

Awarding Federal Agency: US Department of Transportation, Office of the Assistant Secretary for Research and Technology (OST-R)

Federal Grant Number: 69A3551847102

Project Title: Center for Advanced Infrastructure and Transportation (CAIT) Region 2 UTC Consortium Led by Rutgers, The State University of New Jersey

Center Director Name, Dr. Ali Maher, CAIT Director.

E-mail address: mmaher@soe.rutgers.edu **Phone number:** 848-445-0579

Name of Submitting Official, Title, and Contact Information (e-mail address and phone number), if other than PD: Dr. Patrick Szary, CAIT Associate Director. **E-mail address:** szary@soe.rutgers.edu **Phone number:** 848-445-2999

Recipient Organization (Name and Address): Rutgers, The State University of New Jersey, Center for Advanced Infrastructure and Transportation, 100 Brett Road, Piscataway, NJ 08854-8058

DUNS Number: 001912864000

EIN Number: 1226001086A1

Recipient Identifying Number or Account Number, if any: Rutgers' account #824227

Project/Grant Period: June 05, 2018 through September 30, 2023

Reporting Period End Date: September 30, 2022

Report Term or Frequency: Semiannual

Submission Date: October 31, 2022

Signature of Submitting Official:

A handwritten signature in black ink, consisting of a large, stylized loop followed by a horizontal line extending to the right.

Impact Statement

In the ten years since Superstorm Sandy decimated New Jersey costing **\$30 billion** in damages, the Northeast region has been struck by other major storms such as: Hurricanes Maria and Irma in 2017 (Puerto Rico-**\$100B**), Tropical Storm Ida in 2021 (NY/NJ-nearly **\$20B**), and recently Hurricane Fiona in Puerto Rico that is expected to have caused billions in damages and left thousands without access to power, water, and vital resources. These storms—coupled with some of the world’s oldest and overburdened infrastructure in Region 2, recent State of Good Repair (SGR) investments, and the goal of improving the durability of our transportation infrastructure—demonstrate the need to enhance transportation-infrastructure resilience and to better implement resiliency into long-term capital planning programs across our region.

Region 2 is facing time-critical projects reliant on advancements in durability, construction, finance, asset management, and resilience. The challenges to be economically competitive and socially equitable have put significant stress on regional agencies to maintain, retrofit, and expand aging infrastructure. Recognizing this, CAIT has emphasized research that centers on resilience, creates value, addresses equity imbalance, and is most cost-effective long-term. Using Region 2 as a complex system-of-systems laboratory and living testbed, CAIT has established impactful, real-world programs with agency partners and launched innovative pilot projects as highlighted below. The Center is well positioned to continue improving infrastructure durability, service life, economic opportunity, and resilience, while supporting safety, equity, and inclusion outcomes.

Select Impacts and Outcomes of UTC Activities or UTC Seed Projects:

- Preserving Infrastructure and Improving the Durability: With the **Port Authority of NY & NJ**, CAIT built a digital twin of a pilot PANYNJ bridge and developed a case study, 20-year maintenance program for the agency. (*Econ. Strength, Transformation, Safety*).
- Helped **NJ Transit** in planning and technical assistance for the **Portal North Bridge** and to improve **Northeast Corridor** SGR. UTC projects also studied the impacts of fire on tunnels and bridges, in alignment with the **Gateway Program**. (*Econ. Strength, Equity, Safety, Transformation, Climate*).
- Developed a comprehensive database of Recycled Concrete Aggregate for the **NYC DOT** to guide use of this sustainable material as demand grows. The database supports agencies developing more sustainable construction methods. (*Climate, Econ. Strength*).
- Recognizing Climate, Sustainability, and Resilience Needs: Developed a Storm Surge Early Warning System for **NJ Transit** using their Hoboken NJ terminal. CAIT conducted LiDAR scans to build digital twins of the facility, as well as Flood Elevation Models that help agencies visualize risks ahead of time. The system can be modified for other buildings and infrastructure as well. (*Climate, Econ. Strength, Safety, Transformation*).
- After **Tropical Storm Ida**, CAIT researchers used LiDAR, sensors and other technology to collect post-disaster data and build digital Flood Elevation Models that support data-driven and improved storm mitigation efforts. (*Climate, Safety, Equity, Econ. Strength*).
- Ensuring Safety Across Networks: Built an Artificial Intelligence (AI)-based tool for trespassing detection at rail grade crossings to improve safety and prevent fatalities.

Follow up projects supported by **FRA** and **FTA** are being conducted now and are engaging stakeholders at **NJDOT** and **NJ Transit**. (*Safety, Transformation*).

- **Building a More Equitable Transportation System:** Partnering with the **NJ Dept. of Labor & Workforce Development**, CAIT is providing career development opportunities in transportation to justice-impacted youth in Camden, NJ — one of the most impoverished and underserved communities nationwide. (*Equity, Econ. Strength*).
- CAIT has partnered with **Johnson & Johnson** on an **NJDOL** grant to support local high school students in pursuing STEM career pathways. These students are from **Franklin Township, NJ**, a historically underserved community in NJ. (*Equity, Econ. Strength*).
- **Transformative Tech & Approaches:** The BEAST Lab was recognized by **FHWA** as an “**EDC Innovation of the Month**” for new research validating advanced UHPC and other more resilient construction materials. (*Econ. Strength, Transformation, Safety*).
- CAIT is in the planning and development phase for a “Living Pavement Testbed” supported by **industry partners** to study the impacts of advanced construction techniques, such as “Cold in Place Recycling” and others, on pavement performance and durability. (*Climate, Transformation, Econ. Strength, Safety*).

