SEMI-ANNUAL PERFORMANCE REPORT

APRIL 1, 2019 TO SEPTEMBER 30, 2019

SAPR #5

SAFE-D: SAFETY THROUGH DISRUPTION UNIVERSITY TRANSPORTATION CENTER

SAN DIEGO STATE UNIVERSITY

Texas A&M Transportation Institute

VT VIRGINIA TECH TRANSPORTATION INSTITUTE

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

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Accomplishments

Major Goals of the Program

Fueled by the inevitable changes in our transportation system, the Safety through Disruption (Safe-D) National University Transportation Center (UTC) endeavors to maximize the potential safety benefits of disruptive technologies through targeted research that addresses the most pressing transportation safety questions. With the outstanding leadership of the Virginia Tech Transportation Institute (VTTI) and the Texas A&M Transportation Institute (TTI) in a mentoring collaboration with the new transportation research group at San Diego State University (SDSU), a Hispanic-Serving Institution known for educating the transportation workforce, our geographically balanced consortium encompasses the largest group of transportation safety researchers in the nation and provides unparalleled expertise, facilities, and resources to conduct impactful research toward our long-term vision. The Safe-D National UTC focuses its efforts in three 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.

Accomplishments During This Reporting Period

Project Awards and Activity

The Safe-D competitive award process employs a rigorous peer review process, including reviews by the Safe-D Leadership Team at both the Research Statement and full Work Plan stages and a review of invited pitch presentations by the Safe-D Stakeholder Advisory Board. While Safe-D did not solicit research proposals during this reporting period, both VTTI and TTI funded multiple directed projects. Directed projects are awarded by the Safe-D team mid-year based on a high impact merit, strong collaborators, and resource availability. These awards included two separate projects at VTTI and TTI focused on e-scooter safety, an emerging transportation service. Two of the awarded projects received matching funding from industry sponsors exceeding the federal funding. Industry partners from this round of awards include Ford, GM, VDOT, and the National Surface Transportation Safety Center for Excellence (NSTSCE).

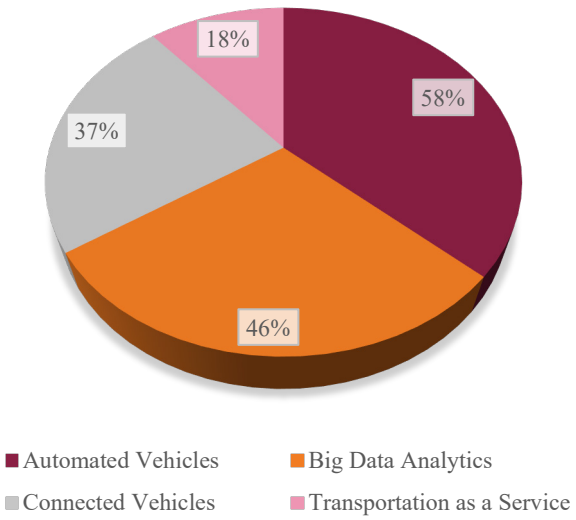

Figure 1. Portfolio of Safe-D Projects by Theme Area (total exceeds 100% due to projects covering multiple theme areas)

At the end of this reporting period, the Safe-D National UTC had a project portfolio of more than $15.4 million, with nearly one-half of project funding sourced from non-federal matching funds. Safe-D projects are selected according to their focus on four Center theme areas: automated vehicles, connected vehicles, big data analytics, and transportation as a service. The coverage of Safe-D themes by project portfolio to-date is shown in Figure 1. 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 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 (*denotes lead institution).

Project TTI-04-02: Delving into Safety Considerations of E-Scooters: A Case Study of Austin, Texas
Institutions: TTI; Award Round: Fall 2019; Theme Area(s): Big Data Analytics, Transportation as a Service*
Dockless electric scooters (e-scooters) are one of the fastest growing transportation methods emerging in the United States Market. During this time, e-scooters have quickly become an exciting transportation method; however, they still pose many safety concerns. This case study builds upon a study performed by the Austin Public Health Department in 2019 to provide a more in-depth examination of e-scooter safety concerns based on a data-driven approach with Austin as a study site. Numerous tools are used to develop a better understanding of e-scooter safety, including: a literature review on e-scooter safety evaluations, analysis of crash characteristics involving e-scooters, and an examination of people's perceptions of e-scooter safety.

Project VTTI-00-023: E-Scooter Safety Assessment and Campus Deployment Planning
Institutions: VTTI; Award Round: Summer 2019; 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 are also deployed to evaluate a variety of additional measures through a classification system designed by the team.

Project VTTI-00-0024: Characterizing Level 2 Automation in a Naturalistic Driving Fleet
Institutions: VTTI; Award Round: Fall 2019; Theme Area(s): Big Data Analytics, Automated Vehicles*
In this project, vehicles with Society of Automotive Engineers (SAE) Level 2 features will be instrumented with data acquisition systems that can collect multiple video views, sensor data, and vehicle network data. The goal of this project is to answer research questions associated with Level 2 automation feature use including the frequency, timing, and characteristics of activations and deactivations. In addition, take-over requests are used to examine the effectiveness of Level 2 systems in handling diverse road features and environmental conditions. These efforts will result in the creation of a framework to characterize the real-world operational domain of Level 2 features based on naturalistic data.

Project VTTI-00-026: Guiding Driver Responses During Manual Takeovers from Automated Vehicles
Institutions: VTTI; Award Round: Fall 2019; Theme Area(s): Automated Vehicles, Connected Vehicles*
The goal of this project is to explore human–machine interfaces to improve driver's situational awareness and response selection, and to guide appropriate driver responses in challenging situations where the driver is forced to take control of a vehicle as a result of automated system use. The work leverages VTTI's virtual reality driving platform that allows the research to quickly prototype human–machine interface options and examine the responses of human subjects in various scenarios. This work will help identify the most appropriate human–machine interfaces to facilitate accurate situational awareness responses during takeover scenarios. It will also inform original equipment manufacturers by providing information on future design and evaluation of human–machine interfaces.

Completed Projects

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

- 02-008: Pavement Perspective on AV Safety through Optimizing Lateral Positioning Pattern
- 02-019: Identification of Railroad Requirements for the Future Automated and Connected Vehicle (AV/CV) Environment
- 02-020: Behavior-based Predictive Safety Analytics – Pilot Study
- 03-050: Design and Evaluation of a Connected Work Zone Hazard Detection and Communication System for Connected and Automated Vehicles (CAVs)
- 03-051: Response of Autonomous Vehicles to Emergency Response Vehicles
- 03-072: Preventing Crashes in Mixed Traffic with Automated and Human-Driven 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.

