota’s Humphrey School of Public Affairs. Lindsey’s research, which began in 2014, has developed new methods and tools to help transportation engineers estimate bicycle and pedestrian traffic volumes and assess how risky it is to bike or walk.

Lindsey’s initial RSI-sponsored project began with researchers collecting bicycle and pedestrian counts in several Minnesota case communities, ranging in size from the large Twin Cities metropolitan area to much smaller cities such as Grand Marais and Bemidji. The team collected data using a mix of automated counting devices and manual counts, and the project involved the cooperation of state and local agencies such as the Minneapolis Public Works Department.

Based on these counts, researchers were able to develop models that adjust and extrapolate the data for different road segments and networks—giving an estimated average of how many bicyclists and pedestrians go through a given spot over the course of the day. By combining these models with traffic volume estimates, it becomes easier to predict and understand the risk of bicyclist or pedestrian car crashes at various locations and times.

“Within our case study communities, these results will be used to inform decision-making about strategies that can reduce the risk of crashes for bicyclists and pedestrians,” says Lindsey.

Using these models, city planners can better pinpoint problem spots where bicyclists and pedestrians stand a greater chance of getting hit by a car and where further research is needed.

“This research will add to our collective knowledge of bicycle use and inform bicycle safety improvements in Minneapolis,” says Simon Blenski, a transportation planner with the City of Minneapolis. Michael Petesch, bicycle and pedestrian data coordinator with MnDOT’s Office of Transit & Active Transportation, says that the study, along with several ongoing MnDOT efforts to characterize risk, “will be useful in developing proactive approaches for planning and programming safety countermeasures on projects throughout Minnesota.”

Lindsey cautions that the models are too broad to be used for designing specific safety countermeasures: “If we want to
RSI researchers receive NSF grant

An estimated 48,000 injuries and 700 fatalities occur each year in the U.S. as a result of bicycle-vehicle collisions. Mechanical engineering professor and RSI researcher Rajesh Rajamani and a team that includes RSI director Max Donath, HumanFIRST Lab director Nichole Morris, and computer science and engineering professor Loren Terveen at the University of Minnesota (UMN) were awarded a nearly $1 million grant from the National Science Foundation for research aimed at reducing these numbers.

This “Partnerships for Innovation: Building Innovation Capacity” grant awards funding to academe-industry partnerships whose proposals move research toward implementation of a human-centered smart service system. In this new project, Rajamani and Donath have partnered with Quality Bicycle Products (QBP) to explore implementation and possible commercialization of the bicycle collision-warning system developed by Rajamani in his Institute-funded research.

The project is titled Smart Human-Centered Collision Warning System: Sensors, Intelligent Algorithms and Human-Computer Interfaces for Safe and Minimally Intrusive Car-Bicycle Interactions. This system under development will help motorists keep a safe distance when passing bicyclists and alert only those drivers who are most likely to collide with a bicycle—while minimizing false alarms and unnecessary distractions to motorists. Bicyclists will get guidance cues from the system to ensure a safe and respectful response to vehicles. Human factors concepts are being incorporated to design an alert system that gives motorists specific and effective audio-visual cues—and to help ensure cyclists don’t respond to the improved security by riding more recklessly.

“Bicyclists face far greater consequences in a crash than a motorist,” Rajamani says. “So it’s in the best interest of the bicyclist to be proactive in preventing a collision.”

Morris is leading work on the human factors components of the research, which includes improving the warning system.
Improving intersection safety through variable speed limits

Research on connected and automated vehicle (CAV) technology is an emerging field with a variety of applications. Researchers from the University of Minnesota are combining CAVs with another emerging technology—variable speed limits (VSLs)—to improve driving safety and efficiency at intersections.

The Roadway Safety Institute-sponsored project aims to model how CAVs behave at intersections if they are told to obey VSLs—which can be changed from minute to minute as traffic conditions fluctuate.

“There are a lot of vehicle interactions around intersections,” says Michael Levin, assistant professor in the University of Minnesota (UMN) Department of Civil, Environmental, and Geo-Engineering and the project’s principal investigator. “Intersections force vehicles to come to a stop, [and] there are vehicles moving in conflicting paths that inherently cause safety issues,” Levin says.

With CAVs and VSLs, however, it might be possible to mitigate some of those safety issues. Levin, together with research assistant Rongsheng Chen and senior research associate Chen-Fu Liao from the Department of Mechanical Engineering, have been running computer simulations to determine if VSLs could be used to reduce the amount of deceleration or acceleration of cars approaching a stoplight. If a CAV knows that an upcoming light is about to turn green, for example, it might slow down slightly to ensure that it never has to come to a complete stop before the light turns. If there’s a crash on the road, CAVs could be warned to slow down more gradually, ahead of time, so that no vehicles have to brake suddenly. Not only is this safer, but it’s also more fuel-efficient.

CAVs, however, are not widespread and probably won’t be for a long time. VSLs also change so frequently (often every 200 to 500 feet) and by such small amounts that it’s unreasonable to expect human drivers to follow them exactly. To account for this, the computer models assumed that a small number of CAVs would be mixed in with a larger number of human-driven vehicles. What the models have shown so far is that even a small number of CAVs could have a large impact on traffic flow; a CAV that is following the speed limit creates a barrier for speeding human drivers. This forms a moving “bottleneck” and slows the overall flow of traffic. The idea is based on the standard kinematic wave model of traffic flow, which assumes that traffic moves like water—fast when the banks are wide, slower when it is constricted.

