

ROADWAY SAFETY INSTITUTE

Human-centered solutions to advance roadway safety

Program Progress Performance Report for University Transportation Centers

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ACCOMPLISHMENTS

Major goals and objectives of the program

The Roadway Safety Institute (RSI) draws on highly innovative researchers located across Region 5 to focus on targeted research, education, and technology transfer activities aimed at determining and delivering the next wave of transportation safety improvements.

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, user-centered transportation systems are being developed and deployed to focus our work on specific users of the system and on how systematic improvements can affect both key user groups and broader groups of travelers.

We are pursuing this objective by meeting the goals that follow in research, education and workforce development, and technology transfer activities. We are also collaborating with stakeholders across our region and promoting diversity in our educational initiatives.

Research

The Institute is focusing on traffic safety system approaches by researching design- and operation-related safety solutions that reduce fatalities and life-changing injuries across the nation. In addition, the Institute is addressing the following MAP-21 priorities to improve highway safety: rural road safety measures, human factors and behavior risk metrics, data collection and analysis, and safety policy studies. The Institute is also focusing on high-risk road users by addressing key safety issues for these groups through research and by examining public engagement strategies to help improve safety on tribal lands.

Countermeasures are effective tools for practitioners to use to improve roadway safety, and our research is working to develop strategies that can be put to use. In addition, our research is investigating methodologies and metrics, in particular related to pedestrian and bicycle travel. Results of this work should provide practitioners with tools for better decision making, ultimately improving safety for those roadway users.

Education and workforce development

The Roadway Safety Institute is developing a variety of activities targeted to primary and secondary students throughout Region 5 that raise awareness of transportation safety topics and identify exciting career opportunities in related fields. Goals include demonstrating safe driving concepts to students in STEM summer camps; developing a roadway-safety-themed museum exhibit to be displayed at a STEM-related museum; and partnering with WTS's Transportation YOU program to encourage young female students to pursue transportation-related degrees.

We will continue to demonstrate a commitment to workforce development through activities that engage both practicing professionals and students. For practitioners, we are providing continuing education through multiple seminars and webinars; connecting practitioners and researchers to facilitate discussion and encourage implementation; and delivering pedestrian safety workshops to professionals in Region 5 states.

Technology transfer

We are working to expand our existing partnerships to foster research innovation and deployment that includes increasing public agency and private-sector partners, and we are developing versions of research hardware and software that can be deployed through collaboration with state DOTs, public safety agencies, foundations, and the private sector. We are also communicating research findings to the transportation community for their successful implementation, and we have created a consortium website, an electronic newsletter, topical briefs, research videos, and an Institute biennial report.

Collaboration

The Institute brings together the diverse strengths, knowledge, and experience of our consortium members to work toward the shared goal of reducing fatalities and injuries on our roadways. Through collaboration, RSI draws on and expands our many successful partnerships with public, private, academic, and not-for-profit entities. Our goal is to advance the roadway safety knowledge base, address critical workforce needs, implement research activities, and transfer research findings using our established relationships.

Diversity

We are working to broaden participation and enhance diversity in the transportation sector by supporting female and minority STEM faculty, leveraging the existing Transportation YOU programs in our region, and expanding STEM opportunities for American Indians. Efforts include developing and delivering safety curriculum for the White Earth Summer Camp; hosting tours and demonstrations for students in WTS's high school mentoring program; and identifying ways to support leadership development for female and minority STEM students and faculty.

Accomplishments

Research

Our consortium draws on our members' safety-related expertise and complementary research strengths to achieve measurable gains in safety. The Institute currently has 35 federally funded research projects (27 active, 8 completed) and 33 match projects (6 active, 27 completed). Descriptions of all projects are available on our website, and all active projects have records in the Transportation Research Board (TRB)'s Research in Progress (RiP) database.

Programmatic research accomplishments include:

- The Institute awarded funding to 10 new research projects; each project will be 12 months in length. Topics range from developing a course on automated vehicle technologies to improving EMS response on American Indian reservations. In a request for proposals issued in October 2017, the Institute solicited projects that would move current RSI research toward implementation or position its researchers and the Institute for future funding. The Institute also considered funding for educational initiatives such as the development of curriculum, training materials, or instructional labs. Projects were required to fall under the Institute's research focus areas of rail-crossing safety, safety on tribal lands, bicycle and pedestrian safety, connected vehicles, or safety policy. An external review panel of five experts from across the country reviewed projects and provided input, considering the proposed projects' uniqueness, innovativeness of approach, potential for deployment within five years, potential for partnerships with government agencies or industry, and likely impact in terms of lives saved or contributions to knowledge, among other criteria.
- We published 8 final research reports: 6 for federally funded projects and 2 for match projects.

- The Center for Transportation Studies (CTS), which houses the Roadway Safety Institute, received the 2017 Local Agency Technology Initiative Award from ITS Minnesota at the organization's Fall Forum on October 17. RSI director Max Donath accepted the award. The annual award recognizes achievements in advancing ITS technology in Minnesota. According to ITS Minnesota, the 2017 award was given for outstanding contributions to the ITS community through the research and development of new strategies to improve the safety and efficiency of travel throughout the state.

