SEMI-ANNUAL PERFORMANCE REPORT

OCTOBER 1, 2018 TO MARCH 31, 2019

SAPR #4

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)
Federal Grant Number	69A3551747115
Project Title	Safety through Disruption (Safe-D) National University Transportation Center
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Submission Date	April 30, 2019
DUNS / EIN	0031370150000 / 54-6001805
Recipient Organization	Virginia Tech Transportation Institute
Recipient Identifying Number	N/A
Grant Period	November 30, 2016 – September 30, 2022
Reporting Period End Date	March 31, 2019
Report Term/Frequency	Semi-annual reporting periods
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

Safe-D Fall 2018 Competition Project Awards and Activity

The Safe-D Fall 2018 Workshop and Call for Proposals commenced during the previous reporting period. Awards from this competitive cycle were expected to be made during December 2018. However, with the delayed release of Year 3 funding from USDOT, final awards were deferred to later in the reporting period. Under this competition, 36 proposals (research statements) were received, including 11 that were collaborative across consortium university team members. Of the total proposals received, 11 projects were selected to give a seven-minute, entrepreneurial-style pitch presentation to the Safe-D Leadership Team and Safe-D Stakeholder Advisory Board. The presentations described the value of the project to industry partners and allowed for direct discussion that could help refine the project. Ultimately, 13 of the 36 proposals received were selected for development of a full Work Plan, the next step in the Safe-D Proposal Process, with 12 projects awarded during this reporting period (one proposal team was asked to further develop its idea and resubmit in the future).

At the end of this reporting period, the Safe-D National UTC had a project portfolio totaling more than $13.7 million, with nearly one-half of project funding sourced from non-federal matching funds. Safe-D projects are selected according to their focus on the four Center theme areas: automated vehicles, connected vehicles, big data analytics, and transportation as a service. The coverage of Safe-D theme areas by project portfolio to-date can be seen in Figure 1. The Safe-D Leadership Team feels strongly that the projects that were selected and awarded during this reporting period contribute to the overall

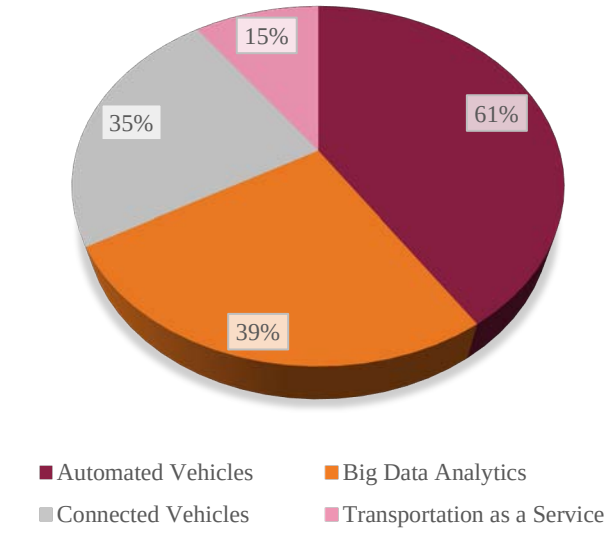

Figure 1. Portfolio of Safe-D Projects by Theme Area (total exceeds 100% due to projects covering multiple theme areas)

Safe-D vision and mission and are excited about the potential impacts that this research in disruptive technologies will have on maximizing the safety of these technologies as they are integrated into our transportation system.

Safe-D research projects awarded during this reporting period, along with respective theme area(s) and short descriptions, are reported below (*denotes lead institution). Note that Safe-D projects are identified using a numbering scheme where the first number refers to the award round (e.g., "Project 01-xxx" denotes a project awarded under the first competitive award cycle). Research statement submissions are also numbered as they are received by Safe-D, without regard to the award round, and are identified by the second number.

Project 04-098: Data Mining Twitter to Improve Automated Vehicle Safety
Institution(s): TTI, VT; Award Round: Fall 2018; Theme Area(s): Big Data Analytics, Automated Vehicles*
Automated vehicle technologies may significantly improve driving safety, but only if they are widely adopted and if drivers use them appropriately. This project will seek to understand the conversation about automated vehicles on Twitter through a network and natural language processing analysis. We further focus on responses and changes of opinion surrounding automated vehicle crashes.

Project 04-100: Development of a Diagnostic System for Air Brakes in Autonomous and Connected Trucks
Institution(s): TTI; Award Round: Fall 2018; Theme Area(s): Automated Vehicles, Connected Vehicles, Transportation as a Service*
Air brakes are sensitive to maintenance and are employed in trucks; proper functioning of air brakes is critical to safety of autonomous and connected trucks. This project will develop a diagnostic system for estimating the leakage and stroke of the pushrod and corroborate the efficacy of the system on an experimental air brake system setup. The system can be used to facilitate pre-trip and enforcement inspections of air brakes in trucks and as an on-board monitoring system autonomous and connected trucks.

Project 04-101: Safety Impact Evaluation of a Narrow Automated Vehicle-Exclusive Reversible Lane on an Existing Smart Freeway
Institution(s): SDSU; Award Round: Fall 2018; Theme Area(s): Automated Vehicles*
This study will evaluate the safety impact of an innovative infrastructure solution for safe and efficient integration of Automated Vehicle (AV) as an emerging technology into an existing transportation system. Filling the gap in the limited research on the effect of AV technology on infrastructure standards, this project will evaluate whether AVs could operate safely in a narrow lane next to regular traffic lanes on an expressway.

Project 04-103: Examining Senior Drivers' Adaptation to Mixed-Level Automated Vehicles: Phase II
Institution(s): VTTI; Award Round: Fall 2018; Theme Area(s): Automated Vehicles*
This study is a follow-on to a recently completed Safe-D project (Phase I). The first phase focused on how driving exposure to automated vehicle technologies (AVT) can change how seniors, a particularly vulnerable and growing segment of our population, use and accept AVT over time. The goal of the Phase II follow-on proposed herein is to analyze these already collected NDS data to evaluate the safety and mobility benefits of AVT for senior drivers.

Project 04-104: Development of a Connected Smart Vest for Improved Roadside Work Zone Safety
Institution(s): VTTI, TTI; Award Round: Fall 2018; Theme Area(s): Connected Vehicles, Automated Vehicles*
Roadside work zones (WZs) present imminent safety hazards for roadway workers and passing motorists. In 2016, 764 fatalities occurred in WZs in the U.S. due to motor vehicle traffic crashes. This project aims to develop a wearable worker localization and communication device (i.e., Smart Vest) that uses the previously-developed Threat Detection Algorithm (Safe-D project 03-050) to communicate workers' locations to passing connected and automated vehicles (CAVs) and proactively warn workers and passing motorists of potential collisions.

Project 04-110: Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities
Institution(s): SDSU, VTTI; Award Round: Fall 2018; Theme Area(s): Big Data Analytics*
Traditional transportation management centers (TMCs) have limited capability to use 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 (ITS) technologies and big data analytics can be used to proactively assess transportation safety at signalized intersections.

Project 04-113: Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements

Institution(s): TTI, VTTI; Award Round: Fall 2018; Theme Area(s): Big Data Analytics*

The goal of this project is to examine whether traffic volume estimates developed from disruptive technologies such as cell phones, GPS/Bluetooth devices, and alternative data sources (e.g., demographic, socioeconomic, land use data) can be used confidently and accurately to support data-driven safety analysis (i.e., network screening) to meet the 2016 Highway Safety Improvement Program (HSIP) Final Rule requirements.

