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COVID-19 Impact on Consortium Activities

In the previous Semi-Annual Progress Report, data showed the Northeast region was the area hardest hit by the COVID-19 pandemic nationwide, and as a result saw significant impacts. Today New Jersey is still number one in fatalities across the nation with 283 COVID-19 deaths per 100,000 people as of April 2021. Even with the increased rollout of vaccines, work-from-home and social distancing measures are still largely in affect.

The impact of these changes brought on by the global pandemic has been felt at the Rutgers Center for Advanced Infrastructure and Transportation (CAIT) as well. As addressed in the previous Semi-Annual Progress Report, CAIT and its partners across New York, New Jersey, and Puerto Rico took a situational approach to each challenge raised by COVID-19, realizing that no two places would be impacted the same way. For example, while some research projects were able to continue along as planned, others had to be extended or updated to reflect behavioral changes due to the pandemic. CAIT laboratories that support State agencies were classified as essential and remained operational but did require adaptations to meet safety protocols and modified research plans. Lastly, safety precautions at Rutgers University stopped undergraduate students from being allowed to work on campus during the pandemic, which shifted support more toward graduate students and research staff. CAIT found paths forward despite these obstacles by switching to online meetings, opening new lines of communication, practicing leniency when needed, and working together as a cohesive unit.

Throughout the pandemic, CAIT has also had successes both in continuing much of its usual research and work with stakeholders, as well as in taking on new opportunities. For example, CAIT has continued its new Seminar Series, a set of monthly webinars on key topics ranging from port logistics to geotechnical asset management designed to help spread and share research results in a digital space. The Center has also continued providing vital information about COVID-19 and its effect on the regional economy through publishing its “Fast Track Research Notes” that track economic recovery in New Jersey.

New research was started as well, including projects linked to COVID-19 response. CAIT has been working with NJ Transit to support their response efforts and will be funding a supplemental UTC project to expand the agency’s bus fleet COVID-19 response effort. The Center’s engineering and public health staff are also serving as an ad-hoc 3rd-party reviewer of potential technologies to combat COVID-19 on public transit vehicles.

All in all, although Region 2 has been one of the most significantly COVID-19 impacted regions, CAIT has adapted to changes in work, research, and communication throughout the pandemic. One such “build back better” success has been establishing the Middlesex County — Smart Mobility Testing Ground, which was recently accepted and set in motion with plans to turn downtown New Brunswick into a test bed for high-resolution mobility data-gathering and autonomous vehicle technology. As vaccines continue to roll out and the region and nation get closer to “normal” again, CAIT will continue to be a dynamic and flexible organization and respond to changing needs to meet business and research expectations.

1. **ACCOMPLISHMENTS** (What was done? What was learned?)

What are the major goals and objectives of the program?

The CAIT Region 2 UTC Consortium's research vision aligns with the ongoing national dialogue on the state of the U.S. transportation infrastructure, and the emerging consensus on the need for significant investment to fill condition gaps, improve/expand existing systems, and build for the future.

The Consortium's **primary research focus** will be on "Improving the Durability and Extending the Life of Transportation Infrastructure," with additional elements of "Preserving the Existing Transportation System," such as resilience. Using Region 2 as a complex infrastructure laboratory, the Consortium will contribute to: 1) extending the life of the region's legacy systems, 2) building future systems with consideration to changes in living patterns and where people and products will move to and from, and 3) the use of technologies and better design approaches to maximize the use of both old and new transportation infrastructure assets.

The Consortium will structure its **education and workforce development activities** around a "cradle to grave" approach, developing programs that attract more people to the transportation industry, fostering skills to sustain them within the industry, and provide the workforce with professional development.

Gaining and sharing knowledge is the critical first step toward developing a transportation system that improves the durability and extends the life of transportation infrastructure. To this end, the Consortium will conduct **technology transfer** of research through implementation projects, knowledge transfer activities, and exploration of patents.

What was accomplished under these goals?

Research

The peer-review panel has approved 16 projects during this cycle. Three research projects are currently under review.

New Projects:

CAIT-UTC-REG38	Risk and Resilience Analysis Tool for Infrastructure Asset Management *Abstract:* There is a pressing need from agencies for a quantitative, risk- and resilience-based framework that can address high-level IAM questions. The primary goal of this proposal is to evaluate and demonstrate the application of prevailing risk and resilience assessment approaches and integrate them in a holistic transportation asset management (TAM) framework.	RU
CAIT-UTC-REG-40	Zero Speed Profiler Assessment for Pavement Smoothness and Continuous Pavement Texture Measurements *Abstract*: The primary goal of this proposal is to evaluate a state-of-the-art technology in roadway profiling called Zero Speed Profiling. Conceptually developed under NCHRP Project 10-93, "Measuring, Characterizing, and Reporting Pavement Roughness of Low-Speed and Urban Roads," this research study will evaluate the methodologies and concepts proposed in NCHRP 10-93 on New Jersey pavements and bridges. This technology will provide a better assessment of the current pavement profile compared to the High-Speed Profiler, which will lead to better decisions regarding preserving or rehabilitating pavement.	RU
CAIT-UTC-REG42	Enhanced Maritime Asset Management System (MAMS) *Abstract*: Rutgers CAIT has worked with NJDOT to develop a prototype Maritime Asset Management System (MAMS) that can be used to meet the transportation asset management plan (TAMP) requirements and aid with capital planning and resource allocation. The state-of-the-art TAM approach has been implemented in	RU