Highlights from active research projects:

- *Exploring Links Between Medical Conditions and Safety Performance in Tractor Trailer Drivers:* Stephen Burks compared differences in the costs of medical insurance claims for a control group of tractor trailer drivers and drivers diagnosed with obstructive sleep apnea (OSA) who have full, partial, or no adherence with treatment. Burks also continued to work on the analysis of crash cost differences for drivers at the study firm across OSA study sub-groups and continued to make progress involving the required legal conditions for acquiring new data. The research found that non-adherence with employer-mandated OSA treatment increases the risk of serious truck crashes. For example, if 1,000 drivers were followed for one year, the research showed that the control and treatment-adherent groups would both have had 14 preventable crashes, compared with 70 such crashes for the non-adherent group.
- *Examining the Relationship Between Speed Enforcement Laws and Traffic Safety:* Frank Douma has completed this project, which showed that a climate of public ambivalence toward speed allows state speed laws to be created according to a set of political incentives. A report of the research will be published in the 2019 spring issue of the *Journal of Transportation Law, Logistics and Policy*. Douma's research also showed that existing quantitative data-collection efforts are inadequate to effectively measure the impacts of different speed regulatory regimes, and that the National Transportation Safety Board's 2017 report *Reducing Speed-Related Crashes Involving Passenger Vehicles* provides an acceptable opportunity for designing safe roads that do not induce higher speeds.
- *Development and Demonstration of Merge-Assist System Using Connected Vehicle Technology:* Imran Hayee has designed an algorithm to estimate a merge-time cushion to help facilitate safe mergers by drivers in vehicles merging into freeway traffic. The research team considered two types of ramp geometries to test their algorithm by post-processing the travel trajectories of both the vehicles merging into traffic and those already traveling on the freeway.
- *Using GIS to Improve Tribal Traffic Safety:* Tom Horan developed the Data Sovereignty Framework: Tribal Community and Culture, Tribal Governance, Data Management, and Data Domain Structures for GIS implementation to be used for traffic safety in tribal lands. He then identified key indicators and descriptors within each dimension of the framework and evaluated the level of fulfillment each descriptor played in contributing to the selected data domain. Once the key descriptors were examined, Horan conducted a more in-depth analysis of the tribal traffic safety domain. Preliminary interviews with members of two tribes suggested the main value of Horan's work has been in creating a way for tribes to integrate safety and transportation management with related infrastructure and economic development considerations.
- *Performance Measures for Bicycle and Pedestrian Safety: Methodologies for Monitoring Traffic Volumes and Assessing Exposure to Risk:* Greg Lindsey completed work on demand modeling and modeling of crash risk in Duluth, Minnesota, in the ongoing development of tools to estimate bicycle and pedestrian traffic volumes that can be used to assess safety risks for these road users. The research found that a data-driven approach is essential to analyzing risk and increasing safety for pedestrians and cyclists; it is feasible to monitor bicycle traffic and demand; it is possible to

develop measures of crash risk; crash risk is associated with cyclist and vehicular risk exposure; counts are useful in planning-level studies to assess the need for countermeasures; and more work is needed to build the tools for practice.

- *Directional Rumble Strips for Reducing Wrong-Way-Driving Freeway Entries*: Albert Luo's research team designed a new directional rumble strip (DRS), called Pattern E.1, to double the number of strips placed on the inside of the travel lane and increase the vibration for wrong-way drivers entering the freeway. The E.1 DRS was designed to be placed before a ramp's curve. Field tests of in-cab sound and vibration were conducted at three ramps near Auburn, Alabama, along I-85, where the strips were installed to record average speed at specific spots along both the off and on ramps. The speed study results showed that the mean speeds of 17.7 and 15.8 mph were similar on both on- and off-ramp curves with a radius of 106 feet, which can be used to develop recommendations for where to install the rumble strips.
- *Older Driver Support System (ODSS) Usability and Design Investigation*: Nichole Morris spent the last six months preparing a final report and drafting a manuscript to submit to an appropriate journal. The research found that little change was needed to adapt a smartphone-based teen driver support system for use by older drivers. The resulting product is a universally applied design for the Road Coach® smartphone app. The app received a high rate of acceptance among older drivers in a controlled field test.
- *Teen Driver Support System (TDSS) Technology Transfer*: Brian Davis has been preparing the Road Coach® app—a teen driver support system—for use in an older driver support system (ODSS). Davis has finalized the necessary modifications, selected a vendor to make the modifications, defined the scope of work, and received a quote for the cost of the work.
- *Factors Affecting the Adoption of Evidence-Based Approaches to Road Safety by State Policymakers*: Lee Munnich developed a draft final report that provides unique insight into various factors contributing to adoption of evidence-based policy countermeasures to reduce road fatalities and serious injuries in six Midwest states. The findings suggest that special interest group activity can have clear impacts on policy countermeasure adoption, but prevailing political culture and, in some cases, state court rulings play an even deeper role in whether a state legislature adopts certain policy countermeasures.
- *Collaborating with American Indian Communities to Re-Interpret and Strategize about Transportation Safety Risks in Tribal Lands*: Kathy Quick's efforts focused on data analysis and bringing this long, complicated project together into one final report that contains four draft manuscripts for publication in peer-reviewed journals. The four major contributions of the study were: 1) data generation and methodological innovation that create new sources of data, strengthen capacity in tribal governments, and enable in-depth analysis and problem-solving on particular reservations; 2) pedestrian safety, road maintenance and repair, and cooperation among tribal, state, and local governments were identified as key safety risks on reservations that need more attention; 3) improving road infrastructure, driver education and enforcement, and seatbelt and child-seat education and grants were identified as national funding and program priorities and 4) tribal, federal, state, and local inter-agency coordination were deemed to be vitally important to mitigating transportation safety risks on tribal lands.
- *Novel Collision-Avoidance System for Bicycles*: Rajesh Rajamani focused efforts on two activities over the past six months: evaluating the developed collision prevention system on real roads, in real traffic; and completing a final report that documents the developed system and results obtained. Rajamani's work showed that due to weight, size, and cost, collision avoidance systems and vehicle tracking systems used on cars cannot be used on bicycles. To monitor side vehicles and detect danger, the research team developed a low-cost (\$20) custom sonar sensor. To track rear vehicles,

the team mounted an inexpensive (\$89) single-beam laser sensor on a rotationally controlled platform. After being tested on a city road, the collision-avoidance system was found to be reliable in tracking all rear vehicles within the designated area of interest.

