SEMI-ANNUAL PERFORMANCE REPORT

APRIL 2021 TO SEPTEMBER 2021

SAPR #9

SAFE-D: SAFETY THROUGH DISRUPTION UNIVERSITY TRANSPORTATION CENTER

SAN DIEGO STATE UNIVERSITY

Texas A&M Transportation Institute

VIRGINIA TECH TRANSPORTATION INSTITUTE
VIRGINIA TECH

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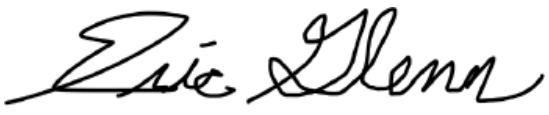
Signature of Submitting Official	

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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

Safe-D did not solicit research proposals during this reporting period. However, Safe-D funded multiple directed projects along with rescoping projects from the previous call for proposals. Directed projects were awarded by the Safe-D team based on a high impact merit, opportunity to work with strong collaborators, resource availability, and having a diversity equity or inclusion component. Nearly all awards made during this reporting period received matching funding from industry sponsors, meeting or exceeding the federal funding match requirement. Industry partners for projects from this round of awards includeThe Global Center for Automotive Performance Simulation, Commonwealth Cyber Initiative Cyber Security Research Collaboration, Ford, the Insurance Institute for Highway Safety, and the Virginia Department of Transportation.

At the end of this reporting period, the Safe-D National UTC had a project portfolio of more than $28.0 million, with over one-half of project funding sourced from non-federal matching funds. Safe-D projects are selectedaccording to their focus on four Center theme areas: automated vehicles, connected vehicles, 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%.

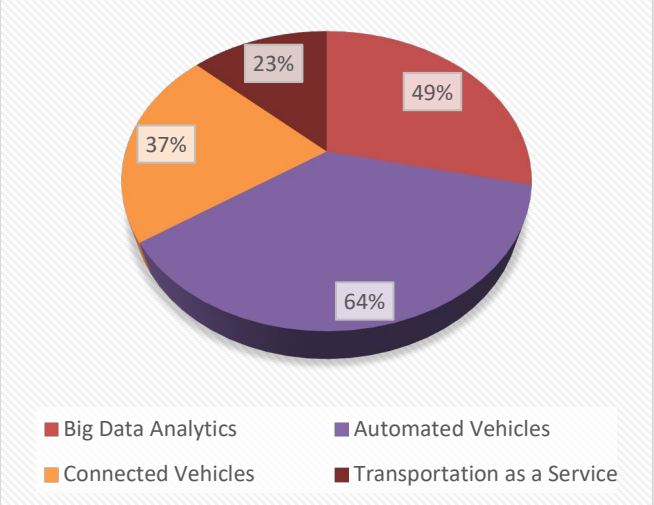

Figure 1.Portfolio of Safe-D Projects by Theme Area (total exceeds 100% due to projects covering multiple theme

The Safe-D Leadership Team feels strongly that the projects awarded during this reporting period contribute to the overall Safe-D vision and mission. The Leadership Team is excited about the potential of these projects to maximize the safety of disruptive technologies as they areintegrated into our transportation

system. 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 06-001: Building Equitable Safe Streets for All: Data-Driven Approach and Computational Tools

Institution(s): TTI, VTTI; Award Round: Fall 2021; Theme Area(s): Automated Vehicles

This project explores what types of curb management practices can improve safety for all pedestrians and vehicles in multimodal environments. It will address how vehicles in a multimodal environment are managed and prioritized at curb loading and unloading zones between different public and private vehicles and/or use cases. The research will analyze the effectiveness of curb management practices in improving safety through reduced collisions with pedestrians and other vehicles. The research will look at current curb management practices across large and small urban areas in U.S., including use of technology, temporal management, street design and infrastructure, zoning for mode uses and prioritization, traffic monitoring, policies and regulations, permitting and monetization, and enforcement. The project will gather data and learn about safety outcomes as a result of the curb management practices in place and measure their effectiveness in reducing different kinds of collisions.

Project 06-002: Developing AI-driven Safe Navigation Tool

Institution(s): TTI; Award Round: Fall 2021; Theme Area(s): Big Data Analytics, Automated Vehicles, Transportation as a Service

This study aims to make a unique contribution to the identified theme areas by developing a robust, AI-driven, safe navigation tool, which can provide an informed decision of the safest route instead of providing several uninformed decisions, as offered by current navigation tools. Traffic crashes are a leading cause of death in the U.S. Conventional safety evaluation methods incorporate safety modeling to determine roadway risk scoring and provide these risk maps in non-reproducible format. These risk maps are not useful to roadway users in their daily roadway trips. On the other hand, popular navigation applications such as Google Maps and Apple Maps provide distance-based or travel time-based alternative routes with no real-time risk scoring. There is a need for a real-time navigation system that can provide data-driven decision on the safest path or route. When conducting safety prediction by using multiple big data sources, AI-driven algorithms perform better than conventional statistical models.

Project 06-003: Critical Areas in Advanced Driver Assistance Systems Safety: Point of Sale and Crash Reporting

Institution(s): TTI; Award Round: Fall 2021; Theme Area(s): Big Data Analytics, Automated Vehicles

This project addresses gaps that create a substantial safety risk where salespeople, drivers, and law enforcement may not understand the correct use and limitations of advanced driver assistance systems (ADAS). ADAS seek to alert a driver to critical events or even intervene to prevent crashes; however, they aren't available equally across the passenger vehicle fleet. ADAS variables are not currently included in the Model Minimum Uniform Crash Criteria guidelines and thus are unlikely to exist on crash reports for most states. Realizing the full benefit of ADAS relies on salespeople, consumers, and law enforcement personnel understanding these systems' benefits and limitations in improving traffic safety. Through three interrelated studies, this project will investigate the state of knowledge and current practices on how ADAS technologies are marketed, sold, and demonstrated at point-of-sale; how information on ADAS is collected in crash reports; and what existing crash data reveal about the state of knowledge on ADAS in crash involvement.

Project 06-004: Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas

Institution(s): TTI; Award Round: Fall 2021; Theme Area(s): Big Data Analytics, Automated Vehicles

The objective of this project is to develop an efficient sensing and navigation system for small and rural communities (SRCs) that uses crowdsourced topological maps, such as Open Street Map (OSM). The system is intended to provide high-level road network information in concert with onboard sensing systems that include LIDAR and cameras to localize and provide navigation guidance to an autonomous vehicle. A large number of rural roads in the U.S. do not have lane markings and have irregular boundaries. The system will be tested and validated on a large number of rural roads in the SRCs around College Station, TX.

