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SAFE-D: SAFETY THROUGH DISRUPTION UNIVERSITY TRANSPORTATION CENTER

SAN DIEGO STATE UNIVERSITY

Texas A&M Transportation Institute

VIRGINIA TECH TRANSPORTATION INSTITUTE
VIRGINIA TECH

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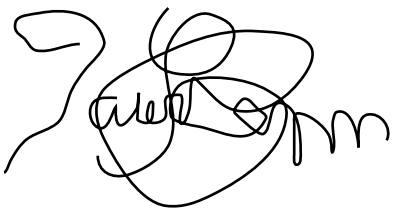
Signature of Submitting Official	

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Accomplishments

Major Goals of the Program

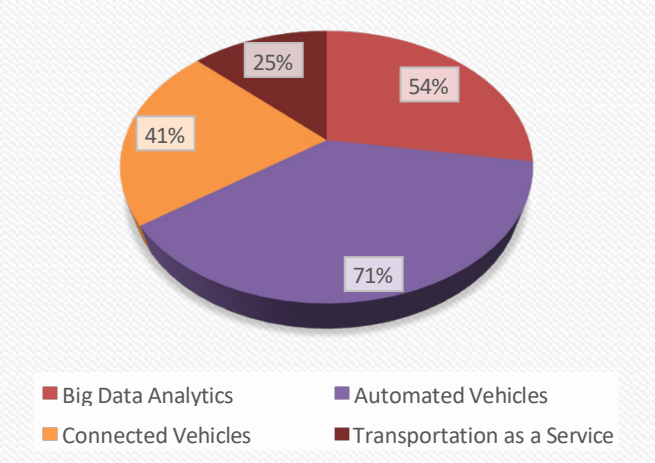
Fueled by the inevitable changes in our transportation system, the Safety through Disruption (Safe-D) National University Transportation Center (UTC) endeavors to maximize the potential safety benefits of disruptive technologies through targeted research that addresses the most pressing transportation safety questions. With the outstanding leadership of the Virginia Tech Transportation Institute (VTTI) and the Texas A&M Transportation Institute (TTI) in a mentoring collaboration with the new transportation research group at San Diego State University (SDSU), a Hispanic-Serving Institution known for educating the transportation workforce, our geographically balanced consortium encompasses the largest group of transportation safety researchers in the nation and provides unparalleled expertise, facilities, and resources to conduct impactful research toward our long-term vision. The Safe-D National UTC focuses its efforts in four key areas: (1) cutting-edge research conducted by leading transportation safety experts and their students; (2) education and workforce development (EWD) for programs of all levels, from grade school through college and extending to continuing education for professionals; and (3) fully supported technology transfer (T2), including practitioner training partnerships, social networking, commercialization, and intellectual property management; (4) Implementing diversity, equity, and inclusion components in all aspects of our research from the researchers involved to the communities it will support.

Accomplishments During This Reporting Period

Project Awards and Activity

The grant is heading towards its conclusion, and as such Safe-D has not solicited any research proposals during this period and will not hereafter. In addition, no extra funding was awarded to any remaining, on-going projects.

Over the life of this grant, we have developed a portfolio of more than $31 million. Safe-D projects have been selected according to their focus on four Center theme areas: automated vehicles, (AVs) connected vehicles (CVs), big data analytics, and transportation as a service. The coverage of Safe-D themes by project portfolio to-date is shown in Figure 1. Note that percentages are based on the number of projects reporting a focus in one or more Safe-D theme area(s), resulting in a total of over 100%. Due to no more projects being funded through the end of the grant, these are the final project theme distribution numbers.



Completed Projects

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

- VTTI 00-023 E-Scooter Safety Assessment and Campus Deployment Planning
- VTTI-00-032 E-Scooter Design
- TTI 05-04 Micromobility Safety Regulation: Municipal Best Practices Review
- TTI-05-01 Connected Vehicle Data Safety Applications
- 06-007 Allusion 2: External Communication for SAE L4 Vehicles
- 06-013 Multi-Incident Response Vehicle (MIRV)
- 05-008 Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation
- 06-011 Evaluating the Safe Routes to School (SR2S) Transportation Program in Socially Vulnerable Communities in San Diego County California
- 04-114 Behavior-Based Predictive Safety Analytics Phase II
- 06-002 Developing AI-Driven Safe Navigation Tool
- 06-001 Building Equitable Safe Streets for All Data Driven Approach and Computational Tools
- 01-002 Countermeasures to Detect and Combat Inattention While Driving Partially Automated Systems
- 04-100 Development of a Diagnostic System for Air Brakes in Autonomous and Connected Trucks
- TTI-05-03 Development of a Roadside Lidar-Based situational Awareness System for Work Zone Safety: Proof-of-Concept Study
- TTI-04-02 Delving Into Safety Considerations of E-Scooters: A Case Study of Austin, Texas
- 06-003 Critical Areas in Advanced Driver Assistance Systems Safety Point of Sale and Crash Reporting
- 06-005 Automated Truck Mounted Attenuator: Phase 2 Performance Measurement and Testing
- 05-109 Exploring the Safety Impacts of the Older Population's Access to Automated Vehicles and Telemedicine: A Real-World Experiment in Small and Rural Communities
- VTTI-00-026 Guiding Driver Reponses During Manual Takeovers from Automated Vehicles
- 06-010 Developing a Framework for Prioritizing Bicycle Safety Improvement Projects Using Crowdsourced and Image-Based Data
- 06-012 Real Time Risk Prediction at Signalized Intersection Using Graph Neural Network