- *Improving Railroad Grade Crossing Safety: Accurate Prediction of Train Arrival Times for Emergency Response Management and Driver Decision Support*: Daniel Work developed a data-driven, optimization-based model for predicting train trajectories to be used in grade crossing arrival prediction at the track level. Work also optimized the performance of the estimated time of arrival (ETA) prediction model at each grade crossing using a large parameter search space and more than two years of historical data.
- *Work Zone Intrusion Report Interface Design*: Nichole Morris and her research team successfully created a system for road crew workers to report real-life work-zone intrusions. The data collected from these workers can be used to examine risk factors and provide feedback to the Minnesota Department of Transportation (MnDOT), providing an empirical basis for future policy recommendations. Feedback from the workers resulted in splitting intrusions into minor and more comprehensive, or major, intrusions. Users also tested different interfaces of the reporting tool, including a laptop, tablet, and paper.

Education and workforce development

During this reporting period, the following initiatives helped us meet our goals of attracting and preparing future transportation professionals and expanding the knowledge of current practitioners:

- Institute staff participated in Tech Fest at The Works Museum on February 24, which drew nearly 800 people. RSI's activities drew attention to and supported the permanent Be Safe, Be Seen exhibit that we sponsored at the museum.
- We kicked off the Spring 2018 RSI Seminar Series, holding nine events that drew 322 local and online attendees who learned about safety-related research happening in Minnesota, Michigan, and New Jersey. Seven University of Minnesota students are taking the course ("Advanced Transportation Technologies Seminar") for credit.
- Several RSI-affiliated students received awards during this reporting period:
 - The Institute awarded its 2018 Student of the Year to Frank Alarcon of the University of Minnesota. Advised by Frank Douma, Alarcon expects to complete his master's degree in urban planning in May 2018. Alarcon received a \$2,000 award from the Institute and was presented with a certificate from USDOT officials at a ceremony held in conjunction with the Transportation Research Board (TRB) Annual Meeting in Washington, DC, in January.
 - Ten graduate students working on RSI research projects were awarded travel funding to attend the Transportation Research Board Annual Meeting in January, where they presented research and networked with other attendees. Seven of these students were from the University of Minnesota Twin Cities, one was from the University of Illinois at Urbana-Champaign, and two were from Auburn University (a partner of Southern Illinois University Edwardsville).
 - William Barbour was awarded the 2018 Eno Center for Transportation Fellowship. Barbour was also selected by the Board of Regents of the Eno Center for Transportation to participate in the 26th annual Eno Future Leaders Development Conference in Washington, DC, in May. Barbour is on Daniel Work's research team at Vanderbilt University.
 - PhD candidate Woongsun Jeon received the Center for Transportation Studies' Matthew J. Huber Award at the CTS Annual Meeting in February 2018. The Huber Award recognizes outstanding master's and PhD students in the fields of engineering, science, and technology.

The award was presented by Rajesh Rajamani, who supervises Jeon’s work on the RSI project “A Novel Collision Avoidance System for Bicycles.”

Technology transfer

Roadway users will be safer when our research findings are put into the hands of those who can use them to reduce fatalities and injuries. Toward that goal, we disseminated this information in varied ways to reach both specific groups and broad audiences—from conference presentations to social media. During this reporting period, we engaged in the following technology transfer activities:

- One issue of our e-newsletter was distributed in April, with an open rate of 22 percent. Since the last reporting period, we have added more than 100 new individuals to our subscriber list (for a new total of 2,117).
- To share our work as widely as possible, we continue to maintain a news feed on the Institute’s blog and home page and regularly maintain our RSI Facebook, Twitter, LinkedIn, and YouTube accounts. Highlights from this reporting period include 25 new subscribers and nearly 2,900 video views (totaling more than 34,000 minutes of watch time) on our YouTube channel.

Collaboration

Solving the problem of roadway injuries and fatalities requires multiple approaches from multidisciplinary perspectives. To help the Institute meet this challenge:

- On December 13, 2017, we convened a panel of five national experts to review research proposals received during the fall RFP. The panelists, who came from a variety of academic and public agency backgrounds, spent the day evaluating 13 potential projects.
- The Roadway Safety Institute Advisory Board met on December 14, 2017. The meeting featured two guests: King Gee from AASHTO, who presented on the history and current priority areas of AASHTO, including an overview of recent restructuring to allow for better response to new technologies; and Cory Johnson of MnDOT, who gave an introduction to the Autonomous Shuttle Bus Pilot Project. Interested board members then traveled to MnDOT’s pavement test track to experience a demo of the Easy Mile Autonomous Shuttle bus in person.

Diversity

The Institute is committed to broadening participation and enhancing diversity in the transportation sector through all our activities. Here are some ways we’re working to increase participation by groups currently underrepresented in STEM fields.

- See the research accomplishments section for an update on the tribal safety research being conducted by Tom Horan and Kathy Quick.

Opportunities for training and professional development

Accomplishments are reported in the Education and Workforce Development section.

Dissemination

For the results of Institute work to effect positive change—specifically, safer roadways—they must be delivered to those who can effectively implement them in everyday practice. We strive to communicate this information broadly and purposefully through the following activities:

- RSI researchers received several local and national media mentions for their safety-related work. For a full list of media stories, please visit roadwaysafety.umn.edu/about/news/.

- The Institute’s website is the primary vehicle for distributing information to stakeholders. In this period, the site received approximately 3,040 site visits and 6,240 unique page views. The most popular pages were the home and seminar series pages.