Project VTTI-00-023: E-Scooter Safety Assessment and Campus Deployment Planning

Institutions: VTTI*; Award Round: Fall 2021; Theme Area(s): Transportation as a Service, Big Data Analytics

E-Scooters are a new service that provides last-mile transportation as well as the potential to replace car trips and make transit more pleasant. Safety concerns for riders and other users in right-of-way situations have been reported in areas where e-scooters have already been deployed. Given the limited existing formal research, VTTI teamed with Spin to deploy e-scooters on Virginia Tech's campus, some of which have been instrumented with data acquisition systems. Collected data will be used to assess safety impacts, behaviors exhibited by riders and other road users, and ways that kinematic or other data may be used to predict potentially dangerous behavior and inform corresponding countermeasures. Fixed roadside cameras were also deployed to evaluate a variety of additional measures through a classification system designed by the team.

*Note this project was previously awarded. It was awarded additional funds to expand the scope of the project.

Project 06-005: Automated Truck Mounted Attenuator: Phase 2 Performance Measurement and Testing
Institution(s): VTTI; Award Round: Fall 2021; Theme Area(s): Automated Vehicles, Connected Vehicles
This project seeks to develop an automated control system for TMA vehicles using a short following distance, leader-follower control concept, which will remove the driver from the at-risk TMA vehicle. Truck-Mounted Attenuators (TMAs) are energy-absorbing devices added to heavy shadow vehicles to provide a mobile barrier that protects work crews from errant vehicles entering active work zones. In mobile and short-duration operations, drivers manually operate the TMA, keeping pace with the work zone as needed to function as a mobile barrier protecting work crews. While the TMA is designed to absorb and/or redirect the energy from a colliding vehicle, there is still a significant risk of injury to the TMA driver when struck. TMA crashes are a serious problem in Virginia. The most effective way to protect TMA drivers may be to remove them from the vehicle altogether.

Project 06-006: Private 5G Technology and Implementation Testing
Institution(s): VTTI; Award Round: Fall 2021; Theme Area(s): Automated Vehicles, Performance Measures

NEC has developed a Video Analytics implementation for traffic intersections using 5G technology. This implementation includes both hardware infrastructure and software applications supporting 5G communications which will allow low latency and secure communications. VTTI will work with NEC to facilitate the usage of a 3400-3500 MHz Program Experimental License (PEL) license band without SAS integration to implement a private 5G deployment at VTTI Smart Road intersection and Data Center. Specific use cases will be developed to provide alerting mechanisms to both pedestrians and vehicles using C-V2X/PC5 technology.

Project 06-007: Allusion 2: External Communication for SAE L4 Vehicles
Institution(s): VTTI; Award Round: Fall 2021; Theme Area(s): Automated Vehicles, Transportation as a Service, Vulnerable Users, Vehicle Technology
This project will focus on determining pedestrian and driver decision making in the presence of Level 4 vehicles with external communication displays on the Smart Road. With SAE L4 or Highly Automated Vehicles (L4+ Vehicles) integration into our environment, the development of external communication systems is essential. Mixed fleets, comprised of both human drivers and automated vehicles, must be able to effectively communicate with each other. Most research on L4 vehicle external communication has been conducted using simulator or virtual reality platforms to assess driver/road user knowledge, opinions, and attitudes via survey metrics evaluating a single L4 vehicle. However, it is vital to understand how the external communication is perceived in real world conditions and with multiple L4 vehicles present.

Project TTI-06-01: Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking
Institution(s): TTI; Award Round: Summer 2021; Theme Area(s): Connected Vehicles, Big Data Analytics
This project will address the safety concerns that arise from commercial truck parking shortages nationwide and the dangers of fatigued drivers attempting to find safe locations for parking to meet with National Hours-of-Service regulations. The study will aid transportation agencies in developing solutions to the parking availability problem by identifying effective methods for using data to estimate truck parking demand and areas of parking opportunity, assessing available data sources for estimating truck parking demand and supply, and determining the safest connected vehicle solutions for distributing information on parking availability directly to drivers.

Project TTI-06-02: The Future of Parking: Safety Benefits and Challenges
Institution(s): TTI; Award Round: Spring 2021; Theme Area(s): Connected Vehicles, Automated Vehicles*

This project will address looming concerns about the lack of parking facilities in relation to crashes, injuries and fatalities which occur as a result of needed design changes to accommodate for new emerging technologies such as self-parking features. The research team will identify potential design changes and self-parking penetration scenarios to improve safety. Expected changes to parking and street design will be assessed in terms of the reduced number of conflicts for pedestrians and other vehicles using microsimulation techniques.

Project TTI-Student-08: Identifying Deviations from Normal Driving Behavior
Institution(s): TTI; Award Round: Summer 2021; Theme Area(s): Connected Vehicles, Big Data Analytics*
The goals of this project are to identify relevant datasets for ADAS error prediction, evaluate modeling approaches for predicting driver errors during ADAS use, and developing models to proactively predict driver errors. Results from the project will be used to guide data collection system design at automakers and develop predictive modeling benchmarks.

Project TTI-Student-09: Evaluating Emotion Regulation Techniques for Supporting Driving Safety and Performance

Institution(s): TTI; Award Round: Spring 2021; Theme Area(s): Connected Vehicles, Big Data Analytics*

This project will determine effective methods that ultimately improve driving safety, two classes of Emotion Regulation Techniques (ERTs) will be evaluated in this study: those that are classified as "overt", such as explicitly prompting drivers to perform a cognitive reappraisal of the situation, and those classified as "covert", such as introducing subtle cues that influence physiological systems, such as synchronizing breathing patterns in a manner that is effective in regulating emotions. .

Completed Projects

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

- 03-049: Data Fusion for Non-Motorized Safety Analysis
- TTI-Student-06: Quantifying the Benefits and Harms of Connected and Automated Vehicle Technologies to Public Health and Equity
- TTI-Student-08: Identifying Deviations from Normal Driving Behavior
- 04-117: A Sensor Fusion and Localization System for Improving Vehicle Safety In Challenging Weather Conditions
- 05-098: Crashworthiness Compatibility Investigation of Autonomous Vehicles with Current Passenger Vehicles

[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.

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:

- 03-049: Data Fusion for Non-Motorized Safety Analysis
- 04-098: Data Mining Twitter to Improve Automated Vehicle Safety
- 04-104: Development of a Connected Smart Vest for Improved Roadside Work Zone Safety
- 04-113: Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements
- 04-115: Reference Machine Vision for ADAS Functions
- SDSU-01-01: Prediction of Vehicle Trajectories at Intersections Using Inverse Reinforcement Learning
- VTTI-00-022: Automated Truck mounted Attenuator
- TTI-Student-07 Detecting Pavement Distresses Using Nexar Work Zone Images

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 453 graduate and 996 undergraduate students. Safe-D research projects supported 43 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	25	8
Masters	6	6
PhD	16	6

Highlighted EWD & Other Outreach Activities

- Safe-D Project VTTI-00-033 (Human Factors of Driving Automation: Surprise Event Response Evaluation) researcher, Nicholas Britten, participated in the Northern Virginia Science Fair as a judge.
- Safe-D project TTI-06-01 (Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking) researchers presented to the Girl Scouts of New Jersey.
- Safe-D Project VTTI-00-023 (E-Scooter Safety Assessment and Campus Deployment Planning) was featured in an Exponentially More Stories article for their research efforts.
- Safe-D Project 05-093 (Automated Shuttles and Buses for All Users) held a one-day session on June 17, which introduced individuals with mobility and visual impairments to the Arlington RAPID Shuttle.
- Safe-D Project VTTI-00-028 Driving Risk Assessment Based on High-frequency, High-resolution Telematics Data was featured in the Augusta Free Press and Virginia Tech Exponentially More Stories for their work in driver safety.
- The Texas A&M University Student Chapter of the Institute of Transportation Engineers (TAMU-ITE) visited TTI on July 15 for presentations on Safe-D projects. See Figure 2.

