SEMI-ANNUAL PERFORMANCE REPORT

OCTOBER 2022 TO MARCH 2023

SAPR #12

SAFE-D: SAFETY THROUGH DISRUPTION UNIVERSITY TRANSPORTATION CENTER

SAN DIEGO STATE UNIVERSITY

Texas A&M Transportation Institute

VIRGINIA TECH TRANSPORTATION INSTITUTE
VIRGINIA TECH

Federal Agency	Office of the Secretary of Transportation (OST); U.S. Department of Transportation (US DOT)
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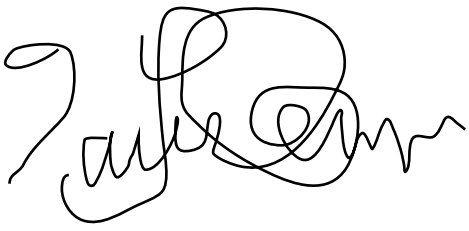
Signature of Submitting Official	

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Accomplishments

Major Goals of the Program

Fueled by the inevitable changes in our transportation system, the Safety through Disruption (Safe-D) National University Transportation Center (UTC) endeavors to maximize the potential safety benefits of disruptive technologies through targeted research that addresses the most pressing transportation safety questions. With the outstanding leadership of the Virginia Tech Transportation Institute (VTTI) and the Texas A&M Transportation Institute (TTI) in a mentoring collaboration with the new transportation research group at San Diego State University (SDSU), a Hispanic-Serving Institution known for educating the transportation workforce, our geographically balanced consortium encompasses the largest group of transportation safety researchers in the nation and provides unparalleled expertise, facilities, and resources to conduct impactful research toward our long-term vision. The Safe-D National UTC focuses its efforts in four key areas: (1) cutting-edge research conducted by leading transportation safety experts and their students; (2) education and workforce development (EWD) for programs of all levels, from grade school through college and extending to continuing education for professionals; and (3) fully supported technology transfer (T2), including practitioner training partnerships, social networking, commercialization, and intellectual property management; (4) Implementing diversity, equity, and inclusion components in all aspects of our research from the researchers involved to the communities it will support.

Accomplishments During This Reporting Period

Project Awards and Activity

The grant is heading towards its conclusion, and as such Safe-D has not solicited any research proposals during this period and will not hereafter. In addition, no extra funding was awarded to any remaining, on-going projects.

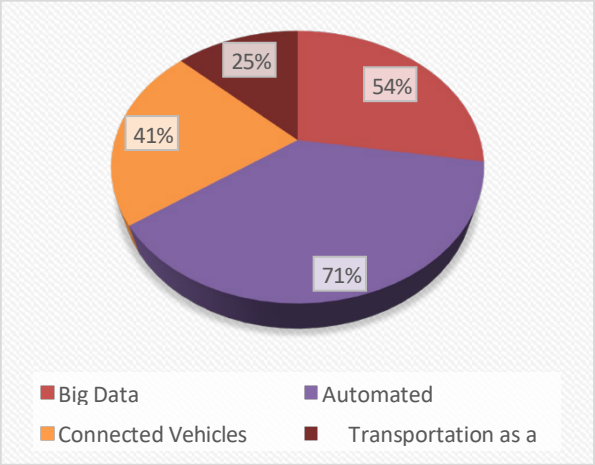

Figure 1. Theme areas.

Over the life of this grant, we have developed a portfolio of more than $31 million. Safe-D projects have been selected according to their focus on four Center theme areas: automated vehicles, (AVs) connected vehicles (CVs), big data analytics, and transportation as a service. The coverage of Safe-D themes by project portfolio to-date is shown in Figure 1. Note that percentages are based on the number of projects reporting a focus in one or more Safe-D theme area(s), resulting in a total of over 100%. Due to no more projects being funded through the end of the grant, these are the final project theme distribution numbers.

Completed Projects

During this reporting period, research activities on the following projects were completed:[1]

- VTTI-00-036: Smart Work Zone System
- 05-113: Evaluation Tools for Low-Speed Automate Vehicle (LSAV) Transit Readiness of the Area
- 06-01: Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking
- 05-082: Lane Change Hazard Analysis Using Radar Traces to Identify Conflicts and Time-To-Collision
- 05-089: A Holistic Work Zone Safety Alert System Through Automated Video and Smartphone Sensor Data Analysis
- 05-086: A Data Driven Approach to the Development and Evaluation of Acoustic Electric Vehicle Alerting Systems for Vision Impaired Pedestrians
- VTTI-00-033: Human Factors of Driving Automation: Evasive Maneuver Event Response Evaluation
- VTTI-00-021: Signal Awareness Applications
- 06-006: Private 5G Technology and Implementation Testing
- VTTI-00-032: E-Scooter Design
- VTTI-00-034: Sensor Degradation Detection Algorithm for Automated Driving Systems

As with the selection of Safe-D projects, Safe-D Final Research Reports undergo a rigorous, iterative peer-review process, including reviews by the Safe-D Leadership Team, Subject Matter Expert(s), and the Technical Editing team at VTTI. The following projects were finalized during this reporting period and/or final research reports were published to the Safe-D website and distributed to repositories, as per grant requirements:

- VTTI-00-030: An Evaluation of Road User Interactions with E-Scooters
- 05-087 Autonomous Delivery Vehicle as a Disruptive Technology: How to Shape the Future with a Focus on Safety?
- 06-008: Introduction to Communications in Transportation
- 05-096: Curb Management Practices and Effectiveness in Improving Safety
- TTI-06-02: The Future of Parking: Safety Benefits and Challenges
- VTTI-00-027: Impact of Highly Automated Vehicle (L4+ AV) External Communication on Other Road User Behavior
- 05-091: Improving Methods to Measure Attentiveness through Driver Monitoring

Educational Courses Taught and Students Supported

Safe-D researchers are actively engaged in teaching efforts at each of the consortium universities and in supporting students through the conduct of research activities. While formal metrics are reported annually in the

[1] The outputs of these projects are currently under final review and are expected to be published during the next reporting period, per the Safe-D data management plan (DMP) and grant requirements.