Project 04-114: Behavior-based Predictive Safety Analytics Phase II

Institution(s): VTTI, SDSU, TTI; Award Round: Fall 2018; Theme Area(s): Big Data Analytics*

This project addresses the emerging field of behavior-based predictive safety analytics, focusing on the prediction of road crash involvement based on individual driver behavior characteristics. This project continues work from a pilot study that created a proof-of-concept demonstration of how crash involvement may be predicted on the basis of individual driver behavior using naturalistic data from the Second Strategic Highway Research Program Naturalistic Driving Study (SHRP 2 NDS). This project seeks to analyze large-scale continuous naturalistic data and event data, both public and proprietary, to study the role of different driving behaviors in the buildup of a safety-critical event.

Project 04-115: Reference Machine Vision for ADAS Functions

Institution(s): TTI; Award Round: Fall 2018; Theme Area(s): Automated Vehicles, Connected Vehicles*

Studies have shown that fatalities due to unintentional roadway departures can be significantly reduced if Lane Departure Warning (LDW) and Lane Keep Assist (LKA) systems are used effectively. However, these systems are not robust due, in part, to the lack of suitable standards for pavement markings that enable reliable functionality of the sensor system. The objective of this project is to develop a reference Lane Detection (LD) system that will provide a benchmark for evaluating different lane markings and perception algorithms.

Project 04-117: A Sensor Fusion and Localization System for Improving Vehicle Safety In Challenging Weather Conditions

Institution(s): TAMU; Award Round: Fall 2018; Theme Area(s): Automated Vehicles, Connected Vehicles, Transportation as a Service*

The safety of autonomous/connected vehicles primarily relies on their ability to accurately sense the environment. The sensing problem is significantly challenging in weather conditions, which include sudden change in lighting, smoke, fog, snow, and rain. The objective of this project is to use a combination of radars and far infrared (FIR) cameras in addition to a LIDAR-based system to map the environment and localize the vehicle with respect to the lanes on the road. This project will develop a prototype of an all-weather sensing and localization system which will be corroborated with several data sets collected at Rellis.

Project 04-120: Impacts of Connected Vehicle Technology on Automated Vehicle Safety

Institution(s): VTTI; Award Round: Fall 2018; Theme Area(s): Connected Vehicles, Automated Vehicles*

Data shared over connected vehicle technologies (CVT) may provide a variety of performance benefits to transportation. CVT could improve safety as events unfold. However, although previous work has characterized some of the potential advantages of connectivity on human-operated vehicles, the impacts of connectivity on automated driving systems (ADS) are not well established. The purpose of this proposed effort is to conduct a focused effort that leverages the SHRP 2 NDS to estimate the potential impact of connectivity on safety for future automated driving systems (ADS) in transportation.

Project 04-121: Development of an Infrastructure Based Data Acquisition System (IDAS) to Naturalistically Collect the Roadway Environment

Institution(s): VTTI; Award Round: Fall 2018; Theme Area(s): Big Data Analytics, Connected Vehicles, Automated Vehicles*

Roadways in the City of Virginia Beach have consistently ranked in the top 10 crash cluster locations in the state of Virginia, many of which occur at signal-controlled intersections that control flow on to and off of the only major interstate in the City, I-264. This project seeks to understand the existing systems and how they can be leveraged to provide the City with insight and suggested countermeasures to address the safety issues on these roadways. In addition, this project seeks to develop methods to populate data from such sensors into formats that can be used by the industry to assist in the development of connected and automated vehicle safety systems.

Additional Project Awards

Beyond competitive research projects, consortium members VTTI and TTI funded directed projects, including one project focused on crowdsourced data (TTI) and two projects working with DOT partners to develop advanced transportation technologies (VTTI). These directed projects include leveraged external funding from the State of Texas and VDOT.

Project TTI-04-01: Exploring Crowdsourced Monitoring Data for Safety
Institution(s): TTI; Award Round: Directed 2018/2019 Projects; Theme Area(s): Big Data Analytics*
This project includes three separate, but related, exploratory studies working with emerging data sources to potentially improve roadway safety analysis. These projects will answer the following research questions: 1) Can bicyclist trips sensed passively through mobile location data support bicyclist activity indices at the city scale? 2) Is it feasible to use crowdsourced incident data to provide a reliable and timely indicator of real-time crash risks? 3) How can exploratory data analysis (EDA) of hazard warning data inform usability for crash surrogate measures?

Project VTTI-00-021: Signal Awareness Applications
Institution(s): VTTI; Award Round: Directed 2018/2019 Projects; Theme Area(s): Connected Vehicles, Automated Vehicles*
Intersection collisions account for 40% of all crashes on our nation's roadways. Although infrastructure-based red-light violation countermeasures have been deployed, intersections remain a top location for vehicle crashes. This project proposes to enhance the current capabilities of Virginia Connected Corridors (VCC) platforms by developing new signal awareness safety and mobility features. In addition, this project will investigate the technical and human factors constraints associated with user interfaces for notifying and alerting drivers to pertinent intersection-related information that may curb unsafe driving behaviors at signalized intersections.

Project VTTI-00-022: Automated Truck Mounted Attenuator
Institution(s): VTTI; Award Round: Directed 2018/2019 Projects; Theme Area(s): Automated Vehicles, Connected Vehicles*
Truck-Mounted Attenuators (TMAs) are energy-absorbing devices added to heavy shadow vehicles to provide a mobile barrier that protects work crews from errant vehicles entering active work zones. While the TMA is designed to absorb and/or redirect the energy from a colliding vehicle, there is still significant risk of injury to the TMA driver when struck. This project seeks to develop an automated control system for TMA vehicles using a short following distance, leader-follower control concept that will remove the driver from the at-risk TMA vehicle.

Completed Projects

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

- **01-001: Big Data Methods for Simplifying Traffic Safety Analyses**
- **01-003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety**
- **01-004: Driver Training for Automated Vehicle Technology**
- **01-006: Implications of Truck Platoons for Roadside and Vehicle Safety Hardware**
- **02-009: Vehicle Occupants and Driver Behavior: An Assessment of Vulnerable User Groups**
- **02-014: Formalizing Human-Machine Communication in the Context of Autonomous Vehicles**
- **02-016: Older Drivers and Transportation Network Companies: Investigating Opportunities for Increased Safety and Improved Mobility**
- **03-040: Examining Senior Drivers Adaptation to Mixed-Level Automated Vehicles: A Naturalistic Approach**
- **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**

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

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:

- **TTI-01-05: K-12 STEM Program: Exploring the Science of Retroreflectivity** (project outreach activities will be ongoing until grant-end, when project will be finalized)
- **02-010: Safety Perceptions of Transportation Network Companies by the Blind and Visually Impaired**
- **02-026: Sources and Mitigation of Bias in Big Data for Transportation Safety**
- **02-027: Street Noise Relationship to Vulnerable Road User Safety**
- **TTI-01-04: Influences on Bicyclists and Motor Vehicles Operating Speed within a Corridor**

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.

Visiting Scholars Program

During this reporting period, Safe-D Researcher Dr. Anthony McDonald, Assistant Professor in Industrial & Systems Engineering at Texas A&M University (Project 03-036: Modeling Driver Responses During Automated Vehicle Failures) visited VTTI and Virginia Tech on November 13, 2018. Dr. McDonald met with fellow project team members at VTTI and engaged with other Safe-D Leadership Team members and VTTI personnel during his visit to foster additional collaborative research projects. In addition, Dr. McDonald presented as guest lecturer in the VT – BME 5984: Advanced Vehicle Safety Systems class during his visit. This presentation aligned with student coursework that involved developing a warning system algorithm and associated human-machine interface. Dr. McDonald's presentation to this class is also recorded under the Outputs section of this report.