Figure 2. Michael Martin is shown here presenting on data fusion topics from his project "Connected Car Data Safety Applications"

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 site in the webinar archive tab. Safe-D was able to increase the average number of webinar attendees during this reporting period to 26. The total number of YouTube views for all Safe-D webinars during this reporting period was 182. 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 is 153.

Safe-D Upcoming Webinar Series

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

Data Fusion for Non-Motorized Safety Analysis

Safe-D is currently working with the authors of project 03-039 Data Fusion for Non-Motorized Safety Analysis Roadside Work Zone Safety to provide a webinar scheduled for November 18 at 2 p.m. EST. The webinar will be hosted by Dr. Ipek Senser and Silvy Sirajum Munira. Nonmotorized activity, despite sharing a low percentage of total trips in the U.S., contributes to a disproportionate share of total fatal and serious injury crashes. The exigency

of the issue has alarmed safety advocates in multiple areas, resulting in their persistent efforts to explore and develop evidence-based, data-driven strategies to reduce nonmotorized crashes. However, such efforts are often stonewalled due to a lack of robust and reliable exposure measures. This webinar presents a Safe-D research study, which explored an emerging research territory—a fusion of nonmotorized traffic data for estimating reliable and robust exposure measures. The research was divided into three sequential stages. The first stage involved developing and applying a guideline to process and homogenize available data sources to estimate annual average daily bike volume at intersections. The research team selected the City of Austin as the study area, gathered five bike data sources (using both traditional and crowdsourced data sources) and developed bike demand models to be used as inputs into the fusion mechanisms developed as part of the study. The second stage was focused on developing and applying the fusion framework, demonstrating the efficacy of multiple fusion algorithms, including two novel mechanisms, suited to the data characteristics and based on the availability of actual counts. The analysis of actual and simulated data illustrated that the fusion methods outperformed the individual estimates in most cases. In the third stage, the fused data were applied in both macro (hot-spot analysis in block group level) and micro (individual safety-related perception) models in Austin to ascertain the significance of incorporating exposure in safety analysis. While the fusion framework contributes to the research in the field of decision fusion, the demand and crash models provide insights to help stakeholders formulate policies to encourage bike activity and reduce crashes.

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:

- Dr. Miguel Perez received the Liviu Librescu Faculty Prize, Gold Pen, and Leader in Teaching awards/honors from the Department of Biomedical Engineering and Mechanics.
- TAMU Student Chapter lead by Safe-D student Hananeh Alambeigi received the Gold Award in recognition of outstanding chapter service to the members for the 2020–2021 academic year from the National HFES - Human Factors and Ergonomics Society.
- Dr. Maryam Zahabi received the Stephanie Binder Young Professional Award, 2021
- Farzaneh Shahini received the Student Travel Award
- Nicholas Britten was honored with the Virginia Tech Department of Industrial and Systems Engineering Masters Student of the Year
- Dr. Ioannis Tsapakis received the TTI Research Award
- Dr. Azim Eskandarian was honored with the best 2020 paper award in the *SAE International Journal of Connected and Automated Vehicles* and the Vincent Bendix Automotive Electronics Engineering Award
- Dr. Reza Akhavian received the National Science Foundation Career Award
- Silvy Munira received the Andy Mullins Transportation Planning Fellowship
- Alexandria Ida Rossi-Alvarez received the Student of the Year award

Dissemination of Results

Research Project Results

Research results from Safe-D projects continued to be finalized during this reporting period. Safe-D researchers have been submitting and publishing results of their projects in peer-reviewed journals and presenting results at conferences nationwide. The publications, presentations, theses and dissertations, websites, and more avenues of dissemination reported thus far by researchers are listed in the Outputs section of this report. Project teams have also actively disseminated the results of their research projects through outreach, EWD, and T2 events, including those listed in the Highlighted EWD & Other Outreach Activities section.

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 DEI related projects that 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 intends to allocate some of the remaining funding to additional DEI in transportation-related projects, specifically projects that help address the lack of sufficient diversity, equity, and inclusion in transportation. Safe-D will also update our survey collections to determine which projects currently have DEI components. The current count for Safe-D projects with a DEI component was 11.

During this reporting period Safe-D was able to find 10 more projects with DEI components based on information provided by researchers, bringing the new total to 21 projects with a DEI component. Most of these projects seek to assist individuals within low income and disabled communities.

Safe-D is also proud to announce that during this reporting period, we fulfilled the commitment we made to our Hispanic-Serving Institution partner, SDSU, since being award the federal UTC grant for a better-quality student and research lab for their transportation group (see figure 3 below).

Figure 3. Newly renovated research lab at SDSU.

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 VTTI-00-036 (Smart Work Zone System) members collaborated with the Virginia Tech Apparel, Housing, and Resource Management for design support for Smart Vest pouch.
- Project VTTI-00-034 (Sensor Degradation Detection Algorithm for Automated Driving Systems) researchers collaborated with Old Dominion University collaborative research.
- The Virginia Department of Transportation assisted Project 05-113 Evaluation Tools for collaborated researcher
- TTI-Student-08 (Identifying Deviations from Normal Driving Behavior) Toyota CSRS and State Farm.
- Project VTTI-00-024 (Characterizing Level 2 Automation in a Naturalistic Driving Fleet) researchers collaborated Automated Mobility Partnership on guidance on establishing suitable standard variables to encompass L2-state data across vehicles
- Project VTTI-00-032 (E-Scooter Design) researchers collaborated with Ford Motor Company and Spin for receive financial support and assistance in data collection
- Project VTTI-00-023 (E-Scooter Safety Assessment and Campus Deployment Planning with Spin and Ford Motor Company for research and financial support.
- VDOT assisted Project 04-113 (Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements) in development.
- Project TTI-05-02 (Analysis of Advanced Driver-Assistance Systems in Police Vehicles) researchers partnered with Texas A&M Engineering Extension Services to assist with recruiting police officers from police departments.
- Project VTTI-00-027 (An Evaluation of Road User Interactions with Automated Shuttles) researchers worked with Daimler, Ford, and State Farm for funding, guidance on research questions, and feedback on scenario development.
- Project 05-087 (Autonomous Delivery Vehicle as a Disruptive Technology: How to Shape the Future with a Focus on Safety?) researchers partnered with Wayne State University and Genex assistance in data collection.
- Project VTTI-00-036 (Smart Work Zone System) researchers collaborated for financial, and research supports.
- Project TTI-06-01 (Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking) researchers partnered with Maryland DOT to receive in-kind and INRIX data..
- Project VTTI-00-027 (An Evaluation of Road User Interactions with Automated Shuttles) researchers worked with Daimler, Ford, and State Farm for funding, guidance on research questions, and feedback on scenario development.
- Project TTI-05-01 (Connected Vehicle Data Safety Applications) partnered with 3M financial support and General Motors for research support.
- Project 05-096 (Curb Management Practices and Effectiveness in Improving Safety) researchers collaborated with City of Roanoke, VA and San Francisco Municipal Transportation Agency for in-kind.
- Project VTTI-00-033 (Human Factors of Driving Automation: Surprise Event Response Evaluation) researchers partnered with For Motor Company for research support.
- Project 04-110 (Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities) members partneredwith the City of Chula Vista for research support.