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

- 05-113 Evaluation Tools for Automated Shuttle Transit Readiness of the Area

[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.

- 06-01: Connected Vehicle Information for Improving Safety Related to Unknown or Inadequate Truck Parking
- VTTI-00-036: Smart Work Zone System
- 05-086: A Data Driven Approach to the Development and Evaluation of Acoustic Electric Vehicle Alerting Systems for Vision Impaired Pedestrians
- 06-006: Private 5G Technology and Implementation Testing
- VTTI-00-021: Signal Awareness Applications
- 05-082: Lane Change Hazard Analysis Using Radar Traces to Identify Conflicts and Time-To-Collision
- TTI-05-02 Analysis of Advanced Driver-Assistance Systems in Police Vehicles
- 05-115 Cooperative Perception of Connected Vehicles for Safety
- VTTI-00-034: Sensor Degradation Detection Algorithm for Automated Driving Systems
- 06-004 Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas
- VTTI-00-033: Human Factors of Driving Automation: Evasive Maneuver Event Response Evaluation
- TTI-01-05 K-12 Stem Program: Exploring the Science of Retroreflectivity
- 05-089: A Holistic Work Zone Safety Alert System Through Automated Video and Smartphone Sensor Data Analysis
- 06-013 Multi-Incident Response Vehicle

Educational Courses Taught and Students Supported

Safe-D researchers are actively engaged in teaching efforts at each of the consortium universities and in supporting students through the conduct of research activities. While formal metrics are reported annually in the Program Performance Indicators, the following is a description of the metrics for this reporting period regarding courses taught and student support provided through the Safe-D program. During this reporting period, researchers involved in Safe-D research projects taught 12 graduate and 11 undergraduate courses, reaching 284 graduate and 685 undergraduate students. Safe-D research projects supported 9 undergraduate- and 9 graduate-level students during this reporting period. The breakdown of the students supported during this period are presented in Table 1.

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

Academic Level	Total Number of Students Supported	Number of Underrepresented Students Identified
Undergraduate	0	0
Masters	9	5
PhD	9	0

Highlighted EWD & Other Outreach Activity

- **Safe-D Project 06-014: Measuring the Safety of ADS: How safe is safe enough?**
  The Radford University Artis College of Science and Technology Summer Bridge WOMEN IN STEM program is a week-long residential experience for rising sophomore, junior, and senior high school students interested in science, technology, and mathematics. Eileen Herbers travelled to Radford University to present some of her research at VTTI, and to talk about how she got involved

in engineering. To garner more interest in the transportation industry, the talk was followed by a Q&A and discussion around the future of transportation, and how to causally investigate driver and vehicle behavior as high school students. The students then showcased their current robotic research projects to exhibit what they learned during the summer, and to receive feedback to generate new ideas and solutions.

Safe-D Webinars

Safe-D has hosted 32 webinars since it began in January 2020. We have built a robust archive of webinars and a listserv of 692 individuals (up from 594 in the previous reporting period) spanning industry, education, and research. Listserv recipients receive information on all upcoming Safe-D webinars. A list of all previous webinars can be found on the Safe-D website in the webinar archive tab. Safe-D webinars hosted 212 attendees for the six webinars held during this reporting period, which averaged to 35 webinar attendees per webinar with the highest attendance being 81. The total number of YouTube views for all Safe-D webinars during this reporting period was 9,868, for a grand total of 11,632 webinar views since they started being published online in February of 2020. A large portion of these views were of the webinar on Safe-D project 05-109 (autonomous Vehicles for Small Towns: System, Service, and Safety from Research to Practice)