The research is currently more preliminary; since there’s no roadside infrastructure in place to broadcast VSLs, the models cannot yet be implemented directly. However, they give an idea of how effective VSLs could be and how best to use them.

“Ultimately,” Levin says, “I hope that state, county, or city departments of transportation could implement this on their arterial roads.”

So far, the research team has finished creating the model of traffic behavior, and from that model they’ve determined what speed limits should be used to maximize fuel efficiency. Next, the team will analyze how VSLs affect safety on the road.

“Intersections force vehicles to come to a stop, [and] there are vehicles moving in conflicting paths that inherently cause safety issues.”

—Michael Levin
Pedestrian fatalities and injuries represent a growing percentage of all traffic fatalities and injuries. According to the Fatality Analysis Reporting System, pedestrian fatalities comprised 10.9 percent of all traffic deaths nationwide in 2004, but 17.4 percent in 2016.

In conflicts between pedestrians and vehicles, pedestrians are clearly at a disadvantage. “The driver has the weapon,” says RSI researcher Ron Van Houten, a professor of psychology at Western Michigan University (WMU). Van Houten has worked extensively in the field of traffic and pedestrian safety and has developed many innovative traffic safety countermeasures.

One such countermeasure is a “gateway” configuration of R1-6 in-street signs for multilane roads. To achieve this, one sign is installed between the two travel lanes in each direction, and one on both edges of the roadway in each direction, to produce an apparent narrowing of the driving lane. Prior research by Van Houten demonstrated that this configuration increased the number of vehicles yielding the right-of-way to pedestrians on uncontrolled crosswalks on multilane roads. These increases produced similar results as several other methods at a small fraction of the cost.

But, Van Houten wondered, would these positive results—improved yielding behavior—continue over time? To find out, he and researcher Jonathan Hochmuth, also of WMU, conducted a follow-up study to examine the long-term effectiveness of permanent installations of the gateway configuration. The team also examined the effect of the gateway configuration on driver speed when pedestrians were not in the crosswalk and considered how to increase the durability and survival of the gateway treatment itself.

The researchers chose 15 sites among locations in Ann Arbor, Grand Rapids, and other areas of south Michigan. They conducted a number of studies over several years,
Assessing the “Stop for Me” campaign

In related work, Van Houten collaborated with University of Minnesota HumanFIRST Lab director and principal investigator Nichole Morris and research associate Curtis Craig for another project aimed at improving pedestrian safety through targeted countermeasures. To that end, the project sought to improve driver compliance with the crosswalk law in St. Paul, MN. The researchers began collecting data in September 2017 to evaluate the effectiveness of the existing “Stop for Me” education and outreach campaign. With funding from the Minnesota Department of Transportation and coordination with the City of St. Paul, the team began working on a multi-step study on the effects of increased education, high-visibility police enforcement, and low-cost engineering on driving behavior. Examples included warning and ticketing drivers who failed to stop and installing feedback signs that displayed the weekly percentage of drivers who stopped for pedestrians.

Data collected through the end of October 2018 showed the average compliance rate of drivers at the eight treated crosswalk sites jumped from 32 to 77 percent. Results were less dramatic at the eight untreated sites that were also being monitored, but compliance still rose to 55 percent.

The researchers are further analyzing the crossing data to determine the influence various characteristics of each crosswalk have on the data, the sustainability of the results, and which countermeasures were most effective.
Every year in the United States, more than 200 people lose their lives at railroad crossings. To help prevent these often-catastrophic crashes, it’s important for transportation departments to invest in safety improvements at the locations where they will have the greatest impact. Unfortunately, models currently used to predict where rail crashes will occur are often imprecise; the good news is that Roadway Safety Institute researcher Rahim Benekohal—a professor in the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign—is changing that with new, improved modeling techniques.

“We started by developing a microscopic method for crash analysis that offers a new tool to extract useful information from the Federal Railroad Administration (FRA) database to pinpoint what safety improvements are needed at railroad crossings,” Benekohal says. “Our method creates a data-driven dynamic tree that allows users to easily visualize any accident trends at a crossing or a group of crossings. Overall, the analysis of multiple crash locations could provide information that would otherwise be difficult to visualize.”

In addition to the microscopic crossing-level analysis, researchers applied the dynamic tree method to identify variables for system-wide analysis in order to spot crash trends. “For example, we found that [crossing] angle was a significant contributing factor to rail crossing crashes,” Benekohal says. “So in our new model, we use crossing angle as one of the variables to predict the number of crashes at a crossing.”

Researchers then used these findings to develop a new “Zero Inflated Negative Binomial (ZINB)” model that improves the prediction of crash frequency at highway-rail crossings. “After developing our ZINB model, we compared it to the crash prediction formula currently used by the U.S. Department of Transportation (DOT) using data from Illinois, Iowa, Pennsylvania, South Carolina, and Texas,” Benekohal says. “In all cases, our model outperformed the DOT model, more accurately predicting both the number of crashes at rail crossings and ranking high-crash locations.”