- 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving
- TTI-Student-05: Exploring Crowdsourced Monitoring Data for Safety

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

- 01-001: Big Data Methods for Simplifying Traffic Safety Analyses
- 01-004: Driver Training for Automated Vehicle Technology
- 01-005: Factors Surrounding Child Seat Usage in Ride-Share Services
- 02-016: Older Drivers and Transportation Network Companies: Investigating Opportunities for Increased Safety and Improved Mobility
- 02-020: Behavior-based Predictive Safety Analytics – Pilot Study
- 03-040: Examining Senior Drivers Adaptation to Mixed-Level Automated Vehicles: A Naturalistic Approach
- 03-050: Design and Evaluation of a Connected Work Zone Hazard Detection and Communication System for Connected and Automated Vehicles (CAVs)
- TTI-01-04: Influences on Bicyclists and Motor Vehicles Operating Speed within a Corridor
- TTI-03-01: Legal and Technological Tools for Accessing AVCV Data Sets
- TTI-Student-04: Motorcycle Crash Data Analysis to Support Implementation of a Concrete Barrier Containment Options for Errant Motorcycle Riders

Safe-D Programming

As noted in the original proposal, Safe-D has commenced a number of programs targeting its Leadership, Education and Workforce Development, Technology Transfer, and Diversity initiatives. The following sections highlight major accomplishments under these directives.

Continuing Education/Professional Development

Safe-D continues to develop and implement many continuing education and professional development activities. All Safe-D researchers are encouraged to seek out opportunities in this area at the project level and conducting these activities at the program level. Many of these activities are described in the Highlighted EWD & Other Outreach Activities and Outputs section; additional activities reported by research teams during this period are listed below:

- 01:003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety. Presented research results at the Caltrans Innovation Fair.
- 04-104: Development of a Connected Smart Vest for Improved Roadside Work Zone Safety. Presented at the Myers-Lawson School of Construction Industry Board Meeting to approximately 70 attendees.
- 04-103: Examining Senior Drivers' Adaptation to Mixed-Level Automated Vehicles: Phase II. Research team presented results at the 8th International Symposium on Naturalistic Driving Research to approximately 65 session attendees.
- 04-100: Development of a Diagnostic System for Air Brakes in Autonomous and Connected Trucks. Project team members participated as panel members and speakers at the Brookings Institution, Panel on Autonomous Vehicles (approximately 50 attendees).
- 04-104: Development of a Connected Smart Vest for Improved Roadside Work Zone Safety. Project team members participated in the Construction Industry Institute Technology Committee, conveying project results to approximately 50 attendees.
- TTI-03-01 - Legal and Technological Tools for Accessing AV/CV Data Sets. This project team presented project results to 75 Texas A&M Law School faculty and students.
- 03-051 Response of Autonomous Vehicles to Emergency Response Vehicles. Graduate students from the project team presented a technical paper at SAE, reaching over 125 industry professionals.
- 04-115 Reference Machine Vision for ADAS Functions. Project team members conducted a workshop presentation and poster session to approximately 200 industry and state DOT professionals.

- 04-115 Reference Machine Vision for ADAS Functions. Results from this project were presented to 75 industry professionals at the 2019 18th European Control Conference in Naples, Italy during this period.

Professional Skills Training Series

Safe-D/CARTEEH Graduate Student Leadership Development Seminar

The Safe-D UTC and Center for Advancing Research in Transportation, Emissions, Energy, and Health (CARTEEH) hosted a seminar titled "Investing in Your Academic Writing" on April 1, 2019. This seminar was the next installment in their Graduate Student Leadership Development series. Dr. Patricia Goodson, a Presidential Professor at Texas A&M, was the key presenter of this interactive seminar focused on the development of helpful writing styles to becoming successful academic writers.

Student Awards Program

Safe-D is proud of its students' accomplishments and continues to encourage students to seek opportunities, including the Eno Leadership Development Program, the Eisenhower Fellowship Program, and other student awards and leadership development opportunities that arise. The following is a selection of awards that our students have received during this reporting period.

Safe-D Student Selected for Traffic Safety Scholar Award at the 2019 Lifesavers National Conference on Highway Safety Priorities

The Lifesavers National Conference on Highway Safety Priorities was held from March 31 to April 2, 2019 in Louisville Kentucky. Sirajum Munira, a Texas A&M Safe-D student, was selected as a Traffic Safety Scholar for her presentation on reducing distractions and aggressive driving through smartphone app use. The Traffic Safety Scholars Program provides up to $1,000 to selected students to help cover the cost to attend the conference.

Safe-D Students Selected for TTI Employee Awards

Two TTI students were selected as TTI employee award winners for their work on Safe-D projects in 2019. TTI Employee Awards are given each year to master's and doctoral graduate research assistants. To receive the award, supervisors nominate students, and their applications are reviewed by senior TTI Research staff. Roshan Sharma was selected as the master's student of the year for their project, Implications of Truck Platoons for Roadside and Vehicle Safety Hardware. Maryam Dastigiri Shirinzad was selected as the doctoral student of the year for their project, Development of Analytic Method to Determine Weaving Patters for Safety Analysis near Freeway Interchanges with Access Management Treatments.

2019 Collegiate Student Safety Technology Design Competition of the ESV 26th International Technical Conference

VTTI and Virginia Tech (VT) Safe-D students won the 2019 Collegiate Student Safety Design Competition (SSTDC) at the Enhanced Safety of Vehicles (ESV) 26th International Technical Conference hosted by National Highway Traffic Safety Administration (NHSTA) in the Netherlands on June 10–13, 2019. A panel of international vehicle safety engineering experts selected the students for their development of PREPARES, a rear-end collision safety feature.

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 (for the Summer 2019 period, only), researchers involved in Safe-D research projects taught four graduate and undergraduate courses, reaching 25 students. Safe-D research projects supported 50 undergraduate- and graduate-level students during this reporting period, including 16 students from underrepresented populations. In addition, research teams reported six students graduating during the course of research activities, five of which were placed for employment in either the public or private sector. The remaining one continued on to pursue higher education. 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	8	1
Masters	17	6
PhD	25	9

Highlighted EWD & Other Outreach Activities

Visit from Deputy Assistant Secretary for Research and Technology Diana Furchtgott-Roth

On September 11, 2019, Deputy Assistant Secretary for Research and Technology Diana Furchtgott-Roth visited Virginia Tech. During her visit, she gave a plenary speech at the 5th International Symposium on Future Active Safety Technology toward Zero Accidents (FAST-zero-19) to researchers and engineers from industry and academia worldwide. VTTI hosted a facility tour and Safe-D student poster session during which students were able to meet Ms. Furchtgott-Roth individually and discuss their research results with her. VTTI researchers then engaged Ms. Furchtgott-Roth in an open discussion about research being conducted at VTTI and through Safe-D, and how VTTI and Safe-D can best support the USDOT's initiatives moving forward.

2019 Summer Undergraduate Research Internship Program

TTI again hosted a summer undergraduate research internship program selecting six students from a pool of 20 applicants. Selected students came from Virginia Tech, San Diego State, Texas A&M, and University of Texas-Rio Grande Valley, a minority serving institution. Each student was matched to a Safe-D mentor and completed an independent project culminated in a presentation of their results at a University-wide research symposium for undergraduate research. Professional development seminars were held throughout the summer on technical topics as well as career options.

Safe-D Student and Faculty Interview Chain

In this reporting period, Safe-D students and researchers started a networking and interviewing chain to help Safe-D students generate better connections with fellow students and professionals in their field of study. This chain provides more opportunities for research and has the potential to increase employment and partnering opportunities for students.