In addition to these efforts, CAIT has many ongoing, multi-year projects and partnerships with our stakeholders. From the DataCity—Smart Mobility Testing Ground with NJDOT and Middlesex County, to the NJ Transit Resource Program and NJDOT Bridge Resource Program, these close relationships allow the Center to tailor research, technology transfer, and educational efforts directly to the changing needs of Region 2. In doing this, we have been able to better serve our stakeholders and use UTC dollars on projects that have real-world impact.

These highlights demonstrate how CAIT has leveraged the UTC grant to engage with regional stakeholders on impactful projects that improve infrastructure durability, enhance system resilience, and save time and money, while also supporting safety, equity, transformation, and sustainability outcomes. They also provide the basis for how we plan to continue engaging our stakeholders and conducting meaningful research moving forward.

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 ongoing national dialogue on the state of the U.S. transportation infrastructure, and the emerging consensus on the need for 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 providing 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 5 projects during this cycle. Multiple research projects are currently under review.

New Projects:

CAIT-UTC-REG68	A Machine Learning Decision-Support System for Selecting Optimal Innovative Project Delivery Methods For Bundled Transportation Projects <i>Abstract:</i> The primary goal of this project is to develop a data-driven decision-support system to help state DOTs, local agencies, and tribal governments select the best project delivery method for each bundled contract by leveraging machine learning algorithms, while also taking into consideration the specific goals of each bundle.	NJIT
CAIT-UTC-REG70	Developing Indicators for Comprehensive Evaluation of Equity in Transportation System <i>Abstract:</i> This study aims to identify transportation equity and develop an evaluation technique to assess equity principles in transportation planning and construction processes, and better incorporate them into decision making.	Rowan
CAIT-UTC-REG71	Bio-mediated method for improving the erosion resistance of coastal embankment <i>Abstract:</i> This research aims to develop a bio-mediated technique that uses enzyme induced calcite precipitation (EICP) under varying temperatures to improve the physical properties of coastal embankment and mitigate coastal erosion in New Jersey.	Rowan

CAIT-UTC-REG74	Rapid Damage Assessment in Infrastructure Systems using Vibration Measurements within a Machine Learning Framework <i>Abstract:</i> The goal of this project is to develop different ML algorithms for the rapid identification of damage in bridge structures using the bridge's dynamic response during regular service operation. These algorithms are in theory applicable to any dynamical system but will be tailored specifically for bridge structures.	Columbia
CAIT-UTC-REG75	Mitigating Cracks in Concrete Members for Durable Bridge Construction <i>Abstract:</i> The objective of this project is to investigate the use of steel wool in concrete to increase its crack resistance (fracture toughness and flexural strength) and enable durable, crack-free bridges.	UB

A Machine Learning Decision-Support System for Selecting Optimal Innovative Project Delivery Methods For Bundled Transportation Projects

One of the earliest decisions in any infrastructure project is selecting a project delivery method. This project will develop a data-driven decision-support system to help agencies select the best project delivery method by leveraging machine learning algorithms. It will assist DOTs, local agencies, and tribal governments in utilizing alternative, innovative contracting methods to ultimately reduce costs and streamline design, construction, and maintenance activities.

Developing Indicators for Comprehensive Evaluation of Equity in Transportation System

There are several important equity impacts resulting from transportation planning decisions, including economic and social opportunities, transportation costs and expenditures, allocation of public resources, land use, job opportunities, and economic development. This project will provide a rigorous method to define transportation equity, evaluate its impacts, and incorporate this evaluation into transportation planning and decision-making processes.

Mitigating Cracks in Concrete Members for Durable Bridge Construction

In developed coastal areas, erosion and flooding are the primary coastal hazards that result in the loss of life or damage to property and infrastructure. This research aims to develop a bio-mediated technique using enzyme induced calcite precipitation under different temperatures to improve the physical properties of coastal embankment and mitigate coastal erosion in NJ.



Ongoing Projects:

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-REG28	Cost-effective Bridge Decks for Improved Durability and Extended Service Life	RU
CAIT-UTC-REG31	Evaluating the Safety and Mobility Impacts of American Dream Complex: Phase I (Feasibility Study, and Data Acquisition)	Rowan
CAIT-UTC-REG40	Zero Speed Profiler Assessment for Pavement Smoothness and Continuous Pavement Texture Measurements	RU
CAIT-UTC-REG51	Real-Time Decision Support System for Transportation Infrastructure Management under a Hurricane Event	SUNY Buffalo
CAIT-UTC-REG53	A Real-Time Proactive Intersection Safety Monitoring System Based on Video Data	Rowan
CAIT-UTC-REG56	Interactive decision support system for tunneling planning and construction: Hudson Tunnel case study	NJIT/Stevens