	a desktop-based user interface software application. The goal of the project is to renovate the current MAMS prototype software to improve the user experience and extend the functionality of the tool.	
CAIT-UTC-REG44	Assessment of Solidification / Stabilization as a Remedial Strategy for PFAS Contaminated Transportation Sites *Abstract*: This project seeks to determine if Solidification and Stabilization (S/S) is a viable remedial strategy for PFAS contaminated sediment. If the process is effective at the sequestration, this previously harmful material can be beneficially used as geotechnical fill. Beneficial reuse of contaminated soils on-site can represent a significant cost savings for treatment while providing a value as a product.	RU
CAIT-UTC-REG45	The Development of the Digital Twin Platform for Smart Mobility Systems with High-Resolution 3D Data *Abstract:* The primary goal of this proposal is the development of the Mobi-Twin, a digital twin platform for urban mobility which will focus on enabling the microscopic accurate modeling and simulation of Urban Mobility System of Systems with the emerging self-driving grade high-resolution 3D data. The proposed Mobi-Twin platform will use data collected from the New Brunswick Innovation Hub Smart Mobility Testing Ground to support academic and industrial research. The proposed test bed will become an ideal test platform for integrated smart infrastructure-based solutions that help monitor and maintain roadside infrastructure and support the transportation systems to accommodate not only the existing human-driven vehicle but also the upcoming connected and automated mobility systems.	RU
CAIT-UTC-REG46	Driving behavioral learning leveraging sensing information from Innovation Hub *Abstract:* The primary goal of this proposal is to develop machine-learning algorithms to improve our understanding of how people drive on both highways and urban roads. The models and algorithms are expected to 1) improve our understanding of human driving behavior using emerging datasets, 2) bridge the gap between traditional driving models and innovative machine learning models using high-resolution datasets, 3) assist traffic engineers in operation and planning of traffic and transportation infrastructure management, and 4) assist AVs to smoothly drive and react in mixed traffic.	Columbia
CAIT-UTC-REG47	Remote Sensing System Enhancement for Digital Twinning of the Built Infrastructure to Support Critical Infrastructure Protection Research *Abstract:* The concept of digital twins is an enabler to address today's infrastructure lifecycle management challenges, including the growing threats of pandemics, natural disasters, funding shortfalls, and social unrests. Digital twins support cost-effective ways of exploring what-if scenarios from which the most effective interventions can be identified. The purpose of this project is to acquire a new terrestrial laser scanner - Faro Focus S350 to further support and strengthen this line of research projects. The addition of this proposed scanner will enable new research in digital twining of built infrastructure to support mitigation of flood threats to transit stations and evaluation of disinfection methods for transportation.	SUNY Buffalo
CAIT-UTC-REG48	Linking Physics-Based Deterioration Model to Field-Based Condition Assessments for Improving Asset Management *Abstract:* The goal of this project is to use field-based data on bridge condition to calibrate a physics-based deterioration assessment that can then be used to inform maintenance actions. The model will also be a new, calibrated tool to aid maintenance engineers in bridge assessment and condition prediction.	SUNY Buffalo
CAIT-UTC-REG49	Post-fire Damage Assessment of Concrete Tunnel Liners *Abstract:* This project will provide recommendations on post-fire tunnel damage assessment. A holistic approach will be used, including (a) post-fire residual mechanical properties of concrete based on the maximum temperature reached during the fire, (b) post-fire damage assessment using common non-destructive testing methodologies, (c) simulated residual deflections of a tunnel section as a function of soil type, and (d) input from experts consisting of stakeholders and researchers. The project outcomes can be used to guide structural repair after a fire event.	SUNY Buffalo
CAIT-UTC-REG50	Post-disaster Damage Assessment of Bridge Systems *Abstract:* Leveraging recent advances in artificial intelligence, a novel signal processing technique will be developed to build a surrogate model for an accurate prediction of engineering demand parameters of interest (e.g., peak column drift ratio). The results of the proposed project are expected to automate the process of damage detection, and to assess and identify risks associated with each bridge immediately after a natural disaster. The proposed risk-informed damage assessment framework will be applicable to various types of civil infrastructure, SHM domains, and natural disasters.	SUNY Buffalo
CAIT-UTC-REG51	Real-Time Decision Support System for Transportation Infrastructure Management under a Hurricane Event *Abstract:* This project will develop a real-time decision support system for transportation infrastructure management under a hurricane event. Beginning with a systematic review of current decision-making practices, the team will investigate hurricane impacts on the critical infrastructures and effects of various	SUNY Buffalo

	traffic control policies on traffic network performance. The project will then identify the optimal traffic control policy to minimize hurricane-induced losses.	
CAIT-UTC-REG52	Bridge Deck Surface Profile Evaluation for Rapid Screening and Deterioration Monitoring *Abstract:* The goal of this research is to develop a procedure that ensures proper LiDAR data collection focused on bridge deck surface geometry capturing for inspection and monitoring. Researchers will collect LiDAR data of bridge decks where other NDE data was previously deployed; compare new data collected to the existing NDE; and analyze the deck surface profile captured by LiDAR based on patterns found on the NDE data. This approach has potential for implementation as a way for rapid screening of bridge decks.	Rowan
CAIT-UTC-REG53	A Real-Time Proactive Intersection Safety Monitoring System Based on Video Data *Abstract:* The primary goal of this project is to develop and assess an innovative real-time proactive safety monitoring system based on the trajectory of road users collected by video cameras. The results will provide an opportunity for transportation agencies to rank intersections based on the analyzed data.	Rowan
CAIT-UTC-REG54	Rotorcraft Landing Sites Identification – Scaling and Generalization of the AI Model *Abstract:* The purpose of this project is to develop an AI-based system for the identification of helipads, heliports, and landing site infrastructure from satellite images. This tool is expected to achieve landing site identification accuracy equal to or higher than that of a trained human operator at a fraction of time and resources. The deployed algorithm will allow FAA to analyze its database for automatic identification of helicopters, helipads, and landing sites from video and satellite data.	Rowan
CAIT-UTC-REG55	JFK Cargo View: A system to speed Truck Traffic Flow at JFK Airport *Abstract:* The primary goal of this proposal is to define and document JFK Cargo View requirements, evaluating the options and costs to acquire, develop, and manage the system, exploring potential business models to operate and monetize it, and establishing an implementation plan to develop and deploy it.	RU/ SUNY Farmingdale
CAIT-UTC-REG58	Supplemental Study of Filter Technology Efficacy for Transit Vehicles to Combat the Spread of COVID-19 and Other Respiratory Infections *Abstract:* Transit agencies are still struggling to find cost-efficient COVID-19 solutions that improve rider safety and restore confidence. Recently, Rutgers CAIT has been in contact with many transit agencies investigating different disinfection strategies to combat the spread of COVID-19. Two potential methods to improve transit vehicle air quality and safety that arose were upgrading the current MERV rated filters to MERV 13 filters or MERV 8 + Ag filters. The goal of this study is to determine whether or not filter performance changes over time in a transit environment, and to compare the results to manufacturer ratings. This work should produce guidelines with a broad appeal to transit and paratransit agencies.	RU

Driving behavioral learning leveraging sensing information from Innovation Hub

The Middlesex County – Smart Mobility Testing Ground plans to kick off the nation's foremost living laboratory for smart city technology R&D in down-town New Brunswick by the fall. Working with stakeholders at Middlesex County, NJDOT, the City of New Brunswick, and more, this project will equip the test corridor with self-driving-grade roadside sensors to continuously collect mobility data that will be converted into digital twin models and field datasets to support R&D efforts. This new proposal will develop machine-learning algorithms to better understand how people drive on highways and urban roads.

Remote Sensing System Enhancement for Digital Twinning of the Built Infrastructure to Support Critical Infrastructure Protection Research

The concept of digital twins is an enabler to address today's infrastructure lifecycle management challenges, including the growing threats of pandemics, natural disasters, and more. Recently, CAIT has partnered with NJ Transit to help them evaluate the potential effectiveness of new high-tech COVID-19 solutions to keep public transit vehicles safe during the pandemic. Digital twins support cost-effective ways of exploring what-if scenarios, such as this one, from which the most effective interventions can

be identified. The purpose of this UTC project is to acquire a new terrestrial laser scanner, Faro Focus S350, to further support and strengthen this line of research projects. This scanner will enable new research in digital twining of built infrastructure, supporting projects such as the mitigation of flood threats to transit stations or evaluating transportation disinfection methods.