Choices and Challenges Forum

Hosted by Virginia Tech's Department of Science, Technology, and Society on April 4th, the 2019 Choices & Challenges forum explored the ethical and social issues around self-driving automobiles in Virginia's New River Valley region by bringing together the public and internationally recognized experts. Moderated by Miguel Perez, VTTI's Director of the Center for Data Reduction and Analysis Support and Safe-D EWD Coordinator, the event opened with a technical plenary of industry and academic panelists discussing the opportunities and challenges raised by the emergence of automated vehicles on our roads and in our lives. The plenary was followed by a series of concurrent roundtable discussions of the social/ethical/political/technical issues surrounding self-driving cars.

"Dialog on Highway Automation" Workshop

The Virginia Department of Transportation's Office of Strategic Innovation hosted Bristol District's "Dialog on Highway Automation Workshop" on April 16th, 2019 at the Higher Education Center in Abingdon, Virginia. Based on the national effort led by the Federal Highway Administration, VDOT is hosting workshops throughout 2019 across Virginia and will be using the information gathered to help develop the Department's AV Strategic Plan.

Explore SDSU Open House 2019

On March 23, 2019, SDSU hosted their Explore SDSU Open House, a free event that could be attended by all SDSU alumni, community members, and potential students. The Safe-D research team at SDSU presented several posters on topics including aggressive driving, intelligent traffic management centers, and vulnerable road users. Through a video demonstration, the Safe-D research team showed participants how road users can be detected and tracked as

they engage with other road users at signalized intersections. The Open House also included activities centered on the safety issues of driving under the influence of narcotics. Participants were provided impairment goggles and encouraged to follow instructions on a drunk buster challenge map or participate in a cup stacking challenge.

4th Annual TTI Transportation Technology Conference

The 4th Annual TTI Transportation Technology Conference was held form April 29 to May 1, 2019 at the Stella Hotel in Bryan, Texas. The conference offered workshops, general sessions, student presentations, and tours of Texas A&M's research facilities. The workshop topics included low-speed autonomous shuttles and transportation blockchain applications. General sessions covered multiple topics, including research projects, pilots, and deployments associated with infrastructure needs, system user perspectives, truck automation, and workforce development. Multiple researchers from TTI and VTTI collaborated and presented the results of their projects, including Dr. Charlie Klauer of VTTI who presented results of Project 01-004, Driver Training for Automated Vehicle Technology.

UTC Spotlight Conference

The UTC Spotlight Conference was held on May 14th, 2019 at the Russell Senate Office Building in Washington D.C. Two Safe-D projects were represented at the event: Project 02-010, Safety Perceptions of Transportation Network Companies by the Blind or Visually impaired, and Project VTTI-00-022, Automated Truck Mounted Attenuator.

2019 Thomas Jefferson Symposium to Advance Research (tjSTAR)

Safe-D Researcher Ralph Buehler of Virginia Tech presented on Project 02-027, Street Noise Relationship to Vulnerable Road User Safety, at the 2019 Thomas Jefferson Symposium to Advance Research (tjSTAR) on May 28th and 29th, 2019 in Alexandria, Virginia. Dr. Buehler presented and discussed sustainable transport with students. He further encouraged students to apply the concept to urban transport using a case study of Vienna, Austria in which Vienna reduced the car share by 13 percent from 1993 to 2015.

11th Annual STEM Robotics, Maker, & Cyber Security Challenge Judges

Two student technology events were held in Virginia Beach, Virginia, both hosted by Virginia Beach Public Schools. Reginald Viray of VTTI represented Safe-D at this event and asked students to use a Raspberry Pi, sensors, and craft supplies to improve summer visitor experience in safety, transportation, entertainment, or accommodations.

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.

Plans for Next Reporting Period

Safe-D Fall 2019 Stakeholder Meeting, Workshop, and Call for Proposals

In late Fall 2019, Safe-D will hold a Stakeholder Advisory Board Engagement Meeting to gain feedback on industry research needs. As in previous rounds, after this feedback is received and distributed during a workshop with researchers interested in proposing projects to Safe-D, a competitive solicitation of research proposals will follow. After proposals are vetted through the review process described in

Project Awards and Activity, awards from this competition are expected to be made in Spring 2020.

Select Outreach and Diversity Activities Planned

Safe-D/CARTEEH Graduate Student Leadership Development Seminar

Safe-D and CARTEEH have planned the Graduate Student Leadership Development seminar series for the 2019-2020 school year. There will be four events total, two in the Fall semester and two in the Spring semester. The first seminar will be held on October 10, 2019. This career readiness discussion will focus on skill development for students to better present the results of their research projects. This seminar will feature two Safe-D students from TTI presenting their research results.

VDOT Career Fair

Safe-D plans to participate in the 15th Annual VDOT Transportation Career Fair, held annually in northern Virginia. During this event, researchers and students from VTTI will present information about the Safe-D National UTC and about careers in transportation research to high school students from the northern Virginia area. Safe-D has participated in this unique event since 2017 to encourage the next generation to seek careers in transportation fields.

VT Science Festival

Safe-D will once again participate in the 6th Virginia Tech Science Festival hosted by the Institute for Creativity, Arts, and Technology (ICAT) at Virginia Tech. This event allows various organizations, colleges, and departments at Virginia Tech to demonstrate different types of engineering, science, arts, and design to a large gathering—covering a wide age range—of individuals from the Blacksburg area. Safe-D will be represented by researchers and students from VTTI, who will host an exhibit with hands-on demonstrations to teach. festival participants about the advanced technologies being implemented in the area of transportation.

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

- VTTI-00-026: Guiding Driver Responses During Manual Takeovers from Automated Vehicles. General Motors agreed to cost share up to $150,000 and contribute as an industry champion.
- 04-101: Safety Impact Evaluation of a Narrow Automated Vehicle-Exclusive Reversible Lane. Linscott, Law & Greenspan engineers contributed in kind and with collaborative research. Caltrans contributed in kind.
- VTTI-00-022: Automated Truck Mounted Attenuator. The Virginia Transportation Research Council contributed financially and with collaborative research. DBi Services contributed financially and with collaborative research. Transurban contributed financially and with collaborative research.
- VTTI-00-023: E-Scooter Safety Assessment and Campus Deployment Planning. Spin and Ford both contributed financially.
- 03-036: Modeling Driver Responses during AV Platooning Failures. Waymo joined meetings and provided valuable feedback on project direction.
- 04-117: A Sensor Fusion and Localization System for Improving Vehicle Safety. Ford contributed by providing use cases for the project.
- 04-114: Behavior-based Predictive Safety Analytics Phase II. SmartDrive contributed in kind.
- 04-120: Impacts of Connected Vehicle Technology on Automated Vehicle Safety. Ericsson contributed financially and in kind.
- 03-064: Automated Vehicle Behavior Monitoring for Vulnerability Management. BlackBerry contributed in kind.

- 04-110: Developing an Intelligent TMC with a Safety Evaluation Focus for Smart Cities. The City of Chula Vista collaborated through monthly meetings and the development of an MOU between the City and SDSU. CohuHD Costar provided a video camera.
- TTI-Student-05: Exploring Crowdsourced Monitoring Data for Safety. The project team collaborated with Streetlight Data which allowed access to their InSight online analytics platform and databases.
- 04-115: Reference Machine Vision for ADAS Functions. 3M collaborated through bi-weekly meetings and provided pavement marking samples for testing.

