SEMI-ANNUAL PERFORMANCE REPORT

OCTOBER 2021 TO MARCH 2022

SAPR #10

SAFE-D: SAFETY THROUGH DISRUPTION UNIVERSITY TRANSPORTATION CENTER

SAN DIEGO STATE UNIVERSITY

Texas A&M Transportation Institute

VIRGINIA TECH TRANSPORTATION INSTITUTE
VIRGINIA TECH

Federal Agency	Office of the Secretary of Transportation (OST); U.S. Department of Transportation (US DOT)
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Program Director Name, Title, and Contact Information	Dr. Zachary R. Doerzaph zdoerzaph@vtti.vt.edu (540) 231 – 1500
Name of Submitting Official	Eric Glenn Program Manager, Safe-D National UTC EGlenn@vtti.vt.edu (540) 231 – 1536
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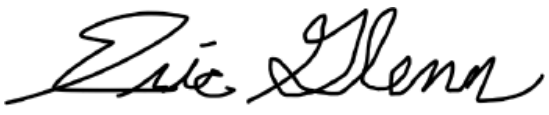
Signature of Submitting Official	

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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

As in the previous Semi-Annual Progress Report (SAPR) Safe-D did not solicit research proposals during this reporting period. However, Safe-D funded five 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 include The Virginia Tech Research Council, Ford, Spin, Toyota Collaborative Safety Research Center, and Oracle Corporation.
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At the end of this reporting period, the Safe-D National UTC had a project portfolio of more than $30.0 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, (AVs) connected vehicles (CVs), big data analytics, and transportation as a service. The coverage of Safe-D themes by project portfolio to-date isshown 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%.

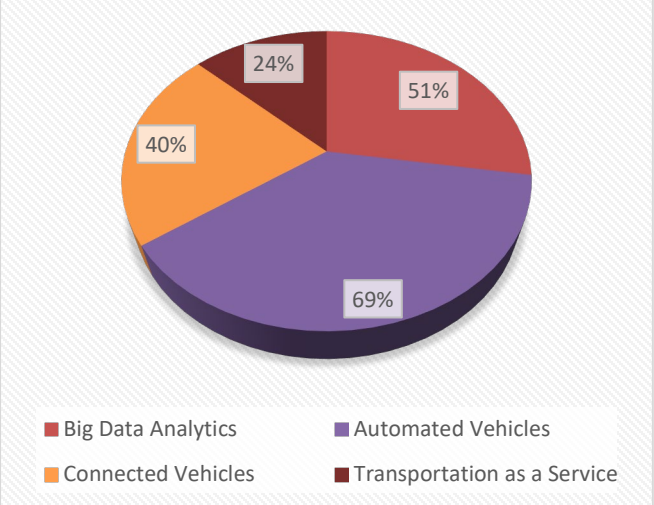

Figure 1.Portfolio of Safe-D Projects by Theme Area (total exceeds 100% due to projects covering multiple themes).

The Safe-D Leadership Team engaged with our stakeholders during this reporting period to update them on our program and make any adjustments to any feedback received. Safe-D believes 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 are integrated 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 06-008: Emerging Communications Training:

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

As new intelligent transportation systems and vehicle-to-everything communication systems and protocols continue to emerge, additional training on those systems and protocols is needed for personnel working in the transportation sector. The Virginia Department of Transportation has already created a training program focusing on general topics pertaining to connected and automated vehicles (CAVs), and they have recently identified a need for a more specific program focusing on communication technologies as they relate to CAVs. To address this need, VTTI plans to develop a 60-minute training course that includes a narrated PowerPoint presentation in conjunction with learning assessments. This training will cover high-level overviews of various types of communications, main use cases for each type of communication, vocabulary, and key protocols currently being utilized by industry owner-operators (IOOs), OEMs, and industry technology providers.

Project 06-009: Enhancing Automated Vehicle Safety Through Testing with Realistic Driver Models:

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

Improving safety during interactions between human drivers and AVs requires an environment where AV software can interact with realistic human driving behavior. Generating this behavior has been challenging due to a lack of driver models that accurately reflect both vehicle kinematics and driver cognition. In this project, the authors propose developing an active inference model of car-following behavior that will resolve these limitations. The model will be trained using the UC Berkeley INTERACTION dataset. After training, researchers will work with Waymo to validate the model on an internal dataset and, if necessary, implement a set of augmentations that will allow the model to be used to improve the safety of AV interactions with human drivers.

Project 06-010: Developing a framework for prioritizing bicycle safety improvement projects using crowdsourced and image-based data:

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

During the last decade, non-motorized modes of transportation have been spreading as they are considered economical, eco-friendly, and energy efficient. With the expansion of active transportation, statistics also show a significant increase in the number of fatalities. Between 2010 and 2019, there was a 36% increase in bicycle deaths in the United States. In 2020, 697 bicyclists lost their lives in crashes; California, with 118 fatalities, was the deadliest state for bicyclists. In this project, the authors propose developing a crash-risk scoring method for prioritizing bicycle safety improvement projects in the county of San Diego. The California Department of Transportation, Caltrans, has a great interest in this topic. Prioritization methodology will have a widespread applicability and can be adopted by Caltrans for similar projects. Most studies on pedestrian and bicycle safety have suffered from a limitation of exposure data, as they relied on traditional data collection methods. In this project, researchers will use a combination of traditional data (e.g., historical crash data, environment characteristics) as well as crowdsourced (e.g., STRAVA, StreetLight data) and image-based data in order to develop a robust model to identify high-risk locations.