Program Performance Indicators, the following is a description of the metrics for this reporting period regarding courses taught and student support provided through the Safe-D program. During this reporting period, researchers involved in Safe-D research projects taught 24 graduate and 22 undergraduate courses, reaching 473 graduate and 1,176 undergraduate students. Safe-D research projects supported 32 undergraduate- and graduate-level students during this reporting period. The breakdown of the students supported during this period are presented in Table 1.

Table 1. Description of Students Supported under Safe-D Research Activities

Academic Level	Total Number of Students Supported	Number of Underrepresented Students Identified
Undergraduate	3	3
Masters	8	2
PhD	21	12

Highlighted EWD & Other Outreach Activities

- Safe-D Project VTTI-05-008: Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation participated in "Hokie for a Day" at the Virginia Tech Campus. During their session, researcher Laurel Glenn and Virginia Tech Transportation Network Manager Nick Quint discussed their Safe-D project as an example of how to conduct research and emphasized the importance of safe and sustainable transportation (Figure 2).

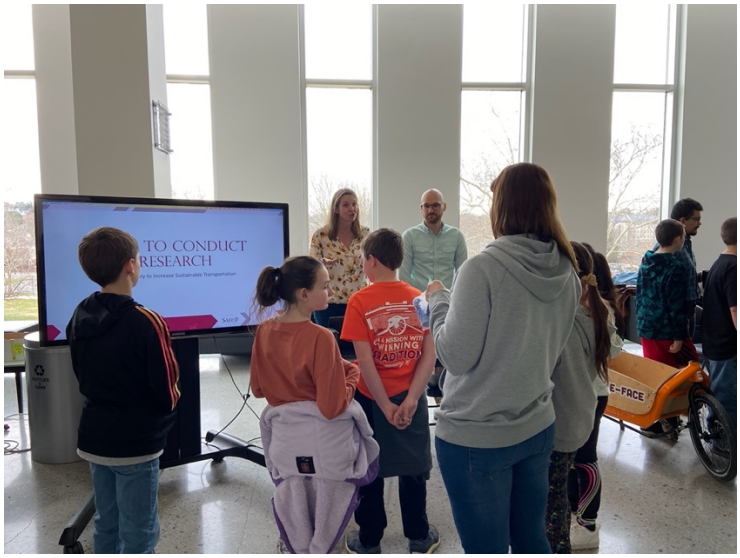

Figure 2. "Hokie for a Day" presentation.

- Safe-D project TTI 01-05 K-12 STEM Program: Exploring the Science of Retro Reflectivity hosted four sessions of elementary and middle school students totaling 460 students at the Texas Transportation Institute (TTI) and booths at a STEM night and career fair. One group (Figure 3) toured the traffic signal lab and the visibility lab at TTI. They also heard a presentation about Transportation and Engineering careers from Melisa Finley, observed a crash test, heard about data science applications for bike safety, and learned about driving safety from the Teens in the Driver's Seat program.

Figure 3. Students in the lab at TTI.

Safe-D Webinars

Safe-D has hosted 27 webinars since it began in January 2020. We have built a robust archive of webinars and a listserv of 594 individuals (up from 346 in the previous reporting period) spanning industry, education and research. Listserv recipients receive information on all upcoming Safe-D webinars. A list of all webinars can be found on the Safe-D website in the webinar archive tab. Safe-D webinars hosted 305 attendees for the five webinars held during this reporting period, which averaged to 61 webinar attendees per webinar with the highest attendance being 100, doubling our numbers from the last reporting period. The total number of YouTube views for all Safe-D webinars during this reporting period was 690, for a grand total of 1,861 webinar views since they started being published online in February of 2020.

Safe-D Webinar Series During this Period

The following Safe-D webinars were posted during this period. Links to their YouTube records can be found below:

- 05-087 Autonomous Delivery Vehicle as a Disruptive Technology: How to Shape the Future with a Focus on Safety?
- 00-027 Impact of Automated Vehicle External Communication on Other Road User Behavior
- 06-01Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking
- 06-006 Private 5G Technology and Implementation Testing for Traffic Intersection Safety
- 05-093 Automated Shuttles and Buses for All Users
- 05-082 Lane Change Hazard Analysis Using Radar Traces to Identify Conflicts and Time-To-Collision Measures

Safe-D Upcoming Webinar Series

We expect the following webinars to be presented in the upcoming months.

Lane Change Hazard Analysis Using Radar Traces to Identify Conflicts and Time-To-Collision Measures

Safe-D Project VTTI-05-082: Lane Change Hazard Analysis Using Radar Traces to Identify Conflicts and Time-To-Collision Measures will be presented by a former Safe-D student, Dr. Balachandar Guduri. This project

analyzed existing data and assessed the safety equivalency of prototype video-based camera systems to support Federal Motor Vehicle Safety Standard No. 111 rulemaking efforts and investigate camera-based side view systems. The researchers mined an existing set of radar data surrounding real-world lane change events. The study was performed in Southwest Virginia using 36 drivers experiencing both conventional and camera-based systems over a month-long naturalistic exposure period (2 weeks conventional, 2 weeks camera-based). Study vehicles were instrumented with a data acquisition system to capture and record time-synchronized video and parametric measures from key-on through key-off (i.e., the entirety of each trip). Analyses focused on potential lane change conflicts and hazards identified using time-to-collision values (which in turn were derived from rear-mounted radar units) surrounding signalized lane change events. Results provided no compelling evidence to suggest that camera-based systems adversely affected lane change performance to lead to riskier or more hazardous lane changes compared to conventional mirror systems. Results instead suggested that camera-based systems, when appropriately designed, can help drivers detect potential conflicts because of the wider field of view afforded by these systems, enabling drivers to assess the presence of a vehicle in the target lane.

