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Center Director: Dr. Habib Dagher, TIDC Director **Email:** hd@maine.edu **Phone Number:** 207.581.2138

Name of submitting official: Amanda Collamore, TIDC Communications, Education, Outreach, and Reporting Manager **Email:** amanda.collamore@maine.edu **Phone Number:** 207.581.4376

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Recipient Organization (name and address): The University of Maine, Transportation Infrastructure Durability Center, 35 Flagstaff Road, Orono, Maine 04469

Recipient Identifying number or account number, if any: N/A

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Report term or frequency: Semi-Annual

Signature of submitting official:

I. ACCOMPLISHMENTS

a. What are the major goals and objectives of the program?

Research

The over-arching research objective of the TIDC is to improve the durability and extend the life of transportation infrastructure, including roads, bridges, and rail facilities. This objective will be achieved through (1) fundamental and applied research that will broaden our overall knowledge base while providing practical solutions to the state and federal agencies responsible for constructing and maintaining the nation's transportation facilities; (2) educational offerings in various fields of transportation that include comprehensive course work and student participation in research; (3) workforce development activities and programs to expand the workforce of transportation professionals; and (4) a perpetual program of technology transfer to ensure TIDC research results are disseminated and applied as widely as feasible.

Specific research projects are selected through a combination of peer-review and state DOT/industry input, and are expected to fall within TIDC's four research thrust areas identified in the table below.

Table 1: TIDC Research Thrusts Areas

Thrust Area Title	Description
Thrust Area 1: Transportation Infrastructure Monitoring and Assessment for Life	Managing aging civil infrastructure is a major challenge facing every country in the world. Research conducted under this theme tackles this issue through the development and implementation of novel strategies for the assessment and health monitoring of highway bridges, rail structures, pavements, slopes, embankments, and foundations. The ability to monitor the performance and health of these vital elements will provide the information required to prioritize the repair and replacement of our transportation infrastructure, while advanced assessment will justify extending the service life of these assets.
Thrust Area 2: New Materials for Longevity and Constructability	This thrust investigates new materials and technologies to improve durability and extend the life of transportation infrastructure. The materials and technologies investigated can apply to a range of transportation modes (vehicular, rail, etc.).
Thrust Area 3: New Systems for Longevity and Constructability	This research thrust focuses on evaluation, development, performance, reliability, and application of engineering systems to improve the durability and longevity of new and existing transportation infrastructure. New England's transit networks face challenges related to cold weather, changing climate, age-related deterioration, evolving load demands, construction efficiencies, and congestion, among others. In these times of economic austerity, innovative engineering systems are needed to alleviate existing and future financial strain on the region.
Thrust Area 4: Connectivity for Enhanced Asset and Performance Management	The system operational efficiency of transportation infrastructure can be improved by smart technologies that connect the infrastructure to information/management systems, vehicles, and roadway users. These emerging, connected technologies – coupled with appropriate and evolving management systems – can improve the durability of existing and new infrastructure. This is essential in the coming age of highly automated, connected vehicles and given the need to improve the performance of the existing infrastructure through more cost-effective and targeted assessments of asset vulnerabilities due to extreme weather events. This research theme applies to all forms of infrastructure including highway, railroad, marine ports, and airports.

TIDC will provide base funding to each member university contingent upon performance. Additional funding of $250,000 will be made available through an annual competitive RFP process.

Base and competitive funding are contingent upon performance, and all funded activities must meet metrics defined in technology transfer, education and workforce development, and collaboration. Each member university will provide performance metrics information to UMaine through quarterly progress reports for each research project to ensure performance is adequately tracked.

Education & Workforce Development

TIDC seeks to attract a more diverse pool of talented students into careers in science and engineering and ensure that these students receive the best education possible. Beyond providing students with a detailed knowledge of existing public transportation infrastructure and system challenges in the realm of durability and life extension, TIDC activities will (1) enhance student communication skills to ensure they can reach a variety of audiences including researchers, the public, and decision-makers; (2) create an inclusive multi-cultural and multi-disciplinary student body by recruiting women and underrepresented racial and ethnic groups into our program; and (3) foster the development of leadership skills through vertically integrated research teams (faculty, post-docs when applicable, graduate students, and undergraduate students) and peer mentoring. Undergraduate and graduate students will be directly supported by TIDC research projects and make meaningful contributions under the mentoring and guidance of faculty that is essential to student success.

TIDC will strengthen diversity and STEM education by sharing research with future members of the workforce at middle and high schools. This will include both exposing young people to opportunities that exist within the field of transportation infrastructure and engaging them in transportation-related educational activities.

Formal metrics to measure program effectiveness include numbers of undergraduate and graduate students participating in intra-consortium exchange initiatives or industrial internships; seminars, workshops, and conferences hosted; number of K-12 students who participate in transportation-focused tours or activities at member institutions; total number of classrooms reached by TIDC activities, including specifics on classrooms populated by under-represented groups of students.

Technology Transfer

The TIDC goals and performance metrics reflect the full spectrum of research activities through technology concept inception and assessment to technology adoption. The projects funded by TIDC will support the following technology transfer activities: (1) development of new technologies, techniques, or methodologies; (2) publishing journal, conference and policy papers that become references for practitioners for the modification of codes and standards for technology adoption; (3) deployment of new technologies, techniques, or practices; (4) improvements in the processes, technologies, and techniques in addressing transportation issues; (5) workforce development; (6) adoption of technologies, techniques, or practices; and, (7) development or modification of codes and standards to facilitate wider technology adoption.

As identified in the TIDC Technology Transfer Plan, the Center's mission is to develop innovative, sustainable, next-generation solutions to improve the durability and extend the lifespan of existing and new transportation assets in New England and beyond. TIDC is committed to making dramatic impacts in the cost-effectiveness of transportation infrastructure through transformative research, education, outreach, workforce development, and technology transfer through four research thrust

areas; 1) monitoring and assessment, 2) new materials for longevity and constructability, 3) new systems for longevity and constructability, and 4) connectivity for enhance asset and performance management.

TIDC's technology transfer objectives are:

- Ensure research developments and findings are accessible, disseminated, and transferred to a variety of users.
- Ensure research developments have long-term value and significant impact to the transportation industry through collaboration with government and non-profit organizations.