CAIT-UTC-REG58	Supplemental Study of Filter Technology Efficacy for Transit Vehicles to Combat the Spread of COVID-19 and Other Respiratory Infections	RU
CAIT-UTC-REG59	Durability of Low Carbon Concrete Mixtures	NJIT
CAIT-UTC-REG60	Low-Carbon Concrete Pilot Program	PU
CAIT-UTC-REG61	QAD (Quality Assurance Division) Inspection Reporting and State of Good Repair (SGR) Planning	RU
CAIT-UTC-REG62	AI-supported Monitoring and Resiliency Analysis for the Coastal Area of the Luis Muñoz Marín International Airport in Puerto Rico	RU/PUPR
CAIT-UTC-REG63	State-of-the-art technologies for structural health monitoring of tunnels: an overview	PU
CAIT-UTC-REG64	NJ Transit Northern Bus Garage Planning and Community Impact Evaluation	RU
CAIT-UTC-REG66	Comparison Analysis of Charging System Designs for Battery Electric Bus	RU
CAIT-UTC-REG67	Enhancing the resilience of coastal box girder bridges through geometric modifications	PU
CAIT-UTC-REG69	Camden Career Pathways Initiative	RU

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-REG5	Implementation and Development of UAS Practical Training for Inspection and Monitoring Activities	ACCC
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-REG9	Delivering maintenance and repair actions via automated/robotic systems	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-REG13	Virtual Tour (VT), Informational Modeling (IM), and Augmented Reality (AR) for Visual Inspections (VI) and Structural Health Monitoring (SHM)	PU
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-REG26	Passenger Flow Modeling on Platform Tracks in Transit Stations	RU
CAIT-UTC-REG27	Designing Concrete Mixtures with RCA	NJIT
CAIT-UTC-REG29	Seismic Vulnerability Assessment of Deteriorated Bridges	SUNY Buffalo
CAIT-UTC-REG30	Durable and Electrified Pavement for Dynamic Wireless Charging of Electric Vehicles	RU
CAIT-UTC-REG32	Rotorcraft Landing Sites – An AI-Based Identification System	Rowan
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
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-REG38	Risk and Resilience Analysis Tool for Infrastructure Asset Management	RU
CAIT-UTC-REG39	FDR Stabilizer Selection Using Simple Soil Tests	Cornell
CAIT-UTC-REG41	Affordable On-Demand Testing of Water Contamination Using a Portable Nanoelectronic Lead Detector	RU
CAIT-UTC-REG42	Enhanced Maritime Asset Management System (MAMS)	RU
CAIT-UTC-REG43	Artificial Intelligence-Aided Rail Transit Infrastructure Data Mining	RU
CAIT-UTC-REG44	Assessment of Solidification / Stabilization as a Remedial Strategy for PFAS Contaminated Transportation Sites	RU
CAIT-UTC-REG45	The Development of the Digital Twin Platform for Smart Mobility Systems with High-Resolution 3D Data	RU
CAIT-UTC-REG46	Driving behavioral learning leveraging sensing information from Innovation Hub	Columbia
CAIT-UTC-REG47	Remote Sensing System Enhancement for Digital Twinning of the Built Infrastructure to Support Critical Infrastructure Protection Research	RU
CAIT-UTC-REG48	Linking Physics-Based Deterioration Model to Field-Based Condition Assessments for Improving Asset Management	SUNY Buffalo
CAIT-UTC-REG49	Post-fire Damage Assessment of Concrete Tunnel Liners	SUNY Buffalo
CAIT-UTC-REG50	Post-disaster Damage Assessment of Bridge Systems	SUNY Buffalo
CAIT-UTC-REG52	Bridge Deck Surface Profile Evaluation for Rapid Screening and Deterioration Monitoring	Rowan
CAIT-UTC-REG54	Rotorcraft Landing Sites Identification – Scaling and Generalization of the AI Model	Rowan
CAIT-UTC-REG55	JFK Cargo View: A system to speed Truck Traffic Flow at JFK Airport	RU/ SUNY Farmingdale
CAIT-UTC-REG57	Comparative analysis of rapid chloride penetration testing for novel reinforced concrete systems	NJIT
CAIT-UTC-REG65	Development of a Geometric Extraction Tool as Part of a Pilot Digital Twin Framework for Open-Deck Rail Bridges	RU

HIGHLIGHTS

Completed Projects

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

Accomplishments: This research modeled and simulated passenger flows in transit stations using computer vision and simulation technologies. It led to the development of an AI-based technology that can be used to monitor trespassing at rail-grade crossings.

ROI: Fatalities due to rail trespassing events have been on the rise in Region 2. This technology can allow stakeholders to develop data-driven trespassing-mitigation approaches. It can also support other safety developments along rail grade crossings in the area.

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

Accomplishments: Built a comprehensive database of Recycled Concrete Aggregate (RCA) mechanical properties. Using this database, researchers investigated RCA system applications, simulating different RCA replacement levels and more than 200 mechanical loading scenarios.

ROI: This research provides agencies with guidance on how to best use RCA in construction projects. By 2027 the global RCA market is projected to pass 6.2 million tons as infrastructure ages and natural aggregate sources and landfill space become increasingly limited.

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

Accomplishments: Developed a new, partially magnetized pavement design of electrified pavement that has durable performance while providing efficient charging functionality.

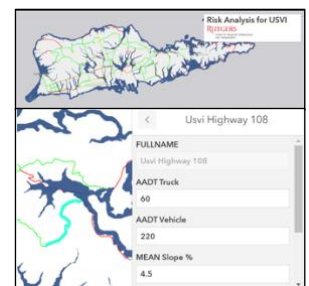
ROI: This innovative design provides a potential EV charging solution by implementing wireless charging techniques into existing roadway pavements. Results show the new design had a 1.5% - 13.3% improvement in charging efficiency over normal pavement for wireless power transfer.