Autonomous Vehicles for Small Towns: System, Service, and Safety from Research to Practice

Safe-D Project 05-109: Autonomous Vehicles for Small Towns: System, Service, and Safety from Research to Practice will be moderated by Dr. Ory and presented by Dr. Wei Li and Dr. Bahar Dadashova from Texas A&M University (TAMU). This webinar will give municipal leaders, transportation professionals, and researchers a better understanding of how AV deployment can serve American small towns. First, audiences will learn about how residents in small towns perceive AVs, including both positive and negative aspects. Second, they will see various challenges and opportunities of AV deployment through a pilot program, ENDEAVRide, which is a novel "Taxi + Telemedicine 2-in-1" service delivered via a self-driving van in central Texas. Third, audiences will recognize the potential of open-source technologies as an affordable AV deployment model, designed to fit small towns' budgets. Fourth, they will come to a deeper understanding of the safety implications of AV deployment. In all, audiences will leave with a more comprehensive view of what AVs have to offer small towns and what their deployment looks like in practice.

Evaluating the Safe Routes to School (SR2S) Transportation Program in Socially Vulnerable Communities in San Diego County, California

Safe-D Project 06-01: Evaluating the Safe Routes to School (SR2S) Transportation Program in Socially Vulnerable Communities in San Diego County, California will be led by Dr. Gabriela Fernandez and Co-PIs from San Diego State University as well as two graduate students. This project evaluated Safe Routes 2 School (SR2S), a federally funded program, in socially vulnerable communities in San Diego County. Researchers identified injury and fatality hot spot areas for future routing improvements. Researchers then developed and designed an SR2S web-based visualization tool for easy road safety monitoring and reporting. Additionally, to strengthen community collaboration in transit safety across San Diego County, researchers created SR2S surveys and developed a virtual reality educational transit safety training game, "KIDS 4 Safe Routes VR," for children ages 11 to 14.

More information on the current or future Safe-D webinars can be found here.

Safe-D Researcher Honors and Awards

During this reporting period, two Safe-D Faculty researchers received awards for their exceptional efforts and research. Safe-D is proud to acknowledge the individuals below for their efforts in research and service.

- Virginia Tech PhD candidate Alexandria Rossi-Alvarez received the Virginia Tech Graduate Student of the Year award.

- TAMU Associate Professor Thomas Ferris was honored with the Industrial and Systems Engineering Department Service Award.

Diversity Equity and Inclusion in Safe-D

Diversity, equity, and inclusion (DEI) in transportation are not only important to the current administration (as described in the American Jobs Plan) and society at large but are also equally important to Safe-D. The Safe-D site has a tab which describes the importance of DEI in transportation and has a list of projects that directly or indirect affect DEI. Safe-D believes that it is important to pursue research initiatives that not only identify roadblocks in DEI in transportation but also to develop real-world, common-sense solutions to these issues. In that light, Safe-D is committed to supporting projects that foster DEI in transportation and have supported 21 projects with a DEI component over the life of the grant. Below are two Safe-D projects that are making the lives of underrepresented populations better:

- Results from Project 06-004, Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas highlight the challenges that are unique to rural areas and emphasize the need for novel approaches that can overcome these challenges. The development of such technologies will not only enable the deployment of AVs in rural areas but will also help bridge the existing urban-rural divide by providing residents of rural communities with access to modern transportation services.
- Project 06-002, Developing AI-Driven Safe Navigation Tool, recognizes that the development and deployment of AI-driven technologies in transportation could have a significant impact on improving mobility and access to transportation for low-income individuals and underserved communities. This project's researchers are working to improve transportation safety and efficiency, which could enable greater access to job opportunities, education, and healthcare for these communities.

Participants and Collaborating Organizations

Partner Organization

In addition to inter-consortium collaborations on Safe-D research projects, the Safe-D T2 Plan requires each new project team to be matched with a project champion from industry who will provide a built-in "customer" for the research, further aligning the project with industry needs. The domestic and international collaborations listed below highlight some of the reported collaborations during this period.

Domestic Collaborators

- Project 06-011 Evaluating The Safe Routes to School (SR2S) Transportation Program in Socially Vulnerable Communities in San Diego County, California collaborated with the school administrators, parents and students in seventh and eighth grades of Feaster Charter Elementary School in Chula Vista, CA.
- Project 06-011 Evaluating The Safe Routes to School (SR2S) Transportation Program in Socially Vulnerable Communities in San Diego County, California had members of the San Diego Association of Governments serve as champions for the project and provide feedback and advice to the team throughout

the research process.

- Project 06-005 Automated Truck Mounted Attenuator: Phase 2 Performance Measurement and Testing received collaborative research support from Mike Fontaine at the Virginia Transportation Research Council.
- Project VTTI-00-034 Sensor Degradation Detection Algorithm for Automated Driving Systems received financial assistance in kind and collaborative research support from Global Center for Automotive Performance Simulation Old Dominion University Commonwealth Cyber Initiative.
- The ENDEAVR Institute and Wocsor LLC collaborated with researchers working on Safe-D Project 05-109 Exploring the Safety Impacts of the Older Population's Access to Automated Vehicles and Telemedicine: A Real-World Experiment in Small and Rural Communities, providing staff and in-kind support.
- Project 06-010: Developing a Framework for Prioritizing Bicycle Safety Improvement Projects Using Crowdsourced and Image-based Data researchers collaborated with Caltrans for research support.
- VTTI 00-021 Signal Awareness Applications received research support from Mike Fontaine at the Virginia Transportation Research Council.
- Project 06-009 (Enhancing Automated Vehicle Safety Through Testing with Realistic Driver Models) collaborated with Waymo for research.

International and Proprietary Collaborators

- Project 06-009 (Enhancing Automated Vehicle Safety Through Testing with Realistic Driver Models) collaborated with Leeds University in the United Kingdom for research.
- Project 06-006 Private 5G Technology and Implementation Testing collaborated with NEC, who provided the 5G infrastructure and video analytics for the project.
- Some Safe-D projects have involved collaboration with entities in the private industry sector who are unable to be named at the current time due to non-disclosure agreements.