Safe-D Webinar Series During this Period

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

- 05-082 Lane Change Hazard Analysis Using Radar Traces to Identify Conflicts and Time-To-Collision
- 05-109 Autonomous Vehicles for Small Towns: System, Service, and Safety from Research to Practice
- TTI 05-02 Analysis of Advanced Driver-Assistance Systems in Police Vehicles
- 06-011 Evaluating the Safe Routes to School (SRS2) Transportation Program in Socially Vulnerable Communities in San Diego County, California
- 05-008 Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation
- 06-009 Learning Active Inference Models of Perception and Control

Safe-D Upcoming Webinar Series

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

Real-Time Risk Prediction at Signalized Intersection Using Graph Neural Network

Safe-D Project 06-012 investigates intersection-related traffic crash and fatalities, which are one of the major concerns for road safety. In this project, the aim is to understand the major cause of conflicts at an intersection by studying the intricate interplay between all the roadway agents. Current traffic camera systems are used to automatically process traffic video data. As manual annotation of video datasets is a very labor-intensive and costly process, researchers leverage modern computer vision algorithms to automatically process these videos and retrieve kinematic behavior of the traffic actors. Researchers demonstrate how traffic actors and road segments can be independently modeled through graphs and how they can be integrated in a framework that can model traffic systems. A graph neural network (GNN) is used to model the interaction of all the roadway agents at any given instance, and their role in road safety, both individually and as a composite system. The proposed model reports a near real time risk score for a traffic scene. Finally, a new drone-based trajectory dataset is presented to accelerate the research in intersection safety.

Connected Vehicle Data Safety Applications

Safe-D Project TTI-05-01 is a large-scale assessment of how driving behavior affects traffic safety and ongoing surveillance is hindered by data collection difficulties, small sample sizes, and high costs. Connected vehicles (CV) now offer massive volumes of observed driving behavior data from newer vehicles with myriad electronics and sensors that monitor the state of the vehicle, environmental conditions, and the driver's actions.

This project evaluated the viability of CV data in roadway safety applications with the objective of improving existing predictive crash methods. The research team developed safety performance functions (SPFs) for rural two-lane segments and urban intersections in Texas. The results showed that the SPFs improved with the addition of hard braking and hard acceleration counts in a majority of areas.

This webinar will cover the details of what it takes to use CV data to help improve crash prediction modelling.

Developing Artificial Intelligence Driven Safe Navigation Tool

Safe-D Project 06-02 involves AI driven navigation. While popular navigation applications such as Google Maps and Apple Maps provide distance-based or travel time-based alternative routes, there is no real-time risk scoring. There is a need for a real-time navigation system that can provide the data-driven decision on the safest path or route. By leveraging data from a diverse range of historical and real-time sources, this study successfully developed a user interface for a navigation tool or application that offers informed and data-driven decisions regarding the safest navigation options. The interface considers multiple scoring factors, including safety, distance, travel time, and an overall scoring metric. This study made a distinctive and valuable contribution by designing and implementing a robust safe navigation tool driven by artificial intelligence. Unlike existing navigation tools that offer multiple uninformed route options, this tool provides users with an informed decision on the safest route. By leveraging advanced AI algorithms and integrating various data sources, this navigation tool enhances the accuracy and reliability of route selection, thereby improving overall road safety and ensuring users can make informed decisions for their journeys.

Measuring the Safety of ADS: How Safe is Safe Enough?

Safe-D Project 06-014 explores a common question determining the eventual deployment of automated driving systems: "how safe is safe enough?" This research uses naturalistic driving data to determine how to measure the potential safety benefit of automated vehicle technologies and automated driving systems (ADS), and where current technology practices may not deliver on projected safety promises. ADS are being developed faster than any point in history. There is a need to have an independent system to measure the safety of ADS across technologies and corporations. There are a variety of efforts around the world trying to estimate the impact of these systems on safety both prior to and after implementation. A missing piece that could allow for more cohesion and safer implementation is the knowledge of what type of data is needed for the refinement and further development of these systems, as well as which scenarios may not be able to be addressed by the currently implemented technology. The purpose of this project is to use naturalistic driving data to inform scenario selection that will be used to measure how ADS will perform in these scenarios.

Specifically, events are chosen partly from the results of a previous project in which naturalistic crash and near-crash scenarios were modeled to determine how the inclusion of line-of-sight and CV technologies could have impacted the event. Safety surrogate measures are calculated to determine the impact of changing event parameters and to estimate the potential crash severity of different scenarios. Other epochs are chosen based on situations where certain perception systems may have difficulty in correctly identifying the location and classification of certain objects. Overall, this research is meant to create and analyze some scenarios in which the technology being developed in ADS may not provide the predicted advantage of reducing or mitigating safety-critical events.

