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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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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. An additional annual amount of $250,000 is available through an internal competitive RFP Process. The competitive RFP is released in conjunction with the base-funded RFP solicitation. The competitive project proposals are reviewed and scored by

the TIDC Advisory Board and other technical professionals. Upon completion of the review, the Advisory Board meets and provides their recommendation(s) for the selection of the competitive proposal(s). The TIDC administrative team (Center Director, Senior Program Manager, Grant and Fiscal Manage, Program Coordinator, and Advisory Board Chair) then reviews the recommendation(s) and makes the final selection of the successful proposal(s). A similar process is followed for the base-funded project selection.

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. In order to ensure successful implementation of research findings, each project's funding is also contingent on the commitment of a Technical Champion in implementing the potential findings of the work. See the Collaboration section on page 4 for more details about the role of the Technical Champion. Funding for research projects is also contingent upon collaboration with transportation organizations, including the region's DOTs and transportation companies.

Formal metrics to measure program effectiveness includes the number of new research initiatives/projects funded, number of continued base-funded research projects funded at member universities, number of research projects completed during the reporting period, number of active industrial and DOT partners involved in TIDC projects, dollar amount invested in TIDC research, and number of times findings have been implemented. Formal metrics under the research section overlap with metrics in other subsections.

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 underrepresented populations 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 STEAM education by sharing research with future members of the workforce in K-12 education settings. 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. TIDC will partner with industry members and non-profit education organizations like 4-H Cooperative Extensions and Jobs for Maine Grads (JMG) to bridge transportation related activities into schools, after-school programs, homeschooling cooperatives, and local libraries throughout New England. TIDC will also create an online resource guide, portfolio, and transportation-related curriculum and activities for educators to utilize in their classrooms. TIDC will work with the College of Education and Engineering Colleges at the partner universities to create opportunities for professional development (continuing education requirements) for educators to create a better understanding of how to incorporate engineering activities into already existing curriculum at school districts.

TIDC will implement a series of webinars, workshops, conference sessions, and symposiums to provide opportunities for current transportation professionals to receive training on new technologies and outputs from TIDC funded research projects to help current professionals implement the findings into practice. Certificates of attendance will be offered to all attendees to be used toward professional development hours for all training opportunities.

Formal metrics to measure program effectiveness includes the number of undergraduate and graduate students participating in industrial internships; number of presentations and poster sessions led by students; number of papers published by students; number of seminars, workshops, and conferences hosted by TIDC researchers; number of

presentations led by TIDC supported students; number of K-12 students who participate in transportation-focused tours or activities at member institutions; and total number of K-12 classrooms reached by TIDC personnel, students, and/or researchers, including specifics on classrooms populated by under-represented groups of students.

Technology Transfer

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 the four research thrust areas identified in Table 1.

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.

The technology transfer objectives of TIDC support the TIDC mission through their emphasis on research impact and dissemination. The TIDC goals and performance metrics reflect the full spectrum of research activities through technology concept inception and assessment to technology adoption. See Table 2: Technology Transfer Goals & Performance Measurers for the goals and performance metrics that TIDC-funded research projects are striving are striving to meet during the course of their work.

Table 2: Technology Transfer Goals & Performance Measures

Goal	Performance Metrics	Annual Target
Output: Develop new technologies, techniques, or methodologies	Number of successfully demonstrate proof-of-concept activities for newly developed technologies, techniques, or methodologies	2
Output: Publish journal, conference, and/or policy papers that become references for practitioners for the modification of codes and standards for technology adoption	Number of technical reports, theses, dissertations, DOT reports, and other report types submitted and/or published	5
	Number of papers published in peer-reviewed journals	4
	Number of papers, abstracts, or posters published and/or presented in conferences, symposia, workshops, and/or meetings	12
Outcome: Deploy new technologies, techniques, or practices	Number of technologies deployed in transportation applications through pilot or demonstration studies	2
Outcome: Improve the processes, technologies, and techniques in addressing transportation issues	Number of licenses granted to industry or patent applications submitted	1
Impact: Workforce development	Number of webinars given to disseminate findings to industry professionals	6
	Number of seminar, workshop, and/or conference sessions delievered by researchers to present findings of research activities to industry professionals	45
Impact: Adoption of technologies, techniques, or practices	Number of instances of technology adoption by industry or transportation agencies and of commercialization	1
	Number of instances that TIDC supported findings were referenced, cited, or mentioned in journal	5

	articles, presentations given by others not active in the research project, newspaper or magazine articles, etc.	
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	1