Researchers have plans to continue testing possible refinements to their model by adding additional data sources and validating the model on each state’s data separately. “With further development of our ZINB model, we believe the DOT should consider eventually replacing their existing model with this new model,” Benekohal says. When funding is limited, such a model could aid in prioritizing which crossings receive safety improvements. “Ultimately, we believe our model can help inform the strategic safety decisions that will help prevent injuries and deaths at railroad crossings,” he says.
Education Highlights

Over the last six years, the Roadway Safety Institute developed a variety of activities targeted to primary and secondary students throughout Region 5 to raise awareness of transportation safety topics and identify exciting career opportunities in related fields. The Institute also fostered workforce development through activities that engaged both practicing professionals and students.

Museum exhibit

The Roadway Safety Institute celebrated the grand opening of its safety-themed museum exhibit at The Works Museum in Bloomington, MN, in December of 2016. The Works is an interactive children’s museum focused on technology and engineering. The RSI exhibit, a permanent installation at the museum, helps teach kids and their parents how to “be safe and be seen” while walking or biking in the dark.

The centerpiece of the exhibit is a dark room where visitors can sit behind the wheel of a “car” while their friends try on reflective clothing to see how visible they would be to drivers at night. Other features of the exhibit are a microscope area for examining reflective materials up close, interpretive signage, engineer and researcher profiles, and a video produced by 3M, “No White at Night,” about the importance of wearing reflective gear. The profiles include those of HumanFIRST director Nichole Morris; 3M engineer Anne Gold, who develops reflective materials; and Gerald Edwards, founder, CEO, and designer for NSOD Clothing (a maker of trendy, fashionable outerwear that uses reflective materials).

According to Institute director Max Donath, the exhibit aims to communicate safety messages to preteens and their parents as well as get them excited about technology, transportation topics, and eventually, perhaps, transportation careers.

“It’s really important that we get kids to think about transportation safety, and then interest them in science and technology,” Donath says. “We’re trying to attract a diverse audience into [the transportation field].”

The exhibit was created for the Roadway Safety Institute in partnership with The Works Museum, Nichole Morris, and educational exhibit fabricator KidZibits based on focus group feedback with local elementary school students. In a recent 12-month period, the museum drew about 76,850 visitors.

Kit Wilhite, educational director at The Works, says the exhibit often sparks discussion among families about the importance of wearing reflective clothing when outside at night. Visitors are also often surprised by the seemingly counterintuitive findings presented in the video about reflective versus light-colored but non-reflective clothing.

Summer camps

For four consecutive summers, the Institute has participated in camps designed to attract students from diverse segments of society to education and career opportunities in transportation.

National Summer Transportation Institute

RSI staff helped introduce the next generation of the workforce to transportation safety topics and careers during a two-week National Summer Transportation Institute (NSTI) camp held on the University of Minnesota–Twin Cities campus. Over the course of four summers, about 110 students in grades 7 to 9 gained hands-on experience with topics that included distracted driving, human factors, and traffic simulation. Students toured campus, visited the

NSOD Clothing founder Gerald Edwards contributed to The Works exhibit.
UMN’s transportation-related labs, attended lab sessions with transportation experts, and took field trips to facilities across the Twin Cities such as MnDOT’s traffic management center.

One session featured UPS’s “Road Code” program, which focused on safe driving principles—from basic instruction to the consequences of risky behaviors such as texting while driving. Students were able to test their driving skills in real time in the Road Code simulator, which featured interactive animation, a steering wheel, and realistic gas and brake pedals.

Camper evaluations indicated that the program helped students become more aware of the wide range of possible careers in transportation. Parents reported that students not only enjoyed the camp but also took the lessons they learned to heart.

The NSTI camp was sponsored by the Center for Transportation Studies with funding from the Federal Highway Administration that was administered by the Minnesota Department of Transportation. RSI sponsored several safety-themed lessons and activities.

In another lesson, students experienced the dangers of distraction by getting behind the wheel of pedal carts, which demonstrated how distractions and multitasking impair essential concentration while driving and walking.

RSI staff also taught several lessons about safe travel in a variety of modes, including pedestrian and bike travel as well as GIS mapping.

Through these interactive lessons, students deepened their science and math skills while learning practical information about being safe travelers. Local engineers and a 3M representative also participated, sparking students’ desire to pursue higher education and STEM careers.

“Just knowing how high the [roadway] death rate is in our reservation communities...anything we can incorporate into our curriculum to try and keep our young people safe is a very worthwhile part of the program,” says Deb Zak, regional director of UMN Extension’s Northwest District.

Students of the Year...and where they are now

Each year, the Roadway Safety Institute selects one graduate student for its Outstanding Student of the Year Award sponsored by the U.S. Department of Transportation (USDOT). Students receive their awards at the Transportation Research Board annual meeting in January. Recipients past and present are:

- **2015**: Stephen Zitzow-Childs, civil engineering master’s student, University of Minnesota. Zitzow-Child’s master’s thesis focused on the layout of high-occupancy toll lanes, culminating in a tool for practitioners to design facilities for either an open- or closed-access framework. Zitzow-Childs is currently an operations research analyst at the USDOT’s Volpe Center. Working within the Program Development and Capacity Building Division, Zitzow-Childs primarily supports research efforts in the Federal Highway Administration’s Offices of Safety and Operations. He has performed data analysis on a wide range of projects for a diverse array of agencies, including the National Park Service, Federal Railroad Administration, and the Maryland State Highway Administration.