More information on the current or future Safe-D webinars can be found here.

Safe-D Researcher Honors and Awards

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

- Virginia Tech professor and VTTI researcher Dr. Miguel Perez received the Golden Pen Award from the Virginia Tech Biomedical Engineering Department.
- Virginia Tech PhD candidate Eileen Herbers placed 3rd in the Distracted Driving Summit Poster Competition.
- Texas A&M University master's student Stephen Ninan was awarded the Byron Anderson '54 Fellowship in the Department of Mechanical Engineering.
- VTTI researcher Andrew Miller was awarded a Virginia Tech Research Excellence Award.

Diversity Equity and Inclusion in Safe-D

Diversity, equity, and inclusion (DEI) in transportation are not only important to the current administration (as described in the American Jobs Plan) and society at large but are also equally important to Safe-D. The Safe-D site has a tab which describes the importance of DEI in transportation and has a list of projects that directly or indirect affect DEI. Safe-D believes that it is important to pursue research initiatives that not only identify roadblocks in DEI in transportation but also to develop real-world, common-sense solutions to these issues. In that light, Safe-D is committed to supporting projects that foster DEI in transportation and have supported 21 projects with a DEI component over the life of the grant. Below is one such Safe-D project that is making the lives of underrepresented populations better:

- Results from Project 06-010, Developing a framework for prioritizing bicycle safety improvement projects using crowdsourced and image-based data, developed a set of transportation equity factors to include in a proposed risk scoring method. According to statistics, there is a disproportionate bicycle crash distribution among people with different socio-demographic characteristics. To the researchers' knowledge, no previous study had included these equity factors in their models to prioritize areas for bicycle safety improvements.

Participants and Collaborating Organizations

Partner Organization

In addition to our inter-consortium collaborations on Safe-D research projects, the Safe-D T2 Plan for proposals necessitated the pairing of each new project team with an industry project champion. These champions served as integral "customers" for the research, enhancing the alignment of projects with industry requirements. While Safe-D has enjoyed extensive support and fruitful collaborations over the years, it is worth noting that at this time, there are no ongoing collaborations to share.

Outputs

The following T2 Performance Goals and corresponding Metrics for Outputs are copied from the currently approved Safe-D T2 Plan. The Safe-D Website Traffic Measures provide evidence that Safe-D products are being viewed by practitioners and potential users. The Safe-D website attracted 1,068 visitors during the first half of the 6-month reporting period. In July 2023, Google Analytics switched to a new method of tracking website analytics. Due to a glitch when implementing the new system, data is not available for July through September 2023. Website traffic usually follows the same monthly trends, so doubling the numbers gives an estimate of traffic for the July through September on par with previous periods. Even with the lack of data for half of this reporting period, the Safe-D website had 2,645 visitors during the previous 6-month reporting period and thus Safe-D exceeded our annual goal of 2,000 visitors per year, with a total of 3,383 visitors from October 1, 2022, to September 30, 2023. Project Page visits averaged just over 13 visits per page for the first 3 months of the reporting period. The Safe-D team remains committed to promoting project page sites in order to boost website visits, a commitment that will persist as the final projects are updated beyond this reporting period. Additionally, the team is actively investigating approaches to sustain the activity and traffic to project pages even after the conclusion of this grant.

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	1.068* (3,383 visitors/previous 12 mo.)
	Project Pages: Average ≥ 150 visitors/year	1,335 total visits/period; average 13 visitors/project page
Journal Articles/Conference Presentations	Project Teams: 1 article/year	3 articles
	Project Teams: 1 conference/year	4 presentations
Facility Tours	Displays Viewed by ≥ 200/year	172 total visitor views
	Follow-up Interest: 5 visitors/year	0

Prior to this reporting period, a total of 72 projects had been completed, resulting in 92 journal articles and 126 conference presentations.

During this reporting period, project teams successfully completed 15 additional projects and reported a total of 4 new conference presentations and 3 new publications. With these new additions, the average rate of publications per completed project stands at 1.09 journal articles and 1.49 conference presentations. These figures demonstrate that Safe-D remains on track for its projects in the current reporting period, and we anticipate an increase in publications as projects conclude, allowing researchers to shift their focus from project completion to publishing their findings. Safe-D researchers also reported 40 views of Safe-D displays during outreach events during the 6-month reporting period. Last period, researchers reported 590 views, bringing the yearly total to 630, surpassing our annual goal of 200 views by over threefold.

