# SEMI-ANNUAL PERFORMANCE REPORT

## APRIL 2022 TO SEPTEMBER 2022

## SAPR #11

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);<br>U.S. Department of Transportation (US DOT) |
| **Federal Grant Number** | 69A3551747115 |
| **Project Title** | Safety through Disruption (Safe-D)<br>National University Transportation Center |
| **Program Director Name, Title, and Contact Information** | Dr. Zachary R. Doerzaph<br>zdoerzaph@vtti.vt.edu<br>(540) 231 – 1500 |
| **Name of Submitting Official** | Eric Glenn<br>Program Manager, Safe-D National UTC<br>EGlenn@vtti.vt.edu<br>(540) 231 – 1536 |
| **Submission Date** | October 31, 2022 |
| **DUNS / EIN** | 0031370150000 / 54-6001805 |
| **Recipient Organization** | Virginia Tech Transportation Institute |
| **Recipient Identifying Number** | N/A |
| **Grant Period** | April 1, 2022 – September 31, 2022 |
| **Reporting Period End Date** | September 31, 2022 |
| **Report Term/Frequency** | Semi-annual reporting periods |
| **Signature of Submitting Official** | |

# Table of Contents

# Accomplishments

## Major Goals of the Program

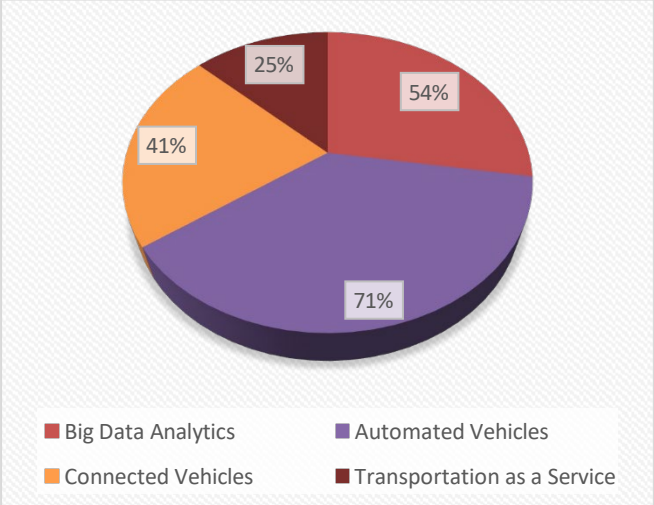
Fueled by the inevitable changes in our transportation system, the Safety through Disruption (Safe-D) National University Transportation Center (UTC) endeavors to maximize the potential safety benefits of disruptive technologies through targeted research that addresses the most pressing transportation 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 research proposals during this period and will not hereafter. Safe-D has used its remaining funds to expand current funded projects along with funding three directed projects. These directed projects were awarded by the Safe-D team based on high impact merit, opportunity to work with strong collaborators, resource availability, and having a diversity, equity, or inclusion component. Safe-D also accomplished our 100% match goal for the grant, including the extended year.

At the end of this reporting period, the Safe-D National UTC had a project portfolio of more than $31 million, with over half of project funding sourced from non-federal matching funds. Safe-D projects are 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 the figure to the right. 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%.




Safe-D research projects awarded during this reporting period, their respective theme(s), and short descriptions are reported below. A (*) denotes the lead institution.

## Newly Awarded

**Project 06-012: Real Time Risk Prediction at Signalized Intersection Using Graph Neural Network:**

*Institution(s): VTTI; Award Round: Spring 2022; Theme Area(s): Automated Vehicles, Connected Vehicles*

The project team will attempt to understand the major cause of conflicts at an intersection by studying the intricate interplay between all the roadway agents. We propose using current traffic camera systems to automatically process traffic video data. As manual annotation of video datasets is a very labor-intensive and costly process, a system that can process these traffic datasets automatically would strongly enhance the effectiveness of the analysis and enable new research questions to be addressed. Therefore, we propose using a computer vision algorithm to process the videos. Also, we propose using advanced machine learning methods, including a graph neural network (GNN) to model the interaction of all the roadway agents at any given instance, and determine their role in road safety, both individually and as a composite system. As a result, the proposed model aims to develop a near real time risk score for a traffic scene.

**Project 06-013: Multi-incident Response Vehicle (MIRV):**

*Institution(s): VTTI; Award Round: Spring 2022; Theme Area(s): Automated Vehicles, Connected Vehicles*

The project team will lead a collaborative effort with Neara Consulting Group to develop and integrate a Multi-Incident Response Vehicle (MIRV) into the Safely Operating Automated Driving Systems (SOADS) vehicle. The MIRV vehicle will be applied as one technical solution to how automated driving systems can be designed to interact safely with public safety in challenging scenarios. This project will explore whether a MIRV can extend the perception of an ADS beyond the vehicle by providing eyes on the ground for better situational awareness, deploy flares to secure a scene surrounding a vehicle, and communicate with emergency, safety, and police personnel. The MIRV will be docked underneath the SOADS F150 vehicle and can be automatically deployed for both autonomous operation and remote teleoperations. Control and supervision of the MIRV will be possible through the cloud, and accessible via mobile device and remote fleet management software. The MIRV will potentially demonstrate a new application of autonomous technology in transportation that could greatly improve safety by performing dangerous tasks, allowing passengers to remain safely in the vehicle while it is disposed on the roadway.

**Project 06-014: Measuring the Safety of ADSs: How safe is safe enough?:**

*Institution(s): VTTI; Award Round: Spring 2022; Theme Area(s): Automated Vehicles, Big Data Analytics*

The purpose of this project is to determine the best method to collect data on the earliest adopter of these advanced vehicle control system and how to rapidly to use this data to evaluate the safety of these systems in the field. A new data acquisition system will be developed through this project according. The data collected by this new data acquisition system will be analyzed, including root cause assessments to measure the safety levels of these systems, as well as how to understand why a system may not be achieving the safety benefit envisioned. The project focus will be on the data that should be collected, how to collect that data, how to rapidly get that data from the field and how to rapidly use that data to assess the safety of these advanced features including any benefit and disbenefits. The project scope will not include developing a data acquisition system for this purpose but will include envisioning, developing, and testing some of the key components required to access and analyze the necessary data.

## Completed Projects

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

[1] The outputs of these projects are currently under final review and are expected to be published during the

- 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?
- 05-082: Lane Change Hazard Analysis Using Radar Traces to Identify Conflicts and Time-To-Collision Measures
- VTTI-00-034: Sensor Degradation Detection Algorithm for Automated Driving Systems
- 06-008: Emerging Communications Training
- 05-096: Curb Management Practices and Effectiveness in Improving Safety
- 05-113: Evaluation Tools for Low-Speed Automated Vehicle Transit Readiness of the Area
- 05-086: A Data Driven Approach to the Development and Evaluation of Acoustic Electric Vehicle Alerting Systems for Vision Impaired Pedestrians
- VTTI-00-036: Smart Work Zone System
- TTI-06-01: Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking
- 05-089: A Holistic Work Zone Safety Alert System through Automated Video and Smartphone Sensor Data Analysis
- 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
- 05-087: Autonomous Delivery Vehicle as a Disruptive Technology: How to Shape the Future with a Focus on Safety?