- **2016**: Brendan Murphy, civil engineering master’s graduate, University of Minnesota. Murphy’s graduate work focused on connecting bicycle and pedestrian infrastructure with safe, multimodal transportation systems and the intelligent use of data in transportation and city
planning. Murphy is currently the lead researcher at the Accessibility Observatory, a program of the Center for Transportation Studies at the UMN.

• **2017:** William Barbour, civil engineering master’s student, University of Illinois at Urbana-Champaign. Barbour’s research interests range from sensors and electrical engineering to data mining and analytics, applied to public and urban transportation systems, systems engineering and optimization, and sustainability. Barbour is currently a PhD student in RSI researcher Daniel Work’s research group at Vanderbilt University. In addition to finishing his RSI project, Barbour has been volunteering time on several service projects for Vanderbilt. He also briefed the chancellor’s leadership team for a discussion on campus dockless bike share in the summer of 2018.

• **2018:** Frank Alarcon, Humphrey School of Public Affairs master’s student, University of Minnesota. Alarcon was a research assistant with the Humphrey School’s State and Local Policy Program, where he researched automated speed enforcement and speed regulation. Alarcon is currently the planning specialist at Ramsey County Public Works, where he helps manage the county’s transitway projects and serves as deputy project manager for the Rush Line BRT project.

• **2019:** Jake Achtemeier, master’s student and an assistant scientist with the HumanFIRST Lab, University of Minnesota. Achtemeier’s thesis is an assessment of severe winter weather impacts on outdoor navigation behavior and infrastructure use of visually impaired pedestrians in urban environments. His research interests include high-performance driving capability, reading and semantic performance while driving, and signal detection in visual psychology.

**Milton Pikarsky Award**

At the 2017 Council for University Transportation Centers (UTC) Awards Reception and Banquet, RSI researcher Chen-Fu Liao received the Milton Pikarsky Memorial Award for Outstanding Doctoral Dissertation in Science and Technology. The award is given annually for the best PhD dissertation and master’s thesis in the field of science and technology in transportation studies to a student at one of the approximately 60 UTCs in the country.

Liao, a senior research associate in the UMN Department of Mechanical Engineering, received the award for his mechanical engineering PhD dissertation, “An Integrated Assistive System to Support Wayfinding and Situation Awareness for People with Vision Impairment.” The dissertation focuses on Liao’s work developing the Mobile Accessible Pedestrian Signal (MAPS) system, which uses a smartphone, GPS, and other technologies to help pedestrians with limited or no eyesight navigate signalized intersections and other locations safely. RSI director Max Donath served as Liao’s PhD adviser.

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**28 activities held for K-12 students with 3,043 participants**

**206 transportation-related courses taught by faculty or teaching assistants**

**245 students conducting transportation research**

**232 students supported, with 61 of them receiving degrees**
For RSI research to effect positive change, results must be put into practice. Collaboration, partnerships, and communication through many mediums are some ways the Institute delivers research results to the transportation community and general public.

Pedestrian workshops

In November and December of 2015, the Institute delivered pedestrian safety workshops for transportation practitioners in Wisconsin, Ohio, and Indiana. Led by RSI researcher Ron Van Houten of Western Michigan University (WMU), the workshops drew about 90 participants from a variety of nonprofit organizations, private firms, and state and local agencies.

Pedestrian deaths are climbing faster than motorist fatalities in the US. The workshops addressed some of the behavioral and cultural reasons contributing to pedestrian fatalities and shared proven, cost-effective ways to improve pedestrian safety and a community’s safety culture. These included in-street sign treatments as well as education and enforcement campaigns.

Van Houten is a professor in the Department of Psychology at WMU and a behavior analysis expert in the areas of traffic safety, pedestrian safety, intelligent transportation systems, traffic calming, bicycle safety, seat belt use, and reducing impaired driving. Many of his projects included social norming elements to target shifts in the safety culture. [See related article on p. 18.]

A summary of the workshops is available at roadwaysafety.umn.edu/publications/documents/pedestrianworkshop_report.pdf.

RSI research in the media

As a testament to the relevance of and interest in Institute work, RSI researchers received numerous local and national media mentions. Of particular note:

- Nichole Morris was interviewed in March 2016 for the New York Times and the NBC “Today” Show for stories on the subject of teen driving safety. Morris, who has done extensive research on this topic, said in the Times...
article that for 16- and 17-year olds, the number of deaths from motor vehicle crashes outstrips those from suicide, cancer, or other causes. Among her recommendations: parents should do much more to supervise their teen’s driving. “Our studies show that the more the parent is involved when a teen is learning, the lower their chances are for a crash,” she said.

• Stephen Burks’s research, which found that non-adherence with employer-mandated sleep apnea treatment significantly increases the risk of serious truck crashes, was featured in US News and World Report in March 2016 and the academic journal Sleep in May 2016. Burks said findings support the need for obstructive sleep apnea screening standards for all commercial drivers.

• Greg Lindsey’s study on road design and infrastructure as they relate to safety on roads shared by cars and bikes was covered in the ITE Journal. “The results provide evidence that investments in...bike facilities may reduce potentially risky interactions between vehicles and cyclists,” Lindsey said.

• The Minneapolis Star Tribune quoted Frank Douma for several stories in fall 2017 related to the challenges and opportunities of autonomous vehicles.

• Kathy Quick’s work with traffic safety on tribal lands, particularly in obtaining better crash data, was featured in ITS International in its May/June 2016 issue.