Ongoing Projects:

CAIT-UTC-REG 5	Implementation and Development of UAS Practical Training for Inspection and Monitoring Activities	ACCC
CAIT-UTC-REG9	Delivering maintenance and repair actions via automated/robotic systems	RU
CAIT-UTCREG13	Virtual Tour (VT), Informational Modeling (IM), and Augmented Reality (AR) for Visual Inspections (VI) and Structural Health Monitoring (SHM)	PU
CAIT-UTC-REG15	Flood Vulnerability Assessment and Data Visualization for Lifeline Transportation Network	Rowan
CAIT-UTC-REG25	Investigation of Balanced Mixture Design for New York State Asphalt Mixtures	RU
CAIT-UTC-REG26	Passenger Flow Modeling on Platform Tracks in Transit Stations	RU
CAIT-UTC-REG27	Designing Concrete Mixtures with RCA	NJIT
CAIT-UTC-REG28	Cost-effective Bridge Decks for Improved Durability and Extended Service Life	RU
CAIT-UTC-REG30	Durable and Electrified Pavement for Dynamic Wireless Charging of Electric Vehicles	RU
CAIT-UTC-REG31	Evaluating the Safety and Mobility Impacts of American Dream Complex: Phase I (Feasibility Study, and Data Acquisition)	Rowan
CAIT-UTC-REG32	Rotorcraft Landing Sites – An AI-Based Identification System	Rowan
CAIT-UTC-REG35	NJDOT Flood Risk Visualization Tool	RU
CAIT-UTC-REG36	Improving the Long-Term Performance of Bridge Decks through Full-Scale Accelerated Testing	RU
CAIT-UTC-REG37	Impact of Recycled Plastic on Asphalt Binder and Mixture Performance	RU
CAIT-UTC-REG39	FDR Stabilizer Selection Using Simple Soil Tests	Cornell

Completed Projects:

CAIT-UTC-REG1	Augmented Reality (AR) in Life-Cycle Management of Transportation Infrastructure Projects	RU
CAIT-UTC-REG2A	Sustainability and Resiliency of Concrete Rapid Repairs Utilizing Advanced Cementitious Materials – Freeze/Thaw Loads	NJIT
CAIT-UTC-REG2B	Sustainable, Rapid Repair Utilizing Advanced Cementitious Materials	SUNY Buffalo
CAIT-UTC-REG3	Large-Amplitude Forced Vibration Testing for St-Id of Bridges and Foundation Reuse Assessment	RU
CAIT-UTC-REG4	Rail Track Asset Management and Risk Management	RU
CAIT-UTC-REG6	Airfield Pavement Management Framework using a Multi-Objective Decision-Making Process	RU
CAIT-UTC-REG7	MEMS Sensor Development for In-Situ Quantification of Toxic Metals in Sediment	RU
CAIT-UTC-REG8	Prioritizing Infrastructure Resilience throughout the Capital Planning Process	RU
CAIT-UTC-REG10	Policies, Planning, and Pilot Testing on Infrastructure Readiness for Electrical, Connected, Automated, and Ridesharing Vehicles	RU/Columbia
CAIT-UTC-REG11	Pavement Design for Local Roads and Streets	Cornell
CAIT-UTC-REG12	Laboratory Performance Evaluation of Pavement Preservation Alternatives	Rowan
CAIT-UTC-REG14	Performance-Based Engineering of Transportation Infrastructure Considering Multiple Hazards	SUNY Buffalo
CAIT-UTC-REG16	Fire In Tunnel Collaborative Project	PU/SUNY-Buffalo/NJIT
CAIT-UTC-REG17	Improving Transportation Infrastructure Resilience against Hurricanes, other Natural Disasters, and Weathering: Part I - Analysis of failure of transportation signs due to Hurricane Maria	PUPR

CAIT-UTC-REG18	Improving Transportation Infrastructure Resilience against Hurricanes, other Natural Disasters, and Weathering: Part II – Analysis of pedestrian bridges failures due to Hurricane Maria	PUPR
CAIT-UTC-REG19	Improving Transportation Infrastructure Resilience against Hurricanes, other Natural Disasters, and Weathering: Part III - Analysis of motor vehicle bridges failures due to Hurricane Maria	PUPR
CAIT-UTC-REG20	Infrastructure Cybersecurity and Emergency Preparedness Academic and Non-academic Credential Development	SUNY Farmingdale
CAIT-UTC-REG21	Autonomous Vehicles: Capturing In-Vehicle Experience & Focus Group Follow-up with Persons with Autism and Other Disabilities at the 2019 Princeton University SmartDrivingCar Summit	RU
CAIT-UTC-REG22	Simulation of Degradation and Failure of Suspension Bridge Main Cables due to Natural and Anthropogenic Hazards	Columbia
CAIT-UTC-REG23	The Development of a Smart Intersection Mobility Testbed (SIMT)	RU
CAIT-UTC-REG24	Application of Advanced Analytic and Risk Techniques to Railroad Operations Safety and Management	RU
CAIT-UTC-REG29	Seismic Vulnerability Assessment of Deteriorated Bridges	SUNY Buffalo
CAIT-UTC-REG33	Real-Time Prediction of Storm Surge and Wave Loading on Coastal Bridges	SUNY Buffalo
CAIT-UTC-REG34	Assessing and Mitigating Transportation Infrastructure Vulnerability to Coastal Storm Events with the Convergence of Advanced Spatial Analysis, Infrastructure Modeling, and Storm Surge Simulations	RU

HIGHLIGHTS

Completed Projects

MEMS Sensor Development for In-Situ Quantification of Toxic Metals in Sediment (CAIT-UTC-REG7, Project Manager: Dr. Mehdi Javanmard)

Accomplishments: Researchers have developed a working prototype of highly accurate Microelectromechanical Systems chemical sensors, capable of detecting lead in sediment samples. This technology can rapidly (within 5 minutes) quantify lead in sediment samples.
ROI: A technology that is capable of rapid and inexpensive identification and triaging of environmental-sediment hotspots in natural water sources. This offers a more cost-effective method of environmental remediation.

Pavement Design for Local Roads and Streets (CAIT-UTC-REG11, Project Manager: Dr. David Orr)

Accomplishments: A user-friendly software tool, RoadPE: LHI, using mechanistic-empirical methods to assist local agencies with designing streets for various traffic spectra associated with low-volume roads has been developed. The tool uses simplified inputs that are easily obtainable by local agencies and allows for local officials to properly account for traffic differences and spend limited funds more efficiently and effectively.
ROI: Stakeholders in New York State have been engaged. The tool allows local agencies to actually design their pavements to meet specific, local needs rather deferring to a “catalog-based” approach. At $100,000 per inch per mile for most asphalt concrete on local road systems, the savings due to optimized design could be significant for many local agencies.

