

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 following goals 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 21 federally funded research projects (18 active, 3 completed) and 33 match projects (7 active, 26 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 University of Minnesota's HumanFirst Laboratory received more than \$186,000 in a 2017 Research Investment Program award from the University's Office of the Vice President for Research. The HumanFirst Lab, which is affiliated with the Roadway Safety Institute, will match the funds. This funding will be used to overhaul and update the lab's two advanced driving simulators, one an immersive simulator and the other a companion portable simulator. Combined, the two simulators host most of the research the lab conducts to understand driver behavior generated during driving-simulation studies designed to reduce risky driving behavior. The upgraded simulators could help Minnesota re-emerge as a national leader in driving behavior research.
- Institute staff started work on an RFP to select new research projects and/or educational initiatives related to roadway safety using the nearly \$1M we have remaining in federal and match funds available for allocation. To allow time for additional research, we requested a no-cost extension to our grant; see page 14 for additional information. During this reporting period, we determined the



list of eligible researchers, drafted an announcement, determined selection criteria, and started work on a proposal template.

- We published seven final research reports: three for federally funded projects and four for match projects.

Highlights from active research projects:

- *Exploring Links Between Medical Conditions and Safety Performance in Tractor Trailer Drivers:* Stephen Burks sent a redrafted paper on obstructive sleep apnea (OSA) status and medical cost differences to non-University of Minnesota co-authors in late July and received a request to provide a breakout of cost differences across study subgroups using the Clinical Classification System. Following integration of co-author input, Burks expects to submit the completed paper to a major medical journal.
- *Developing and Validating a Model of Left-Turn Crashes to Support Safer Design and Operations:* Gary Davis presented this project at the SAE World Congress, describing reconstruction of left-turn crashes using the National Highway Traffic Safety Administration (NHTSA) National Automotive Sampling System/Crashworthiness Data System (NASS/CDS). He also completed a literature review and initial modeling of left-turn, sight-distance obstruction; mined NASS/CDS for rear-end crashes with electronic data recorder (EDR) data; and applied Bayesian crash reconstruction to rear-end crashes with EDR data. Davis has demonstrated feasibility of Bayes reconstruction methods to rear-end crashes and developed a prototype Monte Carlo simulation for left-turn, sight-distance obstruction.
- *Examining the Relationship Between Speed Enforcement Laws and Traffic Safety:* Frank Douma completed a report to submit to the Transportation Research Board (TRB). Study results show that a climate of public ambivalence toward speed allows state speed laws to be created both according to a set of political incentives that downplay safety implications and without thorough consideration of the importance of maintaining a sufficiently severe speed-enforcement regime. Compounding this problem is a lack of consensus regarding the proper relationship between design and posted speed as well as significant variation between state speed laws. Problems with data collection and reporting need to be addressed to enable deeper analysis of the relationship between perception, laws, and safety, which could then be used to recommend improvements to policies and enforcement regimes.
- *Development and Demonstration of Merge-Assist System Using Connected Vehicle Technology:* Imran Hayee designed and implemented an algorithm to identify the relative lane and position of surrounding vehicles in real time, using GPS and dedicated short range communication (DSRC) based vehicle-to-vehicle communication. Hayee then performed experiments on actual roads to test the algorithm and found the system's accuracy to identify the relative lane and position of surrounding vehicles to be 100 percent within a 50-meter radius regardless of the degree of curvature in the road.
- *Using GIS to Improve Tribal Traffic Safety:* Thomas Horan conducted detailed spatial analysis of Minnesota tribal safety trends and developed a tribal framework that can be used by tribes to guide tribal transportation policy. This framework provides a template that can consider tribal transportation safety within a broader construct of data sovereignty.
- *A Positioning and Mapping Methodology Using Bluetooth and Smartphone Technologies to Support Situation Awareness and Wayfinding for the Visually Impaired:* Chen-Fu Liao developed a sustainable power source for the wayfinding system for the visually impaired by integrating solar panels and batteries to power Bluetooth Low Energy (BLE) assemblies. Liao also tested the solar-



powered BLE tag in both outdoor and indoor environments and found the solar panel was able to charge the onboard battery and power the BLE concurrently.