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:

- 05-101: Evaluation of Transportation Safety Against Flooding in Disadvantaged Communities
- 04-120: Impacts of Connected Vehicle Technology on Automated Vehicle Safety
- VTTI-00-025: Radar and LiDAR Fusion for Scaled Vehicle Sensing Test
- 05-084: Behavioral Indicators of Drowsy Driving: Active Search Mirror Checks
- VTTI-00-028: Driving Risk Assessment Based on High-frequency, High-resolution Telematics Data

## 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 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 20 graduate and 23 undergraduate courses, reaching 486 graduate and 1,395 undergraduate students. Safe-D research projects supported 62 undergraduate- and graduate-level students during this reporting period. The breakdown of the students supported during this period are presented in Table 1.

next reporting period, per the Safe-D data management plan (DMP) and grant requirements.

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

| Academic Level | Total Number of Students Supported | Number of Underrepresented Students Identified |
|---|---|---|
| **Undergraduate** | 14 | 6 |
| **Masters** | 19 | 5 |
| **PhD** | 29 | 9 |

### Highlighted EWD & Other Outreach Activities

- Safe-D Project VTTI-00-023: E-Scooter Safety Assessment and Campus Deployment Planning presented their research to Federal Highway and Tech on Tap.
- Safe-D project TTI-05-02 Analysis of Advanced Driver-Assistance Systems in Police Vehicles invited a K-12 teacher to the Texas A&M Human-System Interaction lab for one week of training. The teacher was trained on the use of a driving simulator and eye-tracking devices to collect human subject data.
- Safe-D Program manager Eric Glenn participated in a panel for first generation college students.

## Safe-D Webinars

Safe-D hosted its first webinar in January 2020. Since then, we have built a robust and dynamic archive of webinars, attracting audiences from varying transportation disciplines. A list of all webinars can be found on the Safe-D website in the webinar archive tab. Safe-D averaged 29 webinar attendees during this reporting period with the highest attendance being 49, increasing our numbers from the last reporting period. The total number of YouTube views for all Safe-D webinars during this reporting period was 293. As mentioned in the previous report, Safe-D is working to increase these numbers by adding a mailing list for researchers to sign up and receive notifications of new webinars. The total number of registered mailing list members increased from 236 in the previous reporting period to 346 during the current reporting period.

### Safe-D Webinar Series During this Period

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

- VTTI-00-036 Smart Work Zone System
- VTTI-00-034 ADS Sensor Degradation Testing and Modeling
- 05-091 Improving Methods to Measure Attentiveness through Driver Monitoring

### Safe-D Upcoming Webinar Series

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

### Improving Methods to Measure Attentiveness Through Driver Monitoring

Safe-D Project VTTI-00-027: Impact of Automated Vehicle External Communication on Other Road User Behavior will be presented by the former Safe-D student of the year, Alexandria Rossi-Alvarez, PhD Candidate. The advancement of SAE Level 4/5 Automated Vehicles (L4/5 AVs) has led numerous stakeholders to develop external communication systems for these vehicles. Most research on vehicles emulating these displays has been conducted using one vehicle. However, it is vital to understand how communication with vulnerable road users (VRUs) are affected when multiple L4/5 AVs are present. This study examined how L4/5 AVs can best communicate their intentions (e.g., turning, stopping, yielding) to VRUs and drivers of conventional vehicles. Subjective and objective data were collected to assess road user responses to two vehicles emulating L4/5 displays from both a passenger and pedestrian perspective. Participants with no prior knowledge of the

experiment experienced three light patterns that provided information regarding L4/5 AVs' intent to slow/stop, begin, and travel with simulated automation active. Overall, participants were overwhelmed with multiple vehicles with different light bars in their vicinity and found it challenging to prioritize attention. These results have implications for the future design of external communication displays on L4/5 AVs. Training may be necessary for road users, given the relatively low percentage of participants who understood the meaning of these displays after multiple exposures and participants' confusion about where to look and how to interpret the intention of the display when multiple vehicles were present. More information on the current or future Safe-D webinars can be found here.

## Safe-D Researcher Honors and Awards

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

- Texas A&M Professor in Industrial and Systems Engineering Alfredo Garcia received the Michael and Sugar Barnes Endowed Professorship
- Texas A&M Mechanical Engineering PhD candidate Stephen Ninan was honored with the MEEN Graduate Student Travel Award
- Texas A&M Industrial and Systems Engineering graduate student Farzaneh Shahini received the 2022 HFES Student Member with Honors recognition
- 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 was recognized with the American Planning Association Texas Chapter Implementation Award
- TTI Associate Research Scientist Jason Wu received the 2022 TTI Gibb Gilchrist Fellowship and the 2022 TTI New Researcher Award
- Texas A&M Urban Planning graduate student and TTI employee Brittney Gick was honored with the Andy Mullins Transportation Planning Fellowship and TTI New Researcher Award
- TTI Research Scientist Nicole Katsikides received the TTI Researcher Award
- Texas A&M Civil and Environmental Engineering PhD candidate and TTI Assistant Research Scientist Jack Kong received the Texas A&M Distinguished Graduate Student Award for Excellence in Research
- Django Bergcollins of San Diego State University received the Safe-D Student of Year Award
- Researchers for Safe-D project VTTI-00-033 received recognition for their work at the ATSSA Innovation Awards 52nd Annual Convention & Traffic Expo

## 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 leadership team decided to create a tab on our Safe-D site that describes the importance of DEI in transportation and compile a list of projects that directly or indirect affect DEI, which can be found here. 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. Safe-D has allocated some of the program's remaining funding to additional DEI in transportation-related projects, specifically projects that help address the lack of sufficient DEI in transportation. The previous reporting period count for Safe-D projects with a DEI component was 21. Since the program is coming to an end, Safe-D does not have plans to continue funding new projects. Safe-D projects have made significant contributions to the understanding and awareness of at-risk populations during this reporting period. Following is a list of projects that have contributed to making the lives of underrepresented populations better:

- Results from Project 05-086, A Data Driven Approach to the Development and Evaluation of Acoustic Electric Vehicle Alerting Systems for Vision Impaired Pedestrians can be used to improve the effectiveness of additive warning sounds for electric vehicles. This will improve safety for pedestrians, particularly the vision impaired who rely on hearing to determine when it is safe to cross roads.
- Project VTTI-00-034 Sensor Degradation Detection Algorithm for Automated Driving Systems developed a sensor degradation detection algorithm, which will aid ADS-equipped vehicles in decision-making by identifying degraded sensor performance, which supports disabled and elderly drivers, who rely more heavily on ADS-equipped vehicles.
- Project 05-008 Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation deals with estimating injury risk stratified by demographic variables such as age and race. The results will indicate over-representation of any of particular age and/or racial groups in injury data.
- Project 06-011 Evaluating the Safe Routes to School (SR2S) transportation program in socially vulnerable communities in San Diego County, California targets children in low-income underserved neighborhoods including those who are disabled and LGBTI+ in the city of Chula Vista along the US-Mexico international border. The work aims to develop tools that can be used by all members of society, including children, elderly, and LGBTI+ community
- Project 06-001 Building Equitable Safe Streets for All: Data-Driven Approach and Computational Tools plans to find and explain the unequal crash risks for disadvantaged communities (i.e. communities with lower incomes and larger proportion of minority groups). Finding the unequal crash risks of these communities can attract awareness of researchers, transportation planners, government, and the public. Investigating the reason for this disparity in roadway crashes can provide basic information and scientific evidence for policy makers and transportation planners to make a better transportation plan and allocate the transportation investment to build a safer road environment for all road users, especially those in disadvantaged communities.

- The results of Project 05-093 Automated Shuttles and Buses for All Users will focus on identifying the needs of disabled individuals in the use of automated shuttles.

During this reporting period, the Safe-D project manager participated in a keynote speaking session for Virginia Tech's Jumpstart program run by the Black College Institute. This Jumpstart program is intended to provide first generation college students of color a chance to get better adjusted to college life. Safe-D saw this as a perfect opportunity to get young students interested in a career in transportation research. The keynote session also addressed challenges these students may experience as persons of color in the transportation research field and the importance of representation in the field. Safe-D was able to speak with 47 students.

*Figure. 1 Jumpstart Keynote Event*

# Participants and Collaborating Organizations

## Partner Organizations

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 TTI-04-02 Delving into Safety Considerations of E Scooters: A Case Study of Austin, Texas collaborated with City of Austin for support in analysis and data acquisition.
- Spin, a micromobility company, provided in-kind, financial, and collaborative research support for Safe-D project VTTI-00-023 E-Scooter Safety Assessment and Campus Deployment Planning

- 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 (GCAPS) Old Dominion University (ODU) Commonwealth Cyber Initiative (CCI).
- The Virginia Department of Transportation (VDOT) provide collaborative research support for 05-113 Evaluation Tools for Automated Shuttle Transit Readiness of the Area.
- Project 06-005 Automated Truck Mounted Attenuator: Phase 2 Performance Measurement and Testing collaborated with VDOT and the department service center for research support.
- Project VTTI-00-036 Smart Work Zone System received financial and collaborative research support from VDOT and VTCRI.
- Project 05-096 Curb Management Practices and Effectiveness in Improving Safety researchers received in-kind from the City of Roanoke.
- The ENDEAVR Institute and Wocsor LLC collaborated with 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.
- Project 04-110 Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities researchers received research support from the City of Chula.
- Project 05-093 Automated Shuttles and Buses for All Users received research support from the City of Arlington.

### 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 VTTI-00-036 Smart Work Zone System partnered with Ver-Mac for a Technology Licensing Opportunity.
- 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 all following SAPRs (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 2,645 visitors during the 6-month reporting period. With 2,770 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 5,342 visitors from October 1, 2021, to September 30, 2022. Project Page visits averaged just over 32 visits per page for the 6-month reporting period. The Safe-D team will continue to seek ways to raise awareness about the website Project Pages during the next reporting period.

**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 | 2,582; 5,278 visitors/previous 12 mo. |
| | Project Pages: Average ≥ 150 visitors/year | 3,241 total visits/period; average 32 visitors/project page |
| **Journal Articles/Conference Presentations** | Project Teams: 1 article/year | 8 articles; 0.20 average per reporting project |
| | Project Teams: 1 conference/year | 10 presentations; 0.24 average per reporting project |
| **Facility Tours** | Displays viewed by ≥ 200/year | 340 total visitor views; average of 8 views per reporting project |
| | Follow-up Interest: 5 visitors/year | 12 |

Prior to this reporting period, a total of 50 projects had been completed, resulting in 76 journal articles and 106 conference presentations.

Within this reporting period, 15 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 1.29 journal articles per project and 1.78 conference presentations per completed project. These rates indicate that Safe-D is tracking ahead of its publication goals for projects through the current reporting period. Safe-D researchers also reported 340 views of Safe-D displays during outreach events during the 6-month reporting period. Last period, researchers reported 1,296 views, bringing the yearly total to 1,636, which greatly exceeds the annual goal of 200 views.

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

- Project TTI-05-02 Analysis of Advanced Driver-Assistance Systems in Police Vehicles was mentioned in the VTX news: *Research drives cybersecurity innovation, inspiration in Southwest Virginia*
- Project 06-005 Automated Truck Mounted Attenuator: Phase 2 Performance Measurement and Testing featured in VTX news: *VTTI partners with Commonwealth Cyber Initiative to host technology showcase*
- Project VTTI-00-036 Smart Work Zone System was featured in multiple news outlets for their accomplishments. Examples include items such as VTX news *Virginia Tech Transportation Institute researchers to deploy smart work zone in Wise, Virginia* and Audi *C-V2X deployment with Audi shows real-world safety benefits for drivers and roadside workers on Virginia highways*
- 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 (ENDEAVRide) was mentioned in the local NBC Channel news: *ENDEAVR partners with local churches to deliver healthcare to people in need*
- Project 06-011 Evaluating the Safe Routes to School (SR2S) transportation program in socially vulnerable communities in San Diego County, California was featured in multiple news outlets, including one international outlet, for their accomplishments at ESRI User Conference 2022, International One Health Conference, and International Conference on Sustainable Development

## Publications, Conference Papers, Presentations, Books and Thesis

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

Etaati B., Fernandez G., Jahangiri A., Machiani G. S., Tsou H. M., and Mejia C., 2022. A visualization dashboard of pedestrian and bicycle crashes in Chula Vista. International Conference on Sustainable Development (ICSD 2022): A Decade of ICSD. Columbia University. September 19-20, 2022. New York, USA. Retrieved from: https://ic-sd.org/ (Virtual) (Published)

Etaati B., Fernandez G., Jahangiri A., Machiani G. S., Tsou H. M., and Mejia C., 2022. A visualization dashboard of pedestrian crashes in Chula Vista, CA. ESRI User Conference 2022. July 11-15, 2022, San Diego, California, USA. Retrieved from: https://www.esri.com (Published)

Fernandez G. Jahangiri A., Machiani G. S., Tsou M.H., Etaati B., and Mejia C., 2022. Pedestrian and bicycle safety visualization in Chula Vista, California. International One Health Conference, A system approach to manage urban and natural resources. University of Catania, September 27-28, 2022, Catania, Italy. Retrieved from: http://onehealthconference.it/ (Published)

Goddard, T., McDonald, A., Wei, R., & Batra, D. (2022). Advanced Driver Assistance Systems in Top-Selling Vehicles in the United States: Cost, Vehicle Type, and Trim Level Disparities. Findings.