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

- Project VTTI-00-023 E-Scooter Safety Assessment and Campus Deployment Planning was mentioned in the VT news: *Ground-breaking e-scooter study shows surface transitions as most common hurdle.*

This work was then also mentioned across multiple national and international outlets such as the EurekAlert, Scienmag, Crumpe and the Daily Advent.

- Project VTTI-06-006 Private 5G Technology and Implementation Testing was featured in the Business Wire and was picked up by the Associated Press, Le Lezard, Spoke etc.

Publications, Conference Papers, Presentations, Books and Theses

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

Journal Publications/Conference Papers

Britten, N., Johns, M., Hankey, J., & Kurokawa, K. (2023). Do you trust me? Driver responses to automated evasive maneuvers. *Frontiers in Psychology, 14*, 1128590. (Published)

Schoner, J., Sanders, R., & Goddard, T. (2023). Effects of Advanced Driver Assistance Systems on Impact Velocity and Injury Severity: An Exploration of Data from the Crash Investigation Sampling System. *Transportation Research Record*, 03611981231189740. https://doi.org/10.1177/03611981231189740 (Published)

Sonth, S., Sarkar, A., Bhagat, H., & Jain, S. (2024). Intersection-Related Crash Analysis Through Network Modeling. 104th Transportation Research Board Annual Meeting, Washington, DC, USA. (Submitted)

White, E., Guo, F., Han, S., Mollenhauer, M., Broaddus, A., Sweeney, T., Robinson, S., Novotny, A., & Buehler, R. (2023). What factors contribute to e-scooter crashes: A first look using naturalistic riding approach. *Journal of Safety Research 85,* 182-191. (Published)

Presentations

Herbers, E. (2023). Using Naturalistic Driving Data to Measure the Safety Impact of Automated Driving Systems. Distracted Driving Summit, Blacksburg, VA, September 13-14.

Koirala, P., & Sener, I. N. (2023). Examining E-Scooter Risk Factors: A Multi-Level Exploratory Analysis for Safer Urban Mobility. International Professional Association for Transport & Health (IPATH) Annual Meeting 1-Day Conference Series, June 29, 2023.

Koirala, P., Sener, I. N., & Zhang, Y. (2023). Injury Severity Analysis of Imbalanced E-scooter and Bicycle Crash Data Using Statistical and Machine Learning Models. 103rd Transportation Research Board Annual Meeting Poster Session, Washington, DC, USA.

Ninan S., Rathinam S.,Harsh M., Sunny B. (2023). R2D2: Rural Road Detection Dataset. IEEE International Conference on Intelligent Transportation Systems Conference, Bilbao, Bizkaia, Spain, September 26.

Books and Theses

Koirala, Pranik (2023). Understanding the Factors Affecting Safety of E-Scooter and Bicycle Users in Urban Environments: An Injury Severity Analysis Using Machine Learning and Natural Language Processing. Master's Thesis, Texas A&M University.

Sonth, A. P. (2023). Enhancing Road Safety through Machine Learning for Prediction of Unsafe Driving Behaviors (Doctoral dissertation, Virginia Tech).

Ninan S. (2023). Perception and Localization for Rural Roads, master's Thesis, Texas A&M University.

Sadeghi, A. R. (2023). Developing A Framework for Prioritizing Bicycle Safety Improvement Projects. Master's Thesis, San Diego State University.

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. For the period of April 1 through June 30, 2023, the Safe-D website averaged 324 users per month, with 971 new users during this period. Users viewed pages 3,041 times during this period, visiting an average of 1.98 pages per session. Due to a glitch mentioned previously, data is not available for July through September of 2023. Nevertheless, it's important to note once more that website traffic typically exhibits consistent monthly trends. Therefore, by doubling the figures, we can estimate that the traffic for July through September 2023 will align with the patterns observed in previous periods. These website traffic measures still indicate a steady flow of activity, but it is likely that we will continue to see a decrease in traffic as projects continue to wrap up.

Outcomes

Safe-D projects are continuing to contribute to changes to the transportation system by increasing understanding and awareness of transportation issues; guiding future policy, regulation, rulemaking, and legislation; adding to the body of knowledge; training the future transportation workforce; and improving transportation-related processes, technologies, techniques, and skills. Due in part to the strong Safe-D T2 Plan and industry involvement with each Safe-D project, we are starting to see the adoption of new technologies, techniques, or practices as a result of individual Safe-D projects, as outlined in the next sections.