Formal metrics to measure technology transfer goals include successfully demonstrated proof-of-concept; number of technical reports published; number of relevant papers published through peer-reviewed journals; number of relevant papers published in conferences, symposia, workshops, and meetings; number of technologies deployed in transportation applications through pilot or demonstration studies; number of research deliverables disseminated; number of webinars given; number of instances of technology adoption by Industry or transportation agencies and of commercialization; and, number of instances of research changing Industry or transportation agency practices, decision making, or policies.

As part of TIDC's Technology Transfer Plan (dated November 30, 2018) the following technology transfer goals and performance measures were established:

Table 2: Technology Transfer Goals & Performance Measures

Goal	Performance Metrics
Output: Development of new technologies, techniques, or methodologies	Successfully demonstrate proof-of-concept
Output: Publishing journal, conference and policy papers that become references for practitioners for the modification of codes and standards for technology adoption	Number of technical reports published
	Number of relevant papers published through peer-reviewed journals
	Number of relevant papers published in conferences, symposia, workshops, and meetings
Outcome: Deployment of new technologies, techniques, or practices	Number of technologies deployed in transportation application through pilot or demonstration studies
Outcome: Improvements in the processes, technologies, and techniques in addressing transportation issues	Number of research deliverables disseminated
Impact: Workforce development	Number of webinars given
Impact: Adoption of technologies, techniques, or practices	Number of instances of technology adoption by industry or transportation agencies and of commercialization
Impact: Development or modification of codes and standards to facilitate wider technology adoption	Number of instances of research changing industry or transportation agency practices, decision making, or policies

Collaboration

Institutional leads will serve on the TIDC Management Team which will help to ensure each institution has ownership and is committed to the success of the program. Additionally, in an effort to ensure all TIDC research projects are relevant to Department of Transportation and/or Industry needs, each TIDC research project has a Technical Champion. The Technical Champion has subject

matter expertise and serves as a resource for the principal investigators. The Technical Champion will help integrate the research results into DOT or Industry practice and will help with the implementation or project results during and after the research. Technical Champions on each project are providing in-kind support and are not monetarily compensated for the time they spend working with the principal investigators. As more projects are added and advanced, the number of Technical Champions and their contributions will change. See table 5 on page 10 for a complete list of Technical Champions.

To ensure the successful selection and implementation of relevant research projects, TIDC has assembled an Advisory Board. The role of the Advisory Board is to ensure TIDC continues to meet the needs and challenges of Region 1 within its designated Fast Act topic. The Advisory Board evaluates and recommends the disbursement of competitive funding through an open RFP process to support additional activities at member universities. The Advisory Board also reviews TIDC's annual performance metrics from each member university to determine the status of performance based base funded projects. The Advisory Board is currently comprised of members from state DOTs in Region 1.

Formal metrics to measure collaboration goals include presentations given at non-member universities, documented conversations regarding collaboration between TIDC and other UTCs, the number of industrial partners and state DOTs participating in TIDC research, dollar amount of state DOT and industry invested into TIDC research projects, number of technical champions actively involved in TIDC research projects, and number of outside attendees to the TIDC Annual Conference.

b. What was accomplished under these goals?

Research

In order to ensure TIDC is conducting relevant and transferable research projects, individual projects are required to submit periodic reports to ensure the approved goals and objectives of each research project are being met and are working toward TIDC's mission and research goals. During this reporting period, TIDC has 30 projects that were active during the reporting period. An additional 10 were selected during the reporting period and will begin work in the next reporting period. See Table 3 for a list of all TIDC funded research projects that were active and selected during the reporting period.

Table 3: TIDC Projects Active During the Reporting Period

Project Number & Title Institution	Institution(s)	Start Date
Thrust Area 1: Transportation Infrastructure Monitoring and Assessment of Enhanced Life		
1.2 – Condition/Health Monitoring of Railroad Bridges for Structural Safety, Integrity, and Durability	University of Connecticut	10/1/2018
1.4 – Electromagnetic Detection and Identification of Concrete Cracking in Highway Bridges	University of Massachusetts Lowell	1/1/2019
1.5 – Distributed Fiber Optic Sensing System for Bridge Monitoring	University of Massachusetts Lowell	1/1/2019
1.6 – Progressive Fault Identification and Prognosis of Railway Tracks Based on Intelligent Inference	University of Connecticut	10/1/2018

1.8 – Enhancing Intelligent Compaction with Passive Wireless Sensors	University of Vermont	7/1/2018
1.11 – Energy Harvesting and Advanced Technologies for Enhanced Life	University of Rhode Island	7/1/2018
1.12 – Improved UAV-Based Structural Inspection Techniques & Technologies for Northeast Bridges	University of Maine	10/1/2020
C3.2018 – Condition Assessment of Corroded Prestressed Concrete Bridge Girders	University of Massachusetts Lowell & Western New England University	1/1/2019
C5.2018 – Leveraging High-Resolution LiDAR and Stream Geomorphic Assessment Datasets to Expand Regional Hydraulic Geometry Curves for Vermont: A Blue Print for New England States	University of Vermont	6/1/2019
C11.2019 – Development of System-Level Distributed Sensing Technique for Long-Term Monitoring of Concrete and Composite Bridges	University of Massachusetts Lowell, University of Vermont, University of Maine	10/1/2020
C19.2020 – Damage Modeling, Monitoring, and Assessment of Bridge Scour and Water Borne Debris Effect for Enhanced Structural Life	University of Connecticut	10/1/2020
C20.2020 – Advanced Sensing Technologies for Practical UAV-Based Condition Assessment	University of Maine	10/1/2020
Thrust Area 2: New Materials for Longevity and Constructability		
2.1 – Asphalt Mixtures with Crumb Rubber Modifier for Longevity and Environment	University of Rhode Island	7/1/2018
2.2 – Concrete Systems for a 100-Year Design Life	University of Maine	3/1/2020
2.3 – Avalanche study of the fiber-reinforced cementitious composites	University of Vermont	7/1/2020
2.4 – Thermoplastic Composites by 3D Printing and Automated Manufacturing	University of Maine	1/1/2019
2.5 – Development and testing of High/Ultra-High Early Strength Concrete for Durable Bridge Components and Connections	University of Connecticut	10/1/2018
2.7 – High Performance Concrete with Post-Tensioning Shrinking Fibers	University of Vermont	1/1/2019
2.9 – Carbonating Subgrade Materials for In Situ Soil Stabilization	University of Maine	9/1/2018
2.10 – Durability Evaluation of Carbon Fiber Composite Strands in Highway Bridges	University of Maine	6/1/2019
2.11 – Culvert Rehabilitation Using 3D Printed Diffusers	University of Maine	7/1/2020
2.12 – Evaluation of Processed Glass Aggregate for Utilization in Transportation Projects as a Sand Borrow	University of Vermont	10/1/2020
2.13 – Performance Structural Concrete Optimized for Cost, Durability, and Manufacturability	University of Vermont	10/1/2020