Herbers, E. (2022). Improving Methods to Measure Attentiveness through Driver Monitoring [Conference presentation]. 9th Annual Distracted Driving Summit, Norfolk, VA, United States. (Published)

Johns, M., Britten, N., Hankey, J., Kurokawa, K., "Do you trust me? Driver responses to automated evasive maneuvers." Frontiers in Psychology. (Other)

Khodadadi, A., Tsapakis, I., Das, S., Lord, D., & Li, Y. (2021). Application of different negative binomial parameterizations to develop safety performance functions for non-federal aid system roads. Accident Analysis & Prevention, 156. Khodadadi, A., Tsapakis, I., Das, S., & Lord, D. Application of Different Negative Binomial to Develop Safety Performance Functions for Non- Federal Aid System Roads. Accident Analysis and Prevention, 2021." (Published)

Khodadadi, A., Tsapakis, I., Shirazi, M., Das, S., & Lord, D. (2022). Derivation of the Empirical Bayesian method for the Negative Binomial-Lindley generalized linear model with application in traffic safety. Accident Analysis & Prevention, 170. Khodadadi, A., Tsapakis, I., Das, S., & Lord, D. Derivation of the Empirical Bayesian method for the Negative Binomial-Lindley generalized linear model with application in traffic safety. Accident Analysis and Prevention, 2022. (Published)

Modeling Driver Responses to Automation Failures with Active Inference. (2022). ,IEEE Transactions on Intelligent Transportation Systems., DOI: 10.1109/TITS.2022.3155381. (Published)

Nayak, A., Eskandarian, A., & Doerzaph, Z. (2022). Uncertainty estimation of pedestrian future trajectory using Bayesian approximation. arXiv preprint arXiv:2205.01887.A. Nayak, A. Eskandarian and Z. Doerzaph, "Uncertainty Estimation of Pedestrian Future Trajectory Using Bayesian Approximation," in IEEE Open Journal of Intelligent Transportation Systems, vol. 3, pp. 617-630, 2022, doi: 10.1109/OJITS.2022.3205504. (Published)

O'Hara-Rhi V., & Tavakol-Davani H. (2022) Evaluation of Urban Flood Hazard based on Remote Sensing and Machine Learning. Water Resources Management. (Under review)

Roan, M., Neurauter, L., Beard, M., & Miller, M. (July 18, 2022), Electric Vehicle Additive Warning Sounds, Governmental Regulations and Implementations., Special invitation: 2022 Transportation Noise and Vibration Symposium, Penn State University. (Published)

Schoner, J., Sanders, R., Goddard, T. Effects of Advanced Driver Assistance Systems on Impact Velocity and Injury Severity - An Exploration of Data from the Crash Investigation Sampling System". Transportation Research Record. (Published)

Tanim, A. H., McRae, C. B., Tavakol-Davani, H., & Goharian, E. (2022). Flood Detection in Urban Areas Using Satellite Imagery and Machine Learning. Water, 14(7). https://doi.org/10.3390/w14071140 (Published)

## Presentations

Britten, N., Perez, M. On-Road Assessment of Driver Mode Awareness of Assisted and Automated Driving. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2022. (Accepted)

Ghorai, P., Eskandarian, A., and Nayak, A. Relative Pose Estimation for Cooperative Vehicles and Tracking of Multiple Dynamic Objects, in 2021 International Mechanical Engineering Congress and Exposition. 2021 November 1–5. (Published)

Gick, B. N., Parab, S., Katsikides, N., Hwang, W., Lee, D., Rivera Montes de Oca, J., Farzaneh, R., Kong, X., Srisan, T., Bell, S., Alden, A., Warner, J., Romano, H., Schrank, D. Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking (No. TRBAM-23- 00724). 2022. (Published)

Khodadadi, A., Tsapakis, I., Das, S., & Lord, D. Application of Different Negative Binomial Parameterizations to Develop Safety Performance Functions for Non-Federal Aid System Roads. Transportation Research Board Annual Meeting. January, 2021 (Accepted)

Khodadadi, A., Tsapakis, I., Das, S., & Lord, D. Derivation of the Empirical Bayesian method for the Negative Binomial-Lindley generalized linear model with application in traffic safety. International Conference on Transportation and Development, Seattle, Washington, June 2022. Meeting. June, 2022 (Submitted)

Nayak, A., Eskandarian, A. and Ghorai, P. A Comparative Study on Feature Descriptors for Relative Pose Estimation in Connected Vehicles, in 2021 International Mechanical Engineering Congress and Exposition. 2021 November 1–5. (Published)

Nayak, A., Eskandarian, A., and Doerzaph, D. Uncertainty Estimation of Pedestrian Future Trajectory Using Bayesian Approximation. In ME Graduate Symposium Poster session, 2022. (Published)

Stephen, N. Technology to Ensure Equitable access to Automated Vehicles for Rural Areas [Address]. Hyatt Regency Orange County, Garden Grove, California 92840, United States. July 20, 2022. https://trb.secure-platform.com/a/solicitations/96/sessiongallery/schedule/items/1299/application/8701 (Accepted).

## Books and Theses

Beard, M., Roan, M. J., Barry, O., & Tarazaga, P. A. (n.d.). *An evaluation of laboratory and test road environments and electric vehicle warning sounds and systems*. https://vtechworks.lib.vt.edu/handle/10919/111612 (Published)

O'Hara-Rhi V. (2022). *Evaluation of Urban Flood Hazard based on Remote Sensing and Machine Learning*. San Diego State University. (Accepted)

Sprott, W. 2022. *Microtransit in Small Towns: A Case Study of Nolanville, Texas*. Master's Professional Paper for the Master of Urban Planning Degree. (Accepted)

## Website(s) or Other Internet Sites

### 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. As the website is Safe-D's primary method of external interfacing, the Center is committed to providing up-to-date information through this public website using a modern, minimalist approach to rapid information sharing. The Safe-D website averaged over 430 users per month, with 2,582 new users during this period. Users viewed pages 7,950 times during this period, visiting an average of 2.2 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.

### Safe-D Researcher Portal

With 313 users at the end of this reporting period, the Safe-D Researcher Portal continues to successfully facilitate inter-consortium collaboration and access to Center-level resources across our geographically disperse universities. Safe-D has seen a decrease in users since the last reporting period due to the removal of some users who are no longer affiliated with Safe-D projects. The Safe-D leadership team has continued to use the portal to disseminate information to project teams and researchers interested in proposing projects to Safe-D. Information on the portal is continually updated so that research team members are aware of upcoming reporting deadlines, processes for the submission of deliverables, and other Safe-D project requirements. Safe-D does not expect this number to increase due to the grant coming to a close.