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.

2018 Student of the Year

During this reporting period, Safe-D received five nominations for the 2018 Outstanding Student of the Year Award, with at least one student nomination received from each consortium member university. The Safe-D Leadership Team reviewed the nomination form, faculty nomination letter, student CV, and transcript(s) for each of the nominees. The decision to choose one student for this award was difficult as all nominated students excelled academically, were well-recommended by faculty, and provided significant contributions to their Safe-D project(s) and team members. After review of the candidates, Safe-D recognized Alexis Basantis from Virginia Tech as the 2018 Outstanding Student of the Year. Pursuing her M.S. in Biomedical Engineering, Ms. Basantis was nominated due to her excellence as a student researcher and was presented the honor at the Council of University Transportation Center's 2019 Annual Awards Banquet on January 12 in Washington, D.C. Among her many accomplishments, Ms. Basantis has excelled academically in her coursework while serving integral roles within Safe-D, including assisting with the development and execution of Safe-D outreach programming. She has also developed and led several projects at VTTI and Safe-D focusing on advanced vehicle systems, one of which is currently supporting her thesis.

Other Safe-D Student Awards

Sirajum "Silvy" Munira from Texas A&M University was recognized at the Lifesavers National Conference on Highway Safety Priorities as the 2019 Lifesavers Traffic Safety Scholar for her work on Project TTI-01-01: Analysis of an Incentive-Based Smartphone App for Young Drivers (see Lifesavers National Conference). The Traffic Safety Scholars Program provides awards of up to $1,000 to undergraduate and graduate students to help defray the cost of attending the annual Lifesavers

Conference. Vamsi Vegamoor from Texas A&M University (Project 04-100: Development of a Diagnostic System for Air Brakes in Autonomous and Connected Trucks) was awarded a Dwight David Eisenhower Transportation Fellowship Program (DDETFP). Carolina Rodriguez Paras from Texas A&M University was awarded the Lamar Bruni Bergara Graduate Scholarship for her work on Project 01-002: Countermeasures to Detect and Combat Driver Inattention.

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 recorded during 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 28 graduate courses, reaching 460 students, along with 28 undergraduate courses, reaching 1,118 students. Safe-D research teams supported 46 undergraduate- and graduate-level students during this reporting period, including 14 students from underrepresented populations. In addition, research teams reported 8 students graduating during the course of research activities and that all were placed for employment in either the public or private sector. 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	7	3
Masters	16	3
PhD	23	8

Highlighted EWD & Other Outreach Activities

Safe-D faculty, staff, and students participate in numerous EWD and outreach activities throughout the year, both on a program-level and through each individual Safe-D project. The activities listed below are some of the many events that have been reported during this period.

VDOT Career Fair

VDOT hosted its 14th annual transportation career fair on October 4, 2018, showcasing different careers in transportation to thousands of high school students in the Northern Virginia area. The organizers invited local representatives from organizations ranging from construction to emergency roadway management to attend the fair and discuss their jobs and journeys to their current careers. VTTI was in attendance to present information about the Safe-D National UTC and about careers in transportation research. By having representatives available to answer specific student questions regarding transportation careers and showcasing exciting advances in the industry, the VDOT career fair gave participants the unique opportunity to both learn and become excited about the future of transportation.

VT Science Festival

On Saturday, October 27, 2018, the Institute for Creativity, Arts, and Technology (ICAT) at Virginia Tech hosted its 5th Virginia Tech Science Festival. The event was an opportunity for 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 and VTTI hosted an exhibit called “Technology in Motion – How Computers Move Us,” which aimed to teach festival participants about the advanced technologies being implemented in the area of transportation. Attendees could participate in several demonstrations, including observing

representations of themselves as they traversed a (LIDAR) sensing field and learning about the different functionalities of instrumented helmets, wristbands, and vests. Festival-goers were also briefed on the retroreflective materials used in roadway signs to improve their visibility as drivers.

Gerontology Symposium

Dr. Jon Antin, Director of the Center for Vulnerable Road User Safety at VTTI, delivered a presentation on Project 03-040: Examining Senior Drivers Adaptation to Level 2-3 Automated Vehicles Phase I results at the Virginia Tech Center for Gerontology 5x5x5 panel held on February 20, 2019. This discussion consisted of five panelists given five minutes each to present five informational slides. The presentation format gave an audience of 20 students, faculty, and researchers an intense hour covering a broad spectrum of issues related to gerontology. The event exposed attendees to novel research and opportunities and encouraged collaboration. Dr. Miguel Perez, EWD Coordinator for Safe-D, also briefed attendees on several recent activities of Safe-D.

Explore SDSU 2019

Safe-D researchers presented their mission to the public at the 2019 Explore SDSU Open House on March 23, 2019. Explore SDSU is a free, all-campus event open to all alumni, members of the SDSU community, and prospective students. Presentations, workshops, and tours were held for admitted and prospective students, parents, military students, veterans, and other attendees of all ages. The Safe-D research team at SDSU presented the mission of Safe-D in terms of research themes and EWD activities and encouraged prospective students to become involved. Safe-D graduate students presented several posters on Safe-D research and conducted activities to raise awareness about safety issues of driving under the influence of alcohol or drugs.

Lifesavers National Conference

The Lifesavers National Conference on Highway Safety Priorities was held March 31-April 2, 2019, in Louisville, Kentucky. Texas A&M University student and Traffic Safety Scholar Sirajum Munira was selected to represent Project TTI-01-01: Analysis of an Incentive-Based Smartphone App for Young Drivers by presenting her team's research results from "Deterring Distractions & Aggressive Driving Behavior Using a Smartphone App: What Difference Does it Make?"

Dissemination of 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 been disseminating results of their research projects through outreach, EWD, and T2 events, such as those listed in the Highlighted EWD & Other Outreach Activities and Selected EWD and T2 Outputs sections.

Plans for Next Reporting Period

The Safe-D Leadership Team has adjusted the program schedule such that the next Stakeholder Meeting, Fall Workshop, and Call for Proposals will occur after the next reporting period – these planned activities will be recorded in this section of the next semi-annual progress report (SAPRs). The following are a small selection of the activities the Safe-D Leadership Team and Safe-D researchers have planned for the next reporting period.

Safe-D Project Presentations at Upcoming Conferences

The TTI Transportation Technology conference scheduled for April 2019 will feature student posters from three active Safe-D projects. In addition, Safe-D researcher Chris Simek will be presenting results of Project 02-010: Safety Perceptions of Transportation Network Companies (TNCs) by the Blind and Visually Impaired (BVI) at the American Association for Public Opinion Research Annual Conference which will be held in Toronto, Ontario, Canada in May 2019.

Select Outreach and Diversity Activities Planned

Choices and Challenges Forum

Safe-D faculty and students will be participating in 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. This event is scheduled for April 14, 2019 and will be hosted by Virginia Tech's Department of Science, Technology, and Society.

VDOT "Dialog on Highway Automation Workshop"

Safe-D will participate in the VA Dept of Transportation's Office of Strategic Innovation hosted Bristol District's "Dialog on Highway Automation Workshop" on April 16th. Based off of the national effort led by the Federal Highway Administration, VDOT is hosting workshops throughout 2019 across Virginia and will be using gathered information in the development of the Department's AV Strategic Plan.