Fire in Tunnel Collaborative Project (CAIT-UTC-REG16, Project Manager: Negar Khorasani)

Accomplishments: The project established and disseminated a framework to quantify fire damage through modeling considering uncertainties in the fire scenario and fire spread within the tunnel. The project has also engaged stakeholders and incorporated their feedback, increasing the potential for use within the industry. The program has completed large-scale furnace testing of loaded and restrained concrete tunnel slabs, which include consideration of spalling. These tests address a significant knowledge gap, which cannot be filled using element-level experiments, and will advance analysis and design methodologies.
ROI: The four tested slabs in this project provided data to the community for model verification as well as potential cracking/spalling patterns. In general, repairs to tunnels subject to fire events can take months and can cause delays and millions of dollars in economic losses.

Improving Transportation Infrastructure Resilience against Hurricanes, other Natural Disasters, and Weathering: Part I - Analysis of failure of transportation signs due to Hurricane Maria (CAIT-UTC-REG17, Project Manager: Dr. Héctor J. Cruzado)

Accomplishments: This project looked at damaged highway signs after Hurricane Maria offered improvements to help the island build back with more resilience. For each type of sign studied, a detailed inventory of the different hurricane-induced types of failures was developed. Suitable modes of failures were used to estimate the wind speed required to trigger such responses. For example, the results of the analysis of failures in I-beam supported signs and single-tubular posts for regulatory signs strongly suggest that officials initially underestimated the wind gust speed produced by Maria.
ROI: Several recommendations were generated from the research on reducing vulnerability of transportation signs to high wind speeds in the future. This valuable resilience information can help engineers and agencies make more informed asset management and resilience decisions.

Improving Transportation Infrastructure Resilience against Hurricanes, other Natural Disasters, and Weathering: Part III - Analysis of motor vehicle bridges failures due to Hurricane Maria (CAIT-UTC-REG19, Project Manager: Héctor J. Cruzado)

Accomplishments: The team assembled a compilation of available data on vehicular bridges damaged during Hurricane Maria, consisting of more than 500 related multimedia documents, bridge geolocation and general data, flooding data, and more.
ROI: This project is able to make recommendations to improve the resilience of vehicle bridges. By compiling the collected data, it was found that the main cause of damage to these bridges was souring of the abutments and hydrodynamic pressure on bridge elements. For future bridges researchers recommended reviewing HH studies, required span and abutment location (to reduce souring), and required elevation (to reduce hydrodynamic impact).

Simulation of Degradation and Failure of Suspension Bridge Main Cables due to Natural and Anthropogenic Hazards (CAIT-UTC-REG22, Project Manager: Adrian Brugger)

Accomplishments: The goal of this project was to develop a well-defined methodology to

estimate the remaining strength of a suspension bridge cable exposed to fire. The methodology relies on a general-purpose Finite Element code (ABAQUS) that is commercially available and widely used in the profession.
ROI: The methodology developed can help with estimating the remaining strength of suspension bridge cables exposed to fire through a number of potential variables, providing actionable guidance and engineering tools to support the structural engineering community. A cable FEM model is also being developed and calibrated using the extensive experimental data already available to the research team. This FEM model is expected to 1) provide high-confidence designs of new structures, 2) retrofit existing structures with novel hardening systems, 3) quantify more accurately hazards associated with traffic flow and access to cables, and 4) perform high-fidelity forensic investigations of structures subjected to fire events.

Application of Advanced Analytic and Risk Techniques to Railroad Operations Safety and Management (CAIT-UTC-REG24, Project Manager: Dr. Trefor Williams)

Accomplishments: A prototype system that complements and improves the current tools and DSS used by the cooperating railroads. Specifically, the outcome was a DSS and dashboard prototype system to support short line railroad in prioritizing maintenance activities, operational, and investment decisions.
ROI: It is anticipated the DSS will lead to improved decision processes with railroad management, including the use of empirically derived likelihood estimates of risks and potential outcomes associated with maintenance activities, operational and investment decisions.

Seismic Vulnerability Assessment of Deteriorated Bridges (CAIT-UTC-REG29, Project Manager: Dr. Ravi Ranade)

Accomplishments: The goal of this project was to develop and demonstrate a computational framework that incorporates the effects of reinforcement corrosion on the seismic damage risk of groups of reinforced-concrete (RC) bridges. The framework was developed to assist state DOT's in asset management by estimating whether certain RC bridges will become more vulnerable to seismicity than others over their service lives due to corrosion effects, as vulnerability can vary based on material properties, structural configuration, and more.
ROI: The main takeaway from this project is that the seismic evaluation of bridges should be performed considering the current state of bridge substructures, as documented by inspections or as predicted by a corrosion model such as the one presented in this study. These results can increase awareness about incorporating the effects of corrosion in assessing the seismic vulnerability of bridges for improved asset management and seismic risk assessments.

Real-Time Prediction of Storm Surge and Wave Loading on Coastal Bridges (CAIT-UTC-REG33, Project Manager: Dr. Teng Wu)

Accomplishments: The goal of this study was to lay the groundwork for the development of tools and techniques for rapid prediction of storm surge and wave effects on coastal bridges. Coastal bridges exhibit significant susceptibility to damages caused by storm surges, which requires probabilistic models to quantify bridge vulnerability for risk assessment and mitigation.
ROI: This research is resilience-oriented, with the long-term goal of making wise, science- and engineering-based investments in coastal bridges, with explicit considerations of multiple

hazards and retrofit strategies. This study also presents an efficient risk analysis framework integrating hazard analysis and fragility analysis for coastal bridges under storm surges.

Assessing and Mitigating Transportation Infrastructure Vulnerability to Coastal Storm Events with the Convergence of Advanced Spatial Analysis, Infrastructure Modeling, and Storm Surge Simulations (CAIT-UTC-REG34, Project Manager: Jie Gong)

Accomplishments: To protect the security of the public transportation infrastructure and the enormous amount of public assets, this project is developing a decision support tool that can assist infrastructure stakeholders in making decisions at the day-to-day operation level to protect communities from impeding flooding events as well as in making long-term decisions in mitigating future flood risks facing their current infrastructure assets and their future projects.
ROI: The expected outcome of this study is new software applications that are built for infrastructure resilience centered investigations. The software applications will be cloud-based which will allow infrastructure stakeholders to more easily access and use it.

Ongoing Projects

Implementation and Development of UAS Practical Training for Inspection and Monitoring Activities (CAIT-UTC-REG 5, Project Manager: James Taggart)

Outputs: This proposal aims to design and develop training curricula including the development of assessment instruments for deriving both formative and summative learning outcomes.
Outcomes: These curricula will evaluate the practical flight abilities of prospective UAS pilots. The team will also provide research into powered tether systems for long duration UAS flights. The team will evaluate UAS tether for use cases such as traffic monitoring.
Impacts: The project will evaluate UAS operations and make recommendations on procedures for inspection to assist decision making by regional agencies. This tool can significantly impact the quality of data and lower the risk portfolio for missions.