Risk and Resilience Analysis Tool for Infrastructure Asset Management (CAIT-UTC-REG38, Project Manager: Dr. Yun Bai)

Accomplishments: Developed a Flood Risk and Resilience Analysis Tool, a GIS-based web platform, that can be used to assess and visualize risk for infrastructure susceptible to flooding. The tool was built with the University of the Virgin Islands and the US Virgin Islands Department of Public Works.

ROI: With this information, officials can make data-driven asset management decisions that account for risks and climate change and enhance resilience.

Developed for the US Virgin Islands, the tool can be customized for different agencies.



Enhanced Maritime Asset Management System (MAMS) (CAIT-UTC-REG42, Project Manager: Dr. Yun Bai)

Accomplishments: In this project, CAIT researchers worked with NJDOT stakeholders to develop a prototype Maritime Asset Management System that can meet transportation asset management plan requirements and aid with resource allocation. The state-of-the-art TAM approach has been implemented in a desktop-based user interface software application.

ROI: This project provided a MAMS prototype software tool that supports maintenance and dredging decision making for navigational ship channels in the region.

Assessment of Solidification / Stabilization as a Remedial Strategy for PFAS Contaminated Transportation Sites (CAIT-UTC-REG44, Project Manager: Dr. Robert Miskewitz)

Accomplishments: This project investigated the potential applicability of S/S for remediation of PFAS contamination in a soil matrix. Specific binder mixes were developed and tested using PFAS contaminated soils collected from a former aviation site in NJ.

ROI: The results indicate that S/S of PFAS contaminated soils can effectively sequester the chemical within a stabilized soil matrix. This project tested a strategy to reduce or eliminate the

environmental and human health risks of PFAS contamination and presents a low-cost alternative to ex-situ treatment strategies.

The Development of the Digital Twin Platform for Smart Mobility Systems with High-Resolution 3D Data (CAIT-UTC-REG45, Project Manager: Dr. Peter Jin)



Accomplishments: This project developed the main modules and algorithm models for the digital twin platform being used as part of the DataCity Smart Mobility Testing Ground initiative in partnership with NJDOT and Middlesex County.

ROI: The digital twin uses data collected from DataCity to reproduce high-fidelity reality for modeling vehicles, pedestrians, infrastructure, and other smart mobility objects with seamless object-level integration among different systems—to support CAV research.

Driving behavioral learning leveraging sensing information from Innovation Hub (CAIT-UTC-REG46, Project Manager: Dr. Sharon Di)

Accomplishments: With the accelerated deployment of connected and automated vehicle technologies, public agencies need to know best practices to utilize these rich data sources to improve traffic mobility, safety, and environmental and energy impact. This research investigated a major big-data challenge, mining driving behavior patterns using vehicle-based data sources.

ROI: A digital twin was developed leveraging the COSMOS testbed deployed near Columbia Univ. to validate the model algorithms and results that were generated throughout the project. This research is valuable for digital sibling simulation development and future deployment of autonomous vehicles that need to drive alongside humans.

Linking Physics-Based Deterioration Model to Field-Based Condition Assessments for Improving Asset Management (CAIT-UTC-REG48, Project Manager: Dr. Ravi Ranade)

Accomplishments: This research presents a systematic procedure for establishing a link between a physics-based corrosion model and condition-rating assessments, and addressing current limitations in field-based asset management programs.

ROI: Many state DOT asset management programs rely on field-based condition assessments of bridges for planning repair and maintenance activities, which are labor intensive and subjective. This research can empower DOTs to explore the long-term benefits of investments in innovative technologies and methods for improved asset management programs.

Post-fire Damage Assessment of Concrete Tunnel Liners (CAIT-UTC-REG49, Project Manager: Dr. Negar Elhami-Khorasani)

Accomplishments: Extreme tunnel fires can have serious consequences, including loss of life, structural damage, and major socioeconomic impacts due to service disruptions. This report provides guidelines on post-fire damage assessment procedures for tunnel infrastructure.

ROI: A framework to evaluate fire damage to reinforced concrete tunnel liners was developed. The outcomes can be used to assess damage after a fire event or design the structure and fire protection to minimize losses in the case of an extreme fire.

Post-disaster Damage Assessment of Bridge Systems (CAIT-UTC-REG50, Project Manager: Dr. Xiao Liang)

Accomplishments: Inspired by human speech recognition technology, this project investigated deep vibration-based damage detection utilizing Mel Filter Banks and machine learning.

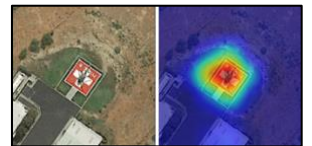
ROI: If appropriately designed, Machine Learning (ML) models can provide valuable information for stakeholders on civil infrastructure repair, maintenance, and safety assessments. This report addresses current limitations in implementing ML algorithms as practical tools for interpreting bridge vibration data and rapidly assessing structural damage.

Bridge Deck Surface Profile Evaluation for Rapid Screening and Deterioration Monitoring (CAIT-UTC-REG52, Project Manager: Dr. Adriana Trias)

Accomplishments: This project evaluated the impact of capturing point cloud data of bridge deck top surfaces to enable a rapid screening method by identifying early-stage deterioration.