International and Proprietary Collaborators

- Some Safe-D projects have involved collaboration with teams 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 2,391 visitors during the 6-month reporting period. With the 1,916 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 4,218 visitors from October 1,2020 to September 30, 2021. Project Page visits averaged just over 37 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	2,391; 4,218 visitors/previous 12 mo.
	Project Pages: Average ≥ 150 visitors/year	3,434 total visits/period; average 37 visitors/project page
Journal Articles/Conference Presentations	Project Teams: 1 article/year	9 articles; 0.21 average per reporting project
	Project Teams: 1 conference/year	4 presentations; 0.10 average per reporting project
Facility Tours	Displays viewed by ≥ 200/year	304 total visitor views; average of 7.1 views per reporting project
	Follow-up Interest: 5 visitors/year	2

As in the previous reporting period, COVID-19 has continued to affect facility tours, conferences, and more. Details about how COVID-19 has affected Safe-D projects can be found in the COVID section. Prior to this reporting period, a total of 38 projects had been completed, resulting in 71 journal articles and 102 conference presentations.

Within this reporting period, 5 additional projects were completed and a total of 9 new journal articles with 4 new conference presentations were reported by project teams. These additions bring the average rate of publications per completed project to 2 journal articles per project and 2.4 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 304 views of Safe-D displays during outreach events during the 6-month reporting period; last period, researchers reported 7,114 views, bringing the yearly total to 7,418, which greatly exceeds with the annual goal of 200 views.

Publications, Conference Papers, Presentations, Books and Thesis

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

Journal Publications/Conference Papers

Bhadoriya, A. S., Vegamoor, V. K., & Rathinam, S. (2021). *Object detection and tracking for autonomous vehicles in adversary weather conditions* (No. 2021-01-0079). SAE Technical Paper.(Published)

Buehler, R., Broaddus, A., Sweeney, T., Zhang, W., White, E., Mollenhauer, M. (2020, July 31). Changes in Travel Behavior, Attitudes, and Preferences among E-Scooter Riders and Non-Riders: Results from Pre and Post E-Scooter System Launch Surveys at Virginia Tech. Transportation Research Board. (Published)

Ghorai, P, Eskandarian, A., Kim, Y.K., and Mehr, G. State Estimation and Motion Prediction of Other Vehicles and Vulnerable Road Users for Cooperative Perception Based Autonomous Driving: A Survey. [revision submitted in *IEEE Transactions on ITS*]. (Under Review)

Ghorai, P., Eskandarian, A., & Kim, Y. K. (2020, November). Study the Effect of Communication Delayfor Perception and Collision Avoidance in Cooperative Autonomous Driving. In *ASME International Mechanical Engineering Congress and Exposition*, 84553, pp. V07BT07A015).American Society of Mechanical Engineers. (Published)

Ghorai, P., Eskandarian, A., & Nayak, A. (2021). Relative Pose Estimation for Cooperative Vehicles and Tracking of Multiple Dynamic Objects. In *2021 International Mechanical Engineering Congress and Exposition '2021*(accepted) [to be held during November 1–5, 2021]. (Accepted)

Jazayeri, M. S., Jahangiri, A. Utilizing B-Spline Curves and Neural Networks for Vehicle Trajectory Prediction in an Inverse Reinforcement Learning Framework, IEEE Transactions on Intelligent Transportation Systems. (Under Review)

Khattar, V. & Eskandarian, A. Stochastic Reachable Set Threat Assessment for Autonomous Vehicles using Trust-Based Driver Behavior Prediction [revision to be submitted in *SAE International Journal of Connected and Automated Vehicles*]. (Under Review)

Khodadadi, A., Tsapakis, I., Das, S., & Lord, D. (2021). Application of Different Negative Binomial Parameterizations to Develop Safety Performance Functions for Non-Federal Aid System Roads. *Accident Analysis and Prevention.* (Published)

Munira, S., Sener, I. N., & Zhang, Y. (2020) Estimating Bicycle Demand in The Austin Area: The Role of Bikeability Index. *Journal of Urban Planning and Development.* (Published)

Nasr, V., Wozniak, D., Shahini, F., & Zahabi, M. (2021). Application of advanced driver-assistance systems in police vehicles. *Transportation Research Record,* 03611981211017144. (Published)

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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 385 users per month, with 2,315 new users during this period. Users viewed pages 8,138 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.

Safe-D Researcher Portal

With 327 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 expects the number of users to increase as more projects are awarded and added to the researcher portal.

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). Even though COVID-19 restrictions have begun to be lifted in some areas, there are still Safe-D project teams that dealt with multiple event cancellations due to the on-going pandemic. Safe-D participated in 4 outreach events to promote the program and projects to an audience totaling 15 in person

practitioners and an undisclosed number of virtual partitioners, including DOT officials, industry partners, and graduate students. 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	4
	Each Event: average 15 practitioners	15
Vendors Using Technology Developed	Average 1/3 projects result in vendorsusing technology	0 project has resulted in vendors using technology
	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