Delivering Maintenance and Repair Actions via Automated/Robotic Systems (CAIT-UTC-REG9, Project Manager: Dr. Jie Gong)

Outputs: Researchers held a workshop on identifying uses, characterizing research priorities in robotic systems, and aligning research visions on various identified research dimensions.
Outcomes: The workshop featured a mélange of three communities: R+D, practitioners, and end-users. Several renowned speakers were invited.
Impact: The workshop informed infrastructure stakeholders and practitioners about available robotics tools to deliver inspection and repair actions and provided critical projection on future jobs in infrastructure maintenance. This will contribute to safer and more efficient practices.

Virtual Tour (VT), Informational Modeling (IM), and Augmented Reality (AR) for Visual Inspections (VI) and Structural Health Monitoring (SHM) (CAIT-UTC-REG13, Project Manager: Dr. Branko Glisic)

Outputs: Virtual Tour (VT)/Informational Modeling (IM) prototype software and Image/Augmented Reality (AR) prototype software.
Outcomes: A demonstration software that can be accessed on a mobile device, laptop, desk computer, virtual reality (VR) headset, or AR headset, depending on a user's needs. Validation will be performed on real structures, such as the Streicker Bridge in Princeton, NJ.
Impacts: This will have an impact on asset durability, resilience, and preservation, as the project method provides means to assist the actions that improves these three features.

Flood Vulnerability Assessment and Data Visualization for Lifeline Transportation Network (CAIT-UTC-REG15, Project Manager: Rouzbeh Nazari)

Outputs: A state of the art flood map for New Jersey towns that offers a unique picture of flood hazards, lifeline infrastructure, vulnerability assessments, and resiliency measures.
Outcomes: This project provides more detailed, reliable, and current data on flood hazards resulting in a better picture of the New Jersey towns most likely to be impacted by flooding and a better foundation from which to make key legislative decisions/changes.
Impacts: This project assists decision makers and coastal communities with understanding the magnitude of floods, quantifying impacts, and assisting with mitigation and resiliency planning.

Investigation of Balanced Mixture Design for New York State Asphalt Mixtures (CAIT-UTC-REG25, Project Manager: Dr. Thomas Bennert)

Outputs: A non-proprietary/non-confidential final report covering all aspects of the work performed under this research study. The report shall include information on the following subjects: Observations and findings and recommendations; Project results and lessons learned regarding configuration, capabilities, and benefits of the project; and Energy and economic benefits, and implementation scenarios associated with such.
Outcomes: Training and specifications around the new design method will be developed and implemented within NY State. In addition, the impact of cost savings of the new design will be assessed using a performance-cost analysis. Technical presentations are proposed for the NY State Materials Conferences and the National Asphalt Pavement Association meetings.
Impacts: It is anticipated that the results of the study will help NYSDOT improve their mixture design and performance testing programs to result in longer lasting asphalt pavements.

Passenger Flow Modeling on Platform Tracks in Transit Stations (CAIT-UTC-REG26, Project Manager: Dr. Xiang Liu)

Outputs: This research aims to model and simulate passenger flows in transit stations using computer vision and agent-based simulation technologies.
Outcomes: The research outcomes can potentially be used by NJ Transit Capital Planning Program in preparing proposals to apply federal grants to improve infrastructure.
Impacts: The information from this project can be used by NJ Transit to understand the benefit of infrastructure design or upgrade in terms of changing passenger flow and less congestion.

Designing Concrete Mixtures with RCA (CAIT-UTC-REG27, Project Manager: Dr. Matthew P. Adams)

Outputs: The use of recycled concrete aggregates (RCA) in new concrete can help to reduce landfilling, improve economics of concrete, and supplement dwindling aggregate supplies in urban areas. The primary goal of this project is to validate and improve a novel RAC design methodology through both experimental and computational methods.
Outcomes: The project is still underway, but notable outcomes so far include the training of civil engineers on production, specification, and use of recycled concrete aggregates through curriculum development at NJIT, support and technical guidance provided to new bills currently under consideration at the NJ and NY state level on procurement incentives for providing low-carbon concrete materials, and raising awareness about incorporating RCA into future projects.
Impacts: Preliminary impacts include potential cost-savings and environmental benefits. For example, If NYC DOT incorporates 20% RCA into their concrete mixture designs, it could save them millions of dollars in purchasing new aggregates and disposing of waste concrete.

Cost-effective Bridge Decks for Improved Durability and Extended Service Life (CAIT-UTC-REG28, Project Manager: Dr. Sougata Roy)

Outputs: The primary goal of this proposal is to develop cost-effective standard open rib SOBD demonstrating similar performance as CRD to promote increased implementation of SOBD for short and medium span highway bridges for improving durability, extending service life and safe operation of US bridge infrastructure; and to enable domestic bridge design and fabrication industry to be productive and competitive.
Outcomes: The new design specifications for open rib SOBD to be developed in this study are expected to be incorporated into the AASHTO Bridge Design Specifications. Additional companion design guide for implementation of small and medium span bridges will be developed as AASHTO/NSBA Collaboration document.
Impacts: The research findings and standardization could be adopted by steel bridge fabricators for streamlining production, economizing fabrication, and competitive advantage.

Durable and Electrified Pavement for Dynamic Wireless Charging of Electric Vehicles (CAIT-UTC-REG30, Project Manager: Dr. Hao Wang)

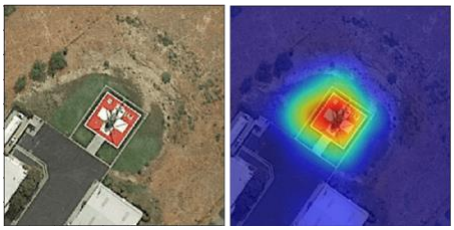
Outputs: The primary goal of this research is to develop new designs of electrified pavement that have durable performance while providing efficient charging functionality.
Outcomes: The intended outcome of the project is to provide an innovative solution on wireless charging techniques integrated in existing roadway pavements.
Impacts: The research results will contribute to the development of electrified roadway that provide energy source for electric vehicles.

Evaluating the Safety and Mobility Impacts of American Dream Complex: Phase I (Feasibility Study, and Data Acquisition) (CAIT-UTC-REG31, Project Manager: Dr. Mohammad Jalayer)

Outputs: The primary goals of this project are to coordinate with stakeholders to identify traffic and safety issues associated with this complex and to collect data to develop an analytics framework using machine learning algorithms to identify conflicts between road user groups.