Plans for next reporting period

There have been no changes to the Roadway Safety Institute’s approved application plans. We anticipate the following activities will take place in the next reporting period (October 1, 2017–March 30, 2018):

Research

- We anticipate the publication of at least 13 final reports: 12 from federally funded projects and 1 from a match project.
- Stephen Burks is waiting for co-authors to return the medical costs paper, now in the submission process to an appropriate journal. Burks also plans to send the crash costs paper to co-authors for review and expects to receive new data from the project’s primary study carrier. (*Exploring Links Between Medical Conditions and Safety Performance in Tractor Trailer Drivers*)
- In the next six months, Brian Davis will develop a final contract for professional services with the vendor to implement changes to the Road Coach® app. Davis will also monitor a separate project, involving a field operational test (FOT), because the findings will inform decisions about how best to utilize Road Coach® moving forward. (*Teen Driver Support System (TDSS) Technology Transfer*)
- Gary Davis will complete the validation testing and the reconstruction and estimation of the National Highway Traffic Safety Administration crashes. Davis will also draft a project report. (*Driver Behavior in Left-Turn and Other Two-Vehicle Crashes*)
- Imran Hayee will next conduct field tests to verify and implement the functionality of the merge-time cushion for vehicles merging into freeway traffic, which could eventually be used to develop a merge-assist system to enhance driver safety and traffic mobility. (*Development and Demonstration of Merge-Assist System Using Connected Vehicle*)
- In conjunction with the Alabama Department of Transportation, Albert Luo and the Auburn University research team will now finalize an implementation plan for the newly developed directional rumble strips to deter wrong-way entries onto freeways and conduct a before-and-after study. (*Directional Rumble Strips for Reducing Wrong-Way-Driving Freeway Entries*)
- Nichole Morris will complete a manuscript for journal publication and collect data from 30 subjects, half in Minnesota and half in Kansas, who are now using Road Coach® in a 12-week field operational test. The field test will determine if risky behaviors can be reduced over a long period of time and whether acceptance of the system remains high after prolonged use. (*Older Driver Support System (ODSS)*)
- Lee Munnich will present the study’s findings at the Transportation Research Forum, possibly present at state roadway safety conferences, and submit a journal article to *Transportation Research* for review. (*Factors Affecting the Adoption of Evidence-Based Approaches to Road Safety by State Policymakers*)
- Daniel Work will aggregate the results of grade-crossing estimated-time-of-arrival (ETA) prediction using machine learning regression, summarize results and analyze these by territory, and then prepare the final report for this project. (*Improving Railroad Grade Crossing Safety: Accurate Prediction of Train Arrival Times for Emergency Response Management and Driver Decision Support*)

Education and workforce development

- The Spring 2018 RSI Seminar Series will conclude with four events in April.
- RSI researchers and staff will participate in the University of Minnesota's National Summer Transportation Institute in July.
- We will secure paid summer internships for two undergraduates in MnDOT's Office of Traffic, Safety and Technology. The interns will receive hands-on experience working on transportation-related projects and learning from professionals in the field.

Technology transfer

- We will distribute at least one issue of the RSI e-newsletter. We will also begin work on an RSI end-of-grant summary report, which will include research, education, and technology transfer highlights.

Collaboration

- Nothing to report.

Diversity

- Kathy Quick and Tom Horan will continue their work with tribal governments on roadway safety needs.

PRODUCTS

Publications, conference papers, and presentations

During this reporting period, RSI researchers and staff gave presentations to local, regional, and national audiences. The settings, ranging from national conferences to local meetings, introduced a wide variety of stakeholders to our work. Presentations include:

- Achtemeier, J., and N. L. Morris. "Mitigating Risk in Work Zones: Informing Drivers Using In-Vehicle Technology." Presentation at the Annual CTS Research Conference, Minneapolis, MN, November 2, 2017.
- Alarcon, F., and F. Douma. "Examining the Relationship Between Speed Enforcement Laws and Traffic Safety." Presentation at the Annual CTS Research Conference, Minneapolis, MN, November 2, 2017.
- Alarcon, F., and F. Douma. "Toward Greater Understanding of the Relationship Between Public Perceptions of Speed, Speed Laws, and Safety." Presentation to the MnDOT Metro Division Management Team, Roseville, MN, March 12, 2018.
- Alarcon, F., and F. Douma. "Toward Greater Understanding of the Relationship Between Public Perceptions of Speed, Speed Laws, and Safety." Presentation to the MnDOT Traffic Engineers Organization, Arden Hills, MN, March 27, 2018.
- Atiquzzaman, M., and H. Zhou. "Modeling the Risk of Wrong-Way Driving Entry at the Exit Ramp Terminals of Full Diamond Interchanges." Poster session at the 97th Annual Meeting of the Transportation Research Board, Washington, DC, January 9, 2018.
- Baireddy, R., H. Zhou, and M. Jalayer. "Identification of Factors Contributing to Pedestrian Crashes in Rural Illinois Using Multiple Correspondence Analysis." Poster session at the 97th Annual Meeting of the Transportation Research Board, Washington, DC, January 8, 2018.