International Collaborators

- 03-036: Modeling Driver Responses during AV Platooning Failures. Leeds University (England), led by Gustav Markkula, provided project direction and exchanged modeling processes and code.
- 04-114: Behavior-based Predictive Safety Analytics Phase II. The Technical University of Braunschweig (Germany), led by Frederick Schewe, contributed in kind and with collaborative research.
- 04-120: Impacts of Connected Vehicle Technology on Automated Vehicle Safety. Ericsson (Global), led by Eric Qian, contributed financially and in kind.
- 03-064: Automated Vehicle Behavior Monitoring for Vulnerability Management. BlackBerry contributed in kind.

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 exposed to practitioners and potential users. The Safe-D website attracted 1,550 visitors during the six-month reporting period. With the 2,088 visitors during the previous six-month reporting period, Safe-D greatly exceeded our annual goal of 2,000 visitors per year with a total of 3,638 visitors between October 1, 2018–September 30, 2019. Project Page visits averaged just over 42 visits per page for the six-month reporting period. During this period, the Safe-D team attempted to increase traffic to the project pages including sending email to stakeholders with links to new project information and adding links to the Safe-D homepage to increase visibility. Unfortunately, these measures did not result in an increase in page visits as expected. The Safe-D team will continue these practices to help raise awareness but will also investigate and try new ways to increase traffic to the actual project pages.

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	1,550; 3,638 visitors/previous 12mo.
	Project Pages: Average ≥150 visitors/year	2,253 total visits/period; average 42.5 visitors/project page
Journal Articles/Conference Presentations	Project Teams: 1 article/year	4 articles; 0.13 average per reporting project
	Project Teams: 1 conference/year	15 presentations; 0.50 average per reporting project
Facility Tours	Displays viewed by ≥ 200/year	850 total visitors; average of 12 visitors per reporting project
	Follow-up Interest: 5 visitors/year	6

Prior to this reporting period, a total of 13 projects had been completed resulting in 30 journal articles and 69 conference presentations. Within this reporting period, eight additional projects have been completed and a total of four new journal articles with 15 new conference presentations were reported by project teams. These additions bring the average rate of publications per completed project to 1.6 journal articles per project and 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 850 views of Safe-D displays during outreach events during the six-month reporting period; last period, researchers reported 100 views, bringing the yearly total to 950 which exceeds with the annual goal of 200 views.

Publications, Conference Papers, and Presentations

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

Journal Publications/Conference Papers

Hasani, M., Jahangiri, , Sener, I. N., Munira, S., Owens, J. M., Appleyard, B., Ryan, S., Turner, S. M., and Ghanipoor Machiani, S. (2019) "Identifying High-Risk Intersections for Walking and Bicycling using Multiple Data Sources in the City of San Diego". (Published)

Liang, D., Antin, J. & Lau, N. (in press). Examining senior drivers' acceptance to advanced driver assistance systems. Proceedings of the 5th International Symposium on Future Active Safety Technology toward Zero Accidents (FAST-zero '19). (Published)

Mao, H., X. Deng, D. Lord, and F. Guo (2019) Adjusting finite sample bias in traffic safety modeling. Accident Analysis & Prevention, Vol. 131, pp. 112-121. (Published)

Shirazi, M., and D. Lord (2019) Characteristics Based Heuristics to Select a Logical Distribution between the Poisson-Gamma and the Poisson-Lognormal for Crash Data Modelling. Transportmetrica A: Transport Science, Vol 15, Issue 2, pp. 1791-1803. (Published)

Presentations

Alambeigi, H., McDonald, A.D., and Tankasala, R. (2020). Crash themes in automated vehicles: A topic modeling analysis of the California Department of Motor Vehicles Automated Vehicle Crash Database. To be presented at the 99th Annual Meeting of the Transportation Research Board. Washington, D.C. January, 2020. (Accepted)

Antin, J., (2019). Examining senior drivers' adaptation to vehicles equipped with advanced driver assistance systems. Poster Session presented at the 8th International Symposium on Naturalistic Driving Research, August 13-14th, 2019. Melbourne, Australia. (Accepted)

Basantis, A., Miller, M., Doerzaph, Z., Neuratuter, L. (2019) "Assessing Alternative Approaches for Conveying Automated Vehicle 'Intentions'". Presented at the Torgersen Awards, Blacksburg, Virginia. May 7, 2019. (Other)

Basantis, A., Miller, M., Doerzaph, Z., Neurauter, L. (2019) "Assessing Alternative Approaches for Conveying Automated Vehicle 'Intentions'". Presented at the 2019 SBES Symposium, Blacksburg, Virginia. May 15, 2019. (Other)

Basantis, A., Miller, M., Doerzaph, Z., Neurauter, L. (2019) "Assessing Alternative Approaches for Conveying Automated Vehicle 'Intentions'". Poster presented at the FAST-Zero Conference, Blacksburg, Virginia. September 11, 2019. (Other)

Das, S., and R. Wang. "Patterns of Origin Destination Travels using Massive GPS Trajectory Data: Insights from Rules Mining," Submitted for consideration for the presentation at the 99th TRB Annual Meeting, Washington DC, Jan 12-16, 2020. (Submitted)

Jefferson, J. A. and McDonald, A.D. (2019). The automated vehicle social network: Analyzing tweets after a recent Tesla Autopilot crash. To be presented at the Human Factors and Ergonomics Society's 2019 International Annual Meeting, Seattle, WA, October 2019. (Accepted)

Li, X., B. Dadashova, S. Turner and D. Goldberg. "Rethinking Highway Safety Analysis by Leveraging Crowdsourced Waze Data" Submitted for consideration for the presentation and publication at the 99th TRB Annual Meeting, Washington DC, Jan 12-16, 2020. (Submitted)

Liang, D. Examining senior drivers' acceptance to advanced driver assistance systems. Poster session with Diana Furchtgott-Roth, Deputy Assistant Secretary for Research and Technology OST-R September 11, 2019. Blacksburg, Virginia. (Other)

Liang, D. Examining senior drivers' acceptance to advanced driver assistance systems. 5th International Symposium on Future Active Safety Technology toward Zero Accidents. September 11, 2019. Blacksburg, VA. (Other)

Liu, S. Rathinam and S. Darbha, "Lateral Control of an Autonomous Car with Limited Preview Information," 2019 18th European Control Conference (ECC), Naples, Italy, 2019, pp. 3192-3197. doi: 10.23919/ECC.2019.8796007

Mao, H., I X. Deng, and F. Guo (2019) Modeling Crash Risk. International Conference on Frontiers of Data Science, Hangzhou, China, May 27, 2019. (Accepted)

Morgan, C. (2019). Railroad Considerations for the Future Connected and Automated Vehicle Environment. Presentation at the 2019 National Highway-Rail Grade Crossing Conference, Pittsburgh, PA. (Published)

Sivakumar Rathinam, Reference Machine Vision for ADAS Functions, Automated Vehicles Symposium, Orlando, Florida, July 16th, 2019. (Accepted)

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Theses and Dissertations

Basantis, A., Miller, M., Doerzaph, Z., Neurauter, L. (2019) “Assessing Alternative Approaches for Conveying Automated Vehicle ‘Intentions’”. Master’s Thesis Presentation, Blacksburg, Virginia. September 27, 2019. (Under Review)

Mao, H. (2019) Decision-Adjusted Approach for Driving Risk Evaluation. Ph.D. Dissertation, Department of Statistics, Virginia Tech, Blacksburg, Virginia. (Accepted)

Website(s) or Other Internet Sites

Safe-D Website

During this reporting period, the Safe-D National UTC website was regularly updated with developments from the Safe-D program, including links to project products (e.g., EWD and T2 outputs) and Safe-D outreach activity descriptions. As the website is Safe-D’s primary method of external interfacing, the Center is committed to providing up-to-date information through this public website using a modern, minimalist approach to rapid information sharing. The Safe-D website averaged over 258 users per month, with 1,491 new users during this period. Users viewed pages 7,275 times during this period, visiting an average of 3.11 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 205 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 dispersed universities. During this reporting period, the Safe-D leadership team 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.