For more on RSI research in the news, see roadwaysafety.umn.edu/about/news.

Safety showcase

In May 2015, RSI researchers from across Region 5 gathered in St. Paul, MN, for the “Roadway Safety Showcase: Safety Innovations for Today and Tomorrow.” The one-day event highlighted research that is developing solutions for some of today’s most pressing safety problems. Researchers from three UMN campuses, the University of Illinois at Urbana-Champaign, and University of Akron participated.

In opening remarks, Greg Winfree, the then-USDOT Assistant Secretary of Transportation for Research and Technology, noted how the Institute’s goal of preventing crashes fit well with the USDOT’s vision for the future of transportation safety.

“The first 50 years of transportation safety focused on occupants surviving crashes,” Winfree said. “The next 50 years will be about avoiding those crashes altogether.”

Automated vehicle technologies course

In an effort to bridge the gap between academia and practitioners, RSI researcher Brian Davis of the UMN is developing a workshop on automated vehicle technologies for interested state and local transportation professionals.

The multi-day professional course will aim to help attendees better understand topics related to vehicle automation, including enabling technologies such as GPS/GNSS, radar, LIDAR, computer vision, and communication; controls and sensor fusion; and application-level algorithms such as localization and guidance. Classroom-based lectures will cover foundational topics, while laboratory exercises will give participants the chance to interact with a small unmanned ground vehicle—a mobile robot. The robot, a Clearpath Husky A200 (shown above), will serve as a platform for experimenting with different sensors and algorithms to see how they affect system performance in a real-world vehicle.

The course will tentatively be offered beginning in February 2019.
Research Projects

The following active and completed projects include those funded by the Institute as well as those funded through match (in alphabetical order of principal investigators). To learn more, visit roadway.safety.umn.edu/research.

**Accident Prediction Models Using Macro- and Micro-Scale Analysis** is developing a methodology for analyzing crashes at a micro level to discover trends at a single railroad crossing or a series of crossings along a corridor or a region, and to improve the accuracy of crash predictions.

*Principal investigator*: Rahim Benekohal, UIUC

*Funding*: RSI

**Exploring Links Between Medical Conditions and Safety Performance in Tractor Trailer Drivers** is exploring the relationship between medical conditions, particularly obstructive sleep apnea, and safety performance for commercial motor vehicle operators.

*Principal investigator*: Stephen Burks, UMN; *co-investigator*: Jon Anderson, UMN

*Funding*: RSI

**The Screening Effectiveness of the Commercial Driver’s Medical Examination** is analyzing pre-registry data to establish the first-ever formal benchmark for the screening effectiveness of the original Commercial Driver’s Medical Examination with regard to specific safety-relevant medical conditions.

*Principal investigator*: Stephen Burks, UMN; *co-investigator*: Jon Anderson, UMN

*Funding*: RSI

**Development of a Course on Automated Vehicle Technologies** is developing a workshop on automated vehicle technologies (e.g., enabling technologies, controls and sensor fusion, and application-level algorithms) for an audience of state and local transportation professionals.

*Principal investigator*: Brian Davis, UMN

*Funding*: RSI

**Improvement of Driving Simulator Eye-Tracking Software** is focusing on improving the eye-tracking tools used in the HumanFIRST driving simulator, resulting in tools and documentation for reducing or eliminating the amount of human intervention when processing eye-tracking data.

*Principal investigator*: Brian Davis, UMN

*Funding*: RSI

**In-vehicle Dynamic Curve Speed Warnings at High Risk Rural Curves** studied the efficacy of in-vehicle dynamic curve speed warnings as deployed on a smartphone app.

*Principal investigator*: Brian Davis, UMN

*Funding*: MnDOT, LRRB

**Teen Driver Support System (TDSS) Technology Transfer** is implementing changes to the TDSS identified in the field operational test. Work will also identify agencies, companies, and other groups as potential partners and demonstrate the app to them to generate interest and secure future research.

*Principal investigator*: Brian Davis, UMN

*Funding*: RSI

**Development of Guidelines for Permitted Left-Turn Phasing Using Flashing Yellow Arrows** investigated left-turn gap acceptance, the trajectories followed by left-turning drivers, and classification of left-turn crash types. The project also developed and validated a simulation model to help transportation engineers identify when to use permitted left-turn treatments versus a protected left turn.

*Principal investigator*: Gary Davis, UMN; *co-investigator*: Abhisek Mudgal, UMN

*Funding*: RSI

**Driver Behavior in Left-Turn and Other Two-Vehicle Crashes** developed and validated a simulation model of left-turn crashes to predict the safety-related effects of design or operational changes.

*Principal investigator*: Gary Davis, UMN; *co-investigator*: Abhisek Mudgal, UMN

*Funding*: RSI

**Estimating the Crash Reduction and Vehicle Dynamics Effects of Flashing LED Stop Signs** conducted an empirical Bayes before/after evaluation to estimate the crash reduction effect of LED stop signs and a field study involving collection and analysis of data on driver behavior at stop-controlled intersection approaches.