ROI: There is a pressing need for the implementation of wireless, non-contact, or remote sensors that can provide rapid and cost-effective bridge assessment data. The information gathered in this project can help bridge owners utilize point cloud data as a screening tool that can better prioritize maintenance work and improve asset management.

Rotorcraft Landing Sites Identification – Scaling and Generalization of the AI Model (CAIT-UTC-REG54, Project Manager: Dr. Ghulam Rasool)



Accomplishments: To assist FAA with updating its database of landing site information for helicopters and rotorcrafts, researchers developed an AI-based algorithm that automates the process of identifying landing sites using video data and Google Earth satellite images — increasing safety and efficiency in the National Airspace System.

ROI: By automating this process, the FAA will have a regularly updated and accurate database of landing site infrastructure. Specifically, the AI algorithm can scan whole cities, towns, or extensive areas to locate and mark landing sites. To date, the team has updated the FAA’s 5010 databases of helipads, heliports, and landing sites using the developed AI.

JFK Cargo View: A system to speed Truck Traffic Flow at JFK Airport (CAIT-UTC-REG55, Project Manager: Dr. Kazem Oryani)

Accomplishments: Researchers analyzed and documented the benefits of an airport-wide Truck Flow Management System at JFK International Airport to coordinate truck traffic and cargo movements. Optimizing cargo flow at this major airport will generate economic, environmental, supply chain, and equity improvements for the local community and beyond.

ROI: This project identified a system that if implemented can have significant environmental and economic impacts such as reduction of excess truck delay time by an average of 38%, CO2 emission reductions by 80 to 512 metric tons annually, and an estimated \$2.5-\$16.0 million in direct trucking cost savings annually.

Comparative analysis of rapid chloride penetration testing for novel reinforced concrete systems (CAIT-UTC-REG57, Project Manager: Dr. Matthew Bandelt)

Accomplishments: This project provides a summary of rapid chloride penetration testing (RCPT) of ductile concrete materials. It analyzed a range of ductile concrete materials with varying fiber

types, fiber lengths, mechanical properties, material constituents, and durability performance, representative of various systems that have been used in transportation projects to improve the durability of infrastructure.

ROI: Based on the findings, recommendations were made for the need to calibrate RCPT results with long-term chloride ponding experiments to accurately measure the resistance of concrete systems to chloride penetration. Overall, this continued line of research can support agencies in using novel concrete materials to improve infrastructure durability and resilience.

Ongoing Projects

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

Outputs: A flood map for NJ towns that depicts 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.

Impacts: Results will assist decision makers and coastal communities in understanding the magnitude of floods, quantifying impacts, and creating mitigation and resiliency plans.



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

Outputs: A non-proprietary final report covering the work performed under this research study.

Outcomes: Training and specifications around the new design method will be developed and implemented within NY State.

Impacts: Study results will help NYSDOT improve mixture design and testing programs.

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

Outputs: This project is developing cost-effective standard open rib SOBDD to promote increased implementation of SOBDD for short and medium span highway bridges.

Outcomes: New design specifications and companion guidelines expected to be incorporated into the AASHTO Bridge Design Specifications.

Impacts: The research findings have the potential to be adopted by steel bridge fabricators for streamlining production, economizing fabrication, and competitive advantage.

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: This project is coordinating with stakeholders to identify and address traffic and safety issues associated with this complex using innovative technology.

Outcomes: Phase I of this project will provide a framework for larger data collection and analytics to develop innovative solutions to alleviate congestion and motor vehicle crashes.

Impacts: This project is providing a framework for alleviating traffic congestion in the area and developing intersection-safety tools using Artificial Intelligence.

Zero Speed Profiler Assessment for Pavement Smoothness and Continuous Pavement Texture Measurements (CAIT-UTC-REG40, Project Manager: Michael Boxer)

Outputs: The primary goal of this project is to evaluate a state-of-the-art technology in roadway profiling called Zero Speed Profiling.

Outcomes: It is anticipated that with successful implementation, the Zero Speed Profiler will provide a more accurate and efficient assessment of the current pavement profile in NJ when compared to other methods currently used by the State.

Impacts: A more realistic and comprehensive pavement surface assessment will result in better decisions regarding how to preserve or rehabilitate the pavement and NJ roadways.



Real-Time Decision Support System for Transportation Infrastructure Management under a Hurricane Event (CAIT-UTC-REG51, Project Manager: Dr. Teng Wu)

Outputs: This project will lay the groundwork for the development of a real-time decision support system for transportation infrastructure management under a hurricane event.

Outcomes: The intended outcome of the project is to deliver a tool to rapidly identify optimal traffic control policies under hurricane events.

Impacts: This project will investigate hurricane impacts on critical infrastructure and effects of various traffic control policies on traffic network performance. The project will then identify the optimal traffic control policy to minimize hurricane-induced losses.

A Real-Time Proactive Intersection Safety Monitoring System Based on Video Data (CAIT-UTC-REG53, Project Manager: Dr. Mohammad Jalayer)

Outputs: This project is developing a real-time proactive safety monitoring system based on the trajectory of road users (e.g., cars, pedestrians, and cyclists) collected by video cameras.

Outcomes: The results of this project will provide a great opportunity for transportation agencies to rank and score intersections based on the analyzed data.