Outcomes

The Safe-D projects described in the previous sections are continuing to create outcomes resulting in changes to the transportation system through increased understanding and awareness of transportation issues; focus and impact on future policy, regulation, rulemaking, and legislation; additions to the body of knowledge; training of the future transportation workforce; and improvements to 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, it is expected that future reporting periods will include descriptions of how the outcomes of Safe-D projects have also resulted in the adoption of new technologies, techniques, or practices.

The T2 Performance Goals and corresponding Metrics for Outcomes/Impacts, as written in the currently approved Safe-D T2 Plan, are listed below. The Safe-D Leadership Team has tracked and will be reporting these metrics in the current and all following SAPRs (Table 3). The Safe-D team participated in eight outreach events to promote the program and projects to an audience totaling 330 practitioners, including DOT officials, industry partners, and graduate students.

During the formalization of its T2 Plan, the Safe-D team modified its processes to solicit greater input from stakeholders with each project team being required to identify an industry champion. The industry champion involvement was intended to help steer the research teams towards delivering project products that better match real industry needs. The goal of this effort was to increase the likelihood of adoption and utilization of research results. During this reporting period, project teams did not report any new instances of vendors or DOTs using technology developed and no licensing activity occurred. It is also our assumption that very few of the projects that went through the new process have reached a point in their timelines where deliverables would be mature enough for implementation. The Safe-D team will monitor this trend closely during the next cycle to determine what, if any, actions could be taken to increase the rate of adoption. In addition, new weighting may be added to the project selection criteria to account for the likelihood that a project will result in deliverables that would be adopted by an industry partner. In general, Safe-D expects that practitioner use of technology will increase with maturity and closer to the end of the program. In general, the Safe-D program is currently on-track to meet its T2 performance goals through this reporting period.

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	8 events, 0.30 average events per reporting project
	Each Event: average 15 practitioners	330 total attendees; average of 33 attendees/event
Vendors Using Technology Developed	Average 1/3 projects result in vendors using technology	0
	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

- 01-007: Preparing Work Zones for Automated and Connected Vehicles. This project is increasing public- and private-sector awareness of issues surrounding the accommodation of autonomous and connected vehicles in work zones.
- 02-019: Identification of Railroad Requirements for the Future AV/CV Environment: Increased understanding and awareness of transportation issues associated with automated and connected vehicles at highway-rail grade crossings.
- 03-082: Assessing Alternative Approaches for Conveying Automated Vehicle 'Intentions.' This project was the first of its kind to expose volunteer participants to fully automated vehicles and to testing HMI systems in a high-fidelity environment, resulting in improved understanding and awareness of vehicle automation among the general public.
- 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving. The outcomes of this project will help transportation agencies become aware of potentially risky locations within their road networks.

- 04-098: Data Mining Twitter to Improve Automated Vehicle Safety. The outcomes of this project were presented to students and at a conference to increase awareness of the utility of social media analysis for transportation-related work.
- VTTI-00-022: Automated Truck Mounted Attenuator. This project will increase awareness about the dangers of roadside workers and TMA truck drivers and increase the body of knowledge about the dangers they face. This project will also result in a new technology that will protect those roadside workers and TMA truck drivers by removing them from the seat of the vehicle. This will hopefully result in the adoption of this new ATMA technology and result in new procedures to be used by roadside operators over time.
- TTI-Student-05: Exploring Crowdsourced Monitoring Data for Safety. This project increased awareness of several crowdsourced datasets that can be applied to improve safety analysis.

Passage of New Policies, Regulation, Rulemaking, or Legislation

- 03-064: Automated Vehicle Behavior Monitoring for Vulnerability Management. This project will contribute to updating the policies for cybersecurity protection by developing algorithms for detecting cybersecurity attacks in automobiles and classifying driver behavior. This project will also produce a cybersecurity reference dataset that can be used for the development of cyberattack detection algorithms, advancing the ability to design and test security incident detection systems.
- 03-073: Autonomous Emergency Navigation to a Safe Roadside Location. By allowing automated vehicles to navigate to safe roadside locations in the event of errors, this project will facilitate changes in regulations that promote the penetration of vehicle with new active safety features.
- 04-115 Reference Machine Vision for ADAS Functions-This project will result in new test method standards for pavement markings and machine vision systems to be used by State DOTs as well as marking material and ADAS system manufacturers.

Increases in the Body of Knowledge

- 03-064: Automated Vehicle Behavior Monitoring for Vulnerability Management. This project will produce algorithms for detecting cybersecurity attacks in automobiles and classifying driver behavior. These will enhance the abilities of prior algorithms by employing a rich set of vehicle and system misbehaviors identified from complex real-time driving data. The project will also increase the body of knowledge by developing a cybersecurity reference dataset that can be used for the development of cyberattack detection algorithms.
- 03-082: Assessing Alternative Approaches for Conveying Automated Vehicle 'Intentions.' This study was the first to expose volunteer participants to a fully automated vehicle and test HMI systems in a high-fidelity environment. The results will also advance the development of future HAV technologies.
- 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving. The interactive web-based tools developed in this project will advance the state of practice for identifying when and where risky driving occurs in the road network.
- 04-120: Impacts of Connected Vehicle Technology on Automated Vehicle Safety. This project is expected to increase the body of knowledge regarding the intersection of connected vehicle technologies and automated driving systems.
- VTTI-00-022: Automated Truck Mounted Attenuator. This project will increase awareness about the dangers faced by roadside workers and TMA truck drivers along with new technology to protect the vulnerable workers.
- VTTI-00-023: E-Scooter Safety Assessment and Campus Deployment Planning, The outcomes of this project will enhance the body of knowledge regarding the safety and mobility aspects of e-scooter deployment and the best practices for the deployment of micromobility programs.