Outputs

The following T2 Performance Goals and corresponding Metrics for Outputs are copied from the currently approved Safe-D T2 Plan. The Safe-D Leadership Team has tracked and will be reporting these metrics in the current and final SAPR (Table 2). The Safe-D Website Traffic Measures provide evidence that Safe-D products are being viewed by practitioners and potential users. The Safe-D website attracted 2,371 visitors during the 6-month reporting period. With 2,645 visitors during the previous 6-month reporting period, Safe-D greatly exceeded our annual goal of 2,000 visitors per year, with a total of 5,016 visitors from April 1, 2022, to March 31, 2023. Project Page visits averaged just over 35 visits per page for the 6-month reporting period. The Safe-D team continues to seek ways to increase visits to the website Project Pages during the next reporting period and consider ways to keep project pages active and receiving traffic after the end of this grant.

Table 2. T2 Performance Goals and Corresponding Metrics for Outputs

T2 Performance Goal	Goal (Annual)	Measures for Current 6-Month Reporting Period
Website Traffic Measures	Website: ≥ 2,000 Visitors/year	2,645 (5,016 visitors/previous 12 mo.)
	Project Pages: Average ≥ 150 visitors/year	3,640 total visits/period; average 35 visitors/project page
Journal Articles/Conference Presentations	Project Teams: 1 article/year	8 articles
	Project Teams: 1 conference/year	10 presentations
Facility Tours	Displays Viewed by ≥ 200/year	590 total visitor views; average of 17 views per reporting project
	Follow-up Interest: 5 visitors/year	1

Prior to this reporting period, a total of 65 projects had been completed, resulting in 84 journal articles and 116 conference presentations.

Within this reporting period, 7 additional projects were completed and a total of 8 new journal articles with 10 new conference presentations were reported by project teams. These additions bring the average rate of publications per completed project to 1.28 journal articles per completed project and 1.75 conference presentations per completed project. These rates indicate that Safe-D is still tracking ahead of its publication goals for projects through the current reporting period and we expect more publications to come as projects close out. Safe-D researchers also reported 590 views of Safe-D displays during outreach events during the 6-month reporting period. Last period, researchers reported 340 views, bringing the yearly total to 930, which is over quadruple our annual goal of 200 views.

Safe-D is proud to announce that we had projects receive media attention for their efforts. The following Safe-D projects received media mentions.

- Project 06-006 Private 5G Technology and Implementation Testing was mentioned in the VTX news (news and stories from VT): *Research Collaboration Initiated to Increase Pedestrian Safety*. This work was also mentioned across multiple national and international outlets such as the Indonesia Newswire, Intelligent CIO, Nasdaq, and others (*NEC and Virginia Tech Transportation Institute Demonstrate Intersection Safety Using AI-Based Video Analytics*).
- Project VTTI-00-036 Smart Work Zone System was featured in the Roanoke Star. That local paper's link was then shared on other forums. The article is entitled *VA Tech Smart Work Zone Technology Improves Safety for Roadside Workers.*

Publications, Conference Papers, Presentations, Books and Theses

The following are the publications, conference papers, presentations, books, and theses that were under review, submitted, accepted, or published during this reporting period.

Journal Publications/Conference Papers

Bian, J., Li, W., Chen, A., Usman, M., Ye, X., Li, X., Dadashova, B., Lee, C., Ory, M. (2023). Smartphone Usage and Daily Trips: An Empirical Study of Small and Rural Communities in Texas. Presented at the 102nd Annual Meeting of the Transportation Research Board, Washington D.C., January 2023. (Published)

Hong, Y. et al. (2023). Evaluation Tools for Low-Speed Automated Vehicles (LSAV) Transit Readiness Of The Area. Transportation Research Board, Transportation Research Board Annual Meeting 2023.

(Published)

Shahini, F., Nasr, V., Wozniak, D., & Zahabi, M. (2022, September). Law enforcement officers' acceptance of advanced driver assistance systems: An application of technology acceptance modeling (TAM). In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 66, No. 1, pp. 325-329). Sage CA: Los Angeles, CA: SAGE Publications.

Shahini, F., Nasr, V., Zahabi, M. (Under review) Impact of Advanced Driver Assistance Systems on Police Officer Driving Performance, Workload, and Trust. Submitted to the Human Factors and Ergonomics Society (HFES) conference.

Sohrabi, S., Weng, Y., Das, S., Paal, S. (2022). Safe route-finding: A review of literature and future directions. Accident Analysis & Prevention, 177.

Wei, R., Garcia, A., McDonald, A., Markkula, G., Engstrom, J., Supeene, I & O'Kelly, M. (2022). World Model Learning from Demonstrations with Active Inference: Application to Driving Behavior. In 3rd International Workshop on Active Inference (IWAI).

Wei, R., McDonald, A., Garcia, A., & Alambeigi. H. (2022). Modeling Driver Responses to Automation Failures with Active Inference. IEEE Transactions on Intelligent Transportation Systems. (Vol. 23, No 10, pp 18064-18075). (Published)

Zhu, C., Brown, C. T., Dadashova, B., Ye, X., Sohrabi, S., & Potts, I. (2023). Investigation on the driver-victim pairs in pedestrian and bicyclist crashes by latent class clustering and random forest algorithm. Accident Analysis & Prevention, 182, 106964. https://doi.org/10.1016/j.aap.2023.106964

Presentations

Bian, J.* Li, W., Chen, A.*, Usman, M.*, Ye, X., Li, X., Dadashova, B., Lee, C., Ory, M. (2023). Smartphone Usage and Daily Trips: An Empirical Study of Small and Rural Communities in Texas. Presented at the 102nd Annual Meeting of the Transportation Research Board, Washington D.C., January 2023.

Etati, B. (2023). Pedestrian and Bicycle involved accidents analysis and reviewing Safe Routes to School Program effectiveness in Chula Vista, CA. SDSU Student Research Symposium 2023 Poster Session. San Diego, CA., March 3-4, 2023.

Li, W., Roscom, K., Chen, A*., Hu, Z.*, Briggs, C., Escajeda, K., Bian, J.*, Lam, M., Masterson, J., Ory, M., Sprout, W., Usman, M.* (2022). Transport and Telemedicine for Small, Rural Communities: Killing Two Birds with One Stone. Presented at the American Planning Association Texas Chapter Annual Conference, El Paso, TX., October 2022.