Outcomes: The research team has developed an innovative artificial intelligence (AI)-based video analytic tool to assess intersection safety using Surrogate Safety Measures (SSMs) such as Post-encroachment Time (PET), with an achieved relative accuracy of 96 percent in detecting and tracking vehicle trajectories.
Impacts: New Jersey has the worst traffic bottleneck in the country and ranked second in the nation with respect to the ratio of pedestrian fatalities to the total number of motor vehicle deaths. Therefore, the newly developed analytic tool can help improve the safety and efficiency of intersections as more than 50 percent of the combined total of fatal and injury crashes occur at or near intersections. This work also aligns with the USDOT strategic goal of improving safety.

Rotorcraft Landing Sites – An AI-Based Identification System (CAIT-UTC-REG32, Project Manager: Dr. Ghulam Rasool)



Outputs: The research team developed an autonomous system that can authenticate the coordinates in the FAA master database and search for helipads in a designated large area.
Outcomes: The process of updating FAA's landing site databases autonomously and continually will lead to improved safety and information about landing sites for rotorcraft pilots.
Impacts: Location data about U.S. heliports is often inaccurate or nonexistent, leaving pilots and air ambulance operators with inaccurate information about where to find safe landing zones. This system will allow the FAA to automatically maintain this critical location data.

NJDOT Flood Risk Visualization Tool (CAIT-UTC-REG35, Project Manager: Dr. Jon Carnegie)

Outputs: The research team has developed a tool to enhance capacity for NJDOT personnel to assess flood vulnerability of its assets. The team is now fine tuning the tool for pilot testing.
Outcomes: The project includes development of tools and workflows designed to better inform NJDOT project development and asset management decisions as well as maintenance and operations procedures. The team has also engaged in technology transfer activities through presentations at NJDOT Research Showcase, and planned trainings on how to use the tool.
Impacts: The tool will enable NJDOT to integrate data about current and future flood hazard vulnerability into existing capital planning and asset management processes. Over time, the intent is to improve overall resilience of transportation infrastructure to climate hazards.

Improving the Long-Term Performance of Bridge Decks through Full-Scale Accelerated Testing (CAIT-UTC-REG36, Project Manager: Dr. Franklin Moon)

Outputs: The goal of this research is to leverage testing being conducted by FHWA within The BEAST to better understand the demands that bridge decks are exposed to while in service.
Outcomes: This project can help determine the role of temperature gradients on structural response and deck stress.
Impacts: This knowledge will provide more accurate estimation of deck demands and ensure that new designs account for temperature effects resulting in more durable bridge decks that are less prone to cracking. Results from this research also have the potential to improve and develop design, material, and construction approaches to produce more durable bridge decks.

Impact of Recycled Plastic on Asphalt Binder and Mixture Performance (CAIT-UTC-REG37, Project Manager: Dr. Thomas Bennert)

Outputs: This project will evaluate the compatibility of different plastics within asphalt and evaluate the resultant asphalt binder and mixture performance of the plastic-modified material.
Outcomes: The outcome of this project is to develop a new material that provides a structural material for long lasting asphalt pavements and a potential end use for recycling plastics.
Impacts: A a series of webinars will provide information pertaining to the appropriate waste plastic stream products for asphalt binders and mixtures, methods on blending recycled plastic with asphalt materials, necessary changes/modifications to current mixture design procedures, and expected change to the handling and performance of plastic modified asphalt mixtures.

FDR Stabilizer Selection Using Simple Soil Tests (CAIT-UTC-REG39, Project Manager: Dr. David Orr)

Outputs: Full Depth Reclamation is a commonly used technique to improve the quality of the base for local roads and streets. One of the most important steps is choosing the correct stabilizer for the current road conditions. However, the choice of the material to be used is too often based upon discussions with a local vendor or other empirical methods.
Outcomes: The most common soil tests that are used are grain size analysis and plasticity. While grain size is critical, the plasticity of most base gravels is very low and not an indicative method for which stabilizer will actually have the best chances of success.
Impacts: The goal of this proposal is to use the sand equivalent test with grain size analysis to overcome limitations and provide an economical method to choose the best stabilizer.

Education and Workforce Development Activities

The consortium has trained more than 1,174 professionals during this period.

- **Classes, Seminars, and Educational Opportunities**

  The 64th Annual NJ Asphalt Paving Conference featured expert speakers from throughout the asphalt paving industry, including CAIT researcher and Rutgers Asphalt Pavement Lab Director Dr. Thomas Bennert who presented on Balanced Mix Design/Ideal CT Research.

  This February, UTC partners from The University at Buffalo discussed their research studying the effects of fire on tunnel structure integrity and establishing a methodology to quantify fire damage to tunnel lining as part of the CAIT Seminar Series.

  In January, CAIT hosted UTC partners from the Polytechnic University of Puerto Rico as part of The CAIT Seminar Series for a presentation on their research studying the damages from Hurricane Maria on Puerto Rico in order to improve future infrastructure resilience.

- **Technology and Tools**

  A UTC partner at Cornell University is part of a new project developing and planning a hyperlocal weather forecasting system designed to improve winter-storm emergency response and enhance natural disaster coordination for NY state's rural communities.

NJ Transit recently selected four companies to test pilot state-of-the-art technology to improve the health and safety of customers and employees during the COVID-19 pandemic, and has partnered with CAIT to help evaluate these different products and technologies.

Technology Transfer

- **Presentations and Events**

  CAIT Celebrated International Women's Day and Women's History Month this year by hosting some of our excellent women researchers for a seminar on their careers, recent research successes, transportation equity, COVID-19, and more.

  In December, CAIT hosted affiliated researchers from Columbia University for a seminar on their latest research studying the "Effects of Exposure to Fire on Strength of Suspension Bridge Cables Over Time" as part of the ongoing CAIT Seminar Series.

- **Research and Publications**

  The Middlesex County – Smart Mobility Testing Ground project that will turn downtown New Brunswick into a test bed for mobility data-gathering and autonomous vehicle technology was recently approved by stakeholders and implementation plans have begun.

  The NJ Task Force on Transportation, Mobility, and Support Service Needs of Adults with Autism, led by Dr. Cecilia Feeley, recently made recommendations that can lessen barriers to transportation equity, some of which are now being considered by the NJ legislature.

  CAIT was recently awarded a Federal Emergency Management Agency grant to characterize the conditions of infrastructure along New Jersey's 500-Year Flood Plain relevant to future climate-related threats using remote sensing, cloud computing, and AI-based technologies.

  Grateful for medical care he received from Rutgers physician and CAIT researcher Clifton R. Lacy, M.D., an NJ business leader has pledged $8 million to fund innovative public health projects at Rutgers, including $250,000 directed to CAIT's UTC MEMS sensor research.

- **CAIT Researchers Win Awards**

  At the 30th annual CUTC Awards Banquet UTC student Prarthana Raja from Rutgers University was recognized by CUTC as the CAIT 2020 Student of the Year.