*To see how TIDC performed against these targets during this reporting period, see section I.b. – Technology Transfer.

Collaboration

Institutional leads serve on the TIDC Management Team which ensures each institution has ownership in 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 is required to have a Technical Champion. The Technical Champion has subject matter expertise and is actively involved in the research activities, from the creation of the project proposal to assisting with the implementation of successful research findings as a result of the work. The Technical Champion acts as a resource, connecting the researchers to the industry and meeting with the researchers to continue to help the teams keep their research relevant. 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 and research team. As more projects are added and advanced, the number of Technical Champions and their contributions will change. See Table 5 on page 11 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, as described within its designated Fast Act topic, in collaboration with New England Transportation Agencies. The Advisory Board evaluates and recommends the Selection of competitively funded research projects through an open RFP process that encourages collaboration and implementation of next-generation solutions. The Advisory Board also reviews TIDC's annual performance metrics from each member university to assess the status of base funded projects. Additionally, the goal is to have all Advisory Board Members work toward facilitating the engagement of researchers and students with Design and Maintenance Department members to encourage real-world solutions. The Advisory Board is currently comprised of members from each state DOT/AOT in Region 1. The Advisory Board meets two to three times annually to ensure effective partnership in achieving TIDC's research objectives and goals and add value to New England's Transportation Infrastructure.

Formal metrics to measure collaboration goals include presentations given at non-member universities, documented conversations regarding collaboration between TIDC and other UTCs, documented conversations/meetings between researchers, DOTs, industry partners, and technical champions, the number of industrial partners and state DOTs participating in TIDC research, dollar amount of state DOT and industry investments in 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 52 projects that were active, 2 projects that concluded their work, 3 new projects were funded, and 16 new projects and two phase II projects were submitted for review as a result of the 2022 RFP Solicitation during the reporting period. See Table 3 for a list of the 52 TIDC funded research projects that were active and/or selected/extended during the reporting period. (* indicates a newly selected/awarded project 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
1.12 – Improved UAV-Based Structural Inspection Techniques & Technologies for Northeast Bridges	University of Maine	10/1/2020
1.13 – Structural Integrity, Safety, and Durability of Critical Members and Connections of Old Railroad bridges Under Dynamic Service Loads and Conditions.	University of Connecticut	10/1/2021
1.14 – Exploring the Safety Impact of Rumble Strips on Prevention of Lane Departure Crashes in Maine	University of Maine	10/1/2021
1.15 – Non-Contact Intelligent Inspection of Infrastructure	University of Connecticut	10/1/2021
1.16 – Wireless Joint Monitoring (j-JMS) for Safety of Highway Bridges	University of Connecticut	10/1/2021
1.17 – Determining Layer Thickness and Understanding Moisture Related Damage of State-Owned Roads Using GPR and Capturing Such in a GIS-Based Inventory	University of Rhode Island	9/1/2021
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	1/1/2020
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		
2.2 – Concrete Systems for a 100-Year Design Life	University of Maine	3/1/2020
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
2.14 – Implementation of UHPC Technology into the New England Construction Industry	University of Connecticut	10/1/2021
2.15 – Incorporation of Pollinator Planning to Enhance Ecosystem Functions and Durability of Transportation Right-of-Way Infrastructure	University of Rhode Island	10/1/2021
2.16 – Enhancing the Durability of Bridge Decks by Incorporating Microencapsulated Phase Change Materials (PCMs) in Concrete	University of Rhode Island	1/1/2022
2.17 – Design and Development of High-Performance Composites for Improved Durability of Bridges in Rhode Island	University of Rhode Island	1/1/2022
2.18 – Recycling Large-Scale 3D-Printed Polymer Composite Precast Concrete Forms*	University of Maine	1/1/2022
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
3.7 – 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
3.10 – Assessment and Optimization of Double CT Bridge Girder Sections with Longitudinal Precast Decks	University of Maine	7/1/2020
3.11 – Phase 1: Assessment of Micropile-Supported Integral Abutment Bridges Phase 2: Development of a Simplified Methodology to Evaluate the Factor of Safety and Link the Magnitude of Lateral Spreading for CSEs Supported on Rigid Inclusions	University of Maine	9/1/2019
3.12 – Phase 1: Lateral Loading of Unreinforced Rigid Elements and Basal Stability of Column-Supported Systems Phase 2: Flexural Strength and Durability of Micropile Threaded Connections	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
3.15 – Nonstructural Approaches to Reduce Sediment and Pollutant Runoff from Transportation Infrastructure in Urbanized Areas	University of Rhode Island	9/1/2021
3.16 – CT Bridge Girder Sections with Precast Decks and FRP girder-deck Shear Connectors*	University of Maine	1/1/2022
3.20 – Analysis of MaineDOT Road and Bridge Infrastructure Construction Costs*	University of Maine	2/7/2022
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
4.9 – 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
4.11 – Safety Assessment of New England Roadways during the COVID-19 Pandemic	University of Maine	9/15/2020
4.12 – Proactive and Intelligent Risk Management in Complex Civil Infrastructure Project Systems	University of Connecticut	10/1/2021