Rossi-Alvarez, A. & Klauer, C. (2023). Impact of External Communication for SAE L4+ Vehicles on Other Road User Behavior. 102nd Transportation Research Board Annual Meeting Poster Session, Washington, DC, USA.

Sadeghi, A., Jahangiri, A., & Ghanipoor Machiani, S. (2023). "Developing a Framework for Prioritizing Bicycle Safety Improvement Projects using Crowdsourced and Image- Based Data" 2023 Student Research Symposium, Poster Session, San Diego State University.

Sinha, N., Shipp E.M., Martin, M and Ramezani, M. (2022, October 10-12). Quantifying Alternative Transportation Injury Risk using Health Records and Household Travel Survey Data. 19th International RS5C Conference, Grapevine, Texas, United States

Thapa, J., Li, W., Roberts, A. (2022). Addressing Rural Challenges with Innovative Technological Strategies.

Presented at the American Planning Association National Annual Conference, May 2022, VIrtual.

Zhu, C., Brown, C. T., Dadashova, B., Ye, X., Sohrabi, S., & Potts, I. (2023). Investigation on the driver-victim pairs in pedestrian and bicyclist crashes by latent class clustering and random forest algorithm. IACP Planning Research and Career Development Symposium Poster Session, Gainesville, FL, USA.

Zhu, C., Brown, C. T., Dadashova, B., Ye, X., Sohrabi, S., & Potts, I. (2023). Investigation on the driver-victim pairs in pedestrian and bicyclist crashes by latent class clustering and random forest algorithm. 102nd Transportation Research Board Annual Meeting Poster Session, Washington, DC, USA.

Zhu, C., Dadashova, B., Ye, X. (2023). Environmental Justice in Roadway Safety: A Structural Equation Model of Neighborhood Disadvantage, Active Transportation Infrastructure, and Non-Motorist Crashes in Houston. Association of Collegiate Schools of Planning 2023 Annual Meeting, Poster Session. Miami, Florida. (Under Review)

Books and Theses

Koirala, P. (2023). *Understanding The Factors Affecting Safety of E-Scooter and Bicycle Users in Urban Environments: An Injury Severity Analysis Using Machine Learning and Natural Language Processing* (Master's Thesis; Accepted).

Li, M. (n.d.). *Older Adults' Demand for Autonomous Public Transit: A Case Study in Nolanville, Texas*. Master's Professional Paper.

Rossi-Alvarez, A. (2023). *Effectiveness of Vehicle External Communication Toward Improving Vulnerable Road User Safe Behaviors: Considerations for Legacy Vehicles to Automated Vehicles of the Future* https://vtechworks.lib.vt.edu/handle/10919/113441. (Published)

Sadeghi, A. (n.d.). *Developing a Framework for Prioritizing Bicycle Safety Improvement Projects.* (Master's Thesis)

Usman, M. (n.d). *A Geographical Comparison of Autonomous Vehicles and their Societal Impacts: Texas Perspective*. (PhD Dissertation; Other).

Website(s) or Other Internet Sites

Project 06-004 Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas created a database which provides large scale annotations for Rural Scenes. https://autonomy.engr.tamu.edu/r2d2/

Project 06-011 Evaluating the Safe Routes to School (SR2S) Transportation Program in Socially Vulnerable Communities in San Diego County, California contributed to a yearlong exhibition within the San Diego State University Library on the Metabolism of Cities. The "Leave No One Behind Exhibition" was developed by Dr. Gabriela Fernandez, PI of the Project.

Exhibition Video: https://www.youtube.com/watch?v=QXiXh_BFMDA

Library Website: https://library.sdsu.edu/exhibits/sustainability/index.html

Virtual Exhibition: https://my.matterport.com/show/?m=6NhNseqHsTM

Safe-D Website

During this reporting period, the Safe-D National UTC website was regularly updated with developments from the Safe-D program, including links to project products (e.g., EWD and T2 outputs) and Safe-D outreach activity

descriptions. The Safe-D website averaged 395 users per month, with 2,300 new users during this period. Users viewed pages 8,249 times during this period, visiting an average of 2.3 pages per session. These website traffic measures indicate a steady flow of activity, exceeding our T2 performance goals, and this trend is expected to continue as projects complete their activities, and as project products become available for download via the website.

Outcomes

Safe-D projects are continuing to contribute to changes to the transportation system by increasing understanding and awareness of transportation issues; guiding future policy, regulation, rulemaking, and legislation; adding to the body of knowledge; training the future transportation workforce; and improving transportation-related processes, technologies, techniques, and skills. Due in part to the strong Safe-D T2 Plan and industry involvement with each Safe-D project, we are starting to see the adoption of new technologies, techniques, or practices as a result of individual Safe-D projects, as outlined in the next sections.

The T2 Performance Goals and corresponding Metrics for Outcomes/Impacts, as found in the currently approved Safe-D T2 Plan, are listed below (Table 3). Safe-D has continued to increase their outreach efforts during this reporting period and participated in 12 outreach events to promote the program and projects to an audience totaling 955 individuals. This is compared to the previous reporting period of 10 outreach activities and 1,292 audience members. Please note that webinar efforts are not included in this reporting section but are rather mentioned above in the webinar section so as not to double count. The Safe-D program is currently on-track to meet its T2 performance goals.

Table 3. T2 Performance Goals and Corresponding Metrics for Outcomes/Impacts

T2 Performance Goal	Goal (Annual)	Measures for Current 6-Month Reporting Period
Practitioner Attendance at Events	Project Teams: average 1 event/team	10
	Each Event: average 95 practitioners	955
Vendors Using Technology Developed	Average 1/3 projects result in vendors using technology	No projects have resulted in vendors using technology during this period
	1 license in later stages of UTC operation	0
DOTs Using Technology Developed	3 DOTs using project technology	0
	Follow-on funding from 2 DOTs	0
	Projects Received Patents	0

Increased Understanding and Awareness of Transportation Issues

- Project TTI-06-01 Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking was able to raise awareness about truck parking issues, new technologies, and truck parking needs among several stakeholders, as well as the process for identifying truck parking demand and opportunities for new development during the Transportation Research Board Annual Meeting Poster Session and the Safe-D Webinar.