Thomas Jefferson Symposium to Advance Research (tjSTAR)

Safe-D researcher Dr. Ralph Buehler (Project 02-027: Street Noise Relationship to Vulnerable Road User Safety) will be representing Safe-D at the Thomas Jefferson Symposium to Advance Research (tjSTAR) in Fairfax, Virginia in May 2019.

Participants and Collaborating Organizations

Partner Organizations

Safe-D has awarded 18 projects to-date which are collaborative across consortium member universities. In addition to these inter-consortium collaborations, many Safe-D research teams have sought to include partners from industry to help develop their research ideas and implement their findings. During the previous reporting period, the Safe-D T2 Plan outlined the process by which each new project team will 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 02-020: Behavior-based Predictive Safety Analytics – Pilot Study continued collaboration with SmartDrive, presenting research results from this and other SDSU projects. The result of this meeting also led to additional collaboration for Project 04-114, a second phase of this pilot study.
- Project 04-101: Safety Impact Evaluation of a Narrow Automated Vehicle-Exclusive Reversible Lane on an Existing Smart Freeway is collaborating with LLG and Caltrans to evaluate the safety impact of an innovative infrastructure solution to integrating AV technologies. The relationship with LLG and Caltrans has evolved out of various discussions and presentations of previous SDSU Safe-D projects. In addition, this project team is using matching funding from the California State University Transportation Consortium, which was awarded to Safe-D Associate Director at SDSU Sahar Ghanipoor Machiani and SDSU researcher Arash Jahangiri for this driving simulator study.
- Project 04-110: Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities is collaborating with the City of Chula Vista to address transportation

safety planning challenges in the era of smart cities. This collaboration evolved out of multiple meetings between SDSU and the City, further building SDSU's external support network and bolstering its status as a strong transportation research laboratory.

- Project 04-115: Reference Machine Vision for ADAS Functions has assembled an industry technical advisory committee comprising representatives from 3M, Continental, and Toyota. Additional public-sector stakeholders are being sought to join the committee.
- Project 04-121: Development of an Infrastructure Based Data Acquisition System (IDAS) to Naturalistically Collect the Roadway Environment has partnered with the City of Virginia Beach, Virginia, to understand the existing systems and how they can be leveraged to provide the City with insight and suggested countermeasures to address the safety issues on these roadways. Numerous City employees will be contributing in-kind, facilities use, and collaborative research sources of match funding.
- Project 04-120: Impacts of Connected Vehicle Technology on Automated Vehicle Safety has established a collaboration with Ericsson to estimate the potential impact of connectivity on future AV safety.

International Collaborators

- Project 03-036: Modeling Driver Responses During Automated Vehicle Failures team members have been collaborating with faculty at Leeds University, UK, throughout the life of the project. Dr. Gustav Markkula has been serving as the advisor for the modeling work involved in this study.
- Project 04-120: Impacts of Connected Vehicle Technology on Automated Vehicle Safety team members' collaboration with Ericsson extends to its international office in Sweden.

Other Collaborators or Contacts

The Safe-D National UTC solidified the Safe-D Stakeholder Advisory Board during the previous reporting period, listed in Table 2.

Table 2. Safe-D Stakeholder Advisory Board Members

Company	Representative	Company	Representative	Company	Representative
3M	Dr. Ken Smith	**Dbi**	Mark Robinson	**Transurban**	Lev Pinelis
Blackberry	Andrew Walenstein	**Ericsson**	Zsolt Parnaki	**Uber**	Nadia Anderson
Caltrans	Sam Amen	**Etrans**	John Estrada	**VDOT**	Cathy McGhee
CEI	Ed Pierce	**SANDAG**	Peter Thompson		
Continental	Jeremy Tuggle	**SmartDrive**	Jason Palmer		

Outputs

All research projects awarded by Safe-D are required to submit EWD and T2 plans, identifying specific outputs from their projects for development and dissemination. To ensure that EWD and T2 plans for each project receive continued attention, the Safe-D EWD and T2 Coordinators contact each of the research teams shortly after the project start date. The purpose of this initial communication is to establish a point of contact within the research team, clearly establish expectations, offer help and guidance, and encourage research teams to expand their activities in this area as much as possible. During this reporting period, many EWD and T2 outputs from Safe-D research projects have been completed or are ongoing. These outputs are described in the sections below.

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 3). 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 2,088 visitors during the six-month reporting period and is on track to roughly double the annual goal of 2,000 visitors per year. Concurrently, Project Page visits averaged just under 50 visits per page for the six-month reporting period, which suggests an annual average of approximately 100 visits per page (tracking just behind the annual goal of 150 visits). The Safe-D team is investigating ways to increase traffic to the actual project pages now that we have an increasing number of completed projects with tangible products. For example, we plan to send announcements and links to a Safe-D stakeholder mailing list as new content is posted to the Safe-D site. We are also considering adding links to highlighted content on the Safe-D homepage to draw additional attention to specific projects as they are completed.

Table 3. 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	2,088 visitors
	Project Pages: Average ≥150 visitors/year	49.8 visits per project page
Journal Articles/Conference Presentations	Project Teams: 1 article/year	15
	Project Teams: 1 conference/year	14
Facility Tours	Displays viewed by ≥200/year	100
	Follow-Up Interest: 5 visitors/year	0

Prior to this reporting period, a total of 7 projects had been completed resulting in 15 journal articles and 55 conference presentations. Within this reporting period, 6 additional projects have been completed and a total of 15 new journal articles and 14 new conference presentations were reported by project teams. These additions bring the average rate of publications per completed project to 2.3 journal articles per project and 5.3 conference presentations per project. These rates indicate that Safe-D is tracking ahead of its publication goals for projects through the current reporting period.

Safe-D researchers reported 100 views of Safe-D displays during outreach events during the six-month reporting period, which aligns with the annual goal of 200 views. The Safe-D management team will be reviewing its methods of capturing this metric, as it is likely that views are underrepresented in only capturing project-specific display views and not capturing general Safe-D display views at these events.

Publications, Conference Papers, and Presentations

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

Publications/Conference Papers

Brewer, M. A., & Stibbe, J. (2019). Investigation of Design Speed Characteristics on Freeway Ramps using SHRP2 Naturalistic Driving Data. Transportation Research Record. https://doi.org/10.1177/0361198118823515 (Published)

McDonald AD, Alambeigi H, Engstrom J, et al. Toward Computational Simulations of Behavior During Automated Driving Takeovers: A Review of the Empirical and Modeling Literatures. Hum Factors J Hum Factors Ergon Soc 2019; In Press. doi:10.1177/0018720819829572 (Published)

Alambeigi H, Tankasala R, McDonald AD. Contrasting automated vehicle experiments and real-world crash databases: A review of literature and analysis of the California Department of Motor Vehicles automated vehicle crash database. Transp Res Part F Traffic Psychol Behav (Under Review)

Rathinam, S., LiuDe M. Lateral Control of an Autonomous Vehicle with limited preview information (Accepted)

Suh, Y. and Ferris, T. (2018). On-road evaluation of in-vehicle interface characteristics and their effects on performance of visual detection on the road and manual entry. Human Factors, 61(1), 105-118. DOI: 10.1177/0018720818790841 (Published)

Han, W., White, E., Mollenhauer, M., Roofigari-Esfahan, N. (2019). Proceedings from ASCE International Conference on Computing in Civil Engineering 2019. Atlanta, GA. (Accepted)

Shirazi, M., and D. Lord (2018) Characteristics Based Heuristics to Select a Logical Distribution between the Poisson-Gamma and the Poisson-Lognormal for Crash Data Modelling. Paper submitted for publication in Transportmetrica Part A. (Under Review)