Improved Processes, Technologies, Techniques, and Skills in Addressing Transportation Issues

- 03-064: Automated Vehicle Behavior Monitoring for Vulnerability Management. This project will develop algorithms for detecting cybersecurity attacks in automobiles and methods for classifying driver behavior. These new algorithms will improve existing processes for anticipating and responding to cybersecurity attacks as well as designing and testing systems to detect security incidents.
- 03-082: Assessing Alternative Approaches for Conveying Automated Vehicle 'Intentions.' This study is the first to expose volunteer participants to a fully automated vehicle and testing HMI systems in a high-fidelity environment. Thus, the results will help to improve AV and HMI technologies by familiarizing the general public with these systems. Recommendations derived from the results will aid in the development of future technologies for HAVs.
- 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving. The interactive web-based tools developed in the project will improve the process of identifying risky driving in road networks. In turn, this will help transportation agencies enact countermeasures to address the issues resulting in risky driving behavior.
- 04-114: Behavior-based Predictive Safety Analytics Phase II. The real-time crash risk algorithms developed during this project may be applied to live vehicles to improve the way that crash risk is assessed and mediated.
- TTI-01-02: Creating a Smart Connected Corridor to Support Research into Connected and Automated Vehicles. Be creating a smart connected corridor for connected and automated vehicle research, this project will improve the processes of developing and testing connected and autonomous vehicles on rural roadways, high-speed roadways, and freeways.
- VTTI-00-021: Signal Awareness Applications. By revealing the technical and human factors constraints associated with user interfaces for notifying and alerting drivers to pertinent intersection-related information, this project will improve the way that signalized intersections are designed to curb unsafe driving behaviors.
- VTTI-00-023: E-Scooter Safety Assessment and Campus Deployment Planning. The outcomes of this project improve the processes implemented by communities to deploy e-scooter programs and other micromobility options.

Enlargement of the Pool of Trained Transportation Professionals

- 04-098: Data Mining Twitter to Improve Automated Vehicle Safety. The results of this project will be presented at the HFES conference to increase the awareness of the utility of social media analysis for transportation work.

Adoption of New Technologies, Techniques, or Practices

- 02-019: Identification of Railroad Requirements for the Future AV/CV Environment. This project will lead to the adoption of new technologies designed to facilitate the interaction of automated and connected vehicles at highway-rail grade crossings.
- 03-064: Automated Vehicle Behavior Monitoring for Vulnerability Management. This project will develop (1) algorithms for detecting cybersecurity attacks in automobiles and classifying driver behavior and (2) a cybersecurity reference dataset. These outputs will be applied to improve how cyberattacks are detected and how security incident detection systems are designed.
- 03-082: Assessing Alternative Approaches for Conveying Automated Vehicle 'Intentions.' By exposing volunteer participants to a fully automated vehicle and testing HMI systems in a high-fidelity environment, this project will improve the process through which future technologies for HAVs are developed.
- 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving. The interactive web-based tools developed in this project will be applied to identify when and where risky driving occurs, improving the ability of agencies to enact appropriate countermeasures.

- 04-104: Development of a Connected Smart Vest for Improved Roadside Work Zone Safety. This project will result in the implementation of a new technology, a smart vest for work zone workers, that will improve worker safety at roadway projects.
- 04-114: Behavior-based Predictive Safety Analytics Phase II. The real-time crash risk algorithms developed in this project will be implemented to reduce crashes related to driver error through inattention, fatigue, and unsafe driving behaviors.
- 04-115: Reference Machine Vision for ADAS Functions. This project will provide a new bench-marking system that allows the characterization of the performance of LDW and LKA systems with different lane markings and in different lighting and weather conditions.
- VTTI-00-022: Automated Truck Mounted Attenuator. This project will also result in a new technology to protect roadside workers and TMA truck drivers by removing them from the seat of the vehicle. This new automated TMA technology is expected to be adopted over time, resulting in a new procedure to protect roadside operators.

Impacts

Impact of Effectiveness on 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. Examples of how Safe-D projects are affecting transportation effectiveness or are expected to in the near future are provided below:

- 01-001: Big Data Methodologies for Simplifying Traffic Safety Analyses. This project is developing new analysis tools for reducing the number and severity of motor vehicle crashes.
- 01-003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety. This project demonstrated how data from multiple sources (automated counting system data, video data, and crash data) can be utilized to estimate pedestrian and bicyclist exposure and risk at signalized intersections. The procedure developed in this project can be used to estimate risk at other units of analysis such as road segments and census tracts. The results demonstrate how high-risk intersections can be identified using different risk quantification methods. The findings are expected to help agencies prioritize facilities with the highest need for safety improvements.
- 01-007: Preparing Work Zones for Automated and Connected Vehicles. The outcomes of this project will help agencies and the private sector develop and implement work zones that can be safely navigated by autonomous and connected vehicles, increasing the safety and efficiency of the transportation system.
- 02-016 Older Drivers and Rideshare Services. Products from this project will be used by eldercare social service organizations to educate older people on how to safely use rideshare services as a transportation alternative.
- 02-026 Sources of Bias in Big Data, project outcomes will inform users of crowd-sourced data about pitfalls to avoid in generalizing to larger transportation system.
- 03-036: Modeling Driver Responses during AV Platooning Failures. When completed, the outcomes of this project research will assist the designers of driving automation systems to introduce limits into their technology (e.g., minimum following distances and maximum speeds) to permit their safe operation.
- 03-064: Automated Vehicle Behavior Monitoring for Vulnerability Management. The algorithms and/or methods resulting from this project will be adopted primarily by automotive technology developers and automotive original equipment manufacturers (OEMs) to make automated and connected vehicles safer in the event of a cybersecurity attack. specifically, the outcomes of this project will enable OEMs and Tier 1 suppliers to systematically engineer validatable anticipatory defenses within autonomous vehicles, as opposed to relying on reactive responses to future breaches. The safety benefits will trickle down to future occupants of these vehicles and other road users.

- 03-073: Autonomous Emergency Navigation to a Safe Roadside Location. The results of this project will allow future autonomous vehicles to navigate to a safe location out of the travel path of following vehicles in the event of an emergency. Autonomous vehicles with these emergency handling capabilities will make government officials and the general public more confident in the abilities of autonomous features in future vehicles. As a result, the increasing penetration of those advanced vehicles will greatly enhance transportation system efficacy.
- 03-082: Assessing Alternative Approaches for Conveying Automated Vehicle 'Intentions.' By enhancing the design of human–machine interaction (HMI) systems, the results of this project will potentially increase user comfort and adoption of highly automated vehicles, which are expected to increase roadway efficiency and safety.
- 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving. This project demonstrated how kinetic data from sources such as connected vehicles and smartphones can be utilized to identify risky driving behavior. The ability to identify risky driving in both space and time will help practitioners implement countermeasures to reduce risky driving, thereby improving the safety of the transportation system.
- 04-098: Data Mining Twitter to Improve Automated Vehicle Safety. While the findings of this project are currently being implemented, the implementation will provide public information officers with reliable information about automated vehicle crashes. Furthermore, the findings related to social networks will lead to the development of new search methods and analyses of transportation-related tweets.
- 04-100: Development of a Diagnostic System for Air Brakes in Autonomous and Connected Trucks. The active brake monitoring system for trucks developed in this project will improve the safety of all road users.
- 04-103: Examining Senior Drivers' Adaptation to Mixed-Level Automated Vehicles: Phase II. This project will help vehicle manufacturers, the research community, and the general public understand the unique adjustment process of seniors to mixed-function automation systems. This understanding will help enhance the purchase and ownership experiences of advanced vehicles for older drivers, leading to increased mobility and enhanced safety.
- 04-104: Development of a Connected Smart Vest for Improved Roadside Work Zone Safety. The Smart Vest developed in this project enhances the situational awareness of workers in roadway work zones, which will improve the safety of both workers and drivers.
- 04-110: Developing an Intelligent TMC with a Safety Evaluation Focus for Smart Cities. This project is developing an intelligent transportation management center (TMC) to identify safety issues at signalized intersections. Specifically, the TMC will use visual analysis to identify critical events (near-crashes) and implement surrogate safety measures. Thus, the TMC will enable proactive safety evaluations at signalized intersections, which will lead to improved safety by identifying critical locations where safety is a concern.
- 04-113: Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements. This project will develop new safety performance functions that allow transportation agencies to improve safety analysis and hot-spot identification, which will improve safety.
- 04-120: Impacts of Connected Vehicle Technology on Automated Vehicle Safety. This project will help companies better understand the potential benefits of connected vehicle technologies. By encouraging companies to invest in connected vehicle technologies, this project is expected to reduce the numbers of near-crashes and crashes along with the associated injuries and fatalities.
- VTTI-00-021: Signal Awareness Applications. This project will produce a new mobile application that will improve the effectiveness of the transportation system by: (1) encouraging drivers to gradually slow down during intersection approaches upon seeing a green light countdown approach zero; and (2) discouraging unsafe driving behaviors such as accelerating through a yellow light.
- VTTI-00-022: Automated Truck Mounted Attenuator. This project will improve the safety of roadside workers and TMA truck drivers, who can be seriously injured or killed when struck by passing motorists. The adoption of the automated TMA developed in this project will remove the drivers from those dangerous locations.