Impacts: The project will provide appropriate safety solutions to reduce intersection-related crashes and incidents and consequently reduce traffic congestion.

Interactive decision support system for tunneling planning and construction: Hudson Tunnel case study (CAIT-UTC-REG56, Project Manager: Dr. Matthew Bandelt)

Outputs: This project aims to increase safety and minimize the risks of building major underground infrastructure systems by enhancing existing methods for risk assessment.

Outcomes: The goal of the project is to develop a framework calibrated for worldwide large-scale tunneling projects capable of determining most likely hazards along a tunnel route.

Impacts: This interactive decision support system will have the potential to be used in the design and construction of different tunnels in the US by local, regional and federal agencies.

Supplemental Study of Filter Technology Efficacy for Transit Vehicles to Combat the Spread of COVID-19 and Other Respiratory Infections (CAIT-UTC-REG58, Project Manager: Shane Mott)

Outputs: Airborne transmission of the COVID-19 virus has been identified as one of the primary modes through which COVID-19 is spread. MERV 13 filters can filter 85% of particles in the ideal size range for capturing respiratory droplets.

Outcomes: MERV 8+Ag filters contain a silver impregnated layer within and on top of the filter material. This silver layer has antiviral properties which can deactivate trapped viruses.

Impacts: The primary goal of this study is to determine if the performance on these filters change over time, specifically in the transit environment, and compare the results.

Durability of Low Carbon Concrete Mixtures (CAIT-UTC-REG59, Project Manager: Dr. Matthew P. Adams)

Outputs: This project will help researchers develop a deeper understanding of the relative performance of low-carbon concrete systems when exposed to chlorides and deicing salts.

Outcomes: Researchers will 1) understand the chloride diffusion rate in low-carbon concrete mixtures; 2) understand the relative resistance of various low-carbon concrete mixtures to salt scaling and 3) develop life-cycle expectancy models for various low-carbon concrete mixtures.

Impacts: The intended outcome of the project is to present a systematic approach to examining the durability of low-carbon concrete mixtures.

Low-Carbon Concrete Pilot Program (CAIT-UTC-REG60, Project Manager: Dr. Reza Moini)

Outputs: This research will help the Port Authority reduce the embodied carbon of the concrete mixtures used in their construction activities.

Outcomes: Support agency wide GHG reduction target of 80% by 2050.

Impacts: This project will provide concrete mixtures that can significantly decrease embodied carbon in Port Authority concrete placements. Additionally, the work will improve other areas of sustainability by working to close materials loops in the region.



QAD (Quality Assurance Division) Inspection Reporting and State of Good Repair (SGR) Planning (CAIT-UTC-REG61, Project Manager: Dr. Ali Maher)

Outputs: The main goal of this project is to develop a proof of concept for the Port Authority Engineering Department that will provide stakeholders with improved access to and visualization of infrastructure assets information (Wharves, retaining walls and bridges etc.).

Outcomes: The prototype application will provide PANYNJ engineers with a collection of visualization and analysis tools that will enhance and support SGR planning.

Impacts: These tools are intended to assemble and leverage existing asset data that may reside in siloed repositories across the agency.

State-of-the-art technologies for structural health monitoring of tunnels: an overview (CAIT-UTC-REG63, Project Manager: Dr. Branko Glisic)

Outputs: Successful implementation and effectiveness of monitoring systems requires good understanding of the structure being monitored.

Outcomes: The primary goal of this project is to perform extensive overview of the state-of-the-art technologies for structural health monitoring of tunnels.

Impacts: This project will generate guidelines for using new tunnel monitoring technologies.

NJ Transit Northern Bus Garage Planning and Community Impact Evaluation (CAIT-UTC-REG64, Project Manager: Dr. Peter Jin)

Outputs: This project will help NJ Transit's Bus Service Planning Dept. to create a complete roster of the 500-bus capacity Northern Bus Garage, and determine statistics such as platform hours and non-revenue mileage totals for potential auditing purposes.

Outcomes: Several modules for bus dispatching, including data archiving, processing and visualization will be developed and integrated with the NJ Transit bus scheduling system.

Impacts: Data generated will provide insights on the impact of the new garage regarding the operational improvement of NJ TRANSIT bus operations in its service areas.

Comparison Analysis of Charging System Designs for Battery Electric Bus (CAIT-UTC-REG66, Project Manager: Dr. Hao Wang)

Outputs: A robust charging system for battery electric buses considering economic and environmental impacts will be developed and analyzed through this research project.

Outcomes: The intended outcome of the project is to develop a sound methodology to help NJ Transit select the most appropriate charging system design with less life-cycle cost and carbon footprint.

Impacts: The research results will help NJ Transit develop its deployment strategy for charging infrastructure and refine its garage modification plans in the future to better support a potentially full zero-emission bus system.



Enhancing the resilience of coastal box girder bridges through geometric modifications (CAIT-UTC-REG67, Project Manager: Dr. Maria Garlock)

Outputs: This project will enhance the resilience of coastal box girder bridges subject to storm and/or tsunami wave loading through an evaluation of their design geometry.

Outcomes: Researchers intend to equip coastal bridge designers with resilient strategies for new coastal bridge designs as well as retrofit strategies of existing T-type and box type decks.

Impacts: This research supports improving the durability and resilient infrastructure goals. It also gives coastal bridge owners knowledge and tools for assessing and designing their assets.