  U.S. News & World Report recently published its 2022 Best Graduate Schools ranking, which evaluated a number of academic programs across disciplines such as engineering, and included programs at Rutgers University, the University at Buffalo, and other UTC partners.

  NJBIZ announced its winners of the 2021 Digi-Tech Innovators Award, which highlights leaders who introduced significant technological advancements in NJ, and included CAIT researcher Dr. Peter Jin who has led the Smart Mobility Testing Ground project.

How have the results been disseminated?

CAIT established the Consortium internet site: https://cait.rutgers.edu/. CAIT has distributed The CAIT Update, its monthly E-newsletter, to subscribers in the transportation industry. CAIT has also shared results to the general public through news media. Select coverage includes:

RailwayAge.com

TrafficTechnologyToday.com

Crain's NY Business

NJTPA Regional Roundup

MassTransitMag.com

NJBiz.com

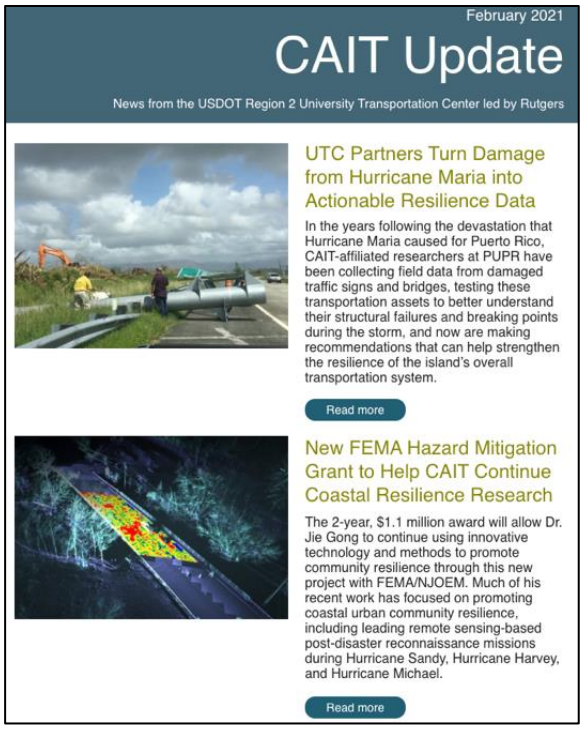
AASHTO Daily Transportation Update

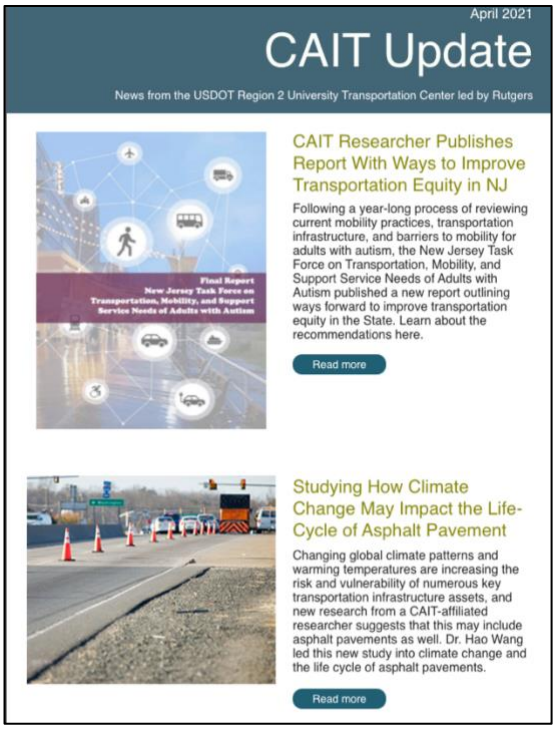
U.S. News & World Report

NJ101.5

Newsletter

CAIT has distributed The CAIT Update, its E-newsletter, on a monthly basis to more than 5,000 subscribers.





What do you plan to do during the next reporting period to accomplish the goals and objectives?
No change to plan and process to accomplish our goals.

2. PARTICIPANTS AND OTHER COLLABORATING ORGANIZATIONS (Who has been involved?)

Consortium Universities Involved

Rutgers, The State University of New Jersey • Piscataway, NJ 08854 (**LEAD**)
Atlantic Cape Community College • Mays Landing, NJ 08330
Columbia University • New York, NY 10027
Cornell University • Ithaca, NY 14853
New Jersey Institute of Technology • Newark, NJ 07102
Polytechnic University of Puerto Rico • San Juan, Puerto Rico 00918
Princeton University • Princeton, NJ 08544
Rowan University • Glassboro, NJ 08028
SUNY–Farmingdale State College • Farmingdale, NY 11735
SUNY–University at Buffalo • Buffalo, NY 14260

- ***What organizations have been involved as partners?***

New Jersey Department of Transportation	Trenton, NJ	Financial support and collaborative research on multiple projects, personnel resources, knowledge exchange
Port Authority of New York and New Jersey	New York, NY,	Collaborative research on multiple projects, personnel resources, knowledge exchange, financial support
New Jersey Board of Public Utilities	Trenton, NJ	Financial support and collaborative research on multiple projects, including PHMSA State Damage Prevention Grant
New York State Department of Transportation	Albany, NY	Financial support, personnel resources, knowledge exchange
New York City Department of Transportation-Division of Sidewalk and Inspection Management	New York, NY	Personnel resources, knowledge exchange
Washington State Department of Transportation	Olympia, WA	Personnel resources, knowledge exchange
Port Authority Trans-Hudson	Jersey City, NJ	Personnel resources, knowledge exchange
New York State County Highway Superintendents Association	Oneida and Chemung Counties	Personnel resources, knowledge exchange
New York Association of Town Superintendents of Highways	Canaan, NY	Personnel resources, knowledge exchange
Mistras Group	Princeton Junction, NJ	Personnel resources, knowledge exchange
Arup	New York, NY	Personnel resources, knowledge exchange
New Jersey Department of Community Affairs	Trenton, NJ	Personnel resources, knowledge exchange
Arora and Associates, P.C.	Lawrenceville, NJ	Personnel resources, knowledge exchange
Pennsylvania Department of Transportation	Bridgeville, PA	Personnel resources, knowledge exchange
Puerto Rico Highway and Transportation Authority	San Juan, PR	Personnel resources, knowledge exchange
Federal Highway Administration, Puerto Rico Division	San Juan, PR	Personnel resources, knowledge exchange
North Jersey Transportation Planning Authority	Newark, NJ	Personnel resources, knowledge exchange

Monmouth County Division of Engineering	Freehold, NJ	Personnel resources, knowledge exchange
Rotorcraft	Atlantic city, NJ	Personnel resources, knowledge exchange
The Everett Railroad	Duncansville, PA	Personnel resources, knowledge exchange
NJ Transit Corporation	Newark, NJ	Personnel resources, knowledge exchange
American Institute of Steel Construction	Lancaster, PA	Personnel resources, knowledge exchange
Monmouth County Sheriff's Office	Freehold, NJ	Personnel resources, knowledge exchange
Washington State Department of Transportation	Olympia, WA	Personnel resources, knowledge exchange

- ***Have other collaborators or contacts been involved?***
  Nothing to report

3. OUTPUTS (What new research, technology or process has the program produced?)
Publications, conference papers, and presentations

- Anuruddha Jayasuriya, Emily S. Shibata, Tola Chen, Matthew P. Adams; "Development and Statistical Database Analysis of Hardened Concrete Properties Made with Recycled Concrete Aggregates;" Journal of Resources, Conservation and Recycling; Volume 164, Issue 1 (2021); Elsevier. https://doi.org/10.1016/j.resconrec.2020.105121

- David Specht, Ghulam Rasool, Nidhal Bouaynaya, and Cliff Johnson, "Intelligent Helipad Detection from Satellite Imagery", accepted for publication in the Vertical Flight Society's (VFS) 77th Annual Forum & Technology Display meeting.