C7.2018 – Alternative Cementitious Materials (ACMs) For Durable and Sustainable Transportation Infrastructures	University of Maine	6/1/2019
Thrust Area 3: New Systems for Longevity and Constructability		
3.4 – Testing, Monitoring, and Analysis of FRP Girder Bridge with Concrete Deck	University of Maine	3/1/2019
3.5 – Prevention of Stressed-Induced Failures of Prestressed Concrete Crossties of the Railroad Track Structure	Western New England University	9/1/2018
3.6 – Optimal Design of Sustainable Asphalt Mixtures with RAP	University of Rhode Island	7/1/2018
3.7 – Development of General Guidelines on the Effects of Bridge Span Range and Skew Angle Range on Integral Abutment Bridges (IAB's)	University of Massachusetts Lowell	7/1/2018
3.8 – Bridge Modal Identification via Video Processing and Quantification of Uncertainties	University of Massachusetts Lowell	11/1/2018
3.10 – Assessment and Optimization of Double CT Bridge Girder Sections with Longitudinal Precast Decks	University of Maine	7/1/2020
3.11 – Assessment of Micropile-Supported Integral Abutment Bridges	University of Maine	9/1/2019
3.12 – Lateral Loading of Unreinforced Rigid Elements and Basal Stability of Column-Supported Systems	University of Maine	6/1/2019
3.13 – Investigating the Effectiveness of Enzymatic Stabilizers for Reclaimed Stabilized Base Products	University of Vermont	10/1/2020
3.14 – FRP-Concrete Hybrid Composite Girder Systems: Web Shear Strength and Design Guide Development	University of Maine	10/1/2020
C9.2019 – A New Method for Determining Payment for In-Pace Concrete with Double-Bounded Compressive Strength Pay Factors	University of Vermont	10/1/2020
C17.2020 – Durability of Modified Helical Piles under Lateral and Torsional Loads: Embracing Efficient Foundation Alternative to Support Lightweight Transportation Structures	University of Maine & University of Rhode Island	10/1/2020
Thrust Area 4: Connectivity for Enhanced Asset and Performance Management		
4.1 – Highly Automated Vehicles and Bridge Infrastructure	University of Maine	9/1/2018
4.2 – Future-Proof Transportation Infrastructure through Proactive, Intelligent, and Public-involved Planning and Management	University of Connecticut	10/1/2018
4.3 – Towards Quantitative Cybersecurity Risk Assessment in Transportation Infrastructure	University of Connecticut	10/1/2018
4.4 – Bridge-stream Network Assessments to Identify Sensitive Structural, Hydraulic, and Landscape Parameters for Planning Flood Mitigation	University of Vermont	7/1/2018
4.7 – Integrated Green Infrastructure and Sustainable Transportation Planning	University of Rhode Island	7/1/2018
4.9 – Analysis of Covid-19 and Travel In Maine (ACTIME) – Validation Study	University of Maine	8/1/2020
4.10 – Road Salt Impact Assessment	University of Maine	8/15/2020

Due to the impact of COVID-19 on the member universities, many researchers were unable to access their labs, conduct field tests, or install equipment/technologies as planned during the reporting period. Some projects were able to achieve/meet goals when labs began reopening in the end of July through September, depending on the university. The following are a few examples of accomplishments achieved under individual research projects. More TIDC research accomplishments can be found in sections III and IV of this report and on the TIDC website on each research project's individual page.

Project 1.2 (UConn): The finite-element model has been created to facilitate an effective field test on the Devon Bridge and to optimize sensor placement.

Project 1.5 (UMass Lowell): A sensor developed in partnership with Saint-Gobain was deployed and tested on a railroad bridge in New Hampshire.

Project 3.12 (UMaine): Dr. Gallant and his Graduate Student, Danilo Botero-Lopez were awarded 1st place for their paper submission in the Deep Foundations Institute Educational Trust's 2020 Young Professor Paper Competition. The journal article has been submitted and is under review for publication in the *DFI Journal*.

Project C11.2020 (UMass Lowell, UVM, & UMaine): In preparation for sensor installation into the CT Girders being installed in Hampden, ME, sensing textiles comprised of optical fibers, strain gauges, and fabrics were completed and rolled up into spools for transportation; two installation cart were designed and manufactured; and the team of researchers and students practiced the installation process on an 8-ft long 1:1 scale mock-up of the bridge girder.

Additionally, in August & September 2020, TIDC selected 9 new base-funded research projects, approved phase II of 3 current research projects, and 3 competitively funded research projects. Emails were sent to the PIs for each selected research project.

Education & Workforce Development

The TIDC Program Coordinator has completed the creation of the curriculum to be turned into an approved 4-H STEM toolkit. While existing 4-H STEM Toolkits provide an experiential science learning opportunity for youth by providing materials needed to successfully complete science-based activities, TIDC's transportation related toolkit will be used to encourage youth to learn more about the transportation industry. The curriculum was scheduled to be piloted beginning in February and March of 2020 in four classrooms at an elementary school in Orono, ME. After the completion of the pilot, TIDC Administration at UMaine was to meet with the elementary school teachers to receive feedback and make recommended adjustments to the curriculum before releasing the curriculum to the rest of the school and additional elementary schools in the State of Maine. The goal was to have a completed curriculum to be implemented throughout all of the classroom in this elementary school and to add 3 more elementary schools to that list for the fall of 2020. Unfortunately, due to the closing of schools for the remainder of the 2019-2020 school year in response to the COVID-19 pandemic, the curriculum implementation has been tentatively rescheduled for spring 2021 with further school involvements planned for spring 2021. It is TIDC's goal to receive final approval in the spring of 2022 for an official 4-H toolkit that can be distributed to schools in the state of Maine and other 4-H participating states in Region 1.