The T2 Performance Goals and their associated Outcome/Impact Metrics, which are detailed in the currently approved Safe-D T2 Plan, are provided in Table 3 below. While Safe-D has sustained its outreach endeavors during this reporting period, there has been a reduction in these efforts. Safe-D researchers actively engaged in 5 outreach events, where they presented the program and projects to a total audience of 372 individuals. This contrasts with the previous reporting period, which involved 12 outreach activities and reached 955 audience members. It's important to note that webinar activities are not included in this reporting section, as they are already referenced in the webinar section above to prevent double counting.

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	5
	Each Event: average 95 practitioners	372
Vendors Using Technology Developed	Average 1/3 projects result in vendors using technology	No projects have resulted in vendors using technology during this period
	1 license in later stages of UTC operation	0
DOTs Using Technology Developed	3 DOTs using project technology	0
	Follow-on funding from 2 DOTs	0
	Projects Received Patents	0

Increased Understanding and Awareness of Transportation Issues

- Project TTI-05-03 Development of a Roadside LiDAR-Based Situational Awareness System for Work Zone Safety: Proof-of-Concept Study Roadway delved into safety issues revolving around road workers. Construction and maintenance have become increasingly more common as the transportation system in the United States ages and the population and traffic volume increase. This fact places more and more work zone workers near high-speed vehicles and increases their probability of being stuck. Roadway workers are more exposed to safety risks, invariably escalating the risk of accidents, injuries, and fatalities. This project gained deeper insight into the problems facing roadway workers in an attempt to create interventions to effectively mitigate the increased safety risk in work zones.

- Project 04-114 Behavior-based Predictive Safety Analytics Phase II demonstrated the feasibility toward predicting crash risk within drivers across and within trips. Researchers emphasize the utilization of trip level data to get at a more nuanced evaluation of driver risk. Typically, drivers are binned into categories of risk based on their driving styles, risk-taking nature, or demographics like age and gender; however, this research emphasizes the variance over time in which drivers will perform differently based on contextual factors.

- Project 06-002 Developing AI-driven Safe Navigation Tool developed a navigation tool which considers multiple factors, including safety, distance, travel time, and an overall scoring metric to provide route guidance. By integrating artificial intelligence algorithms and diverse data sources, this tool offers users informed and data-driven decisions about the safest navigation options available. Unlike existing navigation tools that present multiple uninformed route options, this tool provides users with a well-informed choice regarding the safest route for their journeys. This approach significantly improves the accuracy and reliability of route selection, thereby enhancing road safety and empowering users to make knowledgeable decisions for their travels.

Passage of New Policies, Regulation, Rulemaking, or Legislation

Though results of several Safe-D projects have contributed to new policies, regulations, rulemaking, or legislation over the course of this grant, during this reporting period there were no new policies developed from SAFE-D projects that are currently being considered in regulations or legislation.

Increases in the Body of Knowledge

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

- Project 05-093 Automated Shuttles and Buses for All Users provides guidelines related to planning, service design, operations, vehicles, and monitoring and evaluating automated shuttles and elements of the built environment (streets, sidewalks, intersections, and building access) to ensure the safety and mobility of disabled individuals. This information will be beneficial for public agencies, interest groups, and the private sector.

- Project VTTI-00-033 Human Factors of Level 3 Automation: Surprise Event Response Evaluation represents the first published research on how drivers respond to evasive maneuvers initiated by a Level 3 Automated Driving System during real-world driving. The dissemination of the project's results allows researchers and practitioners to better design Level 3 ADS for evasive driving maneuver scenarios.

- Project VTTI-00-031 Evaluation of Eyes Off Road During L2 Activation on Uncontrolled Access Roadways can help inform the design of driver monitoring systems. Specifically, this project analyzed drivers of a vehicle that uses passive monitoring to determine a driver's attention. That is, torque on the steering wheel is used as a surrogate for driver attention as opposed to a camera-based driver monitoring system. Passive monitoring is not as accurate, as drivers can trick the system into believing they are attentive when they are not (e.g., applying false torque). This suggests camera-based systems might be a better method of monitoring.

Enlargement of the Pool of Trained Transportation Professionals

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

- VTTI-00-024 Characterizing Level 2 Automation in a Naturalistic Driving Fleet. During the data analysis stage of this project, the research team hired an undergraduate student as an undergraduate research assistant to perform data reduction and analysis. This student was given the opportunity to learn about naturalistic driving research methods, which has facilitated their growth as a transportation researcher. In addition, as part of the on-boarding process, the student had the opportunity to learn about the body of literature related to this research topic, including the current understanding of drivers' use of L2 capable vehicles and takeover requests. In addition to this, the project also provided support for three PhD students and one master's level student, all of whom had the opportunity to delve into the intricacies of naturalistic data processing and analysis, further enriching their expertise in this domain.
- TTI-04-02 Delving into Safety Considerations of E Scooters: A Case Study of Austin, Texas. This project formed the central focus of a master's thesis conducted by a civil engineering student at Texas A&M. Throughout this period, the student explored a range of innovative techniques, including those related to machine learning and neural networks, and successfully completed their thesis.
- VTTI-00-033 Human Factors of Level 3 Automation: Surprise Event Response Evaluation This project enlarged the pool of trained transportation professionals by providing an opportunity for the PhD student working on this project to gain experience publishing in a research journal. More specifically, this gave the student increased knowledge in how to write journal papers, analyze data, and work through the journal review process. These skills will help the student further their career and contribute to the transportation research profession.