Increased Understanding and Awareness of Transportation Issues

- Project TTI-05-04: Micromobility Safety Regulation: Municipal Best Practices Review plans to support law and policy makers in developing regulations that are effective in increasing the safety of e-scooter riders and other road and infrastructure users.
- Project VTTI-00-030: An Evaluation of Road User Interactions with E-Scooters is educating the public on how e-scooters behave on the road and how other road users interact with them. This knowledge will increase e-scooter safety on the road.
- Project 05-084: Behavioral Indicators of Drowsy Driving: Active Search Mirror Checks plans to use the outcomes of this research to improve the understanding of driver vigilance, particularly related to degradation in driver vigilance during moments of drowsy driving.
- VTTI-00-024: Characterizing Level 2 Automation in a Naturalistic Driving Fleet will 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 accommodate the growing widespread availability of L2 technology in vehicles.
- Project VTTI-00-032: E-Scooter Design is developing more robust test methods for e-scooters that will ensure that their designs are safe and effective in real-world environments. Safer e-scooter designs will reduce safety concerns for all road users.
- Project TTI-05-02: Analysis of Advanced Driver-Assistance Systems in Police Vehicles findings were shared the Texas A&M Engineering Extension Services Law Enforcement Division. The findings and guidelines proposed so far regarding the ADAS features in police vehicles can improve police departments' awareness regarding these systems and how to increase their effectiveness in police operations to improve officers' safety.
- The findings from Project 05-098: Crashworthiness Compatibility Investigation of Autonomous Vehicles with Current Passenger Vehicles will potentially make no-occupant vehicles equipped with Automated Diving System technologies more compatible with regular passenger vehicles in terms of crashworthiness, thus improving transportation sector safety and reducing the aftermaths of an impact.
- Project 03-049: Data Fusion for Non-Motorized Safety Analysis results will be helpful to researchers, academics, and practitioners who are looking for a methodology to bring their data together and develop analysis/models using more reliable exposure estimates. In a similar vein, through the project's case study

findings, the team expects to continue its activities to support the City of Austin in its efforts to improve nonmotorized safety and encourage safe walking and bicycling in Austin.

Transportation Safety for At Risk Populations

Safe-D projects have made significant contributions to the understanding and awareness of at-risk populations, such as individuals with disabilities. For example, Project 06-004 (Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas) highlighted that the majority of today's technology for Autonomous Vehicles tends to rely on a detailed map of the environment, which includes well defined features such as lane markings and curbs. This approach tends to limit the application of Automated Vehicle technologies to areas where these features are not well defined and creation of a detailed map would not be feasible, thus alienating many small and rural communities. As of 2019, there were 18,723 such communities in the U.S.; these communities are sparsely connected and cover huge areas. The researchers plan to bridge the gap and develop an Autonomous System capable of operating in such environments, which will provide access to safe and reliable transportation facilities to such communities. Project 04-113: Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements developed Safety Performance Functions (SPFs) for lower functional classes. The SPFs could be used by several agencies around the country, particularly those in Texas and Virginia, where Highway Safety Manual and other guides and documents do not provide similar types of SPFs for low-volume roads. Using SPFs for low-volume roads will increase the reliability of the results produced from safety analysis and enhance decision making and allocation of funds for the construction of more effective highway safety improvement projects.

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. For example, project TTI-05-04: Micromobility Safety Regulation: Municipal Best Practices Revie plans to support law and policy makers in developing regulations that are effective in increasing the safety of e-scooter riders and other road and infrastructure users. The results from VTTI-00-023 E-Scooter Safety Assessment and Campus Deployment Planning will be used to provide recommendations to e-scooter developers and city policymakers for deployments. These recommendations will help improve e-scooter safety and reduce nuisance issues for other community members. The results from project 05-113: Evaluation Tools for Automated Shuttle Transit Readiness of the Area may lead to new regulations and legislations on the topic of low speed autonomous vehicles, as well as automated transit buses, which are coming to our traffic system in the near future.

Increases in the Body of Knowledge

Safe-D projects have made meaningful contributions to the body of scientific knowledge during this reporting period. For example, researchers from project 05-096: Curb Management Practices and Effectiveness in Improving Safety anticipates that the outputs will provide new knowledge in curb management practices with respect to improving safety outcomes. While existing research, reports, and examples of curb management are available, there is not a specific understanding of how curb management practices affect levels of safety for pedestrians and vehicles at these locations. These will include in depth information from case study locations and outlined recommendations, scalable to urban areas of different sizes, for different topics areas in curb management. The outputs could be applied by federal, state, tribal, metropolitan planning organizations, and local public agencies associated with traffic and vehicle management. Another study focused on expanding the understanding of e-scooters. Project VTTI-00-023: E-Scooter Safety Assessment and Campus Deployment Planning will continue to expand upon the current knowledge of micromobility. Until recently, there has been little formal research conducted on e-scooters. This study will provide the first naturalistic dataset from e-scooters. The results from this study will work to improve e-scooter safety and may lead to new policies and regulations for e-scooter developers to include with their deployments.

Findings from VTTI-00-033: Human Factors of Driving Automation: Surprise Event Response Evaluation will greatly increase our understanding of how drivers react to avoidance maneuvers performed by Conditionally Automated Driving autonomous vehicles. In Conditionally Automated Driving (CAD) automation, the automated system is in control of the vehicle within its operational driving domain. This means that during CAD driving, the automated system is capable of tactical control of the vehicle and is able to maneuver the vehicle evasively by braking and/or steering to avoid objects in the road. However, during these evasive maneuvers, the human driver is able to intervene and take back control of the vehicle. Human intervention may be suboptimal, as the vehicle would have been able to safely evade the situation. Therefore, it is important to better understand how drivers respond to evasive maneuvers initiated by a CAD system. Project members also discovered that there is no published research indicating how drivers respond to this type of situation.

Improved Processes, Technologies, Techniques, and Skills in

Addressing Transportation Issues

Numerous Safe-D projects have generated processes and technologies that can be applied to improve transportation safety. VTTI-00-028: Driving Risk Assessment Based on High-frequency, High-resolution Telematics Data project members developed a web application that detects/predicts crashes and near-crashes based on kinematic driving data. The model adopts a combination of a convolutional neural network and gated recurrent unit network to capture both local features and temporal dependency of the kinematic signatures. A weighted categorical cross-entropy loss function was used to accommodate the imbalanced data, as normal driving segments consist of substantially more than safety critical events. A window of five seconds moves through the entire streaming data and estimates the probability of crashes, near-crashes, and normal driving at each time point. Several actual crashes, near-crashes, and normal driving events are provided in the demo section. Users can also upload their own data to test the model.

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. For example, 05-091: Improving Methods to Measure Attentiveness through Driver Monitoring Distracted found that driver monitoring systems (DMSs) can address driver-related shortcomings by monitoring the attentiveness of drivers to the driving task. Once inattentiveness is detected, notifications can be issued to either redirect a driver's attention to the forward roadway or to resume manual control, in the case of a semi-automated vehicle. However, these DMSs require algorithms to differentiate between driver states in order to make these time-critical assessments and decisions. Building on previous research and available datasets, this project will develop and evaluate algorithm alternatives, demonstrating different techniques for determining driver attentiveness in real time. DMSs 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 DMS output or paired with other data sources.

Project 05-086: A Data Driven Approach to the Development and Evaluation of Acoustic Electric Vehicle Alerting Systems for Vision Impaired Pedestrians builds on previous research evaluating the detectability of additive sounds applied to otherwise quiet electric vehicles. Development of candidate sounds that meet FMVSS No. 141 criteria, evaluation of varying distribution techniques, and the development of alternate test environments, will help influence future design and testing of these types of applications. Work from this project is also influencing decisions made by an SAE cooperative research project that is formulating changes to additive warning sound regulations in the U.S. and the E.U.