# Outcomes

The Safe-D projects described in the previous sections 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 11 outreach events to promote the program and projects to an audience totaling 2,186 compared to the previous reporting period of 10 outreach activities and 1,292 audience members. 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 | 11 |
| | Each Event: average 15 practitioners | 2186 |
| **Vendors Using** | Average 1/3 projects result in vendors using technology | 2 projects have resulted in vendors using technology |

| | | |
|---|---|---|
| **Technology Developed** | 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 | 1 |

## Increased Understanding and Awareness of Transportation Issues

- Project 05-091 Improving Methods to Measure Attentiveness through Driver Monitoring findings to date have increased the awareness regarding the status of advanced driver assistance systems (ADAS) and determined that distracted drivers remain a critical threat to the safety of all road users. Furthermore, advanced vehicle technologies can benefit from awareness of driver attentiveness for safe operation. Driver monitoring systems can address these driver-related shortcomings by monitoring the attentiveness of drivers to the driving task, whereupon notifications can be issued to either redirect a driver's attention to the forward roadway or, in the case of a vehicle equipped with ADAS, to resume manual control. However, these driver monitoring systems require algorithms to differentiate between driver states to make these time-critical assessments and decisions. Building on previous research and available datasets, the research will continue to develop and evaluate algorithm alternatives, demonstrating different techniques for determining driver attentiveness in real time. Driver monitoring systems will become increasingly available in the vehicle market, so effective use of the available output is critical for supporting the safe operation of ADAS, as well as countering distracted driving under manual control. Upon project conclusion, these algorithms will be broadly shared, along with guidelines on identifying inattentive drivers using only driver monitoring system output or output paired with other data sources.

- Project VTTI-00-032 E-Scooter Design researchers have worked to understand how e-scooter design, road infrastructure, and rider factors contribute to safety. Since the introduction of e-scooter fleet services in 2018, there have been an increase in e-scooter related injuries, and this number continues to increase each year.

- Project 06-008 Emerging Communications was focused on providing information about the types of communications that support intelligent transportation systems, traffic management, and connected vehicle environments including descriptions of the communication technologies, protocols, performance metrics, use cases, and data security.

- Project TTI-04-02 Delving into Safety Considerations of E Scooters: A Case Study of Austin, Texas researchers improved their understanding of e-scooter safety issues and potential causes of crashes. In addition to the technical project work, the graduate student of the project had a field trip examining e-scooter crash sites, which helped improve the knowledge about the impact of infrastructure and surroundings on safety.

- Project VTTI-00-023 E-Scooter Safety Assessment and Campus Deployment Planning is the data collected from researchers to make recommendations to campus officials and e-scooter practitioners on how to more safely deploy e-scooters.

- Project 05-086 A Data Driven Approach to the Development and Evaluation of Acoustic Electric Vehicle Alerting Systems for Vision Impaired Pedestrians built on previous research examining the impact additive sounds have on electric vehicle detectability by pedestrians. Alternate sound distribution methods were evaluated, as well as scientific, yet still FMVSS 141 compliant, sound profiles. Results demonstrate that a lab-based test environment may also provide an alternate method for evaluating candidate sounds. The majority of the localization algorithms used by AVs today either rely on detailed 3D maps or the presence of features such as buildings to help in the localization process. These,

however, are not suitable for use in rural areas, as these areas contain very few of those types of features. Project 06-004 Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas is investigating this by evaluating state of the art algorithms on rural road data. The researchers will then propose a novel approach to help solve this problem.

- Project TTI-05-02 Analysis of Advanced Driver-Assistance Systems in Police Vehicles will increase understanding and awareness regarding the status of advanced driver assistance systems (ADAS) in police vehicles, their limitations, and how to improve such technologies in future police vehicles.
- Project 05-113 Evaluation Tools for Automated Shuttle Transit Readiness of the Area evaluated an L4 automated shuttle's performance in a real-world environment, increasing awareness of automated system's shortcomings and safety concerns.
- Project TTI-05-04 Micromobility Safety Regulation: Municipal Best Practices Review plans to increase awareness and understanding the relationship of e-scooter regulations and e-scooter safety.
- Project 06-003 Critical Areas in Advanced Driver Assistance Systems Safety: Point of Sale and Crash Reporting's published report was the first to systematically look at the availability and costs of safety-related ADAS technologies by vehicle type and automaker. The researchers believe this is important information to share with policy-makers and advocates, particularly because people may be "priced out of safety" when these technologies are viewed as optional, and often luxury, items, and priced accordingly.
- Project 05-096 Curb Management Practices and Effectiveness in Improving Safety will provide new knowledge in curb management, as currently there is not a specific understanding of how curb management impacts safety for pedestrians and vehicles at curbside locations. The findings include information from case study locations and key takeaways in several topic areas in curb management. The researchers anticipate that the outputs could be applied by federal, state, tribal, municipal planning organizations, and local public agencies associated with traffic and vehicle management.
- 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 (ENDEAVRide) provided presentations and community open houses to students, professionals, and community stakeholders to enhance their understanding of the transportation needs of elderly populations.
- Project 06-007 Allusion 2: External Communication for SAE L4 Vehicles assists in understanding what external communication devices impact pedestrian crossing behavior, which can be applied to AV design and implementation.
- VTTI-00-024 Characterizing Level 2 Automation in a Naturalistic Driving Fleet plans to provide a greater understanding of how drivers are using L2-capable vehicles in the transportation system. Observing and understanding the context of when and where drivers activate and deactivate L2 features does not immediately impact the effectiveness of the transportation system. However, the results of this study may help inform what the potential impacts of L2 technology on the transportation system are and how L2 technology is used in the current transportation system. In turn, this information may be of benefit in shaping the transportation system to growing widespread availability of L2 technology in vehicles.
- Project VTTI-00-031 Evaluation of Eyes Off Road During L2 Activation on Uncontrolled Access Roadways plans to increase awareness and understanding of driver behavior when using vehicles equipped with Level 2 automated features.

- Project 04-117 A Sensor Fusion and Localization System for Improving Vehicle Safety In Challenging Weather Conditions plans to focus on the limitations of existing AV perception models in adverse weather conditions such as direct sun-glare, night-time, rain, fog, and others.

- Project VTTI-00-033 Human Factors of Level 3 Automation: Surprise Event Response Evaluation increases the understanding and awareness of transportation issues through the dissemination of the findings to industry partners and the broader transportation community. More specifically, the researchers increase the knowledge of how drivers respond to unplanned evasive maneuvers performed by an SAE L3 ADS. This topic has not been previously explored or discussed in the published research papers. However, understanding driver responses to these evasive maneuvers is critical to the design of SAE L3 ADSs. During this period, the researchers team increased the understanding and awareness of this important transportation issue by presenting the findings of our project to the industry champion and initiating the process for disseminating the findings to the broader transportation community by publishing the work in a journal submission. Additionally, the graduate student on this project presented project findings related to his Master's Thesis at the Human Factors and Ergonomics Society Annual International Meeting.