Adoption of New Technologies, Techniques, or Practices

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

- VTTI-00-026 Guiding Driver Responses During Manual Takeovers from Automated Vehicles. The outcomes of the research have the potential to harmonize human-machine interface (HMI) approaches during control transfer, or can provide guidance. Additionally, the project provides guidance for the use of Virtual Reality systems for the study of human driver interactions, and the design and implementation of suitable HMI for control transfers.
- 04-110 Developing an Intelligent Transportation Management Center (ITMC) with a Safety Evaluation Focus for Smart Cities. In the conventional approach, transportation management centers (TMCs) primarily concentrate on enhancing operational efficiency, managing congestion, responding to incidents, and providing traveler information, among other functions. Safety assessment is typically not

a central focus of TMCs. However, this project takes a different approach by employing safety surrogate measures and visual analysis to proactively evaluate safety at signalized intersections.

- 04-121 Development of an Infrastructure Based Data Acquisition System (iDAS) to Naturalistically Collect the Roadway Environment. The project primarily embraced cutting-edge computer vision and machine learning techniques. Recent research has demonstrated the significant advantages of using computer vision for monitoring movements and interactions. Similarly, graph-based methods have shown great promise in consolidating information. These methods are characterized by speed and precision, and they have unlocked new possibilities for applications and operations that were once deemed unattainable.

Impacts

Impact on Effectiveness of Transportation System

Safe-D research projects are designed to produce implementable results that have both near-term and long-term effects on the transportation system. Although the results of some Safe-D studies have only recently begun to be implemented and/or disseminated to practitioners, the outcomes of some projects are beginning to influence our transportation system.

- Project 05-093 Automated Shuttles and Buses for All Users developed guidelines which will assist in ensuring that automated shuttles consider and address the needs of disabled individuals and the safety and mobility associated with their complete trip, including streets, intersections, sidewalks, and access to buildings. This information is beneficial to public agencies, companies, consultants, and other organizations in creating a more effective transportation system.

- Project TTI-04-02 Delving into Safety Considerations of E Scooters: A Case Study of Austin, Texas: Micromobility serves as a valuable first/last-mile transportation solution and offers convenience for leisure travel. Nevertheless, e-scooters represent a relatively novel addition to urban transportation, and their effects and features are still not completely understood. This study advanced our comprehension of the safety dimensions associated with e-scooters in urban transportation. By pinpointing the traits of e-scooter accidents and the factors that contribute to them, this research enables policymakers, designers, and regulatory bodies to establish effective safety measures for enhancing the urban transportation system.

- Project 06-004 Technology to Ensure Equitable Access to Automated Vehicles for Rural Areas dedicated efforts to the development and rigorous validation of a novel localization algorithm. This algorithm leverages the invaluable resource of open-source topological maps. The implications of the proposed algorithm can hold profound societal and economic consequences. Rural areas have traditionally encountered barriers to adopting and benefiting from emerging autonomous vehicle services. These regions often lack the robust infrastructure and comprehensive mapping data required for traditional autonomous navigation approaches. This project's developed algorithm, by enabling autonomous vehicles to navigate effectively and autonomously in such rural landscapes, marks a significant stride towards bridging this technological divide. The impact is twofold. Firstly, it expands the operational scope of emerging autonomous vehicle services, such as rideshare and goods delivery, into rural communities. This, in turn, holds the potential to unlock an array of new opportunities for these regions, empowering rural inhabitants with enhanced access to essential services and economic opportunities. Secondly, by promoting the equitable dispersion of autonomous vehicle services across both urban and rural domains, this project contributes to the realization of a more inclusive and

accessible future. It emphasizes the importance of technology as an enabler of progress, ensuring that the benefits of advanced transportation services are not confined solely to metropolitan areas but are distributed throughout society, promoting fairness and equal access for all.