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 TTI-05-03: Development of a Roadside LiDAR-Based Situational Awareness System for Work Zone Safety: Proof-of-Concept Study will produce a full-scale roadside LiDAR-based warning system that is deployable in a real work zone environment. Such a system can detect and analyze live traffic and work zone activity, activate the appropriate warning scheme, and deliver information to roadway workers in work zones so that they can take evasive actions instead of passively relying on traditional safety countermeasures.

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:

- Project 05-116: Simulation-based Approach to Investigate the Electric Scooter Rider Protection During Traffic Accidents. A step forward for safer e-scooters and for standardized national safety policies. Based on the injury data recorded in the fall simulations as the overall injury risk and body-region risks, we expect to propose several injury countermeasures in terms of protective equipment (e.g., suggesting using helmets, knee pads, etc.) and standardized national policy (e.g., maximum speed) for the protection of scooter riders.
- Project SDSU-01-01: Prediction of Vehicle Trajectories at Intersections Using Inverse Reinforcement Learning) will contribute to safety monitoring systems. The prediction models could provide critical information about how vehicles may encounter dangerous situations when interacting with other road users. This could potentially aid the transportation system in sending critical information to the users who may be in danger to avoid or mitigate crashes. It could also make changes to the control system at intersections (e.g., signal setting) to avoid potentially unsafe events. This will ultimately enhance the safety of the transportation system.
- Project 04-110: Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities will develop an intelligent transportation management center that focuses on identification of safety issues at signalized intersections. Specifically, visual analysis will be conducted to identify critical events (near crash situations) by employing surrogate safety measures. This will enable proactive safety evaluations at signalized intersections, which will inform the transportation system of the critical locations where safety is a concern.
- Project 05-089: A Holistic Work Zone Safety Alert System through Automated Video and Smartphone Sensor Data Analysis) will contribute to the improvement of transportation workforce safety via the creation of a holistic framework for workers' safety in work zones

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 both Safe-D T2 Coordinators, Dr. Mike Mollenhauer and 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. For example, results from Project VTTI-00-027: Impact of Automated Vehicle External Communication on Other Road User Behavior will provide

the industry with a novel understanding of pedestrian decision-making under complex traffic scenarios when multiple vehicles emulating SAE Level 4+ vehicles are in their environment. Current research is limited in external validity or only focuses on one vehicle in the participants' environment. In contrast, this study tackles complex components of pedestrian-highly automated vehicle interaction that have not been addressed.

Results and findings from Project 04-113: Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements) will be used by the Federal Highway Administration to determine whether probe-based volumes can replace traditional traffic volumes that transportation agencies collect in the field. Private vendors such as INRIX, StreetLight, and Wejo will also benefit from this research that showed that the accuracy of these probe-estimates has significantly improved and will likely continue to increase over the next few years. We expect the probe-based estimates to dominate the traffic monitoring industry in the next decade

The potential for commercialization and adoption of new practices resulting from other Safe-D projects are summarized below:

- Project 05-091: Improving Methods to Measure Attentiveness through Driver Monitoring will develop algorithms and supporting guidelines, for using the output of DMSs to effectively determine driver awareness in real time.
- Project 03-049: Data Fusion for Non-Motorized Safety Analysis research results have started to be shared with both public agencies and data providers who are working with various data sources to improve bike and pedestrian safety. As of now, the research team is not aware of any start-up company initiation due to research outcomes
- The results from VTTI-00-033: Human Factors of Driving Automation: Surprise Event Response Evaluation will have an impact on commercial technology through the dissemination to the industry partner of the project results and a dataset containing the kinematic and participants' behavioral responses during the evasive maneuver.
- Project VTTI-00-030: An Evaluation of Road User Interactions with E-Scooters aims to help e-scooter companies develop a more detailed and extensive deployment checklist and help companies understand the safety limitations of their scooters.
- Project VTTI-00-025: Radar and LiDAR Fusion for Scaled Vehicle Sensing Test research was done in collaboration with Continental Automotive, who is working on implementing these results to enhance the products that they are developing.
- The results 05-098: Crashworthiness Compatibility Investigation of Autonomous Vehicles with Current Passenger Vehicles will propose a new impacting location to align with the adoption of new and modified practices to incorporate the effects of new generation automated vehicles that are designed to carry cargos and other related goods.
- Project 05-089: A Holistic Work Zone Safety Alert System through Automated Video and Smartphone Sensor Data Analysis has a high potential to lead to commercialized products developed by start-up companies targeting traffic safety.
- The outcomes from project VTTI-00-024: Characterizing Level 2 Automation in a Naturalistic Driving Fleet will guide design constraints, parameters, and goals for automotive manufacturers and suppliers.

Impact on the Body of Scientific Knowledge

Through basic and applied research focused on four key disruptive technologies (connected vehicles, automated vehicles, 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. For example, parking is considered as one of the transportation infrastructure elements, but has not been widely reviewed from the safety perspective. Similar to drivers, researchers think that parking is a comparatively safer area. Researchers from project TTI-06-02: The Future of Parking: Safety Benefits and Challenges determined via a literature review that the opposite was true. Based on the 10-years of historical crash data in Texas, there were nearly 40,000 parking lot crashes with more than 3,000 injuries and around 30 fatalities per year. It is believed that with autonomous vehicle technology, those numbers will be reduced. The research team is working on improving models to estimate the rate

of reduction with a simulation on a university campus.

Only a few studies have been conducted that observed how drivers use commercially available ADAS technology, which enables the vehicle to provide longitudinal and lateral control naturally during real-world driving. The analysis in these studies is largely focused on Tesla's Autopilot technology and, due to the availability of ADAS technology when the data was collected, is restricted to high-end models of luxury vehicles such as Audi, Mercedes, Infiniti, Land Rover, and Volvo. In the years since these studies were conducted, this technology has become increasingly common and is now more widely available to consumers. The findings of project VTTI-00-024: Characterizing Level 2 Automation in a Naturalistic Driving Fleet will greatly increase the knowledge of the diverse uses of ADAS technology by analyzing different makes and models (i.e., different ADAS).

The bike demand models developed for project 03-049: Data Fusion for Non-Motorized Safety Analysis not only illustrated the use of different datasets of varying forms and resolutions to make a homogeneous estimate at the micro level (intersection), they also shed light on the characteristics and aspects of bicycle activity and provided unique insights into bike travel behavior within the city, such as the significant and positive influence of the presence of bike signals and bike-accessible bridges. Additionally, Strava and StreetLight data were examined, providing insights into the potential use of crowdsourced data in transportation studies, especially when resources are limited. In summary, the findings benefit stakeholders by explaining the determinants of bicycle activity within the region, thus providing guidance to formulate effective strategies, training, and educational programs geared toward creating a friendlier environment for bicyclists. From a theoretical perspective, this study offers a unique way to incorporate the subjective judgment of experts in mathematical fusion formulation. The experiment on the simulated data, where the proposed approach outperformed the traditional approach in many scenarios, underscores the merit of the mechanism, not only for nonmotorized activity data analysis but also for application in other areas where an analyst's subjective judgment calls for considering context. The novel weighted approach is also expected to add value in fusion endeavors when no ground truth data are available. The proposed fusion framework promotes data-driven safety analysis and informed planning while enhancing the strategic use of available information. From an application perspective, while the macro model set the stage for expanded analysis within the identified high-risk regions, the micro model provided insights into potential strategies to raise awareness through education and encouragement and to implement engineering measures to ascertain whether all residents feel safe and confident to bike more frequently.