- Project VTTI-00-033 Human Factors of Level 3 Automation: Surprise Event Response Evaluation has increased the awareness of how human drivers respond to evasive steering and braking maneuvers initiated by a SAE Level 3 (L3) Advanced Driving System (ADS)-equipped vehicle. The research team's journal publication and published final report increased the understanding and awareness on this transportation issue for the transportation research community.

- Project TTI-05-02 Analysis of Advanced Driver-Assistance Systems in Police Vehicles completed the

second phase of this project, which included a driving simulation study assessing the impact of advanced driver assistance systems (ADAS) on law enforcement officers' driving performance. The results suggested that driving with ADAS technologies would result in significant improvements in driving performance and reduce officers' perceived workload. Additionally, it was found that the ADAS would increase officers' trust in vehicle safety with sufficient training on ADAS capabilities.

- Project 06-007 Allusion 2: External Communication for SAE L4 vehicles increased understanding and awareness by looking at different levels of complexity that were not expanded upon in previous research. The complexity of the current transportation environment was integrated with the inclusion of multiple vehicles. This was a critical factor that allowed a better understanding of the implications of pedestrian crossing behavior.

- Project 06-011 Evaluating the Safe Routes to School (SR2S) Transportation Program in Socially Vulnerable Communities in San Diego County, California evaluated the impact of the SR2S program on schools located in the Chula Vista Elementary School District, which is a vulnerable city in San Diego County. Researchers developed a number of methods and tools to develop awareness on transit safety in Chula Vista by developing i) a linear regression model to assess the program's impact on each school, and a logistic regression model to identify factors influencing students' walking behavior; ii) an SR2S web-based visualization interactive tool (ArcGIS Experience) to identify accident hot spots and facilitate future routing improvements; and iii) a virtual reality (VR) educational road safety training tool for children, which was tested at Feaster Charter Elementary School to assess its effectiveness. The team worked with 26 students to test the VR game before and after watching traffic safety educational videos. Observations were recorded during these sessions. Through an array of technologies and tools, researchers were able to develop awareness of transit safety issues in Chula Vista, CA.

- Project 05-093 Automated Shuttles and Buses for All Users. The SAFE-D webinar for this project exposed additional transportation-involved professionals to the needs of disabled individuals in the use of automated shuttles. The webinar highlighted the needs of individuals in wheelchairs and blind/low vision individuals. The webinar also highlighted elements of the built environment that must be addressed, including sidewalks, handicapped building access, and traffic speeds.

Passage of New Policies, Regulation, Rulemaking, or Legislation

The results of several Safe-D projects have contributed to new policies, regulations, rulemaking, or legislation during this reporting period or are currently being considered in regulations or legislation.

- The results from projects 06-001 Building Equitable Safe Streets for All: Data-Driven Approach and Computational Tools aim to investigate the potential reasons for the disproportionate share of roadway crashes in the communities of Houston City. One of the major reasons investigated is the difference in the provision of safe roadway infrastructure, especially from active transportation infrastructure like sidewalks and bikeways. One of the potential reasons for a disadvantaged community facing higher crash risks is that these communities lack safe active transportation infrastructure, which forces pedestrians and bicyclists to share roads with motor vehicles. The findings of this project will provide information for policymakers to allocate government funding and investment to better build safe streets for all communities, especially for disadvantaged communities, which are exposed to higher crash risks, and ensure environmental justice principles in transportation planning.

- Project 05-086 A data driven approach to the development and evaluation of acoustic electric vehicle alerting systems for vision impaired pedestrians results provide additional input towards the current requirements and testing procedures outlined in FMVSS No. 141, as well as additional insight into

effective notification strategies. Different sound types were examined, targeting characteristics that are correlated with human detection. Also, different sound distribution methods were evaluated, comparing performance between a factory solution and an exploratory method.

- Project 06-005 Automated Truck Mounted Attenuator: Phase 2 Performance Measurement and Testing participated in an Advanced Maintenance Technology pooled fund, comprised of many state departments of transportation (DOTs), which is looking to accelerate the adoption of Automated Truck Mounted Attenuator technologies, contributing to an adoption toolkit to aids DOTs in adopting these technologies. Due to the uniqueness and the operational design constraints of the system, policies and procedures for their public operation must be formulated.

Increases in the Body of Knowledge

Safe-D projects have made meaningful contributions to the body of scientific knowledge during this reporting period.

- Project TTI-05-02 Analysis of Advanced Driver-Assistance Systems in Police Vehicles. The findings of this study provided information regarding the factors that affect officers' use of ADAS features in their vehicles. Results indicated that officer behavior and opinion on ADAS features were influenced by the trust officers had in the available ADAS among other key factors such as ADAS training and perceived usefulness. Researchers provided a list of potentially useful ADAS features in police vehicles. The findings of the driving simulation study provided an empirical validation for the proposed ADAS features based on the literature review. ADAS features including forward collision warning (FCW), automatic emergency braking (AEB), and blind spot monitoring (BSM) had positive effect on police officers' driving performance and reducing workload. The outcomes of this project regarding effective ADAS features/types and can improve officer safety in police operations.

- Project 06-004 Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas submitted to the MDPI Sensors Journal. The findings from this work will help development of technologies to enable better access to AVs for rural communities. The team also generated the Rural Road Detection Dataset (R2D2), a collection of LiDAR, camera and stereo images of rural roads surrounding Bryan-College Station. The dataset is set to be released on the Safe-D portal, providing a valuable resource for research and development in the field of AVs and rural road detection.

- Project 06-003 Critical Areas in Advanced Driver Assistance Systems Safety: Point of Sale and Crash Reporting provides insight on how driver assistance technologies are marketed, deployed and improve road safety and whether they are helping reduce crashes and/or crash severity. This project explores those questions through several avenues, including a review of the current state of knowledge on these questions; a review of which technologies are available on which best-selling vehicles by trim level, and thus price; analysis of crash data from an in-depth federal crash investigation program; and review of existing police crash data collection practices and interviews with law enforcement. All of these complement the large and growing body of work on how these technologies are used by drivers.