Dr. Roberto Lopez-Anido, Dr. Sunil Bhandari, James Anderson, and Alexander Mann, researchers from the Advanced Structures and Composites Center at the University of Maine and the Maine Department of Transportation who work on Project 2.11 received the Best Paper Award of Additive Manufacturing Sessions at the AMTEC 2021 Conference, presented by the Society of Plastics Engineers (SPE). Their paper "*Large Scale Extrusion-Based 3D Printing for Highway Culvert Rehabilitation*" received the recognition on December 13, 2021.

Projects 4.4 and C5.2018 from UVM completed work and submitted final reports during the reporting period.

The following are a few examples of the accomplishments achieved under individual research projects:

- The research team for project 1.13 established a procedure that will allow the team to transfer forces and reaction from a global model of a railroad bridge to a detailed, local members and connections model.
- Project 1.17's team conducted field work collecting data and core samples in collaboration with the Rhode Island Department of Transportation.
- The 6TiSCH Real-Time Wireless Mesh Network created under project 4.3 is being utilized by the project 1.16 research team in their work toward developing a wireless joint monitoring system for the safety of highway bridges.
- Researchers for project C11.2019 collected another round of samples from the Grist Mill Bridge in Hampden, ME using the installed optical sensors and applied an optical sensor (LDV) and an electromagnetic sensor. The sampling proved the technology can last through a New England Winter and has maintained function for one year.
- The research team working on project 2.4 designed a cellular pattern for a 3D-printed formwork to minimize material use, reduce manufacturing time, and decrease cost. The 3D-printed formwork prototype was deployed to a concrete precaster plant to assess the longevity of the formwork during cycles of casting and demolding.
- The researchers on project 4.9 completed the analysis of the weekly, daily, and hourly traffic volume metrics and concluded the validation of turning count movements. After the review of the data was completed, the team confirmed that the vehicle metrics for roads in Maine are reasonably accurate on an annual, monthly, and day of the week average. The variance of the accuracy depends on the seasonality of traffic volume due to tourism and estimates of lower volume roads are less accurate and more variable.
- Researchers working on project 4.10 have finalized their crash severity models and the impact of different factors on the odds of crash severities was determined during the reporting period. The results have been shared with MaineDOT.
- The project 2.7 research team completed the freeze-thaw and chloride penetration tests of larger laboratory specimens and formulated a hypothesis based on the change of the concrete microstructure during curing with the action of shrinking fibers.