Camden Career Pathways Initiative (CAIT-UTC-REG69, Project Manager: Dr. Patrick Szary)

Outputs: This project identifies hyperlocal career pathways in the transportation industry for people from historically underserved NJ communities, who may miss out on these career opportunities as the economy eventually rebounds and new jobs are created in the transportation, shipping, and logistics sectors.

Outcomes: By identifying highly localized transportation-related positions in and around Camden NJ, this project will develop data points on employment opportunities and establish a growing network of partner businesses and employers, to support future job placement efforts.

Impacts: This work will ultimately help provide an entry point into the larger transportation career sector for people from a historically underserved community in the region.

Education and Workforce Development Activities

The consortium has trained more than 578 professionals during this period.

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

CAIT faculty member Dr. Jie Gong gave a 3-hour training to NJ County Offices of Emergency Management, NJDOT, NJDEP, NJ DCA, and the State’s Regional Operations & Intelligence Center, on using his UTC flood research to support state-wide resilience planning.

- Bridge to Employment is a J&J youth development program that inspires young people from historically underserved communities to pursue STEM careers. A local NJ site kicked off year 3 of its program this September with lab tours, technology demonstrations, and presentations at CAIT.



- **Technology and Tools**

CAIT researchers developed an Artificial Intelligence-based, rail-grade-crossing trespassing detection system, designed to help stakeholders such as NJ Transit study, understand, and prevent future rail trespassing events — a major safety concern in the region.

- Working with NJDOT, CAIT developed a Dredging Planning Optimization Model to support asset management and maintenance decision making for navigational ship channels.

Technology Transfer

- **Presentations and Events**

Rutgers CAIT hosted Maritime Studies students from the Univ. of Piraeus in Greece for a day of lab tours and presentations from NJDOT, UTC partners at Columbia University, and more.

- The 2022 Northeast Coastal Conference on “Superstorm Sandy - 10 Years Later” was hosted by CAIT researcher Dr. Dan Barone. The program included presentations from experts across federal, state, and local governments, as well as from Academia and Industry.
- Rutgers faculty member Dr. Mohsen Jafari hosted an inaugural Hydrogen Energy forum to encourage collaboration in meeting clean energy and resilience goals in the Northeast.

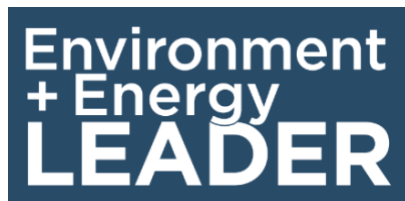
- **Research and Publications**

Dr. Hao Wang published a paper in “Renewable and Sustainable Energy Reviews,” identifying research gaps in the implementation of EV infrastructure, such as eRoads.

- Columbia UTC partner Dr. Sharon Di was featured in ASCE’s “Civil Engineering Source” for her research building Digital Twins of intersections in NYC to monitor and map traffic flow.
- **CAIT Researchers Win Awards**
Dr. Hao Wang was recognized by ASCE with a Walter L. Huber Civil Engineering Research Prize for his innovative work developing sustainable, resilient, and smart pavement systems.
- Mr. Todd Pisani was recognized by Rutgers–Camden with a Chancellor’s Award for Diversity, Inclusion & Civic Engagement for his efforts supporting justice-impacted youth in Camden NJ. He does this work through the Rutgers Youth Success Program now housed at CAIT.

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:



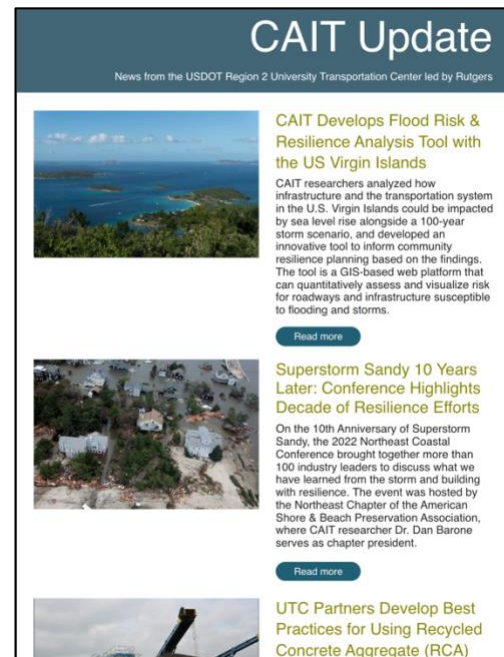
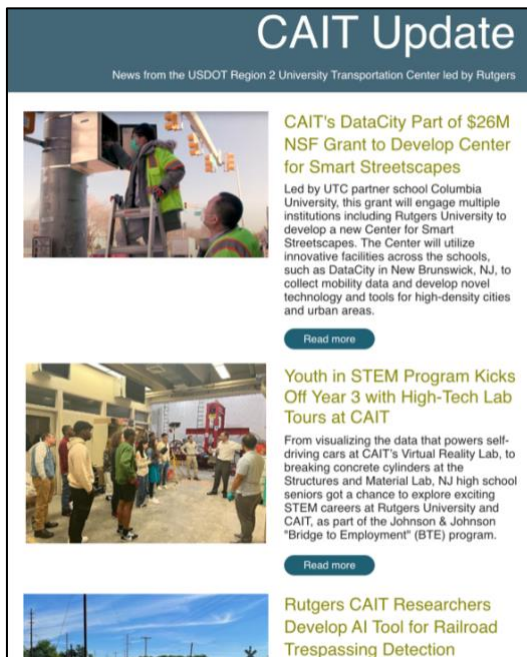
DredgingToday.com



ScienceDaily®

Newsletter

CAIT has distributed The CAIT Update, its E-newsletter, monthly to 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.