Mao, H., D. Xinwei, D. Lord, and F. Guo (2018) Adjusting Finite Sample Bias for Poisson and Negative Binomial Regression in Traffic Safety Modeling. Paper submitted for publication in Accident Analysis & Prevention. (Under Review)

Mahdie Hasani, Arash Jahangiri, Sahar Ghanipoor Machiani (2018). Developing Models for Matching of Short-term and Long-term Data Collection Sites to Improve the Estimation of Average Annual Daily Bicyclists. Presented in 2018 21st International Conference on Intelligent Transportation Systems (ITSC) (pp. 2931-2936), Nov 4-7, 2018, Maui, Hawaii, USA. (Published)

Mahdie Hasani, Arash Jahangiri, Sahar Ghanipoor Machiani (2019) Data Mining to Improve Planning for Pedestrian and Bicyclist. Accepted for presentation in 2019 Safe Systems Summit: Redefining Transportation Safety, Apr 23-24, 2019, Durham, NC. (Accepted)

M. Hasani, A. Jahangiri, I. N. Sener, S. Munira, J. M. Owens, B. Appleyard, S. Ryan, S. M. Turner and S. Ghanipoor Machiani (2019) Identifying High-Risk Intersections for Walking and Bicycling using Multiple Data Sources in the City of San Diego. Submitted to the Journal of Advanced Transportation, Dec 2018. (Under Review)

Yulu Chen, Ming-Hsiang Tsou, Atsushi Nara. (2019 forthcoming). Analyzing Transportation Big Data with GIS: Detecting Over-speeding Vehicles from Traffic GPS Data. CSU Geospatial Review, 2019 issue. (Submitted)

Nayak, A., Gopalswamy, S., and Rathinam, S. Vision-Based Techniques for Identifying Emergency Vehicles, SAE Technical Paper 2019-01-0889, 2019, doi:10.4271/2019-01-0889.

Zhou, F., Hu, S., Chrysler, S., Kim, Y., Damnjanovic, I., Talebpour, A., Espejo, A. Optimization of Lateral Wandering of Automated Vehicles to Reduce Hydroplaning Potential and to Improve Pavement Life. (Accepted)

Rahmati, Y., A., Samimi Abianeh, M., Tabesh, A., Talebpour, and F., Sharifi. Driving to Safety: Who Is at Fault in CAVs Rear-End Collisions. Accepted for presentation at the 98th Annual Meeting of the Transportation Research Board of National Academies, January 13-17, 2019.

Presentations

Brewer, M.A., & Stibbe, J. (2019, January). Investigation of Design Speed Characteristics on Freeway Ramps Using SHRP2 Naturalistic Driving Data. Presented at the 2019 Transportation Research Board Annual Meeting (Published)

Florence, W. Transportation Research Board (TRB) Human Factors Workshop Session F - "Safety Issues of Co-Existing Human and Autonomous Machine Operations," January 13, 2019 (Published)

Liang, D., Baker, S., Lau, N., and Antin, J. F. (2018). Examining senior drivers adaption to mixed level automated vehicles: Focus group results from a naturalistic driving study. Poster presentation delivered at the Automation Hub Ribbon Cutting, VTTI, Blacksburg, VA, November 2018. (Published)

Stoelje, G. Panel Presentation at the Texas A&M Transportation Institute.

McKenzie, J., Zahed, K., Warner, J., Uster, H., and Ferris, T.K. (2018). Survey and modeling approach to predicting driver turnover in long-haul trucking. Proceedings of the Human Factors and Ergonomics Society 62nd Annual Meeting. Philadelphia, PA, October. 1383-1383. (Published)

Stibbe, J., & Brewer, M.A. (2019, January). Processing SHRP2 Time Series Data to Facilitate Analysis of Relationships Between Speed and Roadway Characteristics. Presented at the 2019 Transportation Research Board Annual Meeting (Published)

Florence, W. 2019 TRB Annual Meeting Lectern Session: Considering Railroad System Interaction with Automated/ Connected Vehicle Planning, Lectern Session 1353, Autonomous Train Technology: The Challenges of Implementation, Part 2, January 14, 2019. (Published)

Stoelje, G. Panel Presentation at the Texas A&M School of Law.

Rodriguez Paras, C. and Ferris, T.K. (2018). A model for characterizing startle in driving contexts. Proceedings of the Human Factors and Ergonomics Society 62nd Annual Meeting. Philadelphia, PA, October. (Published)

Florence, W. TRB AR070 Rail Operational Safety Committee Meeting: Autonomous Technology Discussion, January 15, 2019 (Published)

Y.C. Hsu, S. Gopalswamy, S. Saripalli, D. A. Shell. An MDP Model of Vehicle-Pedestrian Interaction at an Unsignalized Intersection"" a workshop paper appearing in IEEE Vehicular Technology Conference (VTC), Chicago, Illinois, August 2018. (Published)

Nayak, A., Gopalswamy, S., and Rathinam, S. Vision-Based Techniques for Identifying Emergency Vehicles, SAE Technical Paper 2019-01-0889, 2019, doi:10.4271/2019-01-0889. (Published)

Munira, S., Henk, R. Deterring Distractions & Aggressive Driving Behavior Using a Smartphone App: What Difference Does it Make? Presented at Lifesavers Conference, March 31, 2019, Louisville, Kentucky. (Accepted)

Rahmati, Y., A., Samimi Abianeh, M., Tabesh, A., Talebpour, and F., Sharifi. Driving to Safety: Who Is at Fault in CAVs Rear-End Collisions. Accepted for presentation at the 98th Annual Meeting of the Transportation Research Board of National Academies, January 13-17, 2019. (Accepted)

Theses and Dissertations

Stibbe, J. (2018) An Investigation into Vehicle Acceleration Characteristics on Freeway Loop Ramps (Master's thesis). Texas A&M University, College Station, TX. (Published)

Han, W. (2019), A Connected Work Zone Hazard Detection System For Highway Construction, (unpublished Master's thesis) Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA. (Under Review)

Shirazi, M. (2018) Advanced Statistical Methods for Analyzing Crash Datasets with Many Zero Observations and a Long Tail: Semiparametric Negative Binomial Dirichlet Process Mixture and Model Selection Heuristics. . Ph.D. Dissertation, Zachry Department of Civil Engineering, Texas A&M University, College Station, Tx. (Submitted)

Mahdie Hasani (2019), Evaluation of Pedestrian and Bicycle Exposure and Crash Risk at Signalized Intersections in San Diego Master's thesis, Department of Civil, Construction, and Environmental Engineering, San Diego State University. (Submitted)

Other Publications, Conference Papers, and Presentations

McDonald, A.D. (2018). Driver modeling and naturalistic data. Presented at the Virginia Polytechnic Institute and State University. Blacksburg, Virginia, November 13, 2018.

Website(s) or Other Internet Sites

In collaboration with TTI and VTTI, Project 01-005: Factors Surrounding Child Seat Usage in Ride-Share Services research team members Justin Owens and Katie Womack conducted an analysis of the current state of child passengers and child safety seat use in ride-sourced vehicles, along with other more traditional sources of transit (e.g., taxicabs). The research team worked with ride-share service companies to develop www.kidsridesafe.org, a website created to provide state-by-state guidance to parents, caregivers, and drivers of ride-share vehicles to help them better understand the laws and regulations surrounding child passenger safety and to assist in planning their trips while traveling with children.