- VTTI-00-023: E-Scooter Safety Assessment and Campus Deployment Planning. This project will improve safety by providing information on how to deploy an e-scooter micromobility program in the safest and most effective way possible for the community.

Impact on Adoption of New Practices or Initiation of Startups

Before research begin 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 the Safe-D T2 Coordinator, Dr. Mike Mollenhauer. While no start-up companies have been created at this point as a direct result of Safe-D projects, opportunities for commercialization have been identified and will be pursued as the research products are further developed. Beyond commercialization, Safe-D projects are expected to lead to the adoption of new practices in various transportation-related areas as the results and outcomes are disseminated. The potential for commercialization and adoption of new practices resulting from several specific Safe-D projects are summarized below:

- 01-003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety. The process of identifying high-risk intersections in this project involved the development of methods for automatically detecting and counting pedestrians and bicyclists. These developments have the potential to be incorporated into commercial technologies.
- 01-007: Preparing Work Zones for Automated and Connected Vehicles. The outcomes of this project will assist agencies in modifying their processes and procedures for designing, implementing, and maintaining work zones. The results will also help technology vendors in identifying opportunities to develop new or modified products that facilitate the operation of autonomous and connected vehicles in work zones.
- 03-064: Automated Vehicle Behavior Monitoring for Vulnerability Management. The algorithms and/or methods resulting from this project will be adopted by automotive technology developers and automotive OEMs to make vehicles safer from cybersecurity attack. Developers and manufacturers will be able to engineer validatable anticipatory defenses within autonomous vehicles instead of relying on reactive responses to future breaches. The algorithms and methods generated during this project will potentially lead to intellectual property.
- 03-073: Autonomous Emergency Navigation to a Safe Roadside Location. The technology developed under this project, which navigates a vehicle autonomously to a safe roadside location, will be marketed to the automotive industry.
- 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive. The project demonstrated how visualization tools can be used to identify risky driving in space and time. Agencies can adopt these tools to identify locations with high frequencies of risky driving and to develop countermeasures to reduce these risky events. The machine learning models and approaches developed in this project may be used to initiate a start-up company focused on using kinetic data to identify risky driving events.
- 04-100: Development of a Diagnostic System for Air Brakes in Autonomous and Connected Trucks. This project can potentially be spun to initiate a start-up company as there currently is no product like the one envisioned in this project.
- 04-104: Development of a Connected Smart Vest for Improved Roadside Work Zone Safety. The primary outcome of this project (i.e., the smart vest) will be commercialized to replace conventional personal protective equipment worn by workers.
- 04-115: Reference Machine Vision for ADAS Functions. Currently, there are no standards for lane detection systems or for lane markings. Therefore, we expect the results of this project will be adopted by automotive OEMs and Tier 1 suppliers developing autonomous vehicles and by transportation authorities who make decisions on infrastructure purchases.
- 04-120: Impacts of Connected Vehicle Technology on Automated Vehicle Safety. The results of this project are expected to encourage companies (e.g., OEMs, suppliers, and telecommunication companies) to invest more heavily in connected vehicle technologies.
- VTTI-00-022: Automated Truck Mounted Attenuator. This project will result in a new technology that can be used by infrastructure-owner operators to protect roadside work crews.

- VTTI-00-023: E-Scooter Safety Assessment and Campus Deployment Planning. The outcomes of this project will be transferred to Spin and other micromobility providers to provide technology providers with data and suggestions for deployment in the future.
- VTTI-00-024: Characterizing Level 2 Automation in a Naturalistic Driving Fleet. The outcomes of this project are expected to be valuable to automotive manufacturers and suppliers that are currently designing and improving automated control systems for surface transportation. The findings will be applied to guide design constraints, parameters, and goals.

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. The impacts of specific Safe-D research projects on scientific knowledge in several important transportation fields are summarized below:

- 01-002: Countermeasures to Detect and Combat Driver Inattention. The results will inform the design of multisensory driver takeover cues that result in the rapid and safe transition of control.
- 01-003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety. This project developed a new method to quantify the risk of walking and bicycling at signalized intersections. A novel sampling strategy was employed to develop a representative sample of intersections for data collection, and a new method to match short-term counters to long-term counters based on similarities in pedestrian and bicyclist activity patterns was proposed.
- 01-007: Preparing Work Zones for Automated and Connected Vehicles. The findings of this project will improve the understanding of public and private-sector practitioners with respect to the hierarchy of autonomous and connected vehicle needs.
- 03-036: Modeling Driver Responses during AV Platooning Failures. This project has led to a new understanding of the processes related to avoidance maneuver decision making, takeover reaction times, and post takeover control.
- 03-049: Data Fusion for Non-Motorized Safety Analysis. Since the concept underlying this project is a newly emergent field, the results are expected to attract significant attention from both researchers and practitioners. The findings will help state and local transportation agencies use their data to develop more reliable exposure estimates. This project is expected to open doors to future opportunities in non-motorized demand and safety research.
- 03-064: Automated Vehicle Behavior Monitoring for Vulnerability Management. This project has advanced the state of knowledge in the areas of transportation-related cybersecurity, machine learning, and signal processing.
- 03-073: Autonomous Emergency Navigation to a Safe Roadside Location. Current machine learning and deep learning technologies have greatly enhanced the capability of robotics perception systems. Although in some cases their capabilities even exceed those of human, they can fail disastrously in corner cases due to the unawareness of the uncertainty of their outputs. This project developed methods to quantify the uncertainty associated with estimation/prediction, thereby enabling the machine to be aware of its own limits. Thus, this project will greatly advance the reliability of autonomous systems in transportation.
- 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving. This project employed both supervised and unsupervised learning algorithms to distinguish risky driving events from normal driving events. A novel approach was presented to label risky driving, and the findings were used to train a supervised model to identify instances of risky driving. This generic approach of combining a supervised and unsupervised learning can be adopted in other circumstances where it is difficult to label specific events required to train predictive models.
- 04-098: Data Mining Twitter to Improve Automated Vehicle Safety. The new search algorithm developed in this project expands on prior work focused on user-centric searches by adding a hybrid search using both keywords and users. This enhancement allows for more targeted topical searches. The natural language

processing analyses conducted on the search results will lead to new insights regarding communications in automated vehicle crashes.