Enlargement of the Pool of Trained Transportation Professionals

Safe-D projects have contributed to the pool of trained transportation professionals.

- Project 05-093 Automated Shuttles and Buses for All Users conducted a webinar which helped provide information to a wider group of professionals. Researchers from this project are also developing a class lecture and PowerPoint presentation that will educate students on the topic. The class lecture includes a summary of the research, a small group project, and discussion questions.

- Project TTI-05-02 Analysis of Advanced Driver-Assistance Systems in Police Vehicles provided training for two female graduate students during this reporting period. This project provided the basis for a PhD dissertation for one of the PhD students. This student's dissertation is focused on modeling and analysis of ADAS in police vehicles, with a dissertation defense planned in May 2023. This student has been interviewed for several transportation-related positions this semester for a possible full-time position after graduation.

- Project 06-003 Critical Areas in Advanced Driver Assistance Systems Safety: Point of Sale and Crash Reporting has aimed to train additional transportation professionals on the issues of vehicle technology through student support and sharing of findings through public venues. The webinar conducted February, in which the principal investigator included discussion of the project, offered continuing education credits. This project also supports a master's student who will graduate in Q2 2023 and go into the transportation workforce. This project also supported a PhD student specializing in transportation who aims to become a transportation faculty member. These individuals will continue the process of transportation research and teaching and advising future transportation professionals.

- Project VTTI-00-023 E-Scooter Safety Assessment and Campus Deployment Planning constituted the core of a master's thesis of a TAMU civil engineering student, who started to work on the project over the last bi-annual period. During this time, the student has studied various new techniques (such as related machine learning and neural networks) and defended his thesis. The results from this project are also expected to help both transportation and public health researchers who want to learn and study new data sources and methodologies in micro mobility safety analysis.

- Project 05-082 Lane Change Hazard Analysis Using Radar Traces to Identify Conflicts and Time-To-Collision Measures financially supported a Ph.D. student, Balachandar Guduri, from July 2022 to October 2022. The knowledge and education gained from this project helped him acquire a full-time research faculty job in the data analytics division at VTTI. The project team developed two MATLAB modules currently being used internally at VTTI. One module focuses on processing noisy radar data acquired from Continental® Radar PLC units with short-range radar (SRR320) and detecting radar traces for signalized lane change events. Another module identifies the principal other vehicle using processed radar data during signalized lane change events. The research team is working on converting these modules into interactive applications for public use to visualize and interact with the project results. The project team is focusing on presenting this work in webinars or presentations. The project team is also making efforts to disseminate the findings of this project through publications in proceedings and industry conferences. A subset of data collected in the study is available via the Safe-D collection on the Safe-D Dataverse. This data includes processed radar traces of signalized lane change events and the corresponding conflict measures at lane change and lane crossover points for three types of fleets.

Adoption of New Technologies, Techniques, or Practices

During this reporting period, Safe-D projects contributed to the adoption of new technologies, techniques, and practices.

- Project 05-113 Evaluation Tools for Automated Shuttle Transit Readiness of the Area presented results of the research in the form of a checklist, which is aimed at guiding future deployment planning. This checklist will potentially become a new practice in assessing the readiness of future areas looking to employ automated shuttles. One example would be that low-speed automated shuttles currently do not have the ability to understand the positions of their passengers, which will make some of the automated maneuvers abrupt, uncomfortable, and potentially risky for passengers onboard. These maneuvers can be

reduced through more comprehensive training of onboard human operators.

- Project 05-097 Investigating and Developing Methods for Traditional Participant-based Data Collection with Remote Experimenters provided researchers with greater flexibility in designing experiments, as they allow for the collection of data in real-world settings, such as on-road tests or driving simulators, while maintaining control over the experiment remotely. This can lead to more efficient and effective data collection and analysis, as researchers can more easily adjust variables or procedures in response to emerging data or unexpected results. By changing how researchers approach experimental design and opening new avenues of research, the remote experimenter technologies developed by the project team may ultimately lead to improvements in transportation safety, efficiency, and usability. By enabling researchers to collect more accurate and objective data and to explore previously unexplored areas of study, the technology has the potential to contribute significantly to advancements in the field of human factors research in transportation.
- Project 06-006 Private 5G Technology and Implementation Testing adopted 5G communications for low latency communications and connected-vehicle-to-everything to reach pedestrians, vehicles, cyclists, and other motorists. Along with a Video Analytics software running on VTTI's Data Center, a Private 5G network implementation was tested to improve safety at traffic intersections.
- Project 05-008 Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation provides first estimate of exposure-based injury Risk to pedestrians and pedalcyclists. The report highlights characteristics of different numerator datasets that can be utilized to make decisions on data choice to inform injury risk estimates. During the outreach phase, safety education practitioners will be informed about the strengths and limitations of using the current available injury data and use of appropriate denominators.
- Project VTTI-00-027 Impact of Automated Vehicle External Communication on Other Road User Behavior investigated the standardization in the design and deployment of AV external communication. The findings of this research are aimed at providing recommendations for future design considerations.

Impacts

Impact on Effectiveness of Transportation System

Safe-D research projects are designed to produce implementable results that have both near-term and long-term effects on the transportation system. Although the results of some Safe-D studies have only recently begun to be implemented and/or disseminated to practitioners, the outcomes of some projects are beginning to influence our transportation system.

- Project 05-082 Lane Change Hazard Analysis Using Radar Traces to Identify Conflicts and Time-To-Collision Measures provided results which suggest that camera-based alternatives to conventional light passenger vehicle exterior mirrors can potentially be designed to provide relatively safe levels of performance. Analyses revealed no critical conflicts or patterns of ill-advised lane changes (e.g., those with small time gaps) under camera displays, suggesting that camera-based systems when appropriately designed, can help drivers detect potential conflicts. This is primarily a result of the wider field-of-view afforded by camera-based systems, which enable drivers to assess the presence of a vehicle in the target lane and represent a potential safety benefit over and above conventional mirror systems with blind spots.
- Project 06-014 Measuring the Safety of ADS: How Safe is Safe Enough? has outcomes which have not

been implemented yet, but the aim of this project is to provide more testing scenarios for developing ADS to improve the algorithms and systems within the vehicle. This has the possibility of reducing crashes for future ADS, or preventing secondary events caused by the incorrect action of ADS. Additionally, the possibility of the impact of infrastructure technology will be explored to determine what baseline technology should be implemented into the infrastructure.