- *Performance Measures for Bicycle and Pedestrian Safety: Methodologies for Monitoring Traffic Volumes and Assessing Exposure to Risk*: Greg Lindsey completed work on the Minnesota case study communities of Minneapolis/Hennepin County, Duluth, Bemidji, and Grand Marais. He submitted a paper to *Transportation and Health*, and was asked to present a paper on the Minneapolis trail crossing case study at a webinar sponsored by the Association of Pedestrian and Bicycle Professionals (APBP) titled “The Best of TRB from APBP: Highlights of Key Research Presented at TRB 2017.”
- *Directional Rumble Strips for Reducing Wrong-Way-Driving Freeway Entries*: Albert Luo selected three locations at which to install various directional rumble strips (DRS) near Auburn, Alabama, along I-85; estimated speed distributions at the selected ramps using SHRP2 Naturalistic Driving Study (NDS) data; and developed the draft implementation guide for the use of DRS by state and local agencies. One directional rumble strip option, called “Pattern D Configuration 3,” can generate a 10 percent louder warning and is recommended for installation close to the stop bar at the end of off-ramps. “Pattern C,” which produced greater sound and vibration than the other two patterns, is best installed on long, straight off-ramps where right-way drivers decelerate to 20 mph and wrong-way drivers accelerate to 35 mph; “Pattern E” is recommended for sharp curve segments of off-ramps. “Evaluation of Sound and Vibration of Directional Rumble Strips for Deterring Freeway Wrong-Way Entries” won first place in a student poster competition; the master’s thesis, “A New Concept Design of Directional Rumble Strips for Deterring Wrong-Way Freeway Entries,” received the 2016 Best Master Thesis Award from Auburn University Graduate School.
- *Older Driver Support System (ODSS) Usability and Design Investigation*: Nichole Morris successfully conducted a field operational test on the older driver support system (ODSS). Responses were positive and the participants provided robust feedback to the research team, but further study is needed before such a system can be provided to older drivers in the marketplace. Morris also completed a final report and submitted it for peer review.
- *Assessing Factors Affecting Policy Leadership in Adopting Road Safety Countermeasures*: Lee Munnich has nearly completed all project tasks, including engagement with state transportation safety officials, examination of special interest influence on states, review of state policies on distracted and drugged driving, in-state roundtable discussions, and report drafting. His research has shown variation in states’ adoption of safety policies as well as considerable variation among states regarding special interest group activity and influence.
- *Novel Collision-Avoidance System for Bicycles*: Rajesh Rajamani is addressing key limitations in the collision-avoidance system that occur when the bicycle is significantly tilted, such as during stopping or turning. To correct these limitations, Rajamani is instrumenting the bicycle with an inertial measurement unit to estimate tilt and reject errors created when the bicycle is stopped or turning.
- *Improving Railroad Grade Crossing Safety: Accurate Prediction of Train Arrival Times for Emergency Response Management and Driver Decision Support*: Dan Work and his team have obtained a unique dataset from CSX Transportation (and in-kind technical support) that contains detailed operational information over its network. To the team’s knowledge, no Class I freight rail network in the U.S. has made a similar dataset available to researchers, so the team is in a unique position to study ETAs at grade crossings. Ultimately the lead graduate student on the project (and RSI’s most recent Student of the Year), Will Barbour, interned at CSX to get a better handle on all of the data attributes and how to best leverage the data for this project. Since then, the team

members have designed and tested algorithms on one branch of the CSX Nashville division, where their methods are substantially outperforming existing (commercial) tools.

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.