Selected EWD and T2 Outputs

Projects reported numerous EWD and T2 activities during this reporting period. For example, two project webinars were held during this reporting period: Project 02-009: Vehicle Occupants and Driver Behavior held a webinar on November 29, 2018, and TTI-03-01: Legal Tools for Barriers to Accessing Data Sets in the Age of AV/CV Technologies held a webinar on March 5, 2019, titled "Emerging Legal Issues for Using Passively Collected Datasets." Project TTI-01-05: K-12 STEM Program: Exploring the Science of Retroreflectivity continued outreach at schools and STEM events in November and December 2018, reaching more than 70 participants. Project 04-100: Development of a Diagnostic System for Air Brakes in Autonomous and Connected Trucks conducted a graduate seminar at UT Dallas to the Nonlinear Analysis and Dynamical Systems Group. In addition to participating in Explore SDSU 2019, Projects 01-003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety and 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving presented results at a meeting with the Institute for Interdisciplinary Brain and Behavioral Sciences at Chapman University on January 30, 2019,

and at meeting with Linscott, Law & Greenspan Engineers (LLG) on March 15, 2019. Project 03-036: Modeling Driver Responses during AV Platooning Failures created a lecture series discussing driver modeling and advanced vehicle technologies, and Project 01-003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety developed a web-based tool to identify high-risk intersections for walking and bicycling in San Diego (https://g-hasani.shinyapps.io/RiskCalc/). The data collected and processed throughout the latter project were used in a group project assignment for CIVE 160 Statistical Methods for the Built Environment course at SDSU.

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; increasing the body of knowledge; training of the future transportation workforce; and improving processes, technologies, techniques, and skills used. 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 4). The Safe-D team participated in three outreach events to promote the program and projects to an audience totaling 62 practitioners, including DOT officials, industry partners, and graduate students. Safe-D expects that goals for practitioner use of technology will increase with maturity and closer to the end of the program. VDOT has incorporated work zone threat and collision warning algorithms developed as part of the Project 03-050: Design and Evaluation of a Connected Work Zone Hazard Detection and Communication System for Connected and Automated Vehicles into its connected vehicle testbed program. This project also led to another follow-on project with VDOT, Project 04-104: Development of a Connected Smart Vest for Improved Roadside Work Zone Safety, which will incorporate the collision threat algorithms and information learned from the prior project into the development of a prototype personal protective equipment product that can be worn by roadside workers to report their position and threat of collision to passing vehicles. In general, the Safe-D program is currently on-track to meet its T2 performance goals through this reporting period.

Table 4. 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/year	3 events
	Each Event: average 15 practitioners	62 practitioners
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	1
	Follow-on funding from 2 DOTs	1

Increased Understanding and Awareness of Transportation Issues

- Project TTI-01-05: K-12 STEM Program: Exploring the Science of Retroreflectivity has connected real-life applications in transportation to academic concepts to enhance the STEM learning experience for students.
- Project 02-019: Identification of Railroad Requirements for the Future AV/CV Environment has increased understanding and awareness of the issues for both rail vehicles and AV/CV at highway rail crossings.
- Project TTI-03-01: Legal Tools for and Barriers to Accessing Data Sets in the Age of AV/CV Technologies has increased understanding and awareness of the shift in legal and regulatory landscapes for researchers due to new research practices and has identified new legal questions. In addition, the Texas A&M Law School students and faculty have benefitted from learning how privacy laws apply to new vehicle technologies.
- Project 03-050: Design and Evaluation of a Connected Work Zone Hazard Detection and Comm Sys for CAVs will ultimately create outputs that include an increased understanding of the potential benefits and difficulties in using ultra-wide band technology in open roadway environments.
- Project 01-006: Implications of Truck Platoons for Roadside and Vehicle Safety Hardware has increased understanding of the capacity and adequacy of the existing roadside safety hardware and occupant risks.
- Project 01-005: Factors Surrounding Child Seat Usage in Ride-Share Services has increased awareness of child passenger safety issues associated with ride-share vehicles among the public, legislators, and ride-share drivers.

Passage of New Policies, Regulation, Rulemaking, or Legislation

- Project 03-040: Examining Senior Drivers Adaptation to Mixed-Level Automated Vehicles results may be helpful to original equipment manufacturers (OEMs) and governmental stakeholders in developing guidelines or best practices in terms of AV technology transfer to senior drivers, an ever-growing and ever-evolving subset of our population.
- Project 04-103: Examining Senior Drivers' Adaptation to Mixed-Level Automated Vehicles: Phase II, a follow-on project to 03-040, expects that the integrated results of the subjective data analyzed under Project 03-040 and the naturalistic data that will be analyzed will provide stakeholders (e.g., OEMs, governmental regulation agencies, and safety advocacy groups) with the evidence needed to document and enhance the safety and mobility benefits associated with use of AVT by seniors. Additionally, it will produce information that can help with the adoption and acceptance of these technologies.
- Project 04-121: Development of an Infrastructure Based DAS to Naturalistically Collect the Roadway Environment has multiple meetings planned with officials from the City of Virginia Beach to update them on project outcomes. As part of these meetings, presentation material will be generated to educate and enlighten the City on innovative and disruptive ways in which data collected by their infrastructure can be used to improve operations and safety. Such materials, along with ad hoc discussions, will help city officials be aware of methods that can be deployed as City agencies adopt a data-driven mindset.

Increases in the Body of Knowledge

- Project 02-019: Identification of Railroad Requirements for the Future AV/CV Environment has increased the body of knowledge by doing a cross-cutting comparison on highway AV/CV planning with rail system operations and planning factors. The project team also conducted Transportation Research Board (TRB) presentations that included discussions of what adding automated train operations may add to the needs. In addition, the team has identified barriers to implementation, information sharing between rail and highway systems, and future research needs.
- Project 03-036: Modeling Driver Responses during AV Platooning Failures notes that a review article published by the team has been read by at least 602 people (as of 04/12/19 on ResearchGate), cited by two international groups (Volvo car corporation and Chalmers University in Sweden), and recommended by four individuals from several international universities. While the readers represent a diverse group, many of them are graduate students (worldwide) who are beginning their research in automated vehicles.

- Project 04-100: Development of a Diagnostic System for Air Brakes in Autonomous and Connected Trucks conducted a seminar at the University of Texas – Dallas, which helped researchers gain an understanding of the basic issues required for developing diagnostic systems for air brakes.
- Project 03-050: Design and Evaluation of a Connected Work Zone Hazard Detection and Comm Sys for CAVs produced a conference paper and presentation increasing the body of knowledge related to connected roadside equipment and localization technologies.

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

- Project 01-003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety created a web-based tool that can be used to explore different methods to quantify the risks of walking and bicycling. The tool can also be used to visualize and identify the locations of high-risk intersections in the San Diego area.
- Project 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving adopted tools such as ArcGIS Pro, ArcGIS Desktop, ESRI Insight, and Tableau, improving the techniques used to identify aggressive driving, which is defined as instances when drivers travel at velocities over the speed limit. The publication and other products and activities resulting from this study have and will continue to increase the understanding of aggressive driving identification using machine-learning techniques.
- Project 02-014: Formalizing Human-Machine Communication in the Context of Autonomous Vehicles developed a probabilistic model to capture implicit and explicit communication between pedestrians and vehicles.
- Project 04-115: Reference Machine Vision for ADAS Functions found that there is currently no reference system for characterizing the performance of LDW and LKA systems against different lane markings and in different lighting and weather conditions. Therefore, the main potential outcome of this project will be the development of an accurate benchmarking system against which other researchers or industry partners can either test the quality of the lane marking materials or the vision algorithms.