Project 06-011: Evaluating the Safe Routes to School (SR2S) Transportation Program in Socially Vulnerable Communities in San Diego County, California:

Institution(s): SDSU; Award Round: Spring 2022; Theme Area(s): Big Data Analytics, Transportation as a Service

Concerns for child safety are among the strongest impediments to children walking or biking to school, but for some, walking or bicycling to school is a necessity due to financial or other circumstances. The Safe Routes to School (SR2S) program is a federally funded initiative developed by the US Department of Transportation and active since 2005 to foster opportunities for students to walk and bike to school safely and routinely. It is important to understand how this program can be evaluated and how socially vulnerable communities benefit from this program. This project will select 2–5 schools located in vulnerable communities in San Diego County to evaluate the impacts of the SR2S programs for each school and identify accident (injuries and fatalities) hot spots for the future routing improvement, develop and design a SR2S web-based visualization tool for easy road safety monitoring and reporting, conduct VR educational road safety training for children, and strengthen community collaboration across San Diego County.

Project 06-011: Real Time Risk Prediction at Signalized Intersection Using Graph Neural Network:

Institution(s): VTTI; Award Round: Spring 2022; Theme Area(s): Big Data Analytics, Transportation as a Service

Intersection-related traffic crash and fatalities are one of the major concerns for road safety. In this project, the authors aim to understand the major cause of conflicts at an intersection by studying the intricate interplay between all the roadway agents. Researchers propose using the current traffic camera systems to automatically process traffic video data. As manual annotation of video datasets is a 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, the authors propose using a computer vision algorithm to process the videos. Advanced machine learning methods, including graph neural network, will also be used to model the interaction of all the roadway agents at any given instance, and 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 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:

Institution(s): TTI; Rescoped: Spring 2022; Theme Area(s): Big Data Analytics, Transportation as a Service, Automated Vehicle

In fall 2020, a novel autonomous-vehicle (AV) service named ENDEAVRide will start pilot testing in Nolanville, a rural town in central Texas. The AV will serve as a taxicab and a mobile telemedicine portal. This project marks the first attempt to conduct a real-world assessment of AV's potential safety impacts as a disruptive technology to offer older adults a pathway to continued independent mobility in underserved communities. Collaborating with industry partners, researchers will explore how older adults (60+) can more safely acquire transit and get access to health care with a "2-in-1" (taxi + telemedicine) service delivered via AVs. The perceived and objective safety impacts of this novel service will be explored along with changing travel patterns and reduced healthcare trips.

Project 04-110: Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities:

Institution(s): TTI; Rescoped: Spring 2022; Theme Area(s): Big Data Analytics

Transportation safety planning challenges in the era of smart cities entails understanding safety impacts from disruptive technologies, measuring the effectiveness of safety countermeasures, proactively identifying high crash risk locations, etc. Recent advancements in communication technologies and big data analytics enables us to deal with these challenges in a computationally efficient way. Traditional transportation management centers (TMCs) have limited capability to utilize large amounts of data to properly evaluate transportation safety. The goal of this project is to develop an intelligent transportation management center (ITMC) that adopts automated video data analysis to evaluate safety. The proposed ITMC demonstrates how intelligent transportation systems technologies and big data analytics can be utilized to proactively assess transportation safety at signalized intersections. Conventional methods of traffic safety risk assessment at signalized intersections, measured by number of roadway crashes per unit of exposure, would require a long observation time, as crashes are rare events. The proposed ITMC adopts safety surrogate measures to identify near crash situations that can be applied in proactive risk calculations.

Completed Projects

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

- VTTI-00-030: An Evaluation of Road User Interactions with E-Scooters
- 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
- 05-087: Autonomous Delivery Vehicle as a Disruptive Technology: How to Shape the Future with a Focus on Safety?

[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
- 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

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	23	11
Masters	14	6
PhD	36	12

Highlighted EWD & Other Outreach Activities

- Safe-D Project TTI-05-02 (Analysis of Advanced Driver-Assistance Systems in Police Vehicles) researchers presented their work as a seminar and workshop to TAMU undergraduates, female graduate TAMU students, and at the Bryan Independent School District, reaching over 50 individuals.
- Safe-D project 06-004 (Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas) had a researcher volunteer as a judge for the 2022 Texas Junior Science and Humanities Symposium.
- Safe-D Project VTTI-00-032 (E-Scooter Design) worked with two senior design teams who have assisted with outreach efforts, and they have also completed/are completing capstone projects related to this effort.
- Safe-D Project 06-007 (Allusion 2: External Communication for SAE L4 Vehicles) researchers presented their study design and experimental setup to undergraduate and graduate students.
- Safe-D Project VTTI-00-027 (Impact of Automated Vehicle External Communication on Other Road User Behavior) presented their research to students enrolled in Industrial and Systems Engineering and Human Factors courses.
- Safe-D Project 05-109 (ENDEAVRide) researchers participated in the Veterans' Day Celebration, Disabled American Veterans and American Legion in Harker Heights, TX.
- A team member from Safe-D Project 05-087 (Autonomous Delivery Vehicle as a Disruptive Technology: How to Shape the Future with a Focus on Safety?) acted as a guest lecture for The University of Texas at San Antonio.
- Safe-D Project 05-089 (A Holistic Work Zone Safety Alert System through Automated Video and Smartphone Sensor Data Analysis) researchers presented their work to students in a construction engineering course, assisted a graduate student in producing a Master's thesis, and presented at a student research symposium.
- TTI hosted 28 students from the San Antonio Young Women's Leadership Academy for a career exploration visit on November 11, 2021 See figure 1. The program was organized by volunteers from Pape-Dawson consulting through the WTS Transportation You program. This program from WTS

International, a professional society dedicating to advancing women in transportation formerly called the Women's Transportation Seminar, works with volunteers from local WTS chapters to encourage girls to consider careers in transportation and to pursue courses in science and math. The students observed a live crash test of roadside safety hardware at the TTI Proving Grounds, visited the Environmental and Emissions Research Facility, Visibility Lab, and the Driving Simulator. They also learned about TTI's Teens in the Driver Seat program and built Puff mobiles.