Additionally, in an effort to meet the goals of TIDC and the US DOT to encourage more individuals to join transportation related fields, member universities will be offering internship opportunities to high school students. Unfortunately, due to the COVID-19 pandemic, member universities were unable to provide high school students with internship opportunities, as planned.

Student researchers at member universities have been disseminating research findings through poster presentations, seminars, and conferences. Students have also participated in webinars and professional development opportunities. For example, a student researcher at UVM attended the FHWA Advanced Sensing Technology (FAST) NDE Webinar Series – FHWA Mobile Concrete Laboratory on July 27, 2020. TIDC faculty taught 16 undergraduate courses and 17 graduate courses during the reporting period.

Technology Transfer

TIDC research results have been disseminated through a variety of ways including the TIDC website and social media platforms.

TIDC researchers have participated in 8 conferences, workshops, and/or seminars during the reporting period. The following table indicates the conferences and workshops attended by TIDC researchers and the activity they conducted to disseminate information during this reporting period.

Table 4: Conferences, Workshops, and Seminars

Name of Conference/Workshop	Activity	Location	Dates
2020 SPIE Smart Structures & NDE Conference	Presentation	Virtual	4/23/2020
2020 TIDC Annual Conference	13 Presentations by TIDC researchers and 2 keynotes speakers	Virtual	8/12/2020
2020 TIDC Student Poster Contest	18 posters and video presentations submitted by Graduate students	Virtually hosted on TIDC Website	Submissions due 9/30/2020. Presentations hosted on TIDC website beginning 10/5/2020
2020 VTrans Research and Innovation Symposium	4 TIDC researchers presented their findings	Virtual	9/9/2020
IEEE International Conference on Industrial Cyber-Physical Systems (ICPS 2020)	Conference Presentation	Virtual	6/10/2020
MaineDOT Presentation of *Behavior of Skewed Integral Abutment Bridges Under Thermal Loading* (UMass Lowell Project 3.7)	Seminar	Virtual	8/3/2020
Northeastern Society for Experimental Mechanics Conference	Conference Presentation	UMass Dartmouth	4/18/2020
UVM Civil & Environmental Engineering Graduate Student Seminar	Presentation	Virtual	4/18/2020

Additionally, TIDC has published or submitted 5 journal papers/articles, 5 conference papers, 18 conference abstracts, and 20 other publications and has held 4 other presentations during the reporting period. For a complete list of the submitted papers, please see Section III, Outputs.

Collaboration

Critical to TIDC's success is the development of partnerships and collaborations with state DOT's, the transportation industry, transportation professionals, and various stakeholders that assist in addressing the center goals.

During this reporting period, the TIDC Management Team met each month, with the exception of August & September, for a total of four meetings. All four meetings were held via Zoom. The Semi-Annual in person meeting was unable to happen in conjunction with the TIDC Annual Conference due to COVID travel restrictions. The Advisory Board held a virtual meeting, during which, Advisory Board members discussed recommendations for the project selection process for the 2020 Base-funded and Competitive funded solicitation and the research needs of their states.

Equally as important to the collaboration with the TIDC Advisory Board and the inter-institutional collaboration is the collaboration that happens with the Technical Champions (TC), industry partners, and State DOT (including maintenance and operations) collaborators. All TIDC funded projects have met the goal of having a Technical Champion (as described in Section I a, Collaboration) assigned to each. Some research projects have additional Technical Champions and Advisors involved in their projects. Each PI is responsible for submitting their quarterly reports to their TC and working with them to ensure their research with have the greatest impact on the transportation industry. In addition to sending their reports to the TC, PIs from multiple projects are meeting with their TC to discuss and adapt their research.
Additionally, TIDC is actively working with industry partners during their research efforts. For example, the research team for Project 3.4 (UMaine) met with AIT Bridges engineers on design details and provided feedback on design assumptions and manufacturing procedures that have been employed by AIT. These meetings and collaborative efforts help ensure the commercialized and future accepted use of new technologies being developed by the Center. More collaborations and stakeholders are identified in table 5 below.

The following table identifies the 34 active Technical Champions and Advisors involved in TIDC research projects during this reporting period. (* Indicates newly added Technical Champions and Advisors during this reporting period.)

Table 6: Active Technical Champions & Advisors

Name and Title of Technical Champion or Advisor	Organization
Andrew Bardow, Director, Bridges and Structures	Massachusetts Department of Transportation
Mary Baker, Transportation Principal Engineer	Connecticut Department of Transportation
Raymond Basar,	Connecticut Department of Transportation
Warren Best, Assistant Deputy Director, Structures	Metro-North Railroad Company
Tanner Blackburn, Chief Geotechnical Engineer*	Hayward Baker
Peter J. Calcaterra, Transportation Planner*	Connecticut Department of Transportation
Steven Cascione, Programming Services Officer	Rhode Island Department of Transportation
Henry Chango, Contract Administrator	D'Ambra Construction Company, Inc.
Bao Chuong,	Connecticut Department of Transportation
Brian Clang, Bridge Inspection Engineer	Massachusetts Department of Transportation
Cassidy Cote, Hydraulics and Structures Engineer	Vermont Agency of Transportation
Haresh Dholakia, Transportation Engineering Supervisor	Connecticut Department of Transportation
Manesh Dodia, Transportation Engineer	Connecticut Department of Transportation
Callie Ewald, P.E., Geotechnical Engineering Manager	Vermont Agency of Transportation
Karen Gross, Geotechnical Engineer	Maine Department of Transportation
Joshua Hasbrouck, Civil Engineer, Bridge Program	Maine Department of Transportation