- Project 05-115 Cooperative Perception of Connected Vehicles for Safety will focus on relative pose estimation through direct and indirect methods as well as develop a cooperative prediction algorithm with uncertainty estimation for VRUs. This probabilistic prediction approach will ensure robust planning in CVs and will be achieved through both simulation and experiments in a mixed dynamic traffic environment. Hence the project will improve safety issues on critical hazards by mainly avoiding accidents through cooperative localization and planning among AVs and VRUs present on the road.

- Project 05-101 Evaluation of Transportation Safety Against Flooding in Disadvantaged Communities engaged with multiple stakeholders across the US through a webinar for transferring knowledge on the findings for informed future design of transportation network considering the flooding risks.

- Project 04-110 Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities equipped an intersection in the City of Chula Vista with cameras and other devices so that this location could be used as a test bed for proactive safety evaluations. The project team holds frequent meetings with the City of Chula Vista to discuss how ITMC can be used for proactive safety evaluation. This will directly aid in both researchers' and the City's understanding of the issues. In the long run, with the project outputs and T2 products, understanding and awareness of proactive safety analyses will be increased.

- Project 04-110 Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities equipped an intersection in the City of Chula Vista with cameras and other devices so that this location could be used as a test bed for proactive safety evaluations. The project team holds frequent meetings with the City of Chula Vista to discuss how ITMC can be used for proactive safety evaluation. This will directly aid in our understanding and City's understanding of the issues. In the long run, with the project outputs and T2 products, understanding and awareness of proactive safety analyses will be increased.

- Project 06-011 Evaluating the Safe Routes to School (SR2S) transportation program in socially vulnerable communities in San Diego County, California has compiled, collected data, and developed maps on socio-economic, accident/bicyclists data, behavioral transit data, infrastructure, crime, weather, land use data, among others indicators for the city of Chula Vista, California. A number of analyses have been developed using past Safe Routes to School survey data from routes along specific elementary schools to find connections to current transportation trends in hotspot areas within the city of Chula Vista, CA.

- Project 05-093 Automated Shuttles and Buses for All Users disseminated information on the use of automated shuttles by disabled individuals, including ways to enhance their use. The project also expanded the understanding of the importance of complete streets and the built environment as they pertain to the ability of disabled individuals to use automated shuttles.
- TTI-06-01 Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking researchers raised awareness of truck parking issues, new technologies, and truck parking needs among several stakeholders through meetings, conferences, and presentations.
- Project 06-001 Building Equitable Safe Streets for All: Data-Driven Approach and Computational Tools is investigating the relationship of roadway crashes, road infrastructure and socioeconomic and demographic characteristics in communities in Houston, TX, to gain a deeper understanding of the unequal distribution of traffic crashes and raise the awareness of transportation planners, and researchers, government and public.

## 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 can provide information for policy makers to allocate government funding and investment to better build safe streets for all communities especially, disadvantaged communities which are exposed to higher crash risks, and ensure environmental justice principles are considered in transportation planning.
- The results from project 06-003 Critical Areas in Advanced Driver Assistance Systems Safety: Point of Sale and Crash Reporting may influence the general public's input into the on-going update to the New Car Assessment Program (NCAP), a key method to rate safety of new vehicles and inform current calls by the NTSB for NHSTA to require standardized and mandatory provision of these safety technologies.
- The results from projects VTTI-00-032 E-Scooter Design and TTI-05-04 Micromobility Safety Regulation: Municipal Best Practices Review plans to affect e-scooter policymakers to improve the safety of e-scooters through the design of the e-scooter, deployment policies, and rider monitoring/training, and to inform policymakers when creating or amending e-scooter regulation.

## Increases in the Body of Knowledge

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

- The main focus of project 06-014 (Measuring the Safety of ADS: How safe is safe enough?) is how to develop a new data acquisition system (DAS), and what variables need to be included when designing a DAS in order to measure the safety of an ADS accurately.
- Project 06-010 Developing a Framework for Prioritizing Bicycle Safety Improvement Projects Using Crowdsourced and Image-based Data aims to develop a risk scoring method for prioritizing bicycle safety improvement projects in the county of San Diego. Caltrans has a great interest in this topic, as many bicycle bridges need to be improved to meet new standards. Due to the limited funding, Caltrans

would like to adopt a procedure to identify the locations that should be targeted first. The prioritization methodology will have a widespread applicability and can be adopted by Caltrans for other similar projects.

- Project 06-009 Enhancing Automated Vehicle Safety Through Testing with Realistic Driver Models developed data-driven models of driving behavior which are informed by active inference, a novel framework for cognition and behavior according to which the agent jointly perceives and acts upon the world so as to minimize the match between perceived vs preferred states of the world. The models obtained are based on real data from recorded driving behavior and are informed by sound neuroscience. Hence, these models would provide a better basis to study complex interactions in transportation systems.

## Enlargement of the Pool of Trained Transportation Professionals

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

- The results from project 06-008 Emerging Communications Training developed training programs designed for use by professionals employed at VDOT as well as students at Virginia Tech and the general public.
- Project 05-008 Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation is being completed through multiple discussions with data managers from the State Health Department and data scientists. These discussions have helped the health department professionals and data scientists understand the injury risk to pedestrians and pedalcyclists and associated demographic variations.
- During the data analysis stage of project VTTI-00-024 Characterizing Level 2 Automation in a Naturalistic Driving Fleet the research team will use an undergraduate student as an research assistant. This research assistant will assist with data reduction and analysis. The undergraduate student will have the opportunity to learn about naturalistic driving research methods, which will facilitate their growth as a transportation researcher. In addition, as part of the on-boarding process, the student will have the opportunity to learn about the body of literature related to this research topic, including the current understanding of drivers' use of L2 capable vehicles and takeover requests. In addition, the project will serve as the topic for at least one PhD dissertation. The process of writing the dissertation will allow the student to grow as a transportation researcher and shape their future contributions to the transportation workforce.

## Adoption of New Technologies, Techniques, or Practices

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

- The results from VTTI-00-032 E-Scooter Design will be provided to e-scooter companies to improve the design of their scooters, implement policy changes, and enhance rider training/monitoring for overall improvements in e-scooter safety.
- The results from VTTI-00-026 Guiding Driver Responses During Manual Takeovers from Automated Vehicles have increased understanding of the relative impact of the effectiveness of various human-machine interface strategies during control transfers (i.e., from Automated to Manual control). The effective presentation of takeover requests is critical to the safety and adoption of new in-vehicle technologies.

- Project TTI-05-01 Connected Vehicle Data Safety Applications is exploring the unanswered question of whether commercially available CV data derived from automotive OEMs can be used for roadway safety applications. The idea is that if leading crash risk indicators can be developed from CV data, then areas of safety concern can be detected before crashes occur, thereby saving lives, time, and resources. Some major automotive OEMs have developed tools to access and visualize the data generated by their CVs but are still lacking the ability to provide risk-based conclusions.