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.

Education & Workforce Development

The TIDC Program Coordinator is actively working with K-12 educators to bring transportation activities into classrooms during the continued COVID-19 restrictions. The Program Coordinator has identified educators in area middle and high schools in Maine, as well as groups, such as Jobs for Maine Grads, that would like to implement the activities created in 2020 and help make adjustments to the curriculum for the target age groups. Additionally, the activities and curriculum will lead up to the TIDC Transportation Challenge planned for December 2022.

In an effort to encourage more individuals to enter the transportation field, TIDC continues to collaborate with the Maine Engineering Promotional Council (MEPC) during the planning process of the Engineering Expo, with the TIDC Program Coordinator acting as a member of the Board. The Expo is planned for April 23 in Portland, ME. THE MEPC Board is comprised of academic and industry members who are all committed to raising awareness of engineering through the Banquet and Expo events. The Program Coordinator began work with industry partners through the Maine State Transportation Innovation Council to create Career Profiles to be used to encourage more K-12 students to enter transportation related fields. The Career Profiles will highlight current professionals in the field, their path to their current position, and any tips they might have for future professionals entering the field. Additionally, in our goal to increase the number of professionals entering the transportation field, TIDC is pleased to

report that a student at UConn graduated in 12/2021 and became a transportation professor at the University of Hartford.

TIDC researchers supported two high school students' science fair project through UConn's Advanced Cementitious Materials and Composites Lab from 12/2021 to 2/2022. The team supported the project by mixing a few UHPC samples to help the students understand strength development of steam curing vs. curing at standardized conditions.

In a continued effort to provide TIDC supported students with more professional development opportunities, researchers at URI worked with RIDOT to provide training for two undergraduate students to use GRP technology (project 1.17). Additionally, the research team for project 2.5 and 2.14 at UConn supported an undergraduate research project that deals with the inclusion of recycled, powdered plastic to investigate how much compression strength would be compromised by using the material.

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. TIDC faculty taught 24 transportation-related undergraduate courses, reaching about 1,200 students, and 17 transportation-related graduate courses, reaching about 240 students, during the reporting period.

TIDC's commitment to workforce development was evidenced by researchers providing training opportunities for practitioners and issuing certificates of attendance for professionals to use toward their required professional development hours. For example, the research team for project 1.4 provided an in-field training for the GPR technology for AECOM on 10/25/21. The training taught attendees how to use the GPR for debonding inspections on concrete bridges. Additionally, Dr. Bill Davids was one of three presenters that delivered a session at the ASCE Live Online Training Course on April, 4, 2022 titled *An Introduction to Designing with Fiber-Reinforced Polymer (FRP) Composites for Civil and Environmental Engineers* resulting in 2.0 professional Development hours.

Technology Transfer

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

TIDC researchers gave 25 presentations at 11 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
ACI Conference 2021	Presented findings	Virtual	10/17/2021
STAM Seminar	Presented findings	Storrs, CT	10/27/2021
34th Rhode Island Transportation Forum	Presented findings to transportation professionals; municipal, State, and Federal agencies; and academics.	Kingston, RI	10/29/2021
ASTM International Conference on Additive Manufacturing	Presented findings	Anaheim, CA	11/1/2021
4th Annual CAMMSE Virtual Research Symposium	Presented findings at a seminar	Virtual	11/5/2021
2021 TIDC New England Railroad Symposium	Presented Findings to rail professionals - a total of 54.5 PDHs awarded	Virtual	11/10/2021
2021 TIDC Student Poster Contest	24 students presented findings through 10-15 minutes videos and posters	Virtual	12/1/2021