Dr. Wilfred Hernandez, P.E., Safety Specialist/EDC Coordinator	Federal Highway Administration – Rhode Island Division
Dr. Mark Jen, P.E., S.E., Technical Manager*	Michael Baker Engineering, Inc.
Garrett Kilfoyle, Assistant Engineer, Bridge Maintenance	Maine Department of Transportation
Brandon Kipp, Project Manager, Pavement Management Section	Vermont Agency of Transportation
John Kocur, Director of Engineering	Sperry Rail Service
Laura Krusinski, Senior Geotechnical Engineer	Maine Department of Transportation
James Lacroix, P.E., State Bridge Design Engineer	Vermont Agency of Transportation
Dr. Dongsheng Li, President*	Advanced Manufacturing LLC
John Moran, Deputy Chief of Performance and Asser Management, Director of Asset Management	Massachusetts Department of Transportation
Sam Maxim, Bridge Maintenance Engineer	Maine Department of Transportation
Andrew Mrockowski, Transportation Engineer	Connecticut Department of Transportation
Dale Peabody, Director, Transportation Research	Maine Department of Transportation
Paul C. Petsching, P.E., Senior Civil Engineer	Rhode Island Department of Transportation
Michael Redman, Business Systems Manager, Concrete Quality Control Specialist, Bridge Program	Maine Department of Transportation
Karen Riemer, Asset Management Group	Connecticut Department of Transportation
Aaron Schwartz, Hot Mix Asphalt Engineer	Vermont Agency of Transportation
Rite L. Seraderian, P.E., FPCI, LEED AP, Executive Director	Precast/Prestressed Concrete Institute Northeast
Joseph Stilwell, Fabrication Engineer*	Maine Department of Transportation
Ken Sweeney, President*	AIT Bridges
Nick Ward, P.E., Hydraulics Engineer, Project Delivery Bureau, Structures	Vermont Agency of Transportation
James Wild, Concrete Materials Manager	Vermont Agency of Transportation
Dr. Kathleen Wilson, P.E., Chief Civil Engineer	Rhode Island Department of Transportation
Mark Woolander, Pavement Engineer	Vermont Agency of Transportation
Hailing Yu, Civil Engineer	U.S. DOT Volpe Center

The following table identifies the 30 active collaborations and stakeholders and their contributions during the reporting period. (* indicates new project collaborators during this period)

Table 5: Research Project Collaborators

Organization	Location	Contribution
AIT Bridges, a division of Advanced Infrastructure Technologies	Orono, ME	In-kind, collaborative research, personnel, facilities
Amtrak	Philadelphia, PA	Collaborative research, personnel
Argonne National Laboratory	Lemont, IL	Collaborative research, personnel
City of Lowell	Lowell, MA	Collaborative research, facilities, personnel
Connecticut Department of Transportation	Newington, CT	Collaborative research, personnel
Connecticut Manufacturing Simulation Center	Storrs, CT	In-kind, facilities
Deep Foundations Institute	Hawthorne, NJ	Financial
Intergraph Corporation	Madison, AL	In-kind

Jacobs Engineering	Herndon, VA	In-kind
Maine Department of Transportation	Augusta, ME	In-kind, collaborative research, financial, personnel, equipment
Massachusetts Department of Transportation	Boston, MA	Collaborative research, personnel
Metro-North Railroad Company	Bridgeport, CT	Collaborative research, facilities, personnel
National Center for Supercomputing Applications	Urbana, IL	In-kind
New Hampshire Department of Transportation	Concord, NH	Collaborative research, personnel
Oak Ridge National Laboratory	Oak Ridge, TN	In-kind, collaborative research, personnel, facilities
Precast/Prestressed Concrete Institute Northeast (PCINE)	CT, MA, ME, NH, NY, RI, VT	Collaborative research, personnel
Rhode Island Department of Transportation	Providence, RI	Collaborative research, personnel
Saint-Gobain	Northborough, MA	In-kind
Sperry Rail Service	Shelton, CT	Collaborative research, in-kind, facilities, personnel
Superior Concrete	Auburn, ME	Financial, facilities, collaborative research
Texas Advanced Computing Center	Austin, TX	Facilities
The Nature Conservancy of Vermont	Montpelier, VT	Collaborative research, personnel
University of Connecticut	Storrs, CT	In-kind, collaborative research, personnel, facilities, financial
University of Maine	Orono, ME	In-kind, collaborative research, personnel, facilities, financial
University of Massachusetts Lowell	Lowell, MA	In-kind, collaborative research, personnel, facilities, financial
University of Rhode Island	Kingston, RI	In-kind, collaborative research, personnel, facilities, financial
University of Vermont	Burlington, VT	In-kind, collaborative research, personnel, facilities, financial
Vermont Agency of Transportation	Montpelier, VT	In-kind, collaborative research, personnel, financial
Vermont Technical College*	Randolph Center, VT	Facilities, collaborative research, personnel
Western New England University	Springfield, MA	In-kind, collaborative research, personnel, facilities, financial

c. How have the results been disseminated?

Research results have been disseminated in a variety of ways throughout this reporting period. Research results are provided on each project's page on the TIDC Website through quarterly progress reports are available at https://www.tidc-utc.org/research/tidc-funded-projects-and-reports/. Information was shared at conference presentations, including the 2020 TIDC Annual Conference held virtually in August 2020 (see table 4 on page 8 for a complete list of Conferences and Workshops). Further results were disseminated

through journal articles, professional magazines, and meetings with New England State DOTs. Additionally, research findings are being disseminated in undergraduate and graduate courses at each university.

d. What do you plan to do during the next reporting period to accomplish the goals?

Research

TIDC will continue to start new, high impact, relevant, and innovative research projects. During the next reporting period, the 2021 Request for Proposals will be released to the member Universities and the awards are estimated to be announced in July 2020. The performance of current research projects will continue to be evaluated against the mission, goals, and objectives of TIDC. Some of the goals for TIDC funded projects are as follows:

Project 1.5 (UMass Lowell): The research team will continue to work in partnership with Saint-Gobain and NHDOT to monitoring the deployed sensors installed on the railroad bridge in New Hampshire. Additionally, the team will continue to develop the temperature compensation process and improve the signal analysis mechanism.