- Over the summer, the Institute placed two undergraduate student interns in MnDOT's Office of Traffic, Safety & Technology. The interns spent 10 weeks with State Safety Engineer Brad Estochen and Bicycle and Pedestrian Safety Engineer Melissa Barnes. The internships introduced the students to potential careers in transportation safety.
- Thirty-one middle school students participated in classroom activities, lab sessions, and field trips around the Twin Cities as part of the University of Minnesota's National Summer Transportation Institute (NSTI), a program designed to attract a diverse range of students to education and career opportunities in transportation. During NSTI's safety-themed day, sponsored by the Institute, students toured the Minnesota Department of Transportation (MnDOT) Regional Traffic Management Center, learned about crash analysis, participated in a demonstration given by the Minnesota State Patrol, and "drove" a plow using MnDOT's snowplow simulator.
- The Roadway Safety Institute seminar series, previously held during fall semester, is moving to the spring semester of 2018. During this reporting period, we secured a location, determined dates, added the series to the University of Minnesota course catalog, and started to identify speakers.

See the Diversity section for further updates related to education and workforce development.

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:

- In September, RSI director Max Donath and RSI Advisory Board chair Laurie McGinnis flew to Washington, D.C., to meet with legislative staff from the offices of Minnesota's senators and representatives. Donath and McGinnis discussed Roadway Safety Institute research and initiatives with the staffers. During his visit, Donath also discussed the Institute with representatives from the Insurance Institute of Highway Safety and the Office of Safety Research and Development at FHWA.
- Two issues of our e-newsletter were distributed, one in April and one in September. Since the last reporting period, our subscriber base finally hit the 2,000 mark (2,007 to be exact!), and the average open rate remained steady, near 24 percent.
- 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. Engagement with our YouTube channel has remained steady. In the last six months, our videos have been viewed nearly 1,100 times by individuals in more than 70 countries around the world.

Collaboration

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

- RSI director Max Donath began assembling a panel of experts to review the submissions for the Roadway Safety Institute RFP, which are due in November. The panel will meet in December to discuss the proposals and will include representatives from federal agencies, state agencies, and academia.

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.

- RSI participated in the White Earth Reservation Summer Academy of Math and Science on June 28. RSI staff, along with local Toward Zero Deaths coordinator Tom Nixon, presented camp activities that integrated transportation safety, STEM, and American Indian heritage. Thirty-five students in grades 4–8 participated in the camp. The camp is a product of a nearly 20-year partnership between the White Earth Reservation and the University of Minnesota Extension, but had not received much outside publicity until the Roadway Safety Institute's participation caught the attention of University Relations. After reading about the camp, former NASA astronaut and University alumnus Duane "Digger" Carey contacted University Relations and camp organizers to see if he could help encourage the students to pursue STEM education and careers. White Earth invited Carey, who piloted the Space Shuttle Columbia to the Hubble Space Telescope in 2002, to judge the reservation's student science fair and share his story.