Impact on Adoption of New Practices or Initiation of Startups

Before research begins on each Safe-D project, a T2 plan is developed that details how the outcomes of the project will be translated for public use or commercialization. The development of the T2 plan and the eventual commercialization of the results are facilitated by Safe-D T2 Coordinator, Luke Neurauter. While no start-up companies have been created at this point as a direct result of Safe-D projects, opportunities for commercialization have been identified and will be pursued as the research products are further developed. Beyond commercialization, Safe-D projects are expected to lead to the adoption of new practices in various transportation-related areas as the results and outcomes are disseminated. The potential for commercialization and adoption of new practices resulting from other Safe-D projects are summarized below:

- The results of Project 05-008 Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation culminated in the development of an educational module for the Virginia Tech University population. This tested module educates individuals on the transportation methods available to/from and around campus and how to engage in those methods safely. The goal is for completion of this educational module to be adopted as a requirement for all university members in order to create a safer and more sustainable campus.
- Project 06-012 Real Time Risk Prediction at Signalized Intersection Using Graph Neural Network has not led to a new start up company as hoped; however, it has great potential to be a part of future startups. Researchers have been in contact with an intelligent traffic platform company which has shown interest in the process and discussed with researchers the potential of adapting such advanced technologies.

Impact on the Body of Scientific Knowledge

Through basic and applied research focused on four key disruptive technologies (CVs, AVs, transportation as a service, and big data analytics), Safe-D projects are expected to make meaningful contributions to the body of scientific knowledge within the broad area of transportation.

- Project TTI-04-02 Delving into Safety Considerations of E Scooters: A Case Study of Austin, Texas used new methods and approaches in the study to enhance the accuracy and efficiency of identifying and examining e-scooter crashes, which can be used for various analyses. Different sources of safety data related to e-scooters were utilized in the study, including hospital emergency data and police report data. By utilizing non-traditional alternative data sources, the study contributed to the body of knowledge by providing a more comprehensive understanding of e-scooter safety beyond the traditional police report data. This approach allows for a more nuanced understanding of the factors contributing to e scooter crashes and injuries, which can inform future research and policy-making efforts.
- Project 06-014 Measuring the Safety of ADS: How safe is safe enough? results expanded our understanding of the actual capabilities of ADS when applied to real-world data. Using a small set of naturalistic data has the potential to convey important information to wide-scale ADS deployment that simulation or closed-track testing cannot. This research develops the understanding of what ADS are and are not capable of through physics-based models that are developed from scenarios that have actually happened. Additionally, although ADS are commonly projected as a cool and convenient piece of technology to the general public, the prospective societal benefit of reducing traffic fatalities and

injuries is enormous. This work aims to address scenarios in which ADS are unable to provide the proposed benefit so that these scenarios can be addressed by infrastructure technologies, infrastructure development, or even more creative solutions. This can inform society of just how safe ADS are and what technologies are in place (or should be in place) which in turn can lead to providing safer roads and vehicles.

- Project 06-003 Critical Areas in Advanced Driver Assistance Systems Safety: Point of Sale and Crash Reporting collected information on aspects particularly neglected in research: buying and selling practices and post-crash data collection. These are important pieces of the whole puzzle to understand and realize the full safety benefits of these technologies and are highlighted in the researchers' conceptual model and research gaps paper.

Impact of Transportation Workforce

Each Safe-D project includes an individually created EWD plan guided by the EWD Coordinator, Dr. Miguel Perez. The EWD plans ensure that Safe-D projects generate significant impacts on the future transportation workforce by providing opportunities for teaching and education; building experience and skill among underrepresented groups in the transportation profession; and exposing practitioners, teachers, and members of the public to science and technology as they relate to Safe-D research. During this reporting period, Safe-D projects have (1) generated valuable educational opportunities for students of varying age groups, including students in underrepresented groups and (2) led to the development of curriculum materials for educators. Specific examples of how Safe-D projects have contributed to EWD are provided below.

- Project 06-014 Measuring the Safety of ADS: How safe is safe enough? has been the main component of the PhD student's dissertation, which allowed her to increase her knowledge and interest in the advancement of technology in transportation, and how to improve the methods to measure the potential safety benefits of ADS. She was able to present this research at the Distracted Driving Summit, and plans to present this research in a Safe-D UTC Webinar in January 2024, and later at the Lifesaver's Conference in 2024. She has been able to discuss this research at many outreach events as well to high school students interested in careers in STEM.

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

- Project 05-008 Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation incorporated both undergraduate and graduate students from the Population Health Sciences Department at Virginia Tech during the research process. The transportation workforce in general needs more public health experts and this particular project sought to expose public health students to transportation research through participating in the project hands on and also by creating course modules to highlight this project specifically as it relates to public health and transportation.