- 04-100: Development of a Diagnostic System for Air Brakes in Autonomous and Connected Trucks. The mathematical models for air brakes will be used in future textbooks and to train graduate students to develop diagnostic/control algorithms for air brakes in trucks.
- 04-101: Safety Impact Evaluation of a Narrow Automated Vehicle-Exclusive Reversible Lane. This project will provide foundational data to inform the future implementation of AV-compatible infrastructure. The primary project output will consist of recommendations and guidelines for implementation of narrow AV-exclusive reversible lanes that contribute to the development of the new infrastructure standards.
- 04-104: Development of a Connected Smart Vest for Improved Roadside Work Zone Safety. Through the development of a connected smart vest for roadside workers, this project will significantly improve the current status quo of safety at roadway work zones.
- 04-110: Developing an Intelligent TMC with a Safety Evaluation Focus for Smart Cities. The intelligent TMC developed in this project will advance the application of machine learning to the real-time detection of road users.
- 04-113: Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements. The results of this project are being incorporated into a highway safety textbook to be published by Elsevier Science.
- 04-120: Impacts of Connected Vehicle Technology on Automated Vehicle Safety. This project will address the current gap in knowledge related to the combination of connected vehicle technologies with automated driving systems.
- TTI-01-03: Comparison of SHRP2 Naturalistic Driving Data to Geometric Design Speed Characteristics. This study has provided a new way to estimate speed on freeway ramps based on many vehicles at many locations. This novel method can be extended to other applications in the future.
- VTTI-00-023: E-Scooter Safety Assessment and Campus Deployment Planning. The results of this project will advance the body of scientific knowledge along with the data available to help micromobility providers conduct future deployments.

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 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.

- 03-049: Data Fusion for Non-Motorized Safety Analysis. The project provided opportunities for students to enhance their knowledge in big data analytics. Coursework generated from this project will allow students to apply big data analytics to real-world transportation safety.
- 01-002: Countermeasures to Detect and Combat Driver Inattention. This work provided the opportunity for more than 15 students at the undergraduate and graduate levels to participate in a meaningful research project with a cutting-edge transportation engineering problem.
- 01-007: Preparing Work Zones for Automated and Connected Vehicles. The research will provide new educational materials about autonomous and connected vehicle accommodation in work zones for practitioners via journal articles and presentations. Introductory information about the topic will be available to be integrated into undergraduate and graduate-level transportation coursework.
- 01-003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety. The data developed during this project were used to create a group assignment for a CIVE 160 course offered at SDSU. Students working on this assignment will use the data to develop statistical models to estimate pedestrian and bicyclist exposure.

- 03-064: Automated Vehicle Behavior Monitoring for Vulnerability Management. This project is providing research experience to one graduate student. Lecture materials based on this project will assist in the education of the cybersecurity, machine learning, signal processing, and transportation workforce.
- 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving. The interactive web-based tools developed in this project can be used by students, researchers, and practitioners to understand how risky driving events can be visualized in both space and time. The project provided an opportunity for students to learn and develop models to identify risky driving events from kinetic data, develop and design databases, and develop visualization tools. The results were also incorporated into Big Data Science and Analytics Platforms (GEOG-594), taught by Dr. Ming, and Data Management for GIS (GEOG-580), taught by Dr. Nara.
- 04-098: Data Mining Twitter to Improve Automated Vehicle Safety. The guidelines produced by the project are expected to help educate public information officers and results in a more targeted discourse on social media.
- 04-100: Development of a Diagnostic System for Air Brakes in Autonomous and Connected Trucks. This project is training graduate students in the area of diagnostics of air brakes in trucks. The outcomes of this project will also be incorporated into a future graduate course.
- 04-101: Safety Impact Evaluation of a Narrow Automated Vehicle-Exclusive Reversible Lane. To educate future transportation engineers and leaders, students involved in this project are becoming familiar with infrastructure design, safety considerations, traffic operations, and AV technology through hands-on, real-world experience. Aspects of this project are being incorporated into a teaching module to transportation courses at the consortium universities. Industry partner LLG also plans to present the findings of the study at meetings of local transportation professional organizations to educate professionals on the growing role of AVs and their integration into the mainstream transportation infrastructure.
- 04-103: Examining Senior Drivers' Adaptation to Mixed-Level Automated Vehicles: Phase II. This project gave one graduate student the opportunity to analyze naturalistic driving data and integrate the naturalistic data with subjective data. Instructional modules drawing on the results of this project are also being created.
- 04-110: Developing an Intelligent TMC with a Safety Evaluation Focus for Smart Cities. The outputs of this project are being used to develop materials for courses in the Civil, Construction, and Environmental Engineering (CCEE) and Electrical and Computer Engineering (ECE) departments at SDSU. The project has also provided funding for master's students in CCEE and ECE.
- 04-115: Reference Machine Vision for ADAS Functions. This project involves one graduate student who is working with fundamental vision processing algorithms. The student will also work closely with industry partners to test the system, providing this student with valuable real-world experience.
- 04-117: A Sensor Fusion and Localization System for Improving Vehicle Safety. The two students currently involved on this project are working on important applied problems relevant to industry. These students are learning about the practical issues that affect ITS; this training will be valuable for future employment in the transportation workforce.
- TTI-01-05: K-12 STEM Program: Exploring the Science of Retroreflectivity. Presentations and educational materials developed under this project have provided grade-school and college-age students with exposure to the transportation field.
- VTTI-00-021: Signal Awareness Applications. The project has allowed a student to work on one of the most advanced V2X test bed deployments in partnership with VDOT and VTRC. These experiences are enriching the student's coursework by having him consider real-world implications in the development and implementation of a commercial application/product.
- VTTI-00-022: Automated Truck Mounted Attenuator. This project is providing an opportunity for transportation research for one PhD student. The results of this project are also expected to be incorporated into new materials on automated construction equipment that can be disseminated to students in related fields.
- VTTI-00-026: Guiding Driver Responses During Manual Takeovers from Automated Vehicles. The methods developed in this study for the analysis, design, prototyping, and evaluation of HMIs will be translated into a learning module entitled "Virtual and Augmented Reality for Automotive HMI Research." This module will

include practical hands-on experience in HMI design ideation, rapid prototyping, and the demonstration of example HMI prototype systems implemented by the project. These learning materials will be designed as a one-week class module for a graduate level course of Advanced Vehicle Safety Systems (BME 5984), a part of the Graduate Certificate in Human Factors of Transportation Safety program at Virginia Tech.

Changes/Problems

Changes in Approach

Nothing to report.

Actual/Anticipated Problems/Delays

Nothing to report.

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