Figure 1

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 averaged 24 webinar attendees during this reporting period with the highest attendance being 43. The total number of YouTube views for all Safe-D webinars during this reporting period was 136. 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 has increased from 234 in the previous reporting period to 236 during the current reporting period.

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 is currently working with the researchers of project 05-091 Improving Methods to Measure Attentiveness through Driver Monitoring Roadside Work Zone Safety to provide a webinar tentatively scheduled for May. More information about this project 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:

- Alexandria Rossi Alvarez received the Eisenhower Fellowship and UTC Student of Year award.
- Azim Eskandarian was honored with the SAE's 2021 Vincent Bendix Automotive Electronics Engineering Award, for the best paper in the SAE International Journal of Connected and Automated Vehicles, and for the third best student paper award at the IEEE ITS Conference 2021 in Indianapolis, Sep. 2021.
- The Research team for Safe-D Project 05-109 ENDEAVRide received the 2021 W.K. Kellogg Award for Exemplary Community Engagement and 2021 Smart 50 Award.
- Farid Shahnavaz was honored with the SDSU Presidential Graduate Research Fellowship.
- Dr. Ipek Sener was honored with the Transportation Research Board Certificate of Appreciation.
- Jean Paul Talledo Vilela received second place for ATSSA Innovation Product 2022.
- Nicholas Britten received the 2021 Dwight D. Eisenhower Transportation Fellowship.
- Maryam Zahabi received the Young Investigator Award at the Applied Ergonomics Conference/Texas A&M Ergo Center, the Barnes Fellowship, and the Stephanie Binder Young Professional 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 project that directly or indirect effect 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 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. The previous reporting period count for Safe-D projects with a DEI component is 19.

During this reporting period, Safe-D was able to fund two more project with DEI components: 06-011 Evaluating the Safe Routes to School (SR2S) transportation program in socially vulnerable communities in San Diego County, California and 06-001 Building Equitable Safe Streets for All: Data-Driven Approach and Computational Tools. This brings the new total to 21 projects with a DEI component.

Safe-D is also proud to announce that during this reporting period, our Safe-D program manager, Eric Glenn,

received the Virginia Tech Principles of Community award partly due to his DEI work with Safe-D.

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 04-113 (Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements) collaborated with Virginia Tech for to gather, process, and integrate data.
- Project 05-087 (Autonomous Delivery Vehicle as a Disruptive Technology: How to Shape the Future with a Focus on Safety?) collaborated with Omnitracs for data collection, analysis, and data acquisition.
- VTTI, TAMU, and SDSU assisted each other on collaborated research for Project 04-114 (Behavior-based Predictive Safety Analytics Phase II).
- Project VTTI-00-023 (E-Scooter Safety Assessment and Campus Deployment Planning) received assistance with subjective surveys, research planning and reporting from the Virginia Tech Research Center School of Public and International Affairs.
- Caltrans provided in-kind support for Project 06-010 (Developing a framework for prioritizing bicycle safety improvement projects using crowdsourced and image-based data).
- Project 05-093 (Automated Shuttles and Buses for All Users) collaborated with the City of Arlington and Texas A&M University Transportation Services.
- Project 06-008 (Emerging Communications Training) received a content review from the VTRC and VDOT.
- Project 06-007 (Allusion 2: External Communication for SAE L4 Vehicles) researchers received funding from Toyota CRC and vehicles from Ford and Daimler.
- 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.
- Global Center for Automotive Performance Simulation (GCAPS) assisted project 05-097 (Investigating and Developing Methods for Traditional Participant-based Data Collection with Remote Experimenters) in development of work.
- Project VTTI-00-036 (Smart Work Zone System) researchers collaborated with VTRC and VDOT for financial support, research, and facilities usage.
- Project VTTI-00-027(Impact of Automated Vehicle External Communication on Other Road User Behavior) researchers received a vehicle from Daimler and Ford. This project also received feedback from State Farm on the analysis and report.
- Project 04-113 (Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements) researchers worked with VDOT for project development and review of deliverables.
- VDOT assisted Project 05-113 (Evaluation Tools for Automated Shuttle Transit Readiness of the Area) on project development.
- 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) received staff support from ENDEAVR Institute and in-kind donation of technology and staff time from Wocsor LLC.
- Project 04-110 (Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities) researchers partnered with the City of Chula Vista for research support.
- Project 04-110 (Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities) members partnered with the City of Chula Vista for research support.

- Project VTTI-00-034 (Sensor Degradation Detection Algorithm for Automated Driving Systems) received financial support from GCAPS, Old Dominion University, and the Commonwealth Cyber Initiative.
- Ford and Spin acted as the project champion for project VTTI-00-023 (E-Scooter Safety Assessment and Campus Deployment Planning).