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 approximately 20 local and national media mentions for their safety-related work. One notable example: in May, Minneapolis's local NBC affiliate featured Chen-Fu Liao and Nichole Morris's work on a smartphone application that alerts drivers to approaching work zones. This research, which was also featured in AASHTO's Daily Update news digest, was funded by the Roadway Safety Institute, and subsequent MnDOT funding was used as match. 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 1,653 visits and more than 3,704 unique page views. The most popular pages were the home and newsletter 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 will issue the Roadway Safety Institute RFP in October, collect proposals in November, and host a panel review meeting in December. Funding decisions will be announced in January, with projects slated to begin in March.
- We anticipate the publication of at least three final reports, all from federally funded projects.
- Stephen Burks plans to continue to move a new draft of the paper on obstructive sleep apnea (OSA) status and medical cost differences toward journal submission, make modest progress on an initial draft of a paper on OSA status and crash cost differences, and further develop the legal and contractual conditions for new data to flow from the participating motor carrier and its medical service providers. (*Exploring Links Between Medical Conditions and Safety Performance in Tractor Trailer Drivers*)
- Brian Davis plans to analyze and interpret the data collected during a controlled pilot study in St. Cloud at the Minnesota Highway Safety and Research Center that allowed drivers to use the warning system on a controlled test course, and then document the project in a final report. (*In-Vehicle Dynamic Curve-Speed Warnings at High Risk Rural Curves*)
- Brian Davis will continue to modify the teen driver support system app for use in an older driver support system field operational test. (*Teen Driver Support System (TDSS) Technology Transfer*)
- Gary Davis will complete reconstruction of left-turn crashes, modify the simulation model to allow for sight-distance obstructions, and continue work on rear-end crashes. (*Developing and Validating a Model of Left-Turn Crashes to Support Safer Design and Operations*)
- Imran Hayee will design and field test an algorithm in various scenarios to estimate a merge-time cushion, which could potentially be used to develop a merge-assist application. Hayee will also conduct field experiments to test the algorithm in various scenarios. (*Development and Demonstration of Merge-Assist System Using Connected Vehicle Technology*)
- Imran Hayee will now focus on an advanced curve-speed warning system, prepare an invention disclosure for lane-departure detection and the warning system, and prepare a manuscript for conference or journal submission. (*Development and Demonstration of a Cost-Effective In-Vehicle Lane-Departure and Advanced Curve-Speed Warning System*)
- Chen-Fu Liao will use the results of a human factors study recently completed at the University's HumanFIRST Laboratory to create recommendations for the in-vehicle message phrasing and structure. (*Investigate the Effectiveness of Using Bluetooth Low-Energy (BLE) Technology to Trigger In-Vehicle Messages at Work Zones*)
- Greg Lindsey will respond to peer reviews on the exposure-to-risk and trail-crossing papers and re-submit manuscripts. He will also develop a new manuscript for the Duluth modeling results or incorporate the results into an existing paper and then prepare the final reports. (*Performance Measures for Bicycle and Pedestrian Safety: Methodologies for Monitoring Traffic Volumes and Assessing Exposure to Risk*)
- Albert Luo and the Auburn University research team will now prepare the final report for this project and submit a proposal to the Alabama Department of Transportation to implement the research results. (*Directional Rumble Strips for Reducing Wrong-Way-Driving Freeway Entries*)
- Kathy Quick will complete geospatial analysis of data collected from reservation residents regarding key sites of interest and concern; check in with the three collaborating tribal governments to review the draft final reports customized for each location; access and analyze data collected by the federal Tribal Transportation Agency Program (TTAP) through the national survey of tribes; and begin design of an additional national survey of related local governments regarding roadway safety needs, programs, and priorities in reservations that overlap the jurisdictions of local

governments. (*Collaborating with American Indian Communities to Re-Interpret and Strategize about Transportation Safety Risks in Tribal Lands*)

- Rajesh Rajamani will incorporate a tilt angle estimation system into the collision-avoidance system to reduce errors due to significant bicycle tilt and then document the project in a final report. (*Novel Collision-Avoidance System for Bicycles*)
- Dan Work will continue to refine methods to further increase accuracy by considering additional attributes that influence both the train arrival time at the crossings as well as its speed. Additionally, the current study has focused on a single 140-mile segment of track, and the team is interested to see how the methods generalize to other parts of the network. Expanding the number of crossings where predictions are made will help get a better perspective of the performance of the methods overall. Finally, the research team is starting to develop a new class of optimization-based algorithms that uses the network structure to further inform the time and speed at crossings. A model has been constructed and will be implemented and tested on a part of the freight rail network in the coming months. (*Improving Railroad Grade Crossing Safety: Accurate Prediction of Train Arrival Times for Emergency Response Management and Driver Decision Support*)

Education and workforce development

- We will plan and deliver the first of several events in our Spring 2018 RSI Seminar Series. Seminar topics will cover a wide range of disciplines, including mechanical engineering, civil engineering, electrical engineering, human factors, statistics, policy and risk analysis, and computer science. Planning, social, and behavioral issues related to roadway safety will also be discussed.
- We will grant a number of student awards, including up to 10 travel awards to the Transportation Research Board Annual Meeting and the annual Outstanding Student of the Year award.

Technology transfer

- We will distribute at least one issue of the RSI e-newsletter.

Collaboration

- The Roadway Safety Institute RFP review panel will meet in December to discuss the proposals.

Diversity

- We will work with the White Earth Reservation to begin planning for the 2018 Summer Academy of Math and Science on June 28. RSI staff will present camp activities that integrate transportation safety, STEM, and American Indian heritage.
- Kathy Quick will continue her work with tribal governments on roadway safety needs; see the Research section for a full update on her project.