- Barbour, W., and D. Work. "Prediction of Arrival Times of Freight Traffic on US Railroads Using Support Vector Regression." Presentation at the INFORMS Annual Meeting, Houston, TX, October 23, 2017.
- Barbour, W., and D. Work. "Prediction of trajectories and arrival times of freight traffic on US railroads." Presentation for the Institute for Software Integrated Systems, Vanderbilt University, Nashville, TN, March 16, 2018.
- Chen, R., and J. Hourdos. "Evaluation of Roundabout Capacity Model in HCM 6th Edition and HCM 2010 on a Multilane Roundabout." Poster session at the 97th Annual Meeting of the Transportation Research Board, Washington, DC, January 8, 2018.
- Craig, C., and N. L. Morris. "Development of a Work Zone Intrusion Reporting System." Presentation at the Annual CTS Research Conference, Minneapolis, MN, November 2, 2017.
- Davis, G., J. Gao, and J. Hourdos. "Safety Impacts of Priced Dynamic Shoulder Lanes on I-35W, and Nonlinear Effect of Traffic Congestion." Poster session at the 97th Annual Meeting of the Transportation Research Board, Washington, DC, January 9, 2018.
- Donath, M. "The University of Minnesota's Driver Assist Augmented Reality." Presentation to staff at the Metropolitan Airports Commission Operations Center, Richfield, MN, October 4, 2017.
- Gao, J., and G. Davis. "Safety Study of the I-35W Improvements Done Under Minnesota's Urban Partnership Agreement (UPA) Project." Presentation at the Annual CTS Research Conference, Minneapolis, MN, November 2, 2017.
- Liao, C.-F. "Using Bluetooth Low-Energy Technology to Trigger In-Vehicle Messages at Work Zones." Presentation at the Annual CTS Research Conference, Minneapolis, MN, November 2, 2017.
- Martinez Mori, J. C., W. Barbour, S. Kuppa, and D. Work. "Predicting Delay Occurrence at Freight Rail Sidings." Lectern session at the 97th Annual Meeting of the Transportation Research Board, Washington, DC, January 8, 2018.
- Rouholamin, M. P., and H. Zhou. "Single-Vehicle Crashes on Rural Two-Lane Highways and Injury Severity: Does the Age Matter?" Poster session at the 97th Annual Meeting of the Transportation Research Board, Washington, DC, January 8, 2018.
- Schmit, M., and L. Munnich. "Factors Influencing Policy and Political Leadership in Improving Roadway Safety." Lectern session at the 97th Annual Meeting of the Transportation Research Board, Washington, DC, January 8, 2018.
- Tian, D., and N. L. Morris. "The Effectiveness of an Intelligent Rural Intersection Conflict Warning System in Promoting Drivers' Gap Acceptance and Safety at Rural Thru-Stop Controlled Intersections." Presentation at the Annual CTS Research Conference, Minneapolis, MN, November 2, 2017.
- Tian, D., and N. L. Morris. "Comparing Novice Teenage Drivers to Experienced Middle Aged Drivers: Trust, Mental Workload, and Driving Behavior towards a Rural Intersection Collision Warning System." Poster session at the 97th Annual Meeting of the Transportation Research Board, Washington, DC, January 8, 2018.
- Van Houten, R. "An Examination of the Effects of the Gateway R1-6 Treatment on Driver's Yielding Right-of-Way to Pedestrians, Speed at Crosswalk, and Sign Durability Over Time." Poster session at the 97th Annual Meeting of the Transportation Research Board, Washington, DC, January 9, 2018.
- Wang, J., and H. Zhou. "Using Naturalistic Driving Study Data to Evaluate the Effects of Intersection Balance on Driver Behavior at Partial Cloverleaf Interchange Terminals." Poster

session at the 97th Annual Meeting of the Transportation Research Board, Washington, DC, January 9, 2018.

RSI researchers published the following papers during this reporting period:

- Jeon, W., and R. Rajamani. 2017. "Rear Vehicle Tracking on a Bicycle Using Active Sensor Orientation Control." *IEEE Transactions on Intelligent Transportation Systems*: 1-12.
- Jeon, W., and R. Rajamani. 2017. "Two-dimensional Active Sensing System for Bicyclist–Motorist Crash Prediction." *Proceedings of the 2017 American Control Conference*: 2315-2320.
- Yang, L., H. Zhou, and L. Zhu. 2017. "New Concept Design of Directional Rumble Strips for Detering Wrong-Way Freeway Entries." *Journal of Transportation Engineering Part A* 144(5).

Federally funded and match projects produced the following final reports during this reporting period:

- Carlson, K., B. Murphy, A. Ermagun, D. Levinson, and A. Owen. *Safety in Numbers: Pedestrian and Bicyclist Activity and Safety in Minneapolis*. Roadway Safety Institute report number 18-05.
- Craig, C., N. L. Morris, D. Libby, and B. Davis. *Work Zone Intrusion Report Interface Design*. MnDOT report number 2018-09.
- Davis, B., N. L. Morris, J. Achtemeier, and B. Patzer. *In-Vehicle Dynamic Curve-Speed Warnings at High-Risk Rural Curves*. MnDOT report number 2018-12.
- Douma, F., and F. Alarcon. *Toward Greater Understanding of the Relationship between Public Perceptions of Speed, Speed Laws, and Safety*. Roadway Safety Institute report number 18-02.
- Morris, N.L., C. Craig, D. Libby, and J. Cooper. *Older Driver Support System (ODSS) Usability and Design Investigation*. Roadway Safety Institute report number 18-01.
- Schmit, M.P., and L.W. Munnich. *Factors Influencing Policy and Political Leadership in Improving Roadway Safety*. Roadway Safety Institute report number 18-07.
- Xie, S., K. An, and Y. Ouyang. *Positioning, Planning and Operation of Emergency Response Resources and Coordination Between Jurisdictions*. Roadway Safety Institute report number 18-03.
- Zhou, H., C. Xue, L. Yang, and A. Luo. *Directional Rumble Strips for Reducing Wrong-Way-Driving Freeway Entries*. Roadway Safety Institute report number 18-04.

Websites or other Internet sites

The Roadway Safety Institute website (roadwaysafety.umn.edu) includes information on research activities, events, news, and key personnel. Each active research project has a web page that includes both the research project description and a downloadable UTC Project Information Form. We will post final research reports on the RSI website as they are completed.