*Principal investigator*: Gary Davis, UMN

*Funding*: MnDOT, LRRB

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**Key**

- Minnesota Local Road Research Board (LRRB)
- Minnesota Department of Transportation (MnDOT)
- Roadway Safety Institute (RSI)
- Southern Illinois University Edwardsville (SIUE)
- University of Illinois at Urbana-Champaign (UIUC)
- University of Minnesota (UMN)
- Western Michigan University (WMU)
Estimation of Traffic Conflicts at Signalized Intersections Using High-Resolution Traffic Signal Data used high-resolution traffic signal data directly collected from existing loop detection systems to build and calibrate a crash-prediction model for traffic engineers to evaluate traffic safety performance at signalized intersections.

Principal investigator: Gary Davis, UMN
Funding: MnDOT

Safety Study of I-35W Improvements Done Under UPA Project employed an interrupted time-series approach to test for changes in safety effects before versus after the Urban Partnership Agreement project (a package of interventions aimed at improving travel on the I-35W corridor) to inform the potential implementation of these interventions in other corridors.

Principal investigator: Gary Davis, UMN; co-investigator: John Hourdos, UMN
Funding: MnDOT

Vehicle Automation and Transportability of Crash Modification Factors is exploring the usefulness of analytic tools by looking at how vehicle automation could impact the crash reduction effects of two roadway-based countermeasures: installation of pedestrian hybrid beacons at uncontrolled crosswalks and offsetting opposing left-turn lanes at signalized intersections.

Principal investigator: Gary Davis, UMN
Funding: RSI

Developing a Digital Highway Framework to Serve County Roads developed and evaluated a low-cost, vehicle-mounted sensor suite capable of generating map data with lane and road boundary information accurate to the 10 cm (4 in) level.

Principal investigator: Max Donath, UMN
Funding: LRRB

Development of a Digital Highway Framework to Facilitate Crash Avoidance is leveraging GPS, smartphone, and LIDAR technologies to create a digital highway high-accuracy map to improve safety while also considering their potential for asset management.

Principal investigator: Max Donath, UMN
Funding: MnDOT

The Teen Driver Support System (TDSS) Field Operational Test was a 12-month field operational test of a system to improve novice teen driver safety involving 300 newly licensed teens in Minnesota in late 2014. This has led to a follow-up project (TDSS Technology Transfer; see p. 26) to improve the smartphone app and eventually move toward commercialization.

Principal investigator: Max Donath, UMN
Funding: MnDOT

Identifying and Reconciling Stakeholder Perspectives in Deploying Automated Speed Enforcement examined the perceptions of affected stakeholders in selected states in Region 5 in order to understand the causes for the continued conflict around deploying automated speed enforcement.

Principal investigator: Frank Douma, UMN; co-investigator: Nichole Morris, UMN
Funding: RSI

Impact of Exempting Low-Level Speed Violations examined the impacts on public safety, frequency of speeding, crash rates, travel time efficiency, travel time reliability, and data privacy of Minnesota’s Dimler Amendment (Statute 171.12, Subd. 6), which keeps certain speeding violations off a driver’s record.

Principal investigator: Frank Douma, UMN
Funding: MnDOT

Examining the Relationship Between Speed Enforcement Laws and Traffic determined that a climate of public ambivalence toward speed allows state speed laws to be created according to a set of political incentives, and that existing quantitative data collection efforts are inadequate to effectively measure the impacts of different speed regulatory regimes.

Principal investigator: Frank Douma, UMN
Funding: RSI

Scenarios and Justification for Automated Vehicle Demonstration in Rural Minnesota aims to develop a model for developing and deploying automated vehicle technologies in small towns and rural areas by identifying the questions that must be addressed, identifying data and other resources that will inform answers to those questions, and suggesting how such a model might be demonstrated.

Principal investigator: Frank Douma, UMN
Funding: RSI

Developing GPS Antenna Error Models For Improved Centimeter Level Positioning is developing a methodology for characterizing GPS receiver error and developing mathematical algorithms that can compensate for it in order to enable after-market systems to provide an accurate position at a reasonable cost.

Principal investigator: Rhonda Franklin, UMN; co-investigators: Demoz Gebre-Egziabher and Robert Sainati, UMN
Funding: RSI

Development and Demonstration of Merge-Assist System Using Connected Vehicle Technology developed a merge-assist system that acquires the relative positioning of vehicles using standard GPS receivers and DSRC-based V2V communication to help vehicles safely merge onto a freeway.

Principal investigator: M. Imran Hayee, UMN
Funding: RSI
Using GIS To Improve Tribal Traffic Safety developed a series of six prototype applications for use by tribes in their transportation safety planning, assessment, and implementation; conducted a series of hot-spot analyses; and developed a framework for considering GIS-based traffic safety analysis within the context of tribal governance and management.

Principal investigator: Thomas Horan, University of Redlands; co-investigator: Brian Hilton, Claremont Graduate University
Funding: LRRB

Assessing the Impact of Pedestrian-Activated Crossing Systems is integrating results from a prior crash-record-based safety study with direct, long-term, and staged observations of pedestrian-vehicle interactions at crosswalks with particular safety treatments to determine their effects on pedestrian crashes.

Principal investigator: John Hourdos, UMN
Funding: MnDOT

Evaluation of Safety and Mobility of Two-Lane Roundabouts is collecting observations of all undesirable driving maneuvers (e.g., yielding violations) on 2x2 roundabouts in Minnesota and relating the frequency of each individual maneuver to specific design features.