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:

- Barbour, W., and D. Work. “A Machine Learning Approach for Predicting the Arrival Times of Freight Traffic on U.S. Railroads.” Presentation at the Rail Infrastructure and Vehicle Inspection Technology Conference, Urbana, IL, June 21, 2017.

- Burks, S. “Truckers and Turnover Project: A Brief Overview.” Presentation for UMM Statistics Day at the University of Minnesota, Morris, MN, April 27, 2017.
- Craig, C., Achtemeier, J., Patzer, B., & Morris, N. (2017). “Effects of In-Vehicle Messaging on Mental Workload During Driving Through Work Zones.” Presentation at the Driving Assessment Conference, Manchester Village, VT, June 28, 2017.
- Davis, G. “Bayesian Estimation of Drivers’ Gap Selections and Reaction Times in Left-Turning Crashes from Event Data Recorder Pre-Crash Data.” Presentation at SAE World Congress, Detroit, MI, April 4-6, 2017.
- Donath, M. “Test and Demonstration of Connected Vehicles Applications to Maintenance Operations.” Presentation at TAP Meeting in the MnDOT Waters Edge Building, Roseville, MN, April 28, 2017.
- Donath, M. “State of the Art Automated Vehicle Technology.” Presentation to the Otter Tail County Board of County Commissioners, August 22, 2017.
- Haider, H., and S. Burks. “Assessment of Obstructive Sleep Apnea in the Commercial Driver Medical Exam.” Poster presentation at the Undergraduate Research Symposium, University of Minnesota Morris, April 22, 2017.
- Hayee, M. I. “Acquisition of Relative Trajectories of Surrounding Vehicles using GPS and SRC-based V2V Communication with Lane Level Resolution.” Presentation at the 3rd International Conference on Vehicle Technology and Intelligent Transport Systems, Porto, Portugal, April 24, 2017.
- Jeon, W., and R. Rajamani. “Two-Dimensional Active Sensing System for Bicyclist-Motorist Crash Prediction (I).” Presentation at the 2017 American Control Conference, Seattle, WA, May 25, 2017.
- Lindsey, G. “Monitoring Shared-Use Paths: Applying Warrants for Pedestrian Hybrid Beacons and Traffic Signals.” Webinar presentation featured in “The Best of TRB from APBP: Highlights of Key Research Presented at TRB 2017.” Online, July 17, 2017.
- Robertson, J., and T. Horan. “Tribal Sovereignty and Transportation GIS.” Presentation at the Esri User Conference, San Diego, CA, July 11-14, 2017.
- Xue, C., D. Xu, and H. Zhou. “Evaluation of Sound and Vibration of Directional Rumble Strips for Deterring Freeway Wrong-way Entries.” Presentation at the 5th Urban Street Symposium, Raleigh, NC, May 21-24, 2017.

RSI researchers published the following papers during this reporting period:

- Chatterjee, I., and G. A. Davis. 2016. “Analysis of Rear-End Events on Congested Freeways by Using Video-Recorded Shock Waves.” *Transportation Research Record: Journal of the Transportation Research Board* 2583: 110-8.
- Davis, G. A. 2017. “Bayesian Estimation of Drivers’ Gap Selections and Reaction Times in Left-Turning Crashes from Event Data Recorder Pre-Crash Data.” *SAE Technical Papers*, paper number 2017-01-1411.
- Davis, G. A., A. Doria, M. Morris, and R. Eldridge. 2016. “Impact Speed Determination in a Head-On Crash Using Bayesian Networks.” *Collision Magazine* 11 (2): 38-49.
- Mathew, J., R. F. Benekohal, and J. C. Medina. 2017. “Nested Sorting and Clustering for Visualization of Accidents at Highway-Rail Grade Crossing.” *Transportation Research Record: Journal of the Transportation Research Board* 2608: 46-57.
- Peng, Z., S. Hussain, M. Hayee, and M. Donath. 2017. “Acquisition of Relative Trajectories of Surrounding Vehicles Using GPS and DSRC-based V2V Communication with Lane Level

Resolution.” *Proceedings of the 3rd International Conference on Vehicle Technology and Intelligent Transport Systems*: 242-51.