Enlargement of the Pool of Trained Transportation Professionals

- Project 01-003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety created a group assignment as part of its EWD outputs. The assignment was designed using the project data and exposes students to real-world problems that increase understanding of how statistical methods can be used to contribute to the solution of transportation problems.

Adoption of New Technologies, Techniques, or Practices

While no projects have reported adoption of technologies, techniques, or practices to-date, it is expected that outcomes of this nature will be realized during later reporting periods. The Safe-D National UTC Leadership Team has processes in place to continue reaching out to project teams beyond completion of their projects to ensure that use of project products by external organizations are accurately reported.

Impacts

Impact of Effectiveness on Transportation System

All Safe-D research projects are designed to produce implementable results that have both near-term and long-term effects on the transportation system. While the results of many Safe-D studies have only recently begun to be implemented and/or disseminated to practitioners, the outcomes of other projects are starting to positively impact our transportation system. Examples of how several specific Safe-D projects are influencing transportation effectiveness or are expected to in the near future are provided below:

- Project 02-019: Identification of Railroad Requirements for the Future AV/CV Environment. To date, the findings have been disseminated at presentations in multiple sessions at the TRB Annual Meeting and will be

presented at the ASME Joint Rail Conference in Salt Lake City, Utah, in April 2019. The results will also be incorporated into a webinar topic for a joint FHWA-FRA webinar on April 15, 2019. These dissemination efforts are expected to contribute to enhancing the effectiveness of railway transit in the future.

- Project 03-040: Examining Senior Drivers Adaptation to Mixed-Level Automated Vehicles. The findings of this are expected to help OEMs and governmental stakeholders develop guidelines or best practices regarding AV technology as it relates to seniors, an ever-growing subset of our population.
- Project 04-103: Examining Senior Drivers' Adaptation to Mixed-Level Automated Vehicles: Phase II. Combined with the results of Project 03-040, the naturalistic data analyzed as part of this effort will provide stakeholders (e.g., OEMs, governmental regulation agencies, and safety advocacy groups) with evidence to document and enhance the safety and mobility benefits associated with use of AV technology by seniors. The findings will also help seniors to adopt and accept AV technologies.
- Project TTI-03-01: Legal Tools For and Barriers to Accessing Data Sets in the Age of AV/CV Technologies. The outcomes of this project have improved the transportation system by illuminating emerging questions that affect the ability of transportation researchers to continue their research in a legal and ethical manner.
- Project 04-121: Development of an Infrastructure Based DAS to Naturalistically Collect the Roadway Environment. The outcomes of this project have immediately benefitted transportation effectiveness in the City of Virginia Beach by identifying specific intersections with safety issues, allowing targeted countermeasures to be implemented.
- Project 03-036: Modeling Driver Responses during AV Platooning Failures. The outcomes of this project have been implemented primarily by the research community to design studies and support further work on automated vehicles. These studies are expected to lead to safer automated driving systems and, ultimately, a more effective transportation system in the future.
- Project 00-021: Signal Awareness Applications. Once implemented, the developed signal awareness application is expected to improve mobility and reduce the environmental impacts of the transportation system by optimizing traffic flow and efficiency.
- Project 00-022: Automated Truck Mounted Attenuator. The outcomes of this project are anticipated to improve safety for passing motorists and roadside workers in applications where TMA trucks are used.
- Project 04-100: Development of a Diagnostic System for Air Brakes in Autonomous and Connected Trucks. Once implemented, the diagnostic system developed under this project is expected to enhance the safety of the transportation system by facilitating pre-trip inspections by drivers before switching to autonomous mode.
- 01-003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety. The primary outcomes of this project are methodologies that can be used to identify high-risk intersections. These methods will allow transportation agencies to prioritize facilities with the greatest need for safety improvements, thereby enhancing transportation safety and efficiency.
- Project 01-005: Factors Surrounding Child Seat Usage in Ride-Share Services. The findings of this project have begun to improve awareness of child passenger safety in ride-share vehicles and are expected to influence legislation related to this topic.
- Project 01-007: Preparing Work Zones for Automated and Connected Vehicles. Once implemented, the findings of this project will help transportation agencies and other stakeholders prepare work zones to better accommodate connected and automated vehicles.
- Project 01-006: Implications of Truck Platoons for Roadside and Vehicle Safety Hardware. The recommendations resulting from this project are expected to help shape the implementation of truck platooning and the development of future truck-platooning routes, thereby enhancing the efficiency of truck transport on our nation's highways.

Impact on Adoption of New Practices or Initiation of Startups

Before beginning work, all Safe-D projects are required to have a T2 plan in place that details how the outcomes of the project will be adapted 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. In addition to commercialization, Safe-D projects are expected to lead to the adoption of new practices in various realms of the transportation system as the results and products are disseminated. The potential for commercialization and adoption of new practices resulting from several specific Safe-D projects are summarized below:

Identified Commercialization Potential

- Project 04-121: Development of an Infrastructure Based DAS to Naturalistically Collect the Roadway Environment. In this project, Safe-D researchers defined and developed components to acquire, process, store, and analyze roadway data. The framework created during this project is expected to be applied by OEMs in new product offerings, including collision avoidance systems.
- Project 00-021: Signal Awareness Applications. The applications developed in this project, which are designed to improve intersection safety and mobility within the VCC environment, will be used by VCC partners and may be developed into commercial products by partners or others invited to use the applications.
- Project 00-022: Automated Truck Mounted Attenuator. The technology produced during this project has commercialized potential throughout the transportation industry. Once adopted and commercialized, the project outcomes will help improve roadside safety for work zone personnel and passing motorists.
- Project 04-100: Development of a Diagnostic System for Air Brakes in Autonomous and Connected Trucks. The diagnostic system developed under this project will be of significant interest for application by government entities and commercialization by industry.
- Project 01-002: Countermeasures to Detect and Combat Driver Inattention. While data collection has only just begun for this project, the findings are expected to contribute to a start-up company focused on human responses to a variety of human–automation interaction instructions/takeover cues.
- Project 03-050: Design and Evaluation of a Connected Work Zone Hazard Detection and Communication System for CAVs. This project will provide an algorithm to be used in a product being developed under Project 04-104. Upon completion, the product will be transferred as a deployable, marketable product to infrastructure owner-operators, who will apply the product to improve the safety of their roadside personnel and passing motorists.
- Project 01-003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety. By developing processes to identify high-risk intersections and to automatically detect and count pedestrians and bicyclists, the outcomes of this project are expected to be applied in commercial technology that will improve pedestrian and bicyclist safety at intersections.
- Project 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving. The web-based tool developed as part of this research will be expanded to other safety applications in the area of big data analytics. This tool has the potential to lead to commercialization.

Adoption of New Practices

- Project 02-019: Identification of Railroad Requirements for the Future AV/CV Environment. The outputs of this project are expected to lead to new practices concerning the interplay between rail and highway operations in the future connected/automated environment. The research team has begun disseminating the findings to both government and industry through presentations and webinars.
- Project 03-040: Examining Senior Drivers Adaptation to Mixed-Level Automated Vehicles. By providing valuable guidance to OEMs and governmental stakeholders, the outcomes of this project are anticipated to lead to new practices for facilitating the adoption of AV technology among seniors.
- Project 03-01: Legal Tools For and Barriers to Accessing Data Sets in the Age of AV/CV Technologies. This project identified the need for new practices regarding data protection and participant privacy, including the need to enhance researchers' understanding of emerging contractual and ethical responsibilities when using new types of data sets. Thus, the findings are expected to change practices related to the analysis of sensitive data sets obtained from automated and connected vehicles. To date, the findings have been disseminated through presentation to students, faculty, and staff of TTI and the Texas A&M University School of Law.