Project 06-002: Developing an AI-driven Safe Navigation Tool aims to address the current research gap by developing, as the title suggests, an AI-driven safe navigation tool. In this study, the research team will conduct a thorough literature review and assessment of available tools or applications; collect and integrate multiple datasets, including crash, roadway, weather, and traffic data, demographic data, vehicle trajectories, incidents, and crowdsourced data from various sources; perform variable selection for modeling; determine the suitable AI algorithm(s); and develop an application tool that provides the safest real-time routing option by predicting scores based on safety, distance, and travel time.

Impact on Transportation Workforce Development

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 older students at the undergraduate and post-graduate levels. For example, project 05-101: Evaluation of Transportation Safety Against Flooding in Disadvantaged Communities will include the design of educational materials to conduct outreach to K-12 students from disadvantaged communities around San Diego via SDSU STEM Exploration Day with the goal of attracting these students to STEM disciplines, specifically to flood control and transportation safety, for building a future diverse workforce.

The outputs from project 04-110: Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities will be used to develop materials 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 advancements 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-05-02: Analysis of Advanced Driver-Assistance Systems in Police Vehicles will conduct lab tours for K-12 students. The students will learn about the applications of driving simulations and physiological measures in human factors research. Further, project team members will organize webinars for law enforcement officers to improve training on police ADAS use and in-vehicle technologies.

Project VTTI-00-027: Impact of Automated Vehicle External Communication on Other Road User Behavior provided students with the opportunities to take part in high-fidelity vehicle research throughout all phases of the experiment. Both undergraduate and graduate students were heavily involved in the development of the literature review, research plan, conducting research, analyzing the data, and final report delivery. Throughout the entire process, students took on the primary responsibility for the project and ensured it adhered to VTTI safety policies. Students also gained vital public speaking skills through presenting the research plan, analysis updates, and final deliverable presentation to all key stakeholders, and even an international organization. Additionally, students expanded their technical writing experience through a paper submission to an academic journal.

Many other Safe-D projects have also provided valuable hands-on experiences for undergraduate and graduate students, including the following:

- Project 05-008: Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation will help bring in transportation research to general public health education students by creating an experience for master's in public heath (MPH) students in transportation research and bringing the examples from this research into the classroom for teaching and learning.
- Project TTI-05-03: Development of a Roadside LiDAR-Based Situational Awareness System for Work Zone Safety: Proof-of-Concept Study provided exposure to emerging sensing technologies (such as LiDAR) for young students, researchers, and practitioners in transportation.
- The models developed in project 05-116: Simulation-based approach to investigate the electric scooter rider protection during traffic accidents are a step forward for safer e-scooters and for standardized national safety policies. The project will provide opportunities for further research in transportation, and could be used in teaching or cap undergraduate projects as well.
- Graduate and undergraduate students from project 05-087: Autonomous Delivery Vehicle as a Disruptive Technology: How to Shape the Future with a Focus on Safety are being trained on big data modeling with the use of advanced statistical modeling and artificial intelligence.
- Project 05-086: A data driven approach to the development and evaluation of acoustic electric vehicle alerting systems for vision impaired pedestrians is supporting graduate and undergraduate students in developing critical expertise in additive sound technologies for electric vehicles.
- Project 06-004: Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas supports a Masters student working with both fundamental sensing and navigation algorithms. It also provides real world experience to the student in implementing the algorithms in the autonomous vehicle

in rural communities. The graduate student will also be registering for research credits (formally accounted towards their degree) for performing this work. The project will train the student in documenting the work and presenting at international conferences and symposiums

- A graduate student is supported by project VTTI-00-025: Radar and LiDAR Fusion for Scaled Vehicle Sensing Test to work with advanced analytical techniques in a real-world problem, and demonstrate the applicability of these techniques to an important area of transportation research. He will use this experience in his continued career as an automotive engineer, where he expects to continue developing technologies that assist drivers and/or automate portions of the driving task. In the earlier parts of the project, the team also exhibited these technologies to K-12 students, some of whom expressed a lot of interest in pursuing similar areas of study in their continued education.

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 TTI-06-02: The Future of Parking: Safety Benefits and Challenges team members presented their findings to the University of Texas at El Paso Civil Engineering department to increase the awareness of the safety and parking on and outside the campus environment among students.
- The results from Project SDSU-01-01: Prediction of Vehicle Trajectories at Intersections Using Inverse Reinforcement Learning will be used to develop materials for use in courses offered from the CCEE department at SDSU. The project provided funding for a graduate student in CCEE, who is currently working on finalizing the project. This project contributed to the student's MS thesis, which he will defend in Summer 2021. With recent advancements in transportation technology, it is imperative to educate future transportation engineers and leaders on how cutting-edge technology (e.g., machine learning and vehicle trajectory prediction) can be utilized to develop advanced safety monitoring systems.
- Project 06-003: Critical Areas in Advanced Driver Assistance Systems Safety: Point of Sale and Crash Reporting results will provide recommendations and training tools for car salespeople and traffic crash investigators.
- Project 05-084: Behavioral Indicators of Drowsy Driving: Active Search Mirror Checks will be incorporated into a learning module, discussing the role of DMSs and the study of PERCLOS (the percentage of eyelid closure over the pupil over time) as educational course materials.

Changes/Problems

Changes in Approach

Given the stresses of today's fast-paced and academically rigorous environment, Safe-D has begun to search for ways to make research teams' experience with Safe-D easier. For example, quarterly reports have been switched to survey format instead of a document format. Switching to a survey format allows researchers to complete a more condensed version of the quarterly report and bypass questions that are not applicable to them. Nearly 70% of the researchers approve of the change. This has also made it easier for administrative members to easily access quarterly reports from their consortiums. Safe-D will also develop a separate Bi-Annual Activity survey for completed projects to capture T2 and EWD information, such as industry and vendors use of technology. Before Safe-D issued the same survey to active and completed project which led to confuse and low response rate from the complete projects. Safe-D believes that implementing a separate and shorter survey for complete projects will increase the survey response from complete projects. Safe-D plans to continue to look for other areas to improve the overall satisfaction of the researchers involved with Safe-D projects.