Principal investigator: John Hourdos, UMN; co-investigator: Stephen Zitzow-Childs, UMN (formerly)
Funding: LRRB

Evaluation of the Effectiveness of ATM Messages Used During Incidents investigated the use of intelligent lane control signs (ILCS)-based active traffic management for managing incidents on a heavily traveled urban freeway and concluded that the use of ILCS has a significant effect on driver behavior, specifically in prompting proper lane selection under capacity-reducing incidents.

Principal investigator: John Hourdos, UMN; co-investigator: Stephen Zitzow-Childs, UMN (formerly)
Funding: MnDOT

Investigation of the Impact the I-94 Active Traffic Management (ATM) System has on the Safety of the I-94 Commons High-Crash Area investigated the effect that the I-94 variable speed limit system has on the safety of the high-frequency crash area located on the westbound lanes of the freeway through downtown Minneapolis (I-94/I-35W commons).

Principal investigator: John Hourdos, UMN
Funding: MnDOT

Work Zone Mapping and Tag Deployment System is one of three components of a work-zone safety research project to investigate the effectiveness of using in-vehicle messages to improve drivers’ understanding of work zones and to reduce risky behavior.

Principal investigator: John Hourdos, UMN
Funding: RSI

Implementation of a V2I Highway Safety System and Connected Vehicle Testbed is using the extensive instrumentation available at the Minnesota Traffic Observatory’s I-94 field lab to develop a connected vehicle testbed specifically for implementing and testing speed harmonization and queue warning systems.

Principal investigator: John Hourdos, UMN; co-investigator: Stephen Zitzow-Childs, UMN (formerly)
Funding: RSI

Improving Intersection Safety Through Variable Speed Limits for Connected Vehicles is aiming to improve safety around intersections by using connected (partially or fully) autonomous vehicles to reduce variations in traffic speeds.

Principal investigator: Michael Levin, UMN; co-investigator: Chen-Fu Liao, UMN
Funding: RSI

Non-linear Spacing Policy and Network Analysis for Shared-Road Platooning is aiming to improve connected and autonomous vehicle (CAV) technology in terms of its impact on traffic characteristics and safety, to provide better traffic modeling of shared roads, to provide improved traffic planning to better utilize CAV technologies, and to foster a long-lasting collaboration between two complementary research groups (CAV technology and traffic planning).

Principal investigator: Michael Levin, UMN; co-investigator: Rajesh Rajamani, UMN
Funding: CTS

A Positioning and Mapping Methodology Using Bluetooth and Smartphone Technologies to Support Situation Awareness and Wayfinding for the Visually Impaired is developing a system (integrating commercial, off-the-shelf Bluetooth devices) that can self-monitor and ensure that the information provided to visually impaired pedestrians through a navigation app is accurate and up to date.

Principal investigator: Chen-Fu Liao, UMN
Funding: RSI
Investigate the Effectiveness of Using Bluetooth Low Energy Technology to Trigger In-Vehicle Messages at Work Zones investigated the effectiveness of using in-vehicle audio messages to calibrate drivers’ understanding of work zones to reduce risky behavior associated with distraction—specifically, examining an inexpensive technology based on Bluetooth Low Energy tags deployed in or ahead of work zones.

Principal investigator: Chen-Fu Liao, UMN
Funding: MnDOT

Test and Evaluate a Bluetooth Based In-Vehicle Message System to Alert Motorists in Work Zones has developed a prototype system to investigate the feasibility of using in-vehicle audio messages to increase drivers’ awareness of safety-critical and pertinent work-zone information.

Principal investigator: Chen-Fu Liao, UMN
Funding: RSI

Using Smartphone App to Help the Visually Impaired Navigate Work Zones Safely developed a smartphone-based navigation system integrated with navigational audible information to alert pedestrians at decision points prior to their arrival at a work zone.

Principal investigator: Chen-Fu Liao, UMN
Funding: MnDOT

Pedestrian and Bicycle Safety, Equity, and Street Funding: New Criteria for Prioritizing Multimodal Street Projects in Minneapolis is demonstrating how estimates of pedestrian and bicyclist exposure to risk, estimates of crash risk, and measures of equity can strengthen approaches to prioritizing multimodal street improvements.

Principal investigator: Greg Lindsey, UMN; co-investigator: Jason Cao, UMN
Funding: RSI

Performance Measures for Bicycle and Pedestrian Safety: Methodologies for Monitoring Traffic Volumes and Assessing Exposure to Risk developed protocols and methodologies for estimating bicycle and pedestrian traffic volumes that can be used to inform assessments of exposure to risk.

Principal investigator: Greg Lindsey, UMN
Funding: RSI

Directional Rumble Strips for Reducing Wrong-Way-Driving Freeway Entries developed a new countermeasure (directional rumble strips) for mitigating wrong-way-driving incidents.

Principal investigator: Albert Luo, SIUE; co-investigator: Huaguo Zhou, Auburn University
Funding: RSI

Field Implementation of Direction Rumble Strips (DRS) for Deterring Wrong-Way Entries is implementing and evaluating three final design patterns of DRSs developed by a previous RSI project and will conduct a before-and-after study to evaluate their effectiveness and develop an installation guideline for transportation agencies.

Principal investigator: Albert Luo, SIUE; co-investigator: Huaguo Zhou, Auburn University
Funding: RSI

Computerized Crash Reports Usability and Design Investigation created an electronic crash report interface that improves the accuracy, speed, reliability, and meaningfulness of crash report data entry by law enforcement personnel. The system is now used by all law enforcement agencies in Minnesota.