1. 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
NYCDOT-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	Financial support, 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
Federal Aviation Administration	Washington, DC	Personnel resources, knowledge exchange
Middlesex County	Middlesex, NJ	Financial support, Personnel resources, knowledge exchange
JFK International Airport	Queens, NY	Personnel resources, knowledge exchange
Gateway JFK	Queens, NY	Personnel resources, knowledge exchange
AAA Mid-Atlantic	Wilmington, DE	Personnel resources, knowledge exchange
Verizon	New York, NY	Personnel resources, knowledge exchange

- ***Have other collaborators or contacts been involved?***

Nothing to report

2. OUTPUTS (What new research, technology or process has the program produced?)

Publications, conference papers, and presentations

- Jiang, Shan & Huang, Yufei & Jafari, Mohsen & Jalayer, Mohammad. (2022). Economic-Driven Adaptive Traffic Signal Control.
- Liu, J.; Huang, B.; Wang, H. & Luo, X. (2022). Sustainability Innovation in Pavement Infrastructure. Journal of Transportation Engineering, Part B: Pavements. 148. 10.1061/JPEODX.0000384.
- Zaman, A. (2022) "American Association of State Highway and Transportation Officials (AASHTO) Council on Rail Transportation 2022 Annual Meeting." Panel Discussion - Advancing Rail Safety. <https://rail.transportation.org/wp-content/uploads/sites/30/2022/09/000-2022-CORT-Annual-Meeting-Kansas-City-Final-Agenda.pdf>
- Hasan, Ahmed Sajid & Kabir, Md Asif Bin & Jalayer, Mohammad & Das, Subasish. (2022). Severity modeling of work zone crashes in New Jersey using machine learning models. Journal of Transportation Safety & Security. 1-32. 10.1080/19439962.2022.2098442.
- Bennert, Thomas & Garg, Navneet & Ericson, Christopher & Cytowicz, Nick. (2022). Evaluation of Test Methods to Identify Asphalt Binders Prone to Surface-initiated Cracking. Transportation Research Record: Journal of the Transportation Research Board. 036119812211191. 10.1177/03611981221119191.
- Hua, Nan & Elhami Khorasani, Negar & Tessari, Anthony. (2022). Numerical modeling of the fire behavior of reinforced concrete tunnel slabs during heating and cooling. Engineering Structures. 258. 114135. 10.1016/j.engstruct.2022.114135.

- Marques Soares, Laura & Wang, Hao. (2022). A study on renewed perspectives of electrified road for wireless power transfer of electric vehicles. Renewable and Sustainable Energy Reviews. 158. 112110. 10.1016/j.rser.2022.112110.
- Fan, Jin & Shirshorshidi, Seyed Masoud & Adams, Matthew & Bandelt, Matthew. (2022). Predicting corrosion in reinforced UHPC members through time-dependent multi-physics numerical simulation. Construction and Building Materials. 340. 127805. 10.1016/j.conbuildmat.2022.127805.
- Pacheco-Crosetti, Gustavo & Collazos-Ordóñez, Omaira & Torres-Rodríguez, Verónica & Vázquez, Joel. (2022). Vulnerability of Schools in Puerto Rico to Tsunamis. 22. 59-88.
- Chen, Xu & Li, Zechu & Di, Sharon. (2022). Social Learning In Markov Games: Empowering Autonomous Driving. 10.1109/IV51971.2022.9827289.
- **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	Annual Metric
1) a traditional or online training program.	3	9
2) a presentation and/or webinar.	10	19
3) a demonstration and/or pilot project.	3	7
4) a guidebook or similar publication in addition to an academic report.	8	8
5) a new specification.	1	2
6) new software or an app.	3	4
7) a new material and/or tangible product.	1	1
8) a potential patent or otherwise marketable product.	2	4
9) Primary or secondary customers will be tracked.	15	15
10) Implementation stakeholders will be tracked.	15	19
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	3/3
b. Researchers and/or developers	1 / 5	2/5
c. Early adopters and problem owners	5 / 5	5/7
d. Late adopters that follow the technology's development	3 / 5	4/5
e. Deployment team	3 / 3	4/7
f. Others, e.g., trade organizations, regulators, suppliers, etc.	1 / 3	1/3
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	18
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	5
b. Infrastructure: Invest in infrastructure to ensure mobility and accessibility and to stimulate economic growth, productivity, and competitiveness for American workers and businesses.	5	7
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	8
d. Accountability: Serve the nation with reduced regulatory burden and greater efficiency, effectiveness, and accountability.	2	3

3. 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	Annual Metric
1) MOU/letters of commitment indicating a customer's commitment to adopt or that they have adopted/used	5	9
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	6

4. 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	Annual Metric
1) cost savings (time, money, or life-cycle performance)	\$280k year one - \$2.575M each subsequent year	\$7,028,526
2) durability and/or resilience and/or preservation	Zero in year one - 30 years each subsequent year	66 years
3) workforce proficiency or documented success stories	4 success stories	10

5. 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