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 and received financial support from Waymo LLC.
- Project 06-006 (Private 5G Technology and Implementation Testing) collaborated with the NEC Corporation out of Japan and California for technology transfer.
- 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 2,770 visitors during the 6-month reporting period. With 2,391 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 5,161 visitors from April 1, 2021, to March 31, 2022. 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	2,770; 5,161 visitors/previous 12 mo.
	Project Pages: Average ≥ 150 visitors/year	3,200 total visits/period; average 31 visitors/project page
Journal Articles/Conference Presentations	Project Teams: 1 article/year	5 articles; 0.10 average per reporting project
	Project Teams: 1 conference/year	4 presentations; 0.09 average per reporting project
Facility Tours	Displays viewed by ≥ 200/year	1296 total visitor views; average of 25 views per reporting project
	Follow-up Interest: 5 visitors/year	6

Prior to this reporting period, a total of 43 projects had been completed, resulting in 71 journal articles and 102 conference presentations.

Within this reporting period, 7 additional projects were completed and a total of 5 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 1.52 journal articles per project and 2.0 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 a massive increase of 1,296 views of Safe-D displays during outreach events during the 6-month reporting period due to 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) outreach efforts at three events: Veterans' Day Celebration, Disabled American Veterans and American Legion in Harker Heights, Texas, and Train Whistle Jamboree and Fall Festival in Nolanville, TX. These events alone resulted in 1,100 views; last period, researchers reported 7,418 views, bringing the yearly total to 8,714, 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 below received media mentions.

- Project 06-007 (Allusion 2: External Communication for SAE L4 Vehicles) was mentioned in the VTTI newsletter: *Survivors Inspired to Save the Lives of Most Vulnerable Roadway Population – Pedestrians*
- Audi Newsroom wrote an article on Safe-D project VTTI-00-036 (Smart Work Zone System): *C-V2X deployment with Audi shows real-world safety benefits for drivers and roadside workers on Virginia highways*
- Project 05-096 (Curb Management Practices and Effectiveness in Improving Safety) was featured in the Roanoke Valley News on WFXR: *Conversations about pedestrian safety continue in Roanoke Valley after man killed while walking along I-81 on-ramp*
- VTTI-00-034 (Sensor Degradation Detection Algorithm for Automated Driving Systems) was mentioned in the VT news: *Research drives cybersecurity innovation, inspiration in Southwest Virginia*

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

Shahini, F., Nasr, V., Wozniak, D., Zahabi. M. (2022). Law enforcement officers' acceptance of advanced driver assistance systems: A survey study. Submitted to the human factors and ergonomics conference (Under review)

Herbers, E. (2022). Improving Methods to Measure Attentiveness through Driver Monitoring [Conference presentation]. Lifesavers Conference, Chicago, IL, United States. (Published)

Ninan, S., & Rathinam, S. (2022). Road Segmentation based Localization using Open Street Maps for Rural Roads. arXiv preprint arXiv:2202.07049. (Under Review)

Bhadoriya, A. S., Vegamoor, V. K., & Rathinam, S. (2021). *Object Detection and Tracking for Autonomous Vehicles in Adverse Weather Conditions* (No. 2021-01-0079). SAE Technical Paper. (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)

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, 156*. (Published)

Khodadadi, A., Tsapakis, I., 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 and Prevention, 170.* (Accepted)

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)

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)

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)

Presentations

Ninan, S. (2022, April 4). LIDAR aided localization on Open Street Maps. [PowerPoint slides]. OneDrive https://tamucsmy.sharepoint.com/:p:/g/personal/nstephen_tamu_edu/EQutWaN3IXpHntEosEoRfgMB_SPCFcmNKkrBYFkvY79TQA?e=RY3e5f (Accepted)

Vazquez, M., Gurbuz, O., Salgado, D., & Aldrete, R.M. (2022) The Evolution of Parking Safety: Past, Present, and Future (No:22-02308) (Submitted)

Rossi-Alvarez, A. I., Klauer, S., Miles, M., Grove, K., Schaudt, A., & Doerzaph, Z Impact of Highly Automated Vehicle (HAV) External Communication on Vulnerable Road User (VRU) Understanding of Vehicle Intention. Paper presented at the Transportation Research Board: 101st Annual Meeting, Washington DC.

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. Transportation Research Board Annual Meeting. (Accepted)

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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 460 users per month, with 2,770 new users during this period. Users viewed pages 7,947 times during this period, visiting an average of 2.1 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 310 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). Although COVID-19 restrictions have continued to be lifted in some areas, there are still Safe-D project teams that encountered roadblocks due to the on-going pandemic. However, Safe-D was able to bounce back from this during the previous reporting period and participated in 10 outreach events to promote the program and projects to an audience totaling 1,292 compared to the previous reporting period of 4 outreach activities and 15 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	10
	Each Event: average 15 practitioners	1292
Vendors Using Technology Developed	Average 1/3 projects result in vendors using 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-05-02 (Analysis of Advanced Driver-Assistance Systems in Police Vehicles) findings to date have increased the 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. The outcomes of the driving simulation study that the authors are currently conducting can provide empirical evaluation for the applicability of these systems in police operations.

- Project VTTI-00-024 (Characterizing Level 2 Automation in a Naturalistic Driving Fleet) researchers anticipate that the outputs of this project 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 growing widespread availability of L2 technology in vehicles.

- Project 06-004 (Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas) tested a number of existing road segmentation algorithms on data from rural roads and found that the segmentation algorithms based on existing data sets do not perform well in these never before seen environments involving rural communities, thus highlighting the need for rural road datasets.

- VTTI-00-032 (E-Scooter Design) researchers expect the results from this study will provide a better understanding of the true capabilities of e-scooters based upon their design factors, as well as rider factors that contribute to safety, which can be used to understand why crashes and injuries result from e-scooter use.