- Petersen, C., F. Douma, and N. Morris. 2017. “Addressing Key Concerns Regarding Automated Speed Enforcement Via Interactive Survey.” *Transportation Research Record: Journal of the Transportation Research Board* 2660: 66-73.

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

- Davis, G. A., J. Gao, and J. Hourdos. 2017. *Safety Impacts of the I-35W Improvements Done Under Minnesota’s Urban Partnership Agreement (UPA) Project*. MnDOT report number 2017-22.
- Liu, H. X., G. A. Davis, S. Shen, X. Di, and I. Chatterjee. 2017. *Estimation of Crossing Conflict at Signalized Intersection Using High-Resolution Traffic Data*. MnDOT report number 2017-08.
- Morris, N., J. Achtemeier, C. Craig, D. Tian, and B. Patzer. 2017. *In-Vehicle Work Zone Messages*. MnDOT report number 2017-19.
- Parikh, G., and J. Hourdos. 2017. *Evaluation of Safety and Mobility of Two-Lane Roundabouts*. MnDOT report number 2017-30.
- Peterson, C., F. Douma, and N. Morris. 2017. *Identifying and Reconciling Stakeholder Perspectives in Deploying Automated Speed Enforcement*. Roadway Safety Institute report number CTS 17-03.
- Schneider IV, W. H., B. Stakleff, and L. Buser. 2017. *Alcohol-Related Hot-Spot Analysis and Prediction*. Roadway Safety Institute report number CTS 17-04.
- Van Houten, R., and J. Hochmuth. 2017. *Evaluation of RI-6 Gateway Treatment Alternatives for Pedestrian Crossings: Follow-Up Report*. Roadway Safety Institute report number CTS 17-05.

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 “A Positioning and Mapping Methodology Using Bluetooth and Smartphone Technologies to Support Situation Awareness and Wayfinding for the Visually Impaired,” Chen-Fu Liao developed a sustainable power source for the wayfinding system for the visually impaired. See the Research Accomplishments section for more detail.

Inventions, patent applications, and/or licenses

Imran Hayee filed a full patent application titled “Work Zone Safety System” in December 2016, though Institute staff didn’t learn about it until this reporting period.

John Hourdos filed a provisional patent application in May 2017 titled “Queue Warning System Utilizing ATM Infrastructure.”

Other products

Nothing to report.

PARTICIPANTS AND OTHER COLLABORATING ORGANIZATIONS

Organizations that have been involved as partners

The Roadway Safety Institute is actively in partnership with 44 organizations across 8 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

Nothing to report.

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:

- *Exploring Links Between Medical Conditions and Safety Performance in Tractor Trailer Drivers:* Stephen Burks anticipates an impact on the field of managerial economics, specifically related to decisions made by motor carriers. His research has the potential to affect the likelihood that more motor carriers will unilaterally institute obstructive sleep apnea screenings for their employee drivers in an attempt to improve safety.
- *Improving Railroad Grade Crossing Safety: Positioning, Planning, and Operation of Emergency Response Resources and Coordination Between Jurisdictions:* Yanfeng Ouyang reports impacts on the discipline of complex transportation systems; his project is the first effort to address the vulnerability of network systems under correlated disruptions caused by disasters.
- *Investigate the Effectiveness of Using Bluetooth Low Energy (BLE) Technology to Trigger In-Vehicle Messages at Work Zones:* Chen-Fu Liao's project had an impact on the discipline of intelligent transportation systems. His work demonstrated that a smartphone app could be used to successfully detect BLE signals at highway speeds and deliver messages to drivers.
- *Long-Term Effects of Gateway R1-6 Treatment on Yielding to Pedestrians, Vehicle Speed, and Sign Survival:* Ron Van Houten's research could have an impact on traffic control. The National Committee on Uniform Traffic Control Devices has expressed significant interest in the treatment and could ultimately make recommendations related to its use.
- *Performance Measures for Bicycle and Pedestrian Safety: Methodologies for Monitoring Traffic Volumes and Assessing Exposure to Risk:* Greg Lindsey reports impacts on the fields of traffic engineering and transportation planning related to this project:
 - Traffic engineering: Project findings related to trail crossings show that warrants for traffic signals and pedestrian hybrid beacons at these locations are most likely to be met on weekends. However, transportation engineers have historically focused on warrants during weekday peak hours because it was assumed motorized and pedestrian traffic volumes were highest at this time. This research illustrates the importance of considering the need for controls during different time periods.
 - Transportation planning: The models of exposure to risk developed as part of this project can be used by planners to identify locations that justify further, site-specific investigation to assess risk factors that may not be included in the models.