In addition:

- The Institute's website reaches a wider audience through links to it from the Center for Transportation Studies (CTS) at the University of Minnesota. CTS (cts.umn.edu) strives to solve persistent transportation problems in innovative ways by convening diverse communities to brainstorm, debate, share, learn, and act.
- The Minnesota Traffic Observatory (MTO) website (mto.umn.edu) notes its affiliation with RSI on its home page. RSI researcher John Hourdos directs MTO, a facility that is used frequently by other RSI personnel.
- The HumanFIRST website (humanfirst.umn.edu) features the work of RSI principal investigators who use the laboratory to conduct psychology and human factors research.

- The website of the Connected Vehicles Research Laboratory at the University of Minnesota Duluth (d.umn.edu/ee/cvrl/) includes information on the research of Imran Hayee.
- The Midwest Tribal Safety website (<http://tribalsafety.maps.arcgis.com/home/gallery.html>), a product of Tom Horan’s research, serves as an online collaborative interface for stakeholders working in tribal transportation safety or with tribal community leaders.
- The Truckers & Turnover Project website (morris.umn.edu/academics/truckingproject) features the research of Stephen Burks, including a link to his recent paper in the journal *Sleep* on crash risk and obstructive sleep apnea among truck drivers.
- The Transportation Research Board website contains a link to the recording of a webinar (trb.org/ElectronicSessions/Blurbs/173634.aspx) given by Kathy Quick and Guillermo Narváez in February 2016 titled “New Methods for Assessing and Addressing Roadway Safety Priorities in American Indian Reservations.”

Technologies or techniques

For his project “Novel Collision-Avoidance System for Bicycles,” Rajesh Rajamani developed a low-cost custom sonar sensor. See the research accomplishments section for more details.

Inventions, patent applications, and/or licenses

On October 4, 2017, a group of current and former RSI researchers submitted a full patent application called “In-Vehicle Work Zone Communication.” The researchers include Max Donath, John Hourdos, Chen-Fu Liao, Nichole Morris, Janet Creaser, Chris Edwards, and Stephen Zitzow.

On December 29, 2017, Imran Hayee and Max Donath submitted a full patent application called “Real-Time Relative Vehicle Trajectories Using Vehicle to Vehicle Communication.” They originally submitted a provisional application in 2017.

On February 15, 2018, Chen-Fu Liao and Max Donath submitted a full patent application called “An Integrated Assistive System to Support Wayfinding and Situation Awareness.”

Max Donath, Brian Davis, and Nichole Morris have secured a trademark for the Road Coach[®] smartphone application.

Other products

For his project “Driver Behavior in Left-Turn and Other Two-Vehicle Crashes,” Gary Davis created two mathematical models of crash events coded for running in the computer program WinBUGS. One code describes impact events in two-vehicle planar-impact crashes; the other describes pre-crash trajectories and driver behavior in two-vehicle crashes.

For his project “Using GIS to Improve Tribal Traffic Safety,” Tom Horan developed the Data Sovereignty Framework: Tribal Community and Culture, Tribal Governance, Data Management, and Data Domain Structures for GIS implementation to be used for traffic safety in tribal lands. See the research accomplishments section for more details. Additionally, Horan created four software applications to assist with tribal roadway safety mapping. The applications can be found at <http://tribalsafety.maps.arcgis.com/home/index.html>.

PARTICIPANTS AND OTHER COLLABORATING ORGANIZATIONS

Organizations that have been involved as partners

The Roadway Safety Institute is actively in partnership with 46 organizations across 9 states and the District of Columbia. For more information on these partners—including their names, locations, and contribution types—please see pages 17 and 18.

Other collaborators or contacts

Greg Lindsey is currently serving on an expert panel for an FHWA project called “Scalable Risk Assessment Methodology.” The objective of the project is to identify approaches to assess nonmotorized exposure to crash risk. Lindsey’s RSI work is cited in the FHWA project as an example of approaches to assessing exposure to risk.

In January, Max Donath and Nichole Morris met with representatives from the Minnesota Safety Council and shared findings from Morris’s project, “Older Driver Support System (ODSS) Usability and Design Investigation.” The representatives plan to reach out to the Insurance Federation of Minnesota to gauge interest in implementing the ODSS.

IMPACT

Impact on the development of the principal discipline(s) of the program

The outcomes of our work will give society ways to improve safety and public health for everyone who uses our region’s and nation’s roadways. By identifying critical areas of focus—such as the effect of medical conditions on crash risk, improved crash reporting, intersections, rail grade crossings, and speeding—our efforts will help prevent fatal and serious-injury crashes for those users who have a greater propensity for risk. Specific guidance will be created to help state and national agencies address these priorities. Our work will also help state departments of transportation and other agencies implement design- and operation-related safety improvements. Specifically, we are focusing on issues that have been inadequately addressed to date through projects that examine policy issues, operational safety, rail grade crossings, and automated speed enforcement.

New impacts from this reporting period include:

- *Factors Affecting the Adoption of Evidence-Based Approaches to Road Safety by State Policymakers*: Lee Munich reports an impact on the disciplines of transportation and public safety policy. This research provided a summary of best practices and status of policy countermeasure adoption, both of which were of interest to various stakeholders in the study states. Measuring such progress and promoting dialogue among stakeholders can help promote general awareness, identify barriers to adoption, and inform policymakers of policy developments in other states.
- *Improving Railroad Grade Crossing Safety: Accurate Prediction of Train Arrival Times for Emergency Response Management and Driver Decision Support*: According to Daniel Work, this project will have an impact on railroad engineering. The methods used in this project estimate train arrival times at grade crossings. Improved estimates can enhance safety by enabling effective management of emergency response resources and supporting driver alerts at unsignalized crossings.