- Project 05-093 (Automated Shuttles and Buses for All Users) is increasing the understanding of the use of automated shuttles and buses by individuals with disabilities. It is raising the awareness of potential issues associated with automated shuttle vehicles (ramps, lifts), service designs and operations, and the built environment (streets, sidewalks, lighting).

- Project 05-084 (Behavioral Indicators of Drowsy Driving: Active Search Mirror Checks) has increased understanding in the area of the issues surrounding glance behavior, and how much time a drowsy driver should be monitored when determining drowsiness level.

- TTI-Student-09 (Evaluating Emotion Regulation Techniques for Supporting Driving Safety and Performance) is investigating the sources of, and mitigations for, road rage and other emotionally-charged behaviors on roadways.

- Project VTTI-00-021 (Signal Awareness Applications) will increase driver awareness of traffic signal phases and timing.

- The training program from project 06-008 (Emerging Communications Training) will offer insight into communication technologies utilized by intelligent transportation systems.

- Project TTI-06-01 (Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking) researchers met with stakeholders to raise awareness of truck parking issues, new technologies, and truck parking needs.

- Project 06-005 (Automated Truck Mounted Attenuator: Phase 2 Performance Measurement and Testing) plans to provide new methods and awareness for work zone deployments by automating TMAs and reducing the risk of fatal injuries

- Project 06-007 (Allusion 2: External Communication for SAE L4 Vehicles) researchers plan to proactively identify weaknesses in the designs and areas of improvement of AVs to ensure that these technologies do not further contribute to the rise in pedestrian fatality rates.

- Project 05-097 (Investigating and Developing Methods for Traditional Participant-based Data Collection with Remote Experimenters) methods were employed by a graduate student at VT as part of research designed to gain an understanding of the unique challenges posed to the blind and low vision community when accessing AVs. Remote experimenter methods and technologies were crucial to the success of the research and enabled the gathering of higher quality data by giving participants a better sense of being alone in an AV.

- 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-00-027 Impact of Automated Vehicle External Communication on Other Road User Behavior) provided an understanding of the impact of external human–machine interfaces (eHMI) location and color on pedestrian decision-making—this aids in developing a better-designed eHMI to allow pedestrians to make more informed decisions.
- Project 04-113 (Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements) provided a better understanding of the accuracy of annual average daily traffic estimates developed from traffic and non-traffic data, such as probe data.
- Project VTTI-00-030 (An Evaluation of Road User Interactions with E-Scooters) increased the understanding of E-scooter behavior and how to govern these vehicles on the road.
- 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) has allowed numerous students, professionals, and community stakeholders to enhance their understanding of the transportation needs of elderly populations. The ENDEAVRide van serving the elderly is a "lead by example" approach to solving this issue.
- Project 06-002 (Developing AI-driven Safe Navigation Tool) will include segment specific scoring to provide safety scores while including distance and travel time in an algorithm. The findings will significantly increase the understanding of this important issue.
- Project 05-087 (Autonomous Delivery Vehicle as a Disruptive Technology: How to Shape the Future with a Focus on Safety?) generated a total of 80 association rules with high likelihood measures from these datasets. The rules can be used as the prospective benchmark rules to examine how these rule-based risk patterns can be replaced by autonomous delivery vehicles by eliminating human-driven trips.
- Project 05-101 (Evaluation of Transportation Safety Against Flooding in Disadvantaged Communities) was able to engage multiple stakeholders across the US via a webinar in order to transfer knowledge of the findings for informed future design of transportation network considering flooding risks.
- Project VTTI-00-033 (Human Factors of Level 3 Automation: Surprise Event Response Evaluation) increased understanding and awareness of transportation issues through the publication of a graduate student's Master's thesis, which highlighted several human factors challenges associated with the adaptation of SAE Level 3 Automated Driving System-equipped vehicles.
- Project 05-096 (Curb Management Practices and Effectiveness in Improving Safety) plans to provide new knowledge in curb management. While information from existing research, reports, and examples of curb management are available, there is not a specific understanding of how curb management impacts safety for pedestrians and vehicles at these locations. The results will include in-depth information from case study locations and outline recommendations in several topic areas in curb management, which could be applied by federal, state, tribal, and local public agencies associated with traffic and vehicle management.
- 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.
- Project 04-114 (Behavior-based Predictive Safety Analytics Phase II) seeks to elucidate the complex nature of crashes by evaluating individuals across time while accounting for environmental, individual, situational, and locational characteristics by evaluating an individual's risk factor as a compounding, multifaceted, and continuously shifting set of data to determine when, at a trip or real-time level, drivers are at highest risk.

- Project 06-011 (Evaluating the Safe Routes to School (SR2S) Transportation Program in Socially Vulnerable Communities in San Diego County, California) plans to provide educational awareness using visualization and a VR tool on public transit in low-income vulnerable groups of people, including children, families, policy makers, and school administrators.

- Project VTTI-00-034 (Sensor Degradation Detection Algorithm for Automated Driving Systems) aims to increase the understanding of sensor degradation, which impacts vehicles equipped with Automated Driving Systems.

- Project 05-115 (Cooperative Perception of Connected Vehicles for Safety) plans to improve safety issues on critical hazards mainly by avoiding accidents through cooperative perceptions among AVs and vulnerable road users present on the road.

- Interdisciplinary research projects such as 05-089 (A Holistic Work Zone Safety Alert System through Automated Video and Smartphone Sensor Data Analysis) address the safety of construction workers in work zones by leveraging advanced technologies and enhancing awareness of transportation issues for individuals external to transportation or civil engineering areas.