Project 2.4 (UMaine): The research team plans to manufacture a scale-down prototype of the pier cap formwork. This plan is dependent upon the availability of the large-scale 3D printer in the Advanced Structures and Composites Center at UMaine.

Project 3.4 (UMaine): Installation of the first Composite Tub (CT) Girder bridge system is planned for November 2020 in Hampden, Maine. The research team will observe and monitor the mobilization of the CT Girders for construction and will be on-site to observe their installation. The team is working with Dr. Yu at UMass Lowell to install sensors before the installation on the bridge to ensure continuous monitoring of the CT Girders from the date of installation. Installation of these sensors is planned for October 2020. After the installation of the girders and the completion of the bridge's construction, live-load testing is planned before the bridge is open for the public.

Education & Workforce Development

TIDC personnel at UMaine have created a partnership with a local elementary school to begin the process of implementing transportation related activities into their curriculum. The pilot of the activities has been delayed again due to COVID. The team is working to created virtual kits that can be sent to students working remotely. TIDC personnel is also working with the Challenger Learning Center of Maine in collaboration with the YMCA to provide these virtual kits to students utilizing their facilities during remote learning days. It is anticipated that the kits will be ready for use by January 2021.

TIDC personnel at UMaine are also working to create better partnerships with MaineDOT departments (including the HR, training, operations, and maintenance departments), industry leaders in Maine, and Maine Community Colleges to create more opportunities for workforce development in the state and beyond. A forum for collaboration is planned for spring 2021. The goal of this forum is to allow TIDC personnel and researchers to better understand the needs of DOTs and industry in regards to workforce development. Focus will be placed on infrastructure durability needs to match with the goals and objectives of TIDC.

TIDC faculty and principal investigators will continue to work with students on their research projects and add new students to replace those who have graduated. Additionally, research findings will continue to be disseminated in university classrooms and curriculum will be updated as new findings are presented.

Technology Transfer

To accomplish TIDC's technology transfer objectives identified in Section I. a., Technology Transfer (pg. 2), the following venues and mechanisms will be employed: (1) a TIDC website and social media accounts that promote findings and opportunities for collaboration directly to the public; (2) widely disseminated, online TIDC bi-annual newsletters to begin in 2021; (3) the expansion of the 2021 TIDC Annual Conference on July 208-29, 2021 through early advertising and outreach activities in New England; (4) continued participation in regional transportation conferences (i.e. the Maine Transportation Conference hosted by the Maine DOT, the Rhode Island Transportation Conference hosted by URI, and others as appropriate); (5) a webinar series focused on sharing findings and engaging with industry professionals is scheduled to begin in 2021; and (6) promotion of all market-ready technology transfer opportunities through industry/trade publications, the TIDC website and social media accounts.

TIDC will continue to update the Center website and social media accounts to inform the public of TIDC activities, workshops, and research. Publications and papers will be submitted for conferences and publication in journals. TIDC principal investigators will attend conferences and workshops to disseminate research findings.

Collaboration

Principal Investigators and TIDC Management team members will continue to collaborate with state DOT representatives. All TIDC projects will continue to be supported by at least one Technical Champion (as described in Section I c – collaboration). Projects are encouraged to seek support from additional technical advisors in DOTs, government agencies, and industry leaders. These additional partnerships will increase the applicability of TIDC's research findings and create more opportunities for the adoption of findings in the region and beyond. Monthly management team meetings will continue and the Program Manager will visit each member university on a quarterly basis, once travel restrictions have been lifted. Additionally, the TIDC Management Team and the TIDC Advisory Board will be meeting in January/February 2021 to discuss the TIDC program and the expansion efforts for greater success. Also, to help with the goal of expanding the next TIDC Annual Conference for more collaboration opportunities, the dates and location for the 2021 conference have been selected (July 28-29, 2021 at UMaine with a hybrid model planned to allow for greater collaboration and attendance within the region).

II. PARTICIPANTS & COLLABORATING ORGANIZATIONS

a. What individuals have worked on the project?

In total, 43 principal investigators, faculty, administrators, and management team members and 75 students participated in TIDC research projects during the reporting period. As the projects progress, more student researchers will be added. All TIDC participants who were active during the reporting period are listed in the table below. (* Indicates students who graduated and received their degree during the reporting period.)

Table 7: Active Principal Investigators, faculty, administrators, students, and Management Team Members

Institution	Principal Investigators, Faculty, Administrators, and Management Team Members	Students
University of Maine	Dr. Habib Dagher, James Anderson, Dr. Warda Ashraf, Kathryn Ballingall, Dr. Keith Berube, James R. Bryce, Amanda Collamore, Dr. Bill Davids,	Madison Ala, Danilo Botero-Lopez, Sunil Bhandari, Justin Harris, Jeffrey Hollstien, SK Belal Hossen, Braedon Kohler, Sebastian Montoya, Luke Peabody*,