- Project TTI-05-01 Connected Vehicle Data Safety Applications, even before being completed, has led to practical applications of CV data for investigating and locating traffic safety issues around the state of Texas. The researchers' goal is to document their methods and results so that others can begin applying CV data in their areas of interest to continue reducing crashes.

Impact on Adoption of New Practices or Initiation of Startups

Before research begins on each Safe-D project, a T2 plan is developed that details how the outcomes of the project will be translated for public use or commercialization. The development of the T2 plan and the eventual commercialization of the results are facilitated by Safe-D T2 Coordinator, Luke Neurauter. While no start-up companies have been created at this point as a direct result of Safe-D projects, opportunities for commercialization have been identified and will be pursued as the research products are further developed. Beyond commercialization, Safe-D projects are expected to lead to the adoption of new practices in various transportation-related areas as the results and outcomes are disseminated. The potential for commercialization and adoption of new practices resulting from other Safe-D projects are summarized below:

- The results of Project TTI-06-01 Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking will provide DOTs with a new methodology to evaluate truck parking demand using probe data, as well as a process to prioritize potential new locations for truck parking facilities.

- The findings from Project TTI-05-03 Development of a Roadside LiDAR-Based Situational Awareness System for Work Zone Safety: Proof-of-Concept Study will deploy lightweight portable 360-Degree LiDAR sensors at the roadside and test their potential for providing work zone safety in terms of accuracy, efficiency, and ease of use. This may lead to the initiation of a start-up company in the smart work zone area: for example, building a roadside LiDAR-based situational awareness system in the work zone.

- The findings from Project 06-004 Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas will explore the majority of existing AV technologies, which heavily rely on detailed 3D maps of the environment to facilitate autonomous navigation. This approach proves to be less feasible in rural communities due to their large, sparsely connected areas. This project addresses these challenges by proposing alternative algorithms and datasets tailored to rural communities. These resources are anticipated to prove useful to the automotive industry and research entities engaged in developing AVs and CVs for deployment in rural environments.

- The findings from Project 06-011 Evaluating the Safe Routes to School (SR2S) Transportation Program in Socially Vulnerable Communities in San Diego County, California will explore the belief that the developed interactive pedestrian and bicycle hot spot dashboard has the potential to be useful for municipal planning organizations (MPOs), research institutions, companies, and non-governmental and non-profit organizations (NGOs/NPOs). Additionally, the KIDS 4 Safe Routes VR game evaluation tool has the capability to be used as an evaluation tool that can be replicated by other school administrators, school districts, universities, companies, and NGOs/NPOs.

- The results of Project 05-093 Automated Shuttles and Buses for All Users will assist in developing new AVs and services to better meet the needs of individuals with disabilities. The results will be of use to transit agencies and operators in designing appropriate services and vehicles. Opportunities for outlining new polices will be examined.

Impact on the Body of Scientific Knowledge

Through basic and applied research focused on four key disruptive technologies (CVs, AVs, transportation as a service, and big data analytics), Safe-D projects are expected to make meaningful contributions to the body of scientific knowledge within the broad area of transportation.

- Project VTTI-00-027 Impact of Automated Vehicle External Communication on Other Road User Behavior study assessed pedestrian and driver decision-making in the presence of highly automated vehicles with external communication displays. The research team is currently involved in domestic and international committees exploring the potential for standardization in the design and deployment of L4 and L5 AV external communication.

- Project 05-008 Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation will inform future use of hospital data to estimate injury counts. The project considered Emergency Medical Services and Trauma Registries data and comprehensively investigated their benefits and weaknesses. The study also presented three different measures of exposure, also stratified by race. All the findings will have significant impact on the literature of injury surveillance and inequity in safety outcomes.

- Project 06-002 Developing AI-driven Safe Navigation Tool has the potential to make a significant impact on the body of scientific knowledge related to transportation safety and AI-driven technologies. The research conducted in this project will contribute to a deeper understanding of how advanced machine learning algorithms can be used to improve transportation safety, while also advancing the state of the art in the field.

Impact of Transportation Workforce

Each Safe-D project includes an individually created EWD plan guided by the EWD Coordinator, Dr. Miguel Perez. The EWD plans ensure that Safe-D projects generate significant impacts on the future transportation workforce by providing opportunities for teaching and education; building experience and skill among underrepresented groups in the transportation profession; and exposing practitioners, teachers, and members of the public to science and technology as they relate to Safe-D research. During this reporting period, Safe-D projects have (1) generated valuable educational opportunities for students of varying age groups, including students in underrepresented groups and (2) led to the development of curriculum materials for educators. Specific examples of how Safe-D projects have contributed to EWD are provided below.

- Project 06-003 Critical Areas in Advanced Driver Assistance Systems Safety: Point of Sale and Crash Reporting will develop “1-pagers” that provide information for practitioners, policy-makers, and the public.

- Project TTI-05-01 Connected Vehicle Data Safety Applications has helped numerous researchers gain access to CV data and the cloud computing services needed to process, analyze, and protect very large data sets. These methods are already flowing into practice to help engineers make more informed designed decisions to help improve roadway safety. As TxDOT has just executed a statewide data contract for CV data, the lessons learned through this project are key in assisting TTI, TxDOT, and private consultants in the application of such data for transportation safety use cases.

- Project TTI 06-01 Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking will result in products that can be used by transportation data and planning courses for use in their studies when work is complete. The work is likely to make an impact on transportation workforce development by providing guidance for DOTs, MPOs, and other transportation agencies to address truck parking availability safety issues.
- Project VTTI-00-027 Impact of Automated Vehicle External Communication on Other Road User Behavior provided student researchers the ability to complete the experimental study, design and execute surveys, instrument one or more vehicles with various lighting configurations, and ultimately translate the findings into technology design recommendations. Students also helped with educational campaigns for the general public.