- The disproportionate share of roadway crashes in disadvantaged communities with lower income and larger proportions of minority populations has drawn the interest of transportation researchers and planners alike. Project 06-001 (Building Equitable Safe Streets for All: Data-Driven Approach and Computational Tools) aims to systematically investigate 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, researchers, government, and the public.

- Project 05-116 (Simulation-based Approach to Investigate the Electric Scooter Rider Protection During Traffic Accidents) looks at taking a step forward for safer e-scooters and for standardized national safety policies. The project will use validated dummy and human models together with a detailed scooter model to investigate the influence of scooter crash variables on rider injuries, which will increase understanding in the field.

- Building on previous research, project 05-086 (A Data Driven Approach to the Development and Evaluation of Acoustic Electric Vehicle Alerting Systems for Vision Impaired Pedestrians) aims to examine the impact that additive sounds have on electric vehicle detectability by pedestrians. Alternate sound distribution methods were evaluated, as were scientific while also FMVSS 141 compliant, sound profiles. A lab-based test environment may also provide an alternate method for evaluating candidate sounds.

- Project VTTI-00-023 (E-Scooter Safety Assessment and Campus Deployment Planning) will raise awareness around e-scooter safety on a campus like Virginia Tech. The results from our data analysis will provide insight for campus alternative transportation management into mitigation strategies for e-scooter safety-critical events.

- VTTI-00-031 (Evaluation of Eyes Off Road During L2 Activation on Uncontrolled Access Roadways) aims to increase understanding of eyes-off road (EOR) time for drivers using Level 2 (L2) automated features on uncontrolled-access roads (e.g., surface streets). This is important as 1) the automated features were not designed to operate on such roads and 2) EOR time during L2 activation implies the user is not monitoring the system appropriately. Both factors suggest a lack of user understanding regarding functional knowledge of the automated features and how to accurately use them.

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.

- Project 06-004 (Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas) highlighted that the majority of today's technology for AVs 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 AV technologies in areas where these features are not well defined and creation of a detailed map would be infeasible, thus leaving out 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 the 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.

- The results from projects 05-093 (Automated Shuttles and Buses for All Users) and 05-113 (Evaluation Tools for Automated Shuttle Transit Readiness of the Area) will be of benefit in considering whether any changes in existing policies and regulations or new policies and regulations are needed to ensure that automated shuttles and buses benefit individuals with disabilities and enhance their mobility. These projects will also create a checklist for future transit planning, and thus can be seen as new policies.

- The results from project 05-086 (A Data Driven Approach to the Development and Evaluation of Acoustic Electric Vehicle Alerting Systems for Vision Impaired Pedestrians) will be used to provide additional input towards the current requirements and testing procedures outlined in FMVSS 141.

Increases in the Body of Knowledge

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

- Researchers from project VTTI-00-024 (Characterizing Level 2 Automation in a Naturalistic Driving Fleet) determined that 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, was 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 this project will greatly increase the knowledge of how drivers' use ADAS technology by analyzing different makes and models (i.e., different ADAS).

- Project 05-093 (Automated Shuttles and Buses for All Users) aims to assist in identifying outreach methods to involve individuals with mobility and vision disabilities in a meaningful way in research, examining their needs associated with the use of automated shuttles and buses. The research will also identify vehicle design and service strategies for ensuring that automated shuttles and buses improve the mobility of individuals with disabilities.
- There is currently a lack of knowledge about how road users will interpret AVs' intent and interact with multiple AVs in a natural setting. Although vehicles equipped with automated driving systems (L3+) are not yet available for purchase, they are under development and tested on public roadways. Project 06-007 (Allusion 2: External Communication for SAE L4 Vehicles) will increase knowledge for human factors and traffic safety researchers in understanding and identifying effective communication strategies between AVs and road users that enhance safety within the transportation ecosystem as AVs are deployed.

Enlargement of the Pool of Trained Transportation Professionals

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

- The findings from project TTI-06-02 (The Future of Parking: Safety Benefits and Challenges) will provide valuable information for the transportation professionals when designing their parking facilities or streets, considering off-street parking for the former and on-street parking for the latter. This study is possibly one of the first to provide insights on self-driving cars from the parking perspective by using simulation tools and measuring the number of conflict points for different scenarios.

- Throughout project 04-117 (A Sensor Fusion and Localization System for Improving Vehicle Safety In Challenging Weather Conditions) two graduate students extensively studied the limitations of existing perception models and developed robust perception models and tracking algorithms for adverse weather conditions.

- The results from TTI-04-02 (Delving into Safety Considerations of E Scooters: A Case Study of Austin, Texas) are expected to help both transportation and public health researchers who want to learn and study new data sources and methodologies in micromobility safety analysis. This project also will constitute the core a Texas A&M civil engineering student's master's thesis.

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.

- Project 06-009 (Enhancing Automated Vehicle Safety Through Testing with Realistic Driver Models) is developing a new model of driver car following that will be used to improve the testing of AV technologies. The model will change the way these technologies are evaluated and likely improve their safety on the roadway.

- The results from 04-114 (Behavior-based Predictive Safety Analytics Phase II) will be utilized in some form for driver monitoring systems, as an identifier of high-risk drivers, or, more specifically, drivers in high-risk situations or conditions. The analytic techniques involve evaluating the driver over trip/time and in various environments and scenarios that are not being utilized by the industry in current applications of their technologies.