Maine Transportation Conference	Presented findings	Virtual	12/2/2021
UML Infrastructure Research Seminars	A series of 4 seminars to present findings from UML-TIDC research	Virtual	2/24/2022, 3/3/2022, 3/15/2022, & 3/24/2022
SPIE Smart Structure & Nondestructive Evaluation Symposium	Conference papers & presentations by UML & UConn	Long Beach, CA	3/8/2022
UConn, School of Engineering Annual Poster Competition	2 posters presented	Storrs, CT	3/8/2022
Geo-Congress 2022	Presented findings	Charlotte, NC	3/21/2022

Additionally, TIDC has published or submitted 18 journal papers/articles, 12 peer-reviewed articles, 7 conference papers, 13 other publications, and was referenced in 2 news articles during the reporting period. One of the conference papers, *Large-Scale Extrusion Based 3D Printing for Highway Culvert Rehabilitation,* submitted by Dr. Roberto Lopez-Anido and his team, received the Best Paper Award of the Additive Manufacturing sessions at the ANTEC 2021 from The Society of Plastics Engineers (SPE). For a sample list of the submitted papers, please see Section III, Outputs.

Lastly, in a continued effort to ensure that technology transfer is communicated effectively, TIDC's administrative team is conducting work to create a new website for the Center. The team is working with researchers at member universities to update each research project's page with images and narratives that clearly identify the work being conducted and any accomplishments achieved under the funded work. The new website is planned to be launched in June 2022.

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.

TIDC researchers are actively working with industry partners during their research efforts to ensure their findings will be able to transition into practice more efficiently. For example, the research team for Project 3.5 (WNEU) met with Kiewit Corporation to discuss the practical application of the project's findings to the job site. The team will use the feedback they received from Kiewit Co. in calibrating their model to overcome any potential issues when transferring the technology into practice.

Also, during this reporting period, the TIDC Management Team met each month, with the exception of December (due to the holiday season), for a total of five meetings. All five meetings were held via Zoom. The Semi-Annual in person meeting was unable to happen in November due to the on-going COVID-19 restrictions. The Advisory Board met twice during the reporting period to discuss the 2022 Solicitation process and goals. Adding to our collaboration efforts and goals, TIDC Administration also met with 4 other UTCs to discuss administrative best practices.

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. The following table identifies the 62 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 5: Active Technical Champions & Advisors

Name and Title of Technical Champion or Advisor	Organization
Ulrich Amoussou-Gueno, Transportation Engineer II	Maine Department of Transportation
Dr. Ian Anderson, Manager	HMA Materials