- Hikmat Khan, Ghulam Rasool, Nidhal Bouaynaya, Tyler Travis, Lacey Thompson, Cliff Johnson, "Deep Ensemble for Rotorcraft Attitude Prediction", accepted for publication in the Vertical Flight Society's (VFS) 77th Annual Forum & Technology Display meeting.

- Hua, N., Tessari, A., & Elhami-Khorasani, N. (2021). Characterizing damage to a concrete liner during a tunnel fire. Tunneling and Underground Space Technology, 109, 103761. https://doi.org/10.1016/j.tust.2020.103761

- Hua, N., Elhami-Khorasani, N. & Tessari, A. (2021). Review of tunnel fire damage assessment methods and techniques. Transportation Research Record, https://doi.org/10.1177%2F0361198120987228

- Hua, N., Tessari, A., & Elhami-Khorasani, N. (2021). Tunnel fire damage assessment: a review. In Proceedings, Transportation Research Board Annual Meeting, Washington DC.

- Hua, N., Tessari, A., & Elhami-Khorasani, N. (2020). Damage assessment framework for tunnel structures subjected to fire. In Proceedings, 11th International Conference on Structures in Fire, Brisbane, Australia.

- Sajedi, S. O., and Liang, X. (2021). Dual Bayesian inference for risk-informed vibration-based damage diagnosis. Computer-Aided Civil & Infrastructure Engineering, early access.

- Sajedi, S. O., and Liang, X. (2021). Uncertainty-assisted deep vision structural health monitoring. Computer-Aided Civil & Infrastructure Engineering, 36(2), 126-142.

- G. Pacheco-Crosetti and H. Cruzado, THE ANALYSIS OF STRUCTURAL FAILURES IN TRANSPORTATION INFRASTRUCTURE USED TO ESTIMATE WIND SPEEDS OF HURRICANE MARIA IN PUERTO RICO, RIDNAIC (2021). Vol. 19-20, 8 URL https://www.scipedia.com/public/Pacheco-Crosetti_Cruzado_2021a

- Chen, X., Wang, H., Horton, R., DeFlorio, J. (2021) Life-cycle assessment of climate change impact on time-dependent carbon-footprint of asphalt pavement. Transportation Research Part D: Transport and Environment, 91, 102697. https://doi.org/10.1016/j.trd.2021.102697.

- Bennert, T., Blight, R., Ganji, V., Tulanowski, D., & Gresavage, S. (2021). Development of High Friction Surface Treatment Prescreening Protocols and an Alternative Friction Application. *Transportation Research Record*. https://doi.org/10.1177/0361198121990027

- **Policy Papers**
  Nothing to report
- **Website(s) or other Internet site(s)**
  https://www.facebook.com/RutgersCAIT/
  https://www.instagram.com/rutgerscait/
- **New methodologies, technologies or techniques**
  Incorporated into earlier sections of this report
- **Inventions, patents, and/or licenses**
  Nothing to report
- **Other products**

Outputs	Annual Goal	Semi-Annual Metric
1) a traditional or online training program.	3	7
2) a presentation and/or webinar.	10	11
3) a demonstration and/or pilot project.	3	3
4) a guidebook or similar publication in addition to an academic report.	8	4
5) a new specification.	1	0
6) new software or an app.	3	2
7) a new material and/or tangible product.	1	1
8) a potential patent or otherwise marketable product.	2	0
9) Primary or secondary customers will be tracked.	15	20
10) Implementation stakeholders will be tracked.	15	31
11) Implementation stakeholders that identify in each of the following will be tracked.	Customer / Implementer	Customer / Implementer
a. Sponsors of research and T2	2 / 2	5/7
b. Researchers and/or developers	1 / 5	4/4
c. Early adopters and problem owners	5 / 5	8/21
d. Late adopters that follow the technology's development	3 / 5	1/7
e. Deployment team	3 / 3	4/6
f. Others, e.g., trade organizations, regulators, suppliers, etc.	1 / 3	1/7

12) Conceptual methodologies to calculate actual impact. How the PI expects to calculate the actual impact that a customer will realize by implementing the results.	15	21
13) The number of projects that help meet each USDOT Strategic Plan goal	-	-
a. Safety: Reduce transportation-related fatalities and serious injuries across the transportation system.	5	9
b. Infrastructure: Invest in infrastructure to ensure mobility and accessibility and to stimulate economic growth, productivity, and competitiveness for American workers and businesses.	5	12
c. Innovation: Lead in the development and deployment of innovative practices and technologies that improve the safety and performance of the nation's transportation system.	5	13
d. Accountability: Serve the nation with reduced regulatory burden and greater efficiency, effectiveness, and accountability.	2	1

4. OUTCOMES (What outcomes has the program produced? How are the research outputs described in section (3) above being used to create outcomes?

Outcomes	Annual Goal	Semi-Annual Metric
1) MOU/letters of commitment indicating a customer's commitment to adopt or that they have adopted/used	5	3
2) full-scale adoption of a new technology technique, or practice, or the passing of a new policy, regulation, rule making, or legislation including commercialized or patented product	5	3

5. IMPACT (What is the impact of the program? How has it contributed to improve the transportation system: safety, reliability, durability, etc.; transportation education; and the workforce?)

Impacts	Annual Goal	Semi-Annual Metric
1) cost savings (time, money, or life-cycle performance)	$280k year one - $2.575M each subsequent year	$1,566,133
2) durability and/or resilience and/or preservation	Zero in year one - 30 years each subsequent year	20 years
3) workforce proficiency or documented success stories	4 success stories	4

6. CHANGES/PROBLEMS

- ***Changes in approach and reasons for change.***
  Nothing to report
- ***Actual or anticipated problems or delays and actions or plans to resolve them.***
  Nothing to report
- ***Changes that have a significant impact on expenditures.***
  Nothing to report
- ***Significant changes in use or care of animals, human subjects, and/or biohazards.***
  Nothing to report