- Adopting wearable sensors and smartphones as well as advanced artificial engineering is a unique aspect of project 05-089 (A Holistic Work Zone Safety Alert System through Automated Video and Smartphone Sensor Data Analysis). These technologies are underutilized for the safety of workers in work zones but have huge potential in this regard.

- Project 06-010 (Developing a Framework for Prioritizing Bicycle Safety Improvement Projects Using

Crowdsourced and Image-based Data) aims to utilize crowdsourced (e.g., STRAVA, StreetLight data) and image-based data to develop a robust model to prioritize locations for bicycle improvement projects. Using the crowdsourced data technology, the researchers would like to account for accurate exposure, which is an important factor in safety analysis. Street-level metrics of the natural and built environments based on Google Street View imagery technology will also be adopted. The value of adding these metrics to the other variable types within the prioritization models will be assessed.

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 VTTI-00-031 (Evaluation of Eyes Off Road During L2 Activation on Uncontrolled Access Roadways) will lead to improved user operation of vehicles equipped with L2 automated features. As a result, the L2 features will be used more frequently under appropriate operating conditions and with a more a vigilant driver present. Both of those aspects will lead to better utilization of automated features and improved driver safety, as crash risk due to EOR time will decrease.

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 findings and guidelines proposed for project TTI-05-02 (Analysis of Advanced Driver-Assistance Systems in Police Vehicles) can improve police departments' awareness regarding these systems and how to increase their effectiveness in police operations to improve officers' safety. In addition, the proposed guidelines can be helpful for police vehicle manufacturers to improve the design and implementation of ADAS features in these vehicles.
- Project VTTI-00-024 (Characterizing Level 2 Automation in a Naturalistic Driving Fleet) outputs are anticipated to provide a greater understanding of how drivers are using L2-capable vehicles in the transportation system.
- Project 05-091 (Improving Methods to Measure Attentiveness through Driver Monitoring) outcomes 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.
- Project VTTI-00-036 (Smart Work Zone System) will improve safety for both work zone workers and CVs when approaching or passing a work zone. The system implementation provides a positive impact on work zone operations and safety.
- Project 06-010 (Developing a Framework for Prioritizing Bicycle Safety Improvement Projects Using Crowdsourced and Image-based Data) will aid agencies in better identifying the candidate locations for safety countermeasure implementation, which ultimately improves the safety of the transportation system.
- The results of Project VTTI-00-032 (E-Scooter Design) can be used to ensure that e-scooter designs are safe and effective in real-world environments. Improving e-scooter design will have safety benefits for e-scooter users and all shared road users.
- The outcomes of Project 05-084 (Behavioral Indicators of Drowsy Driving: Active Search Mirror Checks)

may impact the development of future driver monitoring system technologies, and the application of such technology to refining the existing systems will include considerations of glance behavior for instances of drowsy driving.

- Project VTTI-00-025 (Radar and LiDAR Fusion for Scaled Vehicle Sensing Test) will assist in the development of automated driving systems that transport passengers safety and efficiently to their destination.
- 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.

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.

- Project VTTI-00-033 (Human Factors of Level 3 Automation: Surprise Event Response Evaluation) results will lead to new practices or the initiation of a start-up company. The annotated data and results from this project have been transferred to the industry partner collaborating on this research. It is possible that the results from this project will lead to new practices among the industry partners.
- The findings from Project TTI-06-01 (Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking) will provide departments of transportation with a new methodology to evaluate truck parking demand using probe data, as well as a process to prioritize potential new locations for truck parking facilities.
- 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.

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

- Project 06-004 (Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas) explores how the majority of existing AV technologies rely on detailed 3D maps of the environment for Autonomous Navigation. While this approach is feasible for cities, it is less feasible in case of rural communities, as rural communities are sparsely connected and span large areas. The algorithms and the datasets developed as part of this project provide an alternative approach of tackling these challenges unique to rural communities. The researchers expect that these algorithms and datasets will be used by the automotive industry and research entities developing CAVs, while they develop their AV solutions for autonomous running in rural environments.

- Project 06-007 (Allusion 2: External Communication for SAE L4 Vehicles) will directly affect the direction a start-up company will take once the researchers understand the impact of different eHMI conditions.
- The tracking information provided by Project 04-117 (A Sensor Fusion and Localization System for Improving Vehicle Safety In Challenging Weather Conditions) can be used to enhance safety decisions under conditions such as direct sunlight, fog, low light conditions, etc. These enhanced safety features can be commercialized to make transportation safer in adverse weather conditions.
- The outcomes from Project VTTI-00-026 (Guiding Driver Responses During Manual Takeovers from Automated Vehicles) have the potential to harmonize HMI approaches during control transfer, or provide guidance.

Impact on the Body of Scientific Knowledge

Through basic and applied research focused on four key disruptive technologies (connected vehicles, 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.

- Before project TTI-06-02 (The Future of Parking: Safety Benefits and Challenges), parking has never been linked to safety. This project's literature review showed that there are many crashes that have occurred at parking facilities. Although the severity of crashes is low compared to the roadways, the number of pedestrian fatalities and serious injuries were still significant. This knowledge may lead new researchers to look for other research topics focusing on parking and safety together, eventually addressing the related safety issues and reducing the number of crashes.
- Project VTTI-00-021 (Signal Awareness Applications) shows a proof-of-concept connected signal application that demonstrates how a prediction model can be used to accurately estimate future signal phases in near real-time. The application can be used in real-time in the Virginia Connected Corridors and may be applied in other use cases in the future with additional funding.
- Findings from project 06-006 (Private 5G Technology and Implementation Testing) will make an impact on how the new 5G technology and its implementation can be used in transportation to alert road users in different scenarios along with connected vehicle-to-everything technology. The findings will include metrics in latency, user acceptance, and system integration from the road infrastructure to vehicles and pedestrians.
- Findings from project 05-008 (Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation) will both add to base knowledge of safety in alternative transportation in and around a college town as well as how to obtain information and calculate injury rates using various alternative transportation methods.