University of Maine	Dr. Aaron Gallant, Dr. Douglas Gardner, Dr. Andrew Goupee, Dr. Yousoo Han, Dr. Hosain Haddad Kolour, Dr. Eric Landis, Dr. Roberto Lopez-Anido, Vu Phan, and Dr. Jonathan Rubin.	Andrew Schanck, Parry Seddiqi, Kelsey Weir, and Ryan Worster.
University of Connecticut	Dr. Ramesh Malla, Dr. Jiong Tang, Dr. Kay Wille, Dr. Jin Zhu, and Dr. Song Han	Areej Althubaity, Omar Badawi, Ethan Beattie, Chris Boisvert-Cotulio, Alexander Biron*, Mark Castaldi*, Sudipta Chowdhury, Cydney Alexis Delarosa, Celso de Oliveira, Suvash Dhakal, Alex Distelman, Douglas Hendrix, David Jacobs, Salaah Dean Kanaan, Bradley Kelle, Seerut Mir, Paul Mooh Mooh Sr., Meghan Palumbo*, Dominic Parciasepe, Kelly Quinn*, Bijaya Rai, Zheng Ren, Jeet Rosa, Sachin Tripathi, Jason Trieu, Corey Walker, Jiachen Wang, Peng Wu, Yixin Yao, and Yang Zhang.
University of Massachusetts Lowell	Dr. Tzuyang Yu, Dr. Xingwei Wang, Dr. Susan Faraji, and Dr. Zhu Mao	Ahmed Alzeyadi*, Ronan Bates, Andres M. Biondi Vaccariello, Lidan Cao, Celso do Cabo, Harsh Gandhi, Xu Guo*, Jade Man, Nashire Peralta, Matt Southwick, Nick Valente, Sanjana Vinayaka, Jianing Wang, and Rui Wu.
University of Rhode Island	Dr. K. Wayne Lee, Dr. Michael Greenfield, Dr. Sze Yang, Dr. George Veyera, Dr. Natacha Thomas, Dr. Christopher Hunter, and Dr. Farhad Atash	Austin DeCotis*, Mason Hyde*, Ali Sahraei Joubani, Nick Marchetti, and Stephan Zaets.
University of Vermont	Dr. Mandar Dewoolkar, Dr. Ehsan Ghazanfari, Dr. Ting Tan, Dr. Dryver Huston, Dr. Donna Rizzo, Dr. Arne Bomblies, Dr. Hamid Ossareh, and Dr. Kristen Underwood	Maziar Foroutan, Ahmad Ghazanfari, Diarmuid Gregory, Zhuang Liu, Sienna Roberge*, and Rachel Seigel
Western New England University	Dr. Moochul Shin and Dr. ChangHoon Lee	Cameron Cox*, Abdoulaye Diallo*, Andrew Masullo, Nicholas Pantorno, Tiana Robinson, Georgii Tifaniuk, and Caleb Tourtelotte*.

b. What organizations have been involved as partners?

During the process of selecting research projects, TIDC has received commitments of support and matching funds from 47 collaborators during this reporting period. The type of support provided by the collaborators varies from in-kind, financial, equipment, to supplies. In addition, many collaborators provide direct personnel links in research through Technical Champions (see below for further information). See table 5 on page 10 and table 6 on page 11 for an overview of the collaborators on TIDC research projects and what they have contributed.

c. Have other collaborators or contacts been involved?

The University of Vermont's Physics department has provided equipment for testing.

III. OUTPUTS

a. Publications, conference papers, and presentations:

The following table includes a list of the accepted and submitted papers and reports and presentations given during the reporting period:

Table 8: Publications, Conference Papers, and Presentations

Type	Title	Citation	Date	Status
Conference Abstracts & Presentations	2020 TIDC Annual Conference	18 research abstracts were submitted and accepted, All 18 projects presented via a pre-recorded video presentation followed by a live Q&A.	8/2/2020	Presented
Conference Paper	Large Scale 3D printed thermoplastic composite forms for precast concrete	Sunil Bhandari, Roberto A. Lopez-Anido and James Anderson, ITHEC 2020, 5th International Conference on Thermoplastic Composites, Virtual October 13-14, 2020	6/30/2020	Published
Conference Paper	Structural Damage Identification Using Multi-Objective Optimization Based Inverse Analysis	Zhang, Yang; Tang J., "Structural Damage Identification Using Multi-Objective Optimization Based Inverse Analysis." Proceedings of SPIE, Vol. 11380, id 113800D 6 pp. May 2020. DOI: 10.1117/12.2558982	5/1/2020	Published
Conference Paper	Motion Magnifications for Optical-Based Structural Health Monitoring	https://www.spie.org/SS20/conferencedetails/health-monitoring-structural-biological-systems	4/27/2020 - 4/30/2020	Submitted
Conference Paper	Detecting Rules-Related Attacks in RPL-based Resource-Constrained Wireless Networks	Areej Althubaity, Reda Ammar, Song Han, "Detecting Rules-Related Attacks in RPL-based Resource-Constrained Wireless Networks." submitted to IEEE International Symposium on Signal Processing and Information Technology (ISSPIT), 2020.	9/26/2020	Submitted
Conference Paper	Tensile Test and Stress-Strain Behavior from a more than Century Old Railroad Bridge	de Oliveira, C., Tripathi, S., Castaldi, M., and Malla, R., "Tensile Test and Stress-Strain Behavior from a more than Century Old Railroad Bridge." 2021 TRB Annual Conference.	8/30/2020	Accepted
Conference Presentation	Structural Damage Identification using Multi-Objective Optimization based Inverse Analysis	Tang, J. Structural Damage Identification using Multi-Objective Optimization based Inverse Analysis. 2020 SPIE Smart Structures & NDE Conference	4/23/2020	Presented

Symposium Presentation	2020 VTrans Research and Innovation Symposium	4 TIDC projects presented their findings.	9/9/2020	Presented
Conference Presentation	Specification-based Detection of Rank-related Attacks in RPL-based Resource-Constrained Real-Time Wireless Networks	Han, S. Specification-based Detection of Rank-related Attacks in RPL-based Resource-Constrained Real-Time Wireless Networks. IEEE International Conference on Industrial Cyber-Physical Systems (ICPS 2020)	6/10/2020	Presented
Conference Presentation	Large scale 3D printed thermoplastic composite forms for precast concrete structures	Lopez-Anido, R.A., Large scale 3D printed thermoplastic composite forms for precast concrete structures. ITHEC 2020 - 5th International Conference & Exhibition on Thermoplastic Composites	9/1/2020	Submitted
Conference Presentation	Bridge Modal Identification via Video Processing Motion Magnification	Mao, Z. Bridge Modal Identification via Video Processing Motion Magnification. Northeastern Society for Experimental Mechanics Conference	4/18/2020	Presented

Additionally, all TIDC projects were presented in April 2020 for the first round of quarterly presentations. In addition to researchers and TIDC Advisory Board members, PIs invited guests from outside collaborators. Quarterly presentation were placed on hold due to COVID-19 until the first Quarter in 2021.

b. Journal publications:

The following table includes a list of two TIDC journal publications and their status during the reporting period:

Table 9: Journal Articles and Publications

Title	Citation	Date	Status
Avalanches during flexure of early-age steel fiber reinforced concrete beams	Liu, Zhuang & Worley, Robert & Du, Fen & Giles, Courtney & Dewoolkar, Mandar & Huston, Dryver & Tan, Ting. (2020). Avalanches during flexure of early-age steel fiber reinforced concrete beams. Materials and Structures. 53. 10.1617/s11527-020-01520-w.	8/1/2020	Published
Discrete Event Simulation Thermal Model for Extrusion-Based Additive Manufacturing of PLA and ABS	Bhandari, S., Lopez-Anido, R.A., and Anderson, J., ITHEC 2020, 5th International Conference on Thermoplastic Composites, Virtual, Emerging Technologies III: 3D Printing - 5, pp 182-187, October 13-15, 2020 https://ithec.de/	9/30/2020	Under Review
On the Basal Stability of Embankments Supported on Fractured Unreinforced Rigid Columns over Soft Soils	Gallant, A.P., Botero-Lopez, D. (2020) "On the Basal Stability of Embankments Supported on Fractured Unreinforced Rigid Columns over Soft Soils." DFI Journal.	8/1/2020	Submitted
Live-Load Response of Eyebars on a 110-year-old Steel Truss Railroad Bridge	Jacobs, D.W., Dhakal, S., and Malla, R. B., "Live Load Response of Eyebars on a 110-year-old Railroad Bridge." ASCE Practice Periodical on Structural Design and Construction.	9/1/2020	Published

Interrelation of Morphological Indices and 2-D Generalized Regularity for Coarse Aggregate in Cement-Based Materials	C.H. Lee, S.J. Lee, M. Shin, and S. Bhattacharya, "Interrelation of Morphological Indices and 2-D Generalized Regularity for Coarse Aggregate in Cement-Based Materials," Construction and Building Materials, 2020	8/10/2020	Published

c. Books or other non-periodical, one-time publications:

Nothing to Report

d. Other publications, conference papers, and presentations:

The following table includes a list of the articles and presentations that falls within the other publications, conference papers, and presentations section during the reporting period:

Table 10: Other Publications and Presentations

Type	Title	Citation/Description	Date	Status
Posters & Presentations	2020 TIDC Student Poster Contest	18 Posters and presentations were submitted and accepted by TIDC for presentation in October 2020	9/30/2020	Accepted
Master's Project Report	Temporal Stream Gauge Analysis for Clustering Watersheds In and Around Vermont	Roberge, Sienna, 2020. Temporal Stream Gauge Analysis for Clustering Watersheds In and Around Vermont. Masters Project Report. University of Vermont	5/1/2020	Submitted
Master's Thesis Defense	Temporal Stream Analysis for Clustering Watersheds in and Around Vermont	Master's Thesis Defense Presentation	5/6/2020	Presented
Master's Project Report	Material Tensile Testing and Analysis of Very Old Steel Railroad Bridges for Health Assessment	Castaldi, M. (2020). Material Tensile Testing and Analysis of Very Old Steel Railroad Bridges for Health Assessment. Master's Project Report. University of Connecticut.	5/8/2020	Submitted
Master's Thesis Defense	Material Tensile Testing and Analysis of Very Old Steel Railroad Bridges for Heath Assessment	Master's Thesis Defense Presentation	5/8/2020	Presented
Webinar Presentation	Behavior of Skewed Integral Abutment Bridges Under Thermal Loading	Interactive presentation to MaineDOT.	8/3/2020	Presented
Presentation	Bridge-Stream Network Assessments to Identify Sensitive Structural, Hydraulic, and Landscape Parameters for Planning Flood Mitigation	Presentation given at the UVM Civil & Environmental Engineering Graduate Student Seminar	4/18/2020	Presented

e. Website(s) or other Internet site(s):

The following websites and social media sites are used to disseminate information about TIDC findings.
TIDC website: www.tidc-utc.org
Twitter: https://twitter.com/TIDCatUMaine
Facebook: https://www.facebook.com/TIDCatUMaine/
LinkedIn: https://www.linkedin.com/company/transportation-infrastructure-durability-center/
UMass Lowell's TIDC research page: https://www.uml.edu/Research/tidc/

f. Technologies or techniques:

Project 1.11 (URI): Students working on the project collaborated with RIDOT to install the solar apparatus and strain gauge sensor into the Plains Road at URI.

g. Inventions, patent applications, and/or licenses:

Nothing to report.

IV. OUTCOMES

The researcher working on project 1.1 (UMaine) completed work in December 2019. The resulting output was used to inform the MaineDOT Bridge Posting Committee about a specific bridge that was analyzed during the research efforts. This bridge has been removed from consideration for posting.

V. IMPACTS

a. What is the impact on the effectiveness of the transportation system?

Nothing to report.

b. What is the impact on the adoption of new practices, or instances where research outcomes have led to the initiation of a start-up company?

Nothing to report.

c. What is the impact on the body of scientific knowledge?

Nothing to report.

d. What is the impact on transportation workforce development?

Nothing to report.

VI. CHANGES/PROBLEMS

a. Changes in approach and reasons for change:

Nothing to report.

b. Actual or anticipated problems or delays and actions or plans to resolve them:

The impact of pandemic safeguards has had a significant effect on laboratory operations and field testing. Many labs are still not fully operational as campuses are holding most of their courses in a virtual/hybrid format. Much of the work conducted during this reporting period has been focused on tasks that can be completed remotely, with some lab and field work being allowed as states and universities slowly lift restrictions. Many research projects are behind schedule by 3-6 months. To help TIDC administration and PIs plan for the changes in the research schedules and timelines, a no-cost extension request template was sent to each PI so adjustments can be made to each project's schedule, if needed. TIDC Administration is in

the process of updating the TIDC website and the RiP database to reflect these changes. In order to compensate for the lab closure delays, TIDC has requested a no-cost extension from the USDOT.

c. Changes that have a significant impact on expenditures:

The impact of pandemic safeguards has had a significant effect on laboratory operations and field testing. TIDC is working to identify how these impacts have affected the financial status of the effected research projects and how to adjust budgets accordingly.

d. Significant changes in use or care of human subjects, vertebrate animals, and/or biohazards:

Nothing to report.

e. Change of primary performance site location from that originally proposed:

Nothing to report.

VII. SPECIAL REPORTING REQUIREMENTS

All TIDC projects are in compliance with Research Project Requirements (located in the Grant Deliverables and Reporting Requirements for 2016 and 2018 UTC Grants (Nov 2016, revised June 2018)) in regards to new research projects.