August Arles, Geotechnical Engineer	Vermont Agency of Transportation
Warren Best, Assistant Deputy Director, Structures	Metro-North Railroad Company
Tanner Blackburn, Chief Geotechnical Engineer	Hayward Baker
Robert Blunt, Project Manager	VHB
Richard Bradbury, Director of Materials Testing	Maine Department of Transportation
Peter J. Calcaterra, Transportation Planner	Connecticut Department of Transportation
Andy Cardinali, Principal Engineer of Bridge Design	Connecticut Department of Transportation
David Cist, Chief Technology Officer	Geophysical Survey Systems, Inc. (GSSI)
Bao Chuong, Supervising Engineer of Bridge Design	Connecticut Department of Transportation
Taylor Clark, Assistant Engineer	Maine Department of Transportation
Cassidy Cote, Hydraulics and Structures Engineer	Vermont Agency of Transportation
Jeff DeGraff, P.E., Hydraulics Project Engineer	Vermont Agency of Transportation
Paul DelSignore, Deputy Chief Engineer, Structures*	Amtrak
Haresh Dholakia, Transportation Engineering Supervisor	Connecticut Department of Transportation
Anthony Diba, Engineer	AIT Bridges
Manesh Dodia, Transportation Engineer	Connecticut Department of Transportation
Todd Dragland, Vice President*	Hayward Baker
Lamont Dutra	Maine Department of Transportation
Dennis Emidy, State Safety Engineer	Maine Department of Transportation
Callie Ewald, P.E., Geotechnical Engineering Manager	Vermont Agency of Transportation
Jeff Folsom, Assistant Bridge Program Manager	Maine Department of Transportation
Benjamin Foster, P.E., Deputy Chief Engineer	Maine Department of Transportation
Edward Hanscom, Head of Transportation Systems Analysis	Maine Department of Transportation
Peggy Hagerty Duffy	ADSC-IAFD; Hagerty Engineering
Robert Haradon, Senior Technician	Maine Department of Transportation
Joshua Hasbrouck, Civil Engineer, Bridge Program	Maine Department of Transportation
Peter Healey, Pavement Engineer	Rhode Island Department of Transportation
Dr. Mark Jen, P.E., S.E., Technical Manager	Michael Baker Engineering, Inc.
Gregory Krikoris, Area Bridge Engineer	Massachusetts Department 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
Alexander Mann, Hydrologist	Maine Department of Transportation
Tanya Miller, Research Engineer	Vermont Agency of Transportation
Andrew Mrockowski, Transportation Engineer	Connecticut Department of Transportation
Richard Myers, Senior Structural Engineer	Maine Department of Transportation
Deirdre Nash, Assistant Research Engineer	New Hampshire Department of Transportation
Lily Oliver, Manager of Research	Massachusetts Department of Transportation
Dr. Emily Parkany, P.E., Research Manager	Vermont Agency of Transportation
Dale Peabody, Director, Transportation Research	Maine Department of Transportation
Mario Pineda, Territory Manager*	Polytec, Inc.
William Pratt, Principal Engineer*	Connecticut Department of Transportation
John Preiss, Bridge Engineer*	Rhode Island Department of Transportation
Michael Redmond, Business Systems Manager, Concrete Quality Control Specialist, Bridge Program	Maine Department of Transportation
Karen Riemer, Asset Management Group	Connecticut Department of Transportation
Ann Scholz, Research Engineer	New Hampshire Department of Transportation

Gary Seider, Engineering Manager	Hubbell
Rite L. Seraderian, P.E., FPCI, LEED AP, Executive Director	Precast/Prestressed Concrete Institute Northeast
Robert Skehan, Director, Office of Safety	Maine Department of Transportation
Joseph Stilwell, Fabrication Engineer	Maine Department of Transportation
Craig Stratton, Director of Sensing Sales	Luna Incorporated
James Surwilo, Environmental Analyst	VTDEC, Solid Waste Management Program
Ken Sweeney, President	AIT Bridges
Josh Tyler, Director of Operations	Chittenden Solid Waste District (CSWD)
Nicholas Van Den Berg, Materials & Certification Manager	Vermont Agency of Transportation
Susan Votta	Rhode Island Department of Transportation
Nick Wark, P.E., Hydraulics Engineer, Project Delivery Bureau, Structures	Vermont Agency of Transportation
James Wild, Concrete Materials Manager	Vermont Agency of Transportation
Christos Xenophontos, Assistant Director	Rhode Island Department of Transportation
Hailing Yu, Civil Engineer	U.S. DOT Volpe Center

The following table identifies the 45 active collaborators and stakeholders and their contributions during the reporting period. (* indicates new project collaborators during this period)

Table 6: Research Project Collaborators

Organization	Location	Contribution
AIT Bridges, a division of Advanced Infrastructure Technologies	Brewer, ME	In-kind, collaborative research, personnel, facilities
American Concrete	Auburn, ME	Financial support, facilities, collaborative research
Chittenden Solid Waste District (CSWD)	Williston, VT	Financial support, facilities, personnel
City of Lowell	Lowell, MA	Collaborative research, facilities, personnel
Connecticut Department of Transportation	Newington, CT	Collaborative research, personnel, facilities, in-kind support
Deep Foundations Institute	Hawthorne, NJ	Financial
ENSOFT Inc.*	Austin, TX	In-kind, Personnel
Ernst Conservation Seeds*	Meader, PA	In-kind
Geophysical Survey Systems, Inc. (GSSI)	Lowell, MA	Collaborative research, personnel, in-kind, facilities
Hayward Baker	Hanover, MD	Personnel
Helix Mooring Systems, Inc.*	Cumberland, ME	Financial, in-kind,
Hexagon PPM*	Madison, AL	In-kind, personnel
HMA Materials		Personnel
Hubbell Power Systems, Inc.*	Centralia, MO	Financial, in-kind, facilities, personnel
Jacobs Engineering	Herndon, VA	Personnel
Lehigh Cement*	Glen Falls, NY	In-kind
Luna Innovation*	Roanoke, VA	In-kind, collaborative research, personnel
Maine Department of Transportation	Augusta, ME	In-kind, collaborative research, financial, personnel, equipment