Impact on other disciplines

The interdisciplinary nature of our research means outcomes will reach beyond our core focus areas to impact safety approaches in other disciplines.

- *Improving Railroad Grade Crossing Safety: Positioning, Planning, and Operation of Emergency Response Resources and Coordination Between Jurisdictions:* Yanfeng Ouyang's work is having an impact on network optimization. He's developing new methods to analyze and optimize reliable resource allocation under multiple dimensions of certainty.

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, seventeen RSI projects enlisted undergraduate or graduate student assistants. These jobs provided 37 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, Kathy Quick, Rajesh Rajamani, Ron Van Houten, 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*: The product of this research, Minnesota's MnCRASH system, is now in use for crash reporting by all law enforcement officers across the state. Users include the Minnesota State Patrol, county sheriff's departments, and city police departments.
- *Development of Guidelines for Permitted Left-Turn Phasing Using Flashing Yellow Arrows*: This project resulted in a spreadsheet decision tool for transportation practitioners that is available on the Minnesota Department of Transportation's website.
- *Estimating the Crash Reduction and Vehicle Dynamic Effects of Flashing LED Stop Signs*: Gary Davis reports that the estimates of the crash modification factor developed as part of this project have been included in the online resource CMF Clearinghouse.
- *Investigate the Effectiveness of Using Bluetooth Low Energy (BLE) Technology to Trigger In-Vehicle Messages at Work Zones and In-Vehicle Work-Zone Messages*: The work conducted in these complementary projects led by Liao and Morris is being submitted for a patent by the University of Minnesota.
- *Performance Measures for Bicycle and Pedestrian Safety: Methodologies for Monitoring Traffic Volumes and Assessing Exposure to Risk*: According to Lindsey, the Minnesota Department of Transportation has expressed interest in using the case study results of this research in training materials provided to its traffic 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:

- *Advanced LED Warning Signs for Rural Intersections Powered by Renewable Energy (ALERT System): Phase II:* According to Taek Kwon, residents living near a successful installation of the rural intersection conflict warning system developed by this project have been positively affected by the implementation. In a survey of residents, 92 percent of respondents reported that the ALERT System improved safety at the intersection.
- *Examining the Relationship Between Speed Enforcement Laws and Traffic Safety:* Frank Douma expects this research to contribute to improved collection and reporting of speed-related crash data as well as public perception of speed data, ultimately enabling deeper analysis of the relationship between these bodies of data and speed laws. The research may also expand awareness of the importance of high-quality safety laws and the enforcement of those laws.
- *Using GIS to Improve Tribal Traffic Safety:* According to Tom Horan, the data and tools developed as part of this project will allow American Indian tribes to improve transportation safety, benefiting reservation residents and others who travel through tribal lands.

CHANGES/PROBLEMS

Changes in approach and reasons for change

The Roadway Safety Institute requested and was granted a one-year, no-cost extension to our grant; the new end date will be September 30, 2019. We requested the extension to allow time to fund additional research projects, as we have nearly \$1M remaining in federal and match funds. Our intent is to extend the work of our researchers where additional time and funding will allow for the pursuit of implementation, technology transfer, and field operational tests; the development of additional partnerships with government agencies or industry that will likely lead to research deployment; or where the project shows potential to make a significant impact within the region or nationally.