- Project 01-005: Factors Surrounding Child Seat Usage in Ride-Share Services. Safe-D researchers are working with a major ride-share company to implement findings and promote the website. These efforts are expected to lead to the adoption of new practices related to children traveling in ride-share vehicles.
- Project 01-007: Preparing Work Zones for Automated and Connected Vehicles. Once implemented, the findings are expected to lead to new practices in terms of how agencies design, procure, and manage their work zones. These changes will likely affect how contractors and technology vendors operate work zones.
- Project 01-006: Implications of Truck Platoons for Roadside and Vehicle Safety Hardware. This study will generate recommendations for seat belt and driver seat systems in trucks and their application in truck platooning. Outcomes will be applied by designers and engineers, leading to the adoption of new practices regarding the design of roadside barriers and occupant safety systems in future truck-platooning operations.

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 making significant contributions to the body of scientific knowledge within the broad realm of transportation. The impacts of specific Safe-D research projects on the body of scientific knowledge in several areas of the field of transportation are summarized below:

Transportation Data Collection and Analysis

The findings of numerous Safe-D projects are contributing to advances in the way transportation data are collected and analyzed, including data from advanced vehicular systems, infrastructure, and the road users themselves. Examples of Safe-D projects adding to the body of scientific knowledge regarding transportation data collection and analysis include:

- Project 01-03: Comparison of SHRP2 Naturalistic Driving Data to Geometric Design Speed Characteristics on Freeway Ramps. By developing a new way to estimate vehicle speed on freeway ramps, this project has provided a new tool that can be applied in a wide range of analyses related to transportation infrastructure design and operation.
- Project 03-049: Data Fusion for Non-Motorized Safety Analysis. This project developed a new method to combine disparate data sources that can be used to assess the safety of non-motorized road users. The approach to data fusion represents a significant contribution to big data analysis in many fields.
- Project 04-121: Development of an Infrastructure Based DAS to Naturalistically Collect the Roadway Environment. The results of this project advance the ability to use big data techniques such as machine vision and machine learning to detect roadway users.
- Project 01-001: Big Data Methodologies for Simplifying Traffic Safety Analyses. This project generated fundamental advances in the methodologies used to analyze safety- and transportation-related data.
- Project 04-114: Behavior-based Predictive Safety Analytics Phase II. The results of this project are poised to make significant contributions to the body of knowledge in the emerging field of behavior-based predictive safety analytics. Findings are expected to fundamentally change how data are used to improve driving safety.
- Project 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving. By developing tools and methods for analyzing large quantities of data, the results of this project will improve the ability to apply collected data to solve a variety of transportation problems.

Vulnerable Road Users

Safe-D research has also made significant contributions to the body of knowledge surrounding vulnerable road users, which include seniors, children, bicyclists, and pedestrians. For example, the results of Project 01-04: Influences on Bicyclists and Motor Vehicles Operating Speed within a Corridor have greatly improved the understanding of the relationship between the presence of bicyclists and vehicle operating speed. Projects 03-049 and 01-003 contributed new methodologies that will change how data are collected from vulnerable road users. Two related projects (03-040 and 04-103) have advanced the body

of knowledge surrounding the adoption of vehicle automation by seniors. Lastly, the results of Project 01-005: Surrounding Child Seat Usage in Ride-Share Services have advanced the understanding of issues related to child safety in ride-share vehicles.

Vehicle Automation

With vehicle automation being one of Safe-D's key focus areas, UTC research has produced considerable advances in the body of knowledge in this field of transportation. As highlighted above, Projects 03-040 and 04-103 have contributed to the understanding of how seniors will adopt autonomous technology in the near future. Projects 03-036: Modeling Driver Responses during AV Platooning Failures and 01-006: Implications of Truck Platoons for Roadside and Vehicle Safety Hardware advanced the body of knowledge about the application of vehicle automation to truck platooning by providing guidelines for safe platoon operation. The literature review developed under Project 03-036 has consolidated knowledge of automated vehicle takeovers and identified several critical gaps in the literature; the findings have already been applied in the design of other studies. By revealing how humans interact and interface with automated driving systems, Projects 01-002: Countermeasures to Detect and Combat Driver Inattention and 03-082: Assessing Alternative Approaches for Conveying Automated Vehicle Intentions have improved the ability to design automated systems and associated interfaces that will interact with human "drivers." Finally, the findings of Project 01-007: Preparing Work Zones for Automated and Connected Vehicles provide best practices to support the safe operation of automated vehicles in work zones.

Impact on Transportation Workforce Development

Led by the EWD Coordinator, Dr. Miguel Perez, all Safe-D projects adhere to individually created EWD plans. These plans are designed to ensure that each Safe-D project makes 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; have developed curriculum materials for educators; and have culminated in workforce training/educational events.

Curriculum Development

The results of several Safe-D projects have been translated into educational materials during this reporting period. For example, the data captured during Project 01-003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety were used to develop a group assignment for an engineering course (CIVE 160) offered at SDSU. Students working on this assignment will learn how to use the project data to develop statistical models for estimating pedestrian and bicyclist exposure. The outcomes of Project TTI-01-05: K-12 STEM Program: Exploring the Science of Retroreflectivity have been developed into curricular materials and disseminated to K-12 teachers to help them connect academic concepts to real-life transportation applications. The results of Projects 01-001: Big Data Methodologies for Simplifying Traffic Safety Analyses and 03-087: Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving are currently being incorporated into curricula for college-level courses related to big data. As part of Project 01-004: Driver Training for Automated Vehicle Technology, a teaching module was developed and is being added to a course at SDSU, Seminar in Transportation (CIVE 781).

Educational Opportunities

Safe-D research projects have created a wealth of research and other educational opportunities for students of all ages. For instance, Project 03-036: Modeling Driver Responses during AV Platooning Failures has involved two female Ph.D. students, both of whom have been instrumental in the project's

success. One of these students, Ms. Alambeigi, is the lead or second author on the two journal articles produced so far during this project. In addition, this project has involved five undergraduate students, including one from an underrepresented group. Three of these students have co-authored journal publications, and one has decided to pursue graduate education in data science, partially as a result of his involvement in this project. This project also generated two lectures that were delivered to two groups of graduate students at Virginia Tech and Texas A&M University. For many of the Texas A&M University students, these lectures marked their first exposure to transportation research and automated vehicle technologies. The materials used for these lectures illustrated how techniques learned in other domains could be applied to driving safety and automated vehicle problems. Project 01-006: Implications of Truck Platoons for Roadside and Vehicle Safety Hardware provided learning and research opportunities for a graduate student at TTI and multiple Ph.D. students at Virginia Tech. The students developed valuable skills in LS-Dyna modeling, technical writing, and leadership. The results of this study were also developed into a presentation delivered to elementary school students.

Professional Workforce Development

As part of Project 03-050: Design and Evaluation of a Connected Work Zone Hazard Detection and Communication System for CAVs, Safe-D researchers from VTTI participated in an event held by VDOT on April 9, 2018, in Richmond, Virginia, to bring awareness to work zone safety during the National Work Zone Awareness Week. VTTI shared various VCC applications related to work zone safety—including the Work Zone Mapping Application—with hundreds of VDOT employees. VTTI also organized and conducted a CAV training with approximately 50 VDOT employees on May 31, 2018, in Fairfax, Virginia. This training included the presentation of information on the Work Zone builder application and other work zone safety elements to help prepare the transportation professionals at VDOT for the deployment of CAVs.

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