- *Novel Collision-Avoidance System for Bicycles*: Rajesh Rajamani expects an impact on the disciplines of control systems and intelligent vehicles through this project's use of inexpensive sensors for tracking trajectories of nearby vehicles and its use of active sensing. The project's use of sensors and microprocessors on a bicycle to track nearby vehicles and implement a collision-prevention alarm system will further these impacts.
- *Older Driver Support System (ODSS) Usability and Design Investigation*: Nichole Morris anticipates that this project's demonstration of universal design applications with older driver technology will have an impact on the discipline of human factors.
- *A Positioning and Mapping Methodology Using Bluetooth and Smartphone Technologies to Support Situation Awareness and Wayfinding for the Visually Impaired*: Chen-Fu Liao reports impacts on traffic engineering. The self-aware Bluetooth Low Energy network developed as part of this project allows a smartphone to be precisely located even in areas (such as urban canyons) with poor GNSS availability. This allows for accurate and reliable wayfinding assistance for the visually impaired in a transportation network.

Impact on other disciplines

Nothing to report.

Impact on physical, institutional, and information resources

Nothing to report.

Impact on transportation workforce development and human resources

Our education and workforce development efforts, as described in the Accomplishments section, offer opportunities to engage future transportation professionals in safety-related concepts and careers, enrich the educational experience of university students, and provide professionals with the tools and resources they need to improve roadway safety. The results of these activities support the development of a diverse transportation workforce.

During this reporting period, 14 RSI projects enlisted undergraduate or graduate student assistants. These jobs provided 24 students with research and practical work experience related to roadway safety. PIs supervising students include Ray Benekohal, Stephen Burks, Brian Davis, Gary Davis, Frank Douma, Imran Hayee, Tom Horan, Greg Lindsey, Albert Luo, Nichole Morris, Yanfeng Ouyang, Rajesh Rajamani, and Dan Work.

Impact on technology transfer

Our technology transfer activities will lead to the implementation of research results and promote a safer transportation system. Through partnerships, RSI faculty and researchers will be successful in technology transfer.

New impacts from this reporting period:

- *Computerized Crash Reports Usability and Design Investigation*: This project, led by Nichole Morris, is expected to result in an invitation to conduct a similar investigation of Minnesota's new crash report interface. The results of this new project will be used to help Minnesota seek federal

funds, based on measurable gains in the accuracy of crash data, and will recommend multiple changes to the crash report interface that are expected to be implemented.

- *Directional Rumble Strips for Reducing Wrong-Way-Driving Freeway Entries*: Albert Luo reports that the departments of transportation in Alabama and Illinois have developed implementation plans for directional rumble strips on off-ramps based on this research.
- *Factors Affecting the Adoption of Evidence-Based Approaches to Road Safety by State Policymakers*: This study exposed a broad set of stakeholders, including state legislators and transportation and public safety officials, to various approaches and best practices regarding evidence-based policy countermeasure adoption. Munnich reports that study participants were especially interested in learning about successful approaches to policy adoption in other states.
- *Improving Railroad Grade Crossing Safety: Accurate Prediction of Train Arrival Times for Emergency Response Management and Driver Decision Support*: The close collaboration that Work has established with CSX Transportation through this project is now a foundation for several future research activities.
- *Long-Term Effects of Gateway R1-6 Treatment on Yielding to Pedestrians, Vehicle Speed, and Sign Survival*: The American Association of State Highway Transportation Officials (AASHTO) has formed a Pedestrian Gateway Treatment Lead States Team to promote the findings of this research across the United States. In addition, based on the findings of this project, the Florida Department of Transportation has installed 40 gateway treatments to improve safety at crosswalks.
- *Novel Collision-Avoidance System for Bicycles*: A patent application related to the project has been filed. According to Rajamani, it is likely that the patent will get licensed in the future, especially if the upcoming field operational test planned by the research team is successful.
- *Older Driver Support System (ODSS) Usability and Design Investigation*: Morris and her team have transferred the findings from this research project into their Road Coach[®] smartphone app, currently under development for possible real-world use.
- *Performance Measures for Bicycle and Pedestrian Safety: Methodologies for Monitoring Traffic Volumes and Assessing Exposure to Risk*: According to Greg Lindsey, the Federal Highway Administration is distributing an early version of the bicycle demand model developed as part of this project in its Nonmotorized Planning Toolkit. In addition, a Transportation Research Board (TRB) paper written based on this work was featured in an Association of Pedestrian Bicycle Professionals “Best of TRB” webinar. Papers have also been shared with local planners and engineers.

Impact on society beyond science and technology

The Institute’s work will result in real-world applications—policy approaches as well as engineering and technology solutions—to mitigate the human and economic toll of traffic crashes and traffic-related fatalities by improving safety.

Impacts from individual projects:

- *Exploring Links Between Medical Conditions and Safety Performance in Tractor Trailer Drivers*: Stephen Burks expects this work to influence the decisions of managers of other motor carriers with regard to screening for obstructive sleep apnea (OSA) among their drivers. Because of the increased crash risk associated with untreated OSA, more carriers instituting unilateral screening of drivers could help improve roadway safety. The work may also influence the public policy debate regarding screening for OSA in the commercial driver’s medical exam.

- *Older Driver Support System (ODSS) Usability and Design Investigation*: According to Morris, this work has the potential to change attitudes and practices for designing in-vehicle technology for older drivers. It could also improve social and economic well-being for older drivers by better enabling safe driving independence.
- *Performance Measures for Bicycle and Pedestrian Safety: Methodologies for Monitoring Traffic Volumes and Assessing Exposure to Risk*: Data from nonmotorized traffic counts conducted in Grand Marais, Minnesota, were used in a health impact assessment that is informing bicycle and pedestrian planning for Highway 61 corridor improvements. By influencing the nonmotorized infrastructure included in the corridor project, this work will ultimately help improve safety for bicyclists and pedestrians in the community.

CHANGES/PROBLEMS

Changes in approach and reasons for change

Driver Behavior in Left-Turn and Other Two-Vehicle Crashes: Gary Davis widened the project to include validation testing by comparing vehicle trajectories reconstructed from event data recorder (EDR) pre-crash data with trajectories from crash-test instrumentation.