- Traditionally, transportation management centers (TMCs) mainly focus on strategies to improve operational efficiency, congestion management, incident management, and traveler information dissemination. TMCs are not typically utilized to assess safety. Project 04-110 Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities adopts safety surrogate measures (SSM) and visual analysis to proactively assess safety at signalized intersections by identifying near crashes.

- Project 06-001 Building Equitable Safe Streets for All: Data-Driven Approach and Computational Tools aims to investigate the association between roadway crashes and road infrastructure as well as the socioeconomic and demographic characteristics of communities. The first challenge faced by the team is data availability. The difficulty of the project is there is no adequate road infrastructure data in the Houston city area, especially geographic information system (GIS) sidewalk data. Hence, this project will apply machine learning algorithms to extract the sidewalk data from street view images. The approach used in this project can also be applied in other area which lack road infrastructure data in GIS format through extraction roadway infrastructure data from street view images

# 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. For example, the outcomes of 05-091 Improving Methods to Measure Attentiveness through Driver Monitoring may be applied by industry and suppliers as driver monitoring systems become more commonplace. As availability increases, making use of the available output can be used to help address cases of distracted driving, or inattentive driving while using limited automation, as two primary examples.

### Provision of Tools/Methodologies for Practitioners

Safe-D projects have provided, or are expected to provide, new tools and methodologies that can be applied by practitioners to enhance the effectiveness of the nation's transportation system. Some examples include the following:

- The outcome of VTTI-00-032 E-Scooter Design will help to improve overall e-scooter safety so that e-scooters can continue to be used by all members of the public, which will help the effectiveness and efficiency of the transportation system.

- Project 06-001 Building Equitable Safe Streets for All: Data-Driven Approach and Computational Tools directly investigates the equity issue in traffic safety among communities. By summarizing previous research, this project will produce a literature review about the association of roadway crashes, road infrastructure and socioeconomic and demographic characteristics in place-based crash research at community level. The literature review will provide a better understanding of the crash-contributing

factors from road infrastructure and socioeconomic and demographic characteristics and the equity issue in roadway crashes across communities. In addition, this project will conduct empirical research in the city of Houston, investigating the disparity in roadway crashes and their association with road infrastructure. The results of the empirical study will provide scientific information for policy makers and transportation planners to better allocate investment sin road infrastructure to ensure environmental justice for all kinds of communities.

- Work zone personnel are vulnerable and at risk of being struck by passing motorists when they routinely work in roadway rehabilitation and reconstruction projects. Project TTI-05-03 Development of a Roadside LiDAR-Based Situational Awareness System for Work Zone Safety: Proof-of-Concept Study will provide an active way to protect construction workers and reduce the risks of vehicle intrusions.

- Results from Project 05-086 A Data Driven Approach to the Development and Evaluation Of Acoustic Electric Vehicle Alerting Systems for Vision Impaired Pedestrians can be used to improve effectiveness of additive warning sounds for electric vehicles, aiding in detectability by pedestrians. This, in turn, improves safety for pedestrians, particularly the vision impaired who rely on hearing to determine when it is safe to cross roads.

## 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:

- Findings from Project 06-014 (Measuring the Safety of ADS: How safe is safe enough?) can be used by OEMs when designing and measuring the safety of ADS in order to have a standardized rating of the impact of their technologies.

- The findings from Project 05-086 A Data Driven Approach to the Development and Evaluation of Acoustic Electric Vehicle Alerting Systems for Vision Impaired Pedestrians will provide a guide for new technology that can be used to improve the effectiveness of additive warning sounds, specifically how to achieve a more uniform sound distribution around the vehicle. Depending on the results and production-viability, it could be an approach implemented by OEM vehicle manufacturers.

- 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 fosters a community of engineers dedicated to open-source self-driving technology. They are passionate about using technology to serve the elderly and people with disabilities. They are convened by our key industry partner, Wocsor LLC, in a Discord channel called RetroPilot. This channel now has 1,300+ members. Numerous new techniques and skills have been created in this channel. Wocsor LLC aims to become an industry's leader on using self-driving technologies to serve vulnerable populations.

- Project VTTI-00-034 Sensor Degradation Detection Algorithm for Automated Driving Systems investigates foundational work to advance the critical area of degraded sensor models to industry. The detection algorithm has paths to commercialization for implementation into manufactures products, use in 3rd party evaluations, or to guide research for determining regulations relative to ADS performance

specifications and component specifications. The sensor model work carried out in this project will help fill the identified gap for industry.

- The findings in Project VTTI-00-036 Smart Work Zone System will improve safety for construction workers. The system implementation progress is actively shared with the VDOT team who has shown interest in using the technology in work zone deployments in Virginia. The VDOT team provides feedback and advice on how the system can meet the work zone safety requirements and be deployed in real work zones.

## 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.

- The safety of micromobility transportation systems is an important aspect of a healthy and sustainable urban area. E-scooters have become popular in large cities around the world, leading to increased sharing of urban space, especially with bicycles. It is essential to understand the nature of injury severity and its contributing factors for—as well as the differences and similarities between—e-scooters and bicycles. During the last biannual time period, Project TTI-04-02 Delving into Safety Considerations of E Scooters: A Case Study of Austin, Texas, utilized data from the Texas Department of Transportation Crash Records Information System on 153 e-scooter related and 819 bicycle-related crashes from 2018 to 2021 in the city of Austin. The results of the data analysis shed light on the similarities and differences in the contributing factors that influence the crash injury severity of e-scooter and bicycle riders. This information can help designers and policymakers make better decisions regarding the safe and efficient use of (shared) space in urban environments.

- The research utilized in Project 05-113 Evaluation Tools for Automated Shuttle Transit Readiness of the Area developed a new method in relating naturalistic driving study data to infrastructures. More specifically, it provides a better understanding of automated system performance under different infrastructure elements presents. From the results, researchers can understand different safety concerns, if any, posed by infrastructure elements.

- Findings from project 05-115 Cooperative Perception of Connected Vehicles for Safety will improve transportation safety in CVs. Cooperative perception and planning algorithms will be developed, which can be applied for on-road AVs in heterogeneous traffic scenarios.

- Findings from project 04-110 Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities will utilize safety surrogate measures (SSM) and visual analysis to proactively assess safety at signalized intersections. The ITMC will adopt disruptive technologies that perform machine learning in situ to detect road users in real-time. Known as inferencing at the edge, these technologies allow one to perform computationally intensive artificial intelligence (AI) calculations on the device without needing to transfer streaming video to a centralized facility to perform calculations. There is currently limited research on this topic.

## 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.

### Learning Experiences and Building the Future for the Next Generation

Safe-D projects have contributed to the development of the transportation workforce through direct engagement with both K-12 students and students at the undergraduate and post-graduate levels.