Actual/Anticipated Problems/Delays

Impact of COVID-19 and Partial Government Shutdown

Safe-D output goals such as facility tours, workshops, etc., have continued to struggle due to COVID-19 and now the partial government shutdown. Cancellations, postponements, and adjustment to virtual methods for these output measures have not deterred Safe-D from achieve success in reaching our goals. As the rules and regulations to COVID-19 begin to lessen, Safe-D believes these metrics will continue to be met if not surpassed. However, the unexpected government shutdown added to more setbacks experienced by our researchers. During this reporting period, 19 Safe-D projects reported that research activities had been impacted by COVID-19 in some way and 6 Safe-D projects reported that their research activities had been impacted by the partial government shutdown. Among these projects, 3 reported minor impacts, 11 reported moderate impacts, and 5 reported significant impacts from COVID-19. Projects that were impacted by COVID-19 reported the biggest effects from spring through the summer. The numbers of effected projects have decreased from last reporting period; however, the significant impact experienced has increase and the government shutdown has added to the impact. Although some states have begun to relax COVID-19 restrictions as vaccination numbers have increase and boosters shots become available, many impacts can still be attributed to social distancing measures, spikes of COVID-19, and travel restrictions put in place in response to COVID-19. Below are some specific examples of how COVID-19 has affected Safe-D projects along with some solutions:

Safe-D Projects Reporting Minor Impacts

- Project VTTI-00-036: Smart Work Zone System)experienced some impact on the hardware electronic design and manufacturing due to COVID-19. There is a global electronic component shortage that the team is addressing by making changes to the design and procuring all the bill of materials components without issues for the next hardware revision.
- Project 05-096: Curb Management Practices and Effectiveness in Improving Safety found issues in conducting focus groups to learn more about travel and safety at curb managed locations of focus in the selected case study jurisdictions. The focus groups will be conducted virtually due to the COVID-19 pandemic; we will continue with this plan to have virtual focus groups rather than in-person sessions.
- Project 05-008: Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation had setbacks on their research team due to COVID-19 but have not since experienced additional impacts.

Safe-D Projects Reporting Moderate Impacts

- TTI-05-04: Micromobility Safety Regulation: Municipal Best Practices Review temporarily shut down, replaced the student who left, asked for more time to make up for the delay, and cut tasks to avoid cost overruns.
- VTTI-00-030: An Evaluation of Road User Interactions with E-Scooter experienced working restrictions due to COVID-19,and the project team needs more time to finish the final reports due to a delay in data analysis.
- 05-113: Evaluation Tools for Automated Shuttle Transit Readiness of the Are experienced setbacks but are back on track due to COVID-19 restrictions being lifted.
- VTTI-00-023: E-Scooter Safety Assessment and Campus Deployment Planning had scooter deployment on VT's campus cancelled at the onset of COVID when students went home in March of 2020. The project team worked with stakeholders to redeploy the scooters on VT campus this fall to complete the dataset, which was cut short by 5 months.
- VTTI-00-026: Guiding Driver Responses During Manual Takeovers from Automated Vehicles data collection was terminated early due to COVID-19.
- Project 01-002: Countermeasures to Detect and Combat Driver Inattention While Driving Partially Automated Systems had disrupted data collection and disrupted ability to meet with students during analysis due to COVID-19.
- VTTI-00-027: Impact of Automated Vehicle External Communication on Other Road User Behavior experienced a COVID-19 shutdown, which forced the timeline of their project (fielding, analysis, report

development) to be pushed out.

- 04-117: A Sensor Fusion and Localization System for Improving Vehicle Safety In Challenging Weather Conditions had to adjust the timeline of the project to accommodate for the time lost because of the shelter in place rules due to Covid-19.
- 05-115: Cooperative Perception of Connected Vehicles for Safety experienced a shortage of time for completion of the experimental verification and validation due to COVID-19.
- 05-101: Evaluation of transportation safety against flooding in disadvantaged communities experienced COVID-related inconvenience and delays for the graduate student working on the project in accessing the campus resources, resulting in a delay in the project's progress.
- TTI-05-03: Development of a Roadside LiDAR-Based Situational Awareness System for Work Zone Safety: Proof-of-Concept Study had impacts from COVID-19 restrictions on some field implementation tasks, which may also continue to impact future work in the field. Students are not allowed in TTI Headquarters or the UMS lab area because of COVID-19. However, the undergraduate and graduate students have been successful in workingfrom home on the assigned tasks and communicating virtually. The researchers also anticipate some delay when implementing the system in the field: a real work zone environment. Researchers may spend more time finding the appropriate site, coordinating with a local agency, and performing the experimental work.

Safe-D Projects Reporting Significant Impact

- TTI-05-02: Analysis of Advanced Driver-Assistance Systems in Police Vehicles has experienced a very slow recruitment process due to COVID-19.
- TTI-04-02: Delving into Safety Considerations of E Scooters: A Case Study of Austin, Texas has been on hold due to COVID-19 (primarily since the research team was not able to reach to their contacts at the medical center to access data). Based on discussions with the medical staff, the PI anticipates resuming the research soon in the next reporting period.
- TTI-01-02: Creating a Smart Connected Corridor to Support Research into Connected and Automated Vehicles members are working with an estimator at the construction company who has been seriously ill with COVID-19. This has delayed the ability to get final pricing, which is imperative given supply chain changes and cost increases. More time will be needed to determine final construction pricing and ensure that funds allocated are able to cover the desired implementation. If not, a reduction in field implementation will be determined.
- 05-089: A Holistic Work Zone Safety Alert System through Automated Video and Smartphone Sensor Data Analysis experienced significant impact from to COVID-19.
- 04-110 (Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities) experienced several COVID-19 impacts on project progress, as presented in three items in the previous quarterly report. Below, the three items are presented along with some updates:
    - The project team was in the middle of equipment installation for the new transportation lab when work had to stop since access to campus and buildings were restricted due to COVID-19 concerns.
    - The progress on the Memorandum of Understanding (MOU) between SDSU and the City of Chula Vista/Caltrans was slow in general as we originally expected and mentioned in previous reports, but the progress is currently becoming even slower since personnel at both institutions are adjusting to the new situation (e.g., working from home, etc.) and are less responsive at this point.
    - The project team needs to install several video cameras at a few intersections in the city of Chula Vista. This task can't be started before finalizing the MOU (see previous item). While waiting for the MOU, the team managed to install a video camera on the SDSU campus, and was able to collect some data. However, data collection may not provide meaningful results at this point since there is little activity on campus and thus the need of the project to utilize data for detecting and tracking vehicles, pedestrians, and other road users cannot be fulfilled.

Overall, the main outcome of the above effects of COVID-19 and the government shutdown is expected delay of some Safe-D research projects. The Safe-D administration is working individually with each project team to determine how to best adjust project activities to minimize delays and ensure continued research progress. Where possible, meetings and other project activities will be shifted from in-person to virtual. In some cases, project tasks may be able to be restructured to avoid significant delays. However, more time has been given for certain projects that rely on the collection of participant data or other in-person interactions, and certain project tasks are reliant on human subject data. Human subject research has been approved by the Institutional Review Board to run again with strict guidelines. These guidelines include temperature checks, glass/plastic partitions in vehicles, and sanitation between vehicles, all of which add more time to the overall studies.

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