Principal investigator: Nichole Morris, UMN
Funding: MnDOT

Examination of Driver Performance and Distraction with In-Vehicle Signing explored how well drivers perform in a driving simulator using a smartphone interface to project in-vehicle audio alerts.

Principal investigator: Nichole Morris, UMN
Funding: MnDOT

Examining the Impact of ASE in Work Zones on Driver Attention examined driver attentional patterns as motorists travel through work zones and the impact that automated speed enforcement may have on driver attention.

Principal investigator: Nichole Morris, UMN
Funding: MnDOT

HumanFIRST Driving Simulation Educational Development is capitalizing on the HumanFIRST Lab’s new simulator by creating three distinct, simulated demonstrations focused on handoff of control to human drivers from automated vehicles; distracted driving via non-driving-related, in-vehicle technologies; and speeding in pedestrian-populated areas.

Principal investigator: Nichole Morris, UMN; co-investigator: Peter Easterlund, UMN
Funding: RSI

In-Vehicle Work-Zone Messages is designing and evaluating auditory, in-vehicle messages presented by a smartphone to catch drivers’ attention, especially those who might be already engaged in smartphone use.

Principal investigator: Nichole Morris, UMN
Funding: MnDOT

Older Driver Support System (ODSS) Usability and Design Investigation is conducting interviews, an interface display survey, a usability test, and a controlled field study with older drivers in an effort to better outline the needs of those drivers and to prepare the Older Driver Support System prototype for a field operational test.

Principal investigator: Nichole Morris, UMN
Funding: RSI
Work Zone Intrusion Report Interface Design created a detailed, adaptable report for workers to document intrusions, thus helping to fill a knowledge gap by providing valuable data to the state for addressing this serious worker safety risk.

Principal investigator: Nichole Morris, UMN; co-investigator: Brian Davis, UMN
Funding: MnDOT, LRRB

Assessing Factors Affecting Policy Leadership in Adopting Road Safety Countermeasures analyzed various aspects of state highway safety plans and approaches tied to the Toward Zero Deaths program, focusing on garnering a better understanding of why certain roadway safety provisions have or have not been adopted in the six Midwestern study states.

Principal investigator: Lee Munnich, UMN
Funding: RSI

Positioning, Planning, and Operation of Emergency Response Resources and Coordination Between Jurisdictions developed methods and guidance for strategically positioning and allocating emergency responders and resources in anticipation of potential crashes in a region that may be impacted by rail incidents.

Principal investigator: Yanfeng Ouyang, UIUC
Funding: RSI

Safety in Numbers? Accessibility, Traffic, and Safety of Nonmotorized Travelers developed a risk model for pedestrian and bicycle travel in urban areas that reflects the cross-modal interactions produced by varying levels of nonmotorized and motorized travel on individual road segments or intersections.

Principal investigator: Andrew Owen, UMN; co-investigator: David Levinson, UMN (formerly)
Funding: RSI

Sensing for HOV/HOT Lane Enforcement developed a system involving emerging technology and software algorithms to automatically estimate the occupancy of passenger vehicles in high-occupancy vehicle and high-occupancy toll (HOV/HOT) lanes.

Principal investigator: Nikos Papanikolopoulos, UMN; co-investigator: Vassilios Morellas, UMN
Funding: MnDOT

Collaborating with American Indian Communities to Re-Interpret and Strategize About Transportation Safety Risks in Tribal Lands developed new sources of data and policy-relevant findings to address the unusually high rates of roadway fatalities and injuries among American Indians on tribal lands in the United States.

Principal investigator: Kathryn Quick, UMN; co-investigator: Guillermo Narváez, UMN
Funding: RSI

Improving Emergency Medical Service Response to Motor Vehicle Crashes in American Indian Reservations is working to identify needs and recommend interventions to improve emergency medical services response to motor vehicle collisions in American Indian reservations.

Principal investigator: Kathryn Quick, UMN; co-investigator: Guillermo Narváez, UMN (formerly)
Funding: RSI

Novel Collision-Avoidance System for Bicycles developed a sensor system for a bicycle that can predict imminent bicycle-motorist crashes and provide an audio warning of the bicycle’s presence to the motorist.

Principal investigator: Rajesh Rajamani, UMN
Funding: RSI

Alcohol-Related Hot-Spot Analysis and Prediction identified geospatial trends in alcohol-related motor-vehicle crashes to help law enforcement target efforts for preventing them.

Principal investigator: William Schneider, University of Akron
Funding: RSI

Long-Term Effects of Gateway R1-6 Treatment on Yielding to Pedestrians, Vehicle Speed, and Sign Survival investigated whether the improved effects of the gateway sign configuration on driver yielding persist over time, the effect of the gateway on driver speed when pedestrians are not in the crosswalk, and to how to increase the durability and survival of the gateway treatment.

Principal investigator: Ron Van Houten, WMU; co-investigator: Jonathan Hochmuth, WMU
Funding: RSI, Michigan DOT

Accurate Prediction of Train Arrival Times for Emergency Response Management and Driver Decision Support is studying train delays to accurately estimate train arrival times at grade crossings to support in-vehicle driver alerts on personal navigation devices.

Principal investigator: Daniel Work, Vanderbilt University (formerly UIUC)
Funding: RSI
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