Using GIS to Improve Tribal Traffic Safety: Due to continued difficulties with gaining access to tribal representatives, which limited the extent to which the data sovereignty framework could be validated, Tom Horan decided the study results will need to be considered illustrative of the issues.

Actual or anticipated problems or delays and actions or plans to resolve them

A Positioning and Mapping Methodology Using Bluetooth and Smartphone Technologies to Support Situation Awareness and Wayfinding for the Visually Impaired: Chen-Fu Liao experienced a delay because the University of Minnesota site selected for installation of the wayfinding system was under construction. In order to keep the project on track, Liao contacted and received approval from the City of Saint Paul to let the research team install six solar-powered Bluetooth Low Energy beacons on light posts at an unsignalized intersection in Saint Paul for testing. Thanks to the new site, Liao's delay was short lived and he plans to submit the project's final report in April 2018.

Collaborating with American Indian Communities to Re-Interpret and Strategize About Transportation Safety Risks in Tribal Lands: Kathy Quick is experiencing delays in completing the final report and journal manuscripts due to the breadth and depth of the data collected. She has received approval from Institute staff to deliver her final report in May 2018.

Changes that have a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects, vertebrate animals, and/or biohazards

Exploring Links Between Medical Conditions and Safety Performance in Tractor Trailer Drivers: Stephen Burks manually reviewed the project's entire IRB record and rewrote the application in the new ETHOS



format to simultaneously satisfy the major change in the IRB platform to the new ETHOS system and the usual annual review. The project has been under way for so long that none of its original filings fit the template to migrate existing projects to ETHOS. In addition, a major amendment to the original protocol was undertaken in 2010, when Burks first planned to use protected health information. A modification to the Data Use Agreement with the primary data provider to add data related to ergonomics and pre-work screens to the information collected was also included. This filing, submitted in mid-December 2017, has been approved.

Change of primary performance site location from that originally proposed

Improving Railroad Grade Crossing Safety: Accurate Prediction of Train Arrival Times for Emergency Response Management and Driver Decision Support: The research is now being conducted at Vanderbilt University following Principal Investigator Daniel Work's move from being a tenured associate professor at the University of Illinois at Urbana Champaign to being a tenured associate professor at Vanderbilt University. William Barbour also completed his master's degree in civil and environmental engineering (CEE) at the University of Illinois at Urbana Champaign and is now working on his PhD in CEE at Vanderbilt. Institute staff sought and received approval from their USDOT grant administrator regarding this change.

ORGANIZATIONS THAT HAVE BEEN INVOLVED AS PARTNERS

Organization Name	Organization Location	Type of Contribution				
		Financial Support	In-Kind Support	Facilities	Collaborative Research	Personnel Exchanges
Advocacy Council for Tribal Transportation	Greater Minnesota				X	
American Association of State Highway and Transportation Officials	Washington, DC		X			
American Transportation Research Institute	St. Paul, MN		X			
Ann Arbor, City of	Ann Arbor, MI		X			X
Arrowhead Regional Development Commission	Duluth, MN		X		X	
Civil Engineering Department, Auburn University	Auburn, AL			X	X	
College of Science and Engineering, UMN	Minneapolis, MN	X				
CSX Corporation	Jacksonville, FL		X	X	X	X
Esri Corporation	Redlands, CA		X			
Federal Highway Administration	Washington, DC		X			
Federal Highway Administration, Minnesota Division	St. Paul, MN		X			
Fond du Lac Band of Lake Superior Chippewa	Cloquet, MN				X	
Grand Rapids, City of	Grand Rapids, MI		X			X
Headwaters Regional Development Commission	Bemidji, MN		X		X	
Hennepin County	Minneapolis, MN		X		X	
Humphrey School of Public Affairs, UMN	Minneapolis, MN	X	X			
Leech Lake Band of Ojibwe	Cass Lake, MN				X	
Mayo Clinic	Rochester, MN				X	X
Mechanical Engineering Department, SIUE	Edwardsville, IL			X		
Metro Transit	St. Paul, MN		X			
Michigan Department of Transportation	Lansing, MI	X	X			X
Mille Lacs Band of Ojibwe	Onamia, MN				X	
Minneapolis Department of Public Works	Minneapolis, MN		X		X	X
Minneapolis Park and Recreation Board	Minneapolis, MN		X		X	
Minnesota Department of Public Safety	St. Paul, MN		X			
Minnesota Department of Transportation	St. Paul, MN	X	X	X	X	X
Minnesota Senate	St. Paul, MN		X			
Ohio Department of Transportation	Columbus, OH					
Otter Tail County	Fergus Falls, MN		X			
Quality Bicycle Products	Bloomington, MN				X	

Red Lake Nation	Red Lake, MN				X	
Region 9 Development Commission	Mankato, MN		X		X	
St. Paul, City of	St. Paul, MN		X			
Sawtooth Mountain Clinic	Grand Marais, MN		X		X	
Schneider National	Green Bay, WI		X			
School of Nursing, UMN	Minneapolis, MN				X	X
Southern Illinois University Edwardsville (SIUE)	Edwardsville, IL	X		X		
The Works Museum	Bloomington, MN	X		X		
University of Akron	Akron, OH	X	X	X		X
University of Illinois at Urbana-Champaign	Urbana, IL	X				
University of Minnesota Duluth	Duluth, MN	X				
University of Minnesota Extension					X	
University of Minnesota, Morris	Morris, MN	X	X	X	X	
Vice President for Research, UMN	Minneapolis, MN	X				
Western Michigan University	Kalamazoo, MI	X				
White Earth Nation	White Earth, MN			X		
Wichita State University	Wichita, KS				X	X
WTS Minnesota/Transportation YOU	Minneapolis, MN				X	