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 older students at the undergraduate and post-graduate levels.

- Project 05-101 (Evaluation of Transportation Safety Against Flooding in Disadvantaged Communities) plans to design 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 06-003 (Critical Areas in Advanced Driver Assistance Systems Safety: Point of Sale and Crash Reporting) have provided research opportunities to undergraduate students through the Aggie Research Program and coordinated through the principal investigator's participation in the DeBakey Executive Leadership Program.

- Project VTTI-00-033 (Human Factors of Level 3 Automation: Surprise Event Response Evaluation) has made an impact on the transportation workforce development by supporting two Virginia Tech ISE Ph.D. students, Nicholas Britten and Alec Werner. Nicholas and Alec were given the opportunity to contribute to the data analysis and reporting tasks for this project, thereby increasing their knowledge of data analysis techniques and allowing them the opportunity to complete collaborative research with an industry partner. Furthermore, Nicholas completed his Master of Science degree during this reporting period. In addition, the publication of the planned EWD module for this project will help future transportation research professionals by giving them the opportunity to learn about the Wizard-of-Oz research methodology and apply human factors techniques to consider how to improve in-vehicle displays.

- Project 05-087 (Autonomous Delivery Vehicle as a Disruptive Technology: How to Shape the Future with a Focus on Safety?) utilized different innovative datasets. Students involved in this project learned about data collection, limitations in data, identification of trends, and unsupervised machine learning. Knowledge regarding these innovative data science related tasks help in overall workforce development.

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

- Project VTTI-00-023 (E-Scooter Safety Assessment and Campus Deployment Planning) has provided an opportunity for multiple students and new transportation researchers to analyze and apply the data collected during deployment.

- Project 05-096 (Curb Management Practices and Effectiveness in Improving Safety) plans to include datasets and a slide deck targeted towards higher education audiences in transportation data and planning.

- Project 05-093 (Automated Shuttles and Buses for All Users) will increase the understanding of the needs of disabled individuals in using automated shuttles and buses. The lecture prepared as part of the project will be available for use by faculty and staff throughout the country.

- Project TTI-05-01 (Connected Vehicle Data Safety Applications) will use a big data source that requires data engineering, science, and analytical skills in order to access, process and analyze appropriately. It is these skills and the CV data nuances that we plan to share through educational materials and workshops designed for student and working professionals. The goal is to reduce the learning curve for others so that CV data may be used in design and safety applications.

- Project 06-005 (Automated Truck Mounted Attenuator: Phase 2 Performance Measurement and Testing) will make an impact on the workforce development by reaching out to work zone companies dedicated to deploy a TMA truck and share the benefits of this new system.

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 05-089 (A Holistic Work Zone Safety Alert System Through Automated Video and Smartphone Sensor Data Analysis) has led to teaching and research modules. In addition, being a faculty in the construction engineering field, the lead researcher was able to increase interest in transportation research and practice among those who were not exposed to a lot of transportation-related materials.
- Project 06-008 (Emerging Communications Training) will be presented in graduate course BMES 5234 and is educational material meant to increase awareness and guide agency personnel in the successful operation of intelligent transportation systems. Researchers have been working with a undergraduate student who has gained experience with not only researching content but also in connected technologies.
- 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.

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 projects, which led to confusion and low response rate from the completed project's reportingx individuals. Safe-D believes that implementing a separate and shorter survey for complete projects will increase the survey response for completed 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 achieving 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. During this reporting period, 19 Safe-D projects reported that research activities had been impacted by COVID-19 in some way. Among these projects, 6 reported minor impacts, 6 reported moderate impacts, and 7 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 numbers of affected projects have stayed the same from last reporting period; however, the significant 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
- 05-093 Automated Shuttles and Buses for All Users
- 06-009 Enhancing Automated Vehicle Safety Through Testing With Realistic Driver Models
- 05-096 Curb Management Practices and Effectiveness in Improving Safety
- 04-114 Behavior-based Predictive Safety Analytics Phase II
- 05-008 Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation

Safe-D Projects Reporting Moderate Impacts

- VTTI-00-021 Signal Awareness Applications
- 06-006 Private 5G Technology and Implementation Testing
- VTTI-00-036 Smart Work Zone System
- VTTI-00-026 Guiding Driver Responses During Manual Takeovers from Automated Vehicles
- 06-011 Evaluating the Safe Routes to School (SR2S) transportation program in socially vulnerable communities in San Diego County, California
- 05-115 Cooperative Perception of Connected Vehicles for Safety

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
- Project 01-002: Countermeasures to Detect and Combat Driver Inattention While Driving Partially Automated Systems
- TTI-Student-09 Evaluating Emotion Regulation Techniques for Supporting Driving Safety and Performance
- 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
- 05-089 A Holistic Work Zone Safety Alert System through Automated Video and Smartphone Sensor Data Analysis
- VTTI-00-023 E-Scooter Safety Assessment and Campus Deployment Planning

Overall, the main outcome of the above effects of COVID-19 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 extensions have 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 overall time to the studies. Some of the regulations have and may be lifted once the pandemic

has subsided.

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