Exploring Links Between Medical Conditions and Safety Performance in Tractor Trailer Drivers: The data-sharing agreement with the motor carrier was extended from 2018 to 2022 and amended to include the motor carrier's permission to access data from a new source, a provider of pre-work screening and ergonomics-related therapy services to the study's motor carrier. Stephen Burks has negotiated a new Data Use Agreement with the ergonomics firm and now needs to file a second (small) protocol amendment to get IRB approval to add the ergonomics data. Burks also needs to carry out "project validation" in the IRB's new "ETHOS" document management system, which requires filing much of the IRB paperwork again. When Burks receives final IRB approval, he can make an application to the National Institutes of Health for a Certificate of Confidentiality, after which the specific process for data acquisition can be negotiated.

Developing and Validating a Model of Left-Turn Crashes to Support Safer Design and Operations: Gary Davis is revising his model to accommodate sight-distance obstructions on negative offset turn lanes after

obtaining observational evidence from Minnesota and completing a literature review that indicated this should be considered.

Examining the Relationship Between Speed Enforcement Laws and Traffic Safety: Lack of data consistency related to speed-related crashes and public perceptions of speed prevented robust comparisons for states in Region 5, therefore Frank Douma did not arrive at a definitive conclusion regarding the relationship between speed laws, safety, and public perceptions of speed.

Development and Demonstration of Merge-Assist System Using Connected Vehicle Technology: Instead of using lateral distance to estimate the relative lane of surrounding vehicles, Imran Hayee is now using effective lateral distance after realizing that on curved roads, lateral distance can lead to erroneous decisions. Hayee has found a way to subtract the curvature error to find effective lateral distance, which ensures the accurate estimation of the relative lane of a surrounding vehicle irrespective of the degree of curvature in the road.

Using GIS to Improve Tribal Traffic Safety: Based on research directions of American Indian doctoral student Joseph Roberston (and corresponding Esri interest), Thomas Horan adjusted the project scope to consider data sovereignty.

A Positioning and Mapping Methodology Using Bluetooth and Smartphone Technologies to Support Situation Awareness and Wayfinding for the Visually Impaired: Chen-Fu Liao will need to identify another location to install the wayfinding systems. While the University of Minnesota Facilities Management engineer is willing to install the BLE tags and solar panels on University-owned light poles, the Minneapolis Park and Recreation Board will not allow them to be installed at the unsignalized corner of East River Parkway and SE Harvard Street. In addition, the nearby light poles owned by the University will be removed soon due to renovation of Pioneer Hall.

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

Using GIS to Improve Tribal Traffic Safety: Principal Investigator Thomas Horan accepted a job as dean of the Business School at the University of Redlands, which has caused a three-month delay. Horan will work with Institute staff to extend his contract and wrap up the project.

Improving Railroad Grade Crossing Safety: Accurate Prediction of Train Arrival Times for Emergency Response Management and Driver Decision Support: As described under Research Accomplishments, Dan Work has obtained access to a unique dataset from CSX Transportation. The dataset has more than 500 million rows of data, so it has taken the project team significant time to prepare it for input into the methods they are developing. Additionally, Dan Work has recently taken a job at Vanderbilt University, which has caused an administrative delay as a new subcontractor relationship is established. The Institute has been in touch with the USDOT about this change and the project will likely be extended until June 30, 2018, to accommodate these issues.

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

Nothing to report.

Change of primary performance site location from that originally proposed

Long-Term Effects of Gateway R1-6 Treatment on Yielding to Pedestrians, Vehicle Speed, and Sign Survival: Ron Van Houten added sites in Grand Rapids and lost one site in Kalamazoo, Michigan.

Improving Railroad Grade Crossing Safety: Accurate Prediction of Train Arrival Times for Emergency Response Management and Driver Decision Support: Dan Work will complete his research at Vanderbilt University instead of the University of Illinois at Urbana-Champaign; see “Actual or anticipated problems or delays and actions or plans to resolve them” for more information.

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	
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		
WTS Minnesota/Transportation YOU	Minneapolis, MN				X	