- Project 06-009 Enhancing Automated Vehicle Safety Through Testing with Realistic Driver Models has provided opportunities for research and teaching in transportation and related disciplines. This project has enabled the continued development of a course aimed at introducing recent advances in the state-of-the-art in human perception and decision making. The project has involved undergraduate students in different aspects of the research agenda and has leveraged ongoing interactions with HBCU institutions to ensure diverse participation and to undertake outreach activities. The project has improved the performance, skills, or aptitudes of members of underrepresented groups that will improve their access to or retention in transportation research, teaching, or other related professions. The project developed and disseminated new educational materials or provided scholarships.

- The outputs from project 06-003 Critical Areas in Advanced Driver Assistance Systems Safety: Point of Sale and Crash Reporting provides an opportunity for undergraduate students to receive hands-on experience with the entire research process along with insights into the transportation profession. All of our current undergraduates are from underrepresented groups. We hope this greatly enriches their undergraduate experience and results in them becoming transportation professionals in the future.

- Project VTTI-00-033 Human Factors of Level 3 Automation: Surprise Event Response Evaluation will impact transportation workforce development though the creation and dissemination of the EWD products being developed by the project team. These products will include a module on how to effectively train as an experimenter to simulate an ADS. This is important because few ADSs are available for research teams to utilize to answer research questions about such systems. Thus, learning how to implement this method will provide students the opportunity to learn about a potentially new research method to utilize in their own research projects or future professional work. In addition. the project will create a module for students to practice human factors design principles for the design of the test vehicles used to simulate ADSs. Finally, this project has impacted transportation workforce development through the opportunities afforded to the graduate student working on the project. This student has gained important knowledge on designing research studies, conducting on-road data collection, performing data analyses with time-series and eye glance data, writing research reports, writing journal articles, writing conference articles, presenting at research conferences, and presenting to industry members.

- Project TTI-05-01 Connected Vehicle Data Safety Applications uses a big data source that requires data engineering, science, and analytical skills in order to access, process and analyze data appropriately. It is these skills and the CV data nuances that we the project intends to share through educational materials and workshops designed for students and working professionals. The research team aims to reduce the learning curve for others so that CV data may be used in design and safety applications. These skills will be highly sought after once TxDOT, TTI researchers, and private consultants begin using the CV data.

### Development of Educational Tools and Courses

In addition to the students working directly on Safe-D projects, Center research has reached a broader spectrum of students through the development of educational materials and content for college courses. These outputs range

from teaching modules to classroom exercises based on real-world problems to web-based presentations. Specific examples of educational content produced by Safe-D projects in this reporting period are summarized below.

- Project 04-113 Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements incorporated some of the findings of this study into a graduate course titled CVEN 626 - Highway Safety, provided by TAMU. The lectures will provide the opportunity to discuss the findings of this study with interested individuals and can result in attracting students from all engineering disciplines to work on this subject. Relevant content has also been incorporated in a highway safety textbook recently published for Elsevier Science. The team will also explore the potential for incorporating data and information from this study into course assignments and projects. The students involved in this will project learn how to assemble data, apply statistical techniques related to the validation of data, and develop SPFs. The research team also delivered a webinar that targeted students, faculty, researchers, practitioners, and representatives from federal organizations and the private industry.

- The outcomes from Project 06-010 Developing a Framework for Prioritizing Bicycle Safety Improvement Projects Using Crowdsourced and Image-based Data will be used to develop materials for use in courses offered from both the Civil, Construction, and Environmental Engineering (CCEE) department at SDSU and the Civil Engineering department at VT. The project is expected to develop materials for a CIVE 696 Intelligent Transportation Systems course at SDSU and a SPIA 2314 Active Transportation course at VT. The project provides funding for graduate students. Students will assist in all project tasks, and it is expected that the project will become parts of their theses. With recent advancement in transportation technology, communication, computing, and visualization, it is imperative to educate future transportation engineers and leaders on how cutting-edge technology can be utilized in safety planning.

- Project 04-110 Developing an Intelligent Transportation Management Center (ITMC) will develop materials from their results for use in courses offered from both Civil, Construction, and Environmental Engineering (CCEE) and Electrical and Computer Engineering (ECE) departments at SDSU. The project provides funding for graduate students in CCEE and ECE departments. Students will assist in all project tasks, and it is expected that the project will become parts of their theses. With recent advancement in transportation technology, communication, computing, and visualization, it is imperative to educate future transportation engineers and leaders on how cutting-edge technology can be utilized to develop advanced safety monitoring systems. The project will also build a test bed that can be used by students, faculty, and practitioners to test different technologies, methodologies, and practices that can be utilized for safety evaluation.

- 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. The work is likely to make an impact on transportation workforce development by providing guidance for DOTs, metropolitan planning offices, and other transportation agencies to address truck parking availability safety issues.

# Changes/Problems

## Changes in Approach

None to report

# Actual/Anticipated Problems/Delays

### Impact of COVID-19

Safe-D output goals such as facility tours, workshops, etc., improved; however, some projects have continued to struggle due to COVID-19. Despite these challenges, cancellations, postponements, and adjustment to virtual methods for these output measures have not deterred Safe-D from achieving success in reaching our goals. During this reporting period, 12 Safe-D projects reported that research activities had been impacted by COVID-19 in some way. Among these projects, 2 reported minor impacts, 8 reported moderate impacts, and 2 reported significant impacts from COVID-19. Projects that were impacted by COVID-19 reported the biggest effects during the months of January to March. The number of projects as decrease from last reporting cycle; however, the moderate impact experienced has increase. Below are a list of specific projects that experienced delays due to COVID-19:

### Safe-D Projects Reporting Minor Impacts

- VTTI-00-032 E-Scooter Design
- 05-096 Curb Management Practices and Effectiveness in Improving Safety05-093 Automated Shuttles and Buses for All Users

### Safe-D Projects Reporting Moderate Impacts

- VTTI-00-023 E-Scooter Safety Assessment and Campus Deployment Planning
- Project 01-002: Countermeasures to Detect and Combat Driver Inattention While Driving Partially Automated Systems
- TTI-05-04 Micromobility Safety Regulation: Municipal Best Practices Review
- VTTI-00-036 Smart Work Zone System
- 06-006 Private 5G Technology and Implementation Testing
- 05-008 Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation
- 05-115 Cooperative Perception of Connected Vehicles for Safety
- 06-011 Evaluating the Safe Routes to School (SR2S) transportation program in socially vulnerable communities in San Diego County, California

### Safe-D Projects Reporting Significant Impact

- TTI-05-02 Analysis of Advanced Driver-Assistance Systems in Police Vehicles
- TTI-04-02 Delving into Safety Considerations of E Scooters: A Case Study of Austin, Texas

The Safe-D administration is continuing to work individually with each project team to determine how to best adjust project activities to minimize delays and ensure continued research progress.

# Changes Affecting Expenditures

Nothing to report.

## Changes in Study Protocols

Nothing to report.

## Changes in Performance Site Location

Nothing to report.

# Special Reporting Requirements

N/A