Massachusetts Department of Transportation	Boston, MA	Collaborative research, personnel, facilities, in-kind
Metro-North Railroad Company	Bridgeport, CT	Collaborative research, facilities, personnel, in-kind
Michael Baker Engineering, Inc.	Pittsburg, PA	Personnel
National Center for Supercomputing Applications	Urbana, IL	In-kind
NEC Laboratories America, Inc.*	Princeton, NJ	Financial, Facilities, Collaborative Research
New Hampshire Department of Transportation	Concord, NH	Personnel
Omnisens	Morges, Switzerland	In-kind, collaborative research, personnel, equipment
Polytec, Inc.	Hudson, MA	In-kind, collaborative research, personnel, equipment, facilities
Precast/Prestressed Concrete Institute Northeast (PCI-NE)	CT, MA, ME, NH, NY, RI, VT	Collaborative research, personnel
Rhode Island Department of Transportation	Providence, RI	In-kind, facilities, personnel
Saint-Gobain	Northborough, MA	In-kind, facilities, collaborative research, personnel, equipment
Sebago Technics*	Portland, ME	In-kind
Sperry Rail Service	Shelton, CT	In-kind, facilities, personnel
Texas Advanced Computing Center	Austin, TX	Facilities
U.S. DOT Volpe Center	Cambridge, MA	Personnel
Unistress Corporation*	Pittsfield, MA	In-kind, collaborative research
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 Agency of Transportation, Materials and Certification Section*	Barre, VT	In-kind
Vermont Department of Environmental Conservation	Montpelier, VT	Personnel, in-kind
Vermont Technical College	Randolph Center, VT	Facilities, collaborative research, personnel
VHB	Augusta, ME	Collaborative research, in-kind, 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/. 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. Lastly, presentations from webinars and the 2020 and 2021 Annual Conferences and the 2021 New England Railroad Symposium are available on the TIDC YouTube page and the TIDC website.

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, TIDC will conclude the review of the 16 new research projects and two phase II research proposals submitted as a result of the 2022 RFP Solicitation. Additionally, TIDC will work to allocate any remaining research funds for the remainder of the funding period after the 2022 RFP review is concluded. The performance of current research projects will continue to be evaluated against the mission, goals, and objectives of TIDC.

Education & Workforce Development

TIDC personnel at UMaine plan to work with local school districts to implement transportation related activities created as part of the curriculum developed by the TIDC Program Coordinator. As part of the effort to continue collaborating with Jobs for Maine Grads (JMG) and Career & Technical Centers (CTEs), the TIDC Program Coordinator is working with the Maine STIC and industry partners to create Career Profiles that will be housed on the TIDC website for JMG, CTEs, public and private middle and high schools, homeschool groups, and after school programs at organizations like the Boys & Girls Club to use throughout New England. This new resource will be launched in September 2022.

TIDC plans to attend the MEPC's Engineering Expo on April 23 in Portland, ME. The TIDC Program Coordinator will continue to serve on the MEPC's Board and will be working during the next reporting period to help increase the MEPC's reach throughout the year by updating the Council's bylaws to include more frequent events and outreach effort throughout the year, not just though the Annual Expo.

TIDC personnel at UMaine are continuing to work to create better partnerships with MaineDOT departments (including the HR, training, operations, and maintenance departments), industry leaders in Maine and New England region, and Maine Community Colleges to create more opportunities for workforce development in the state and beyond.

TIDC personnel and researchers are working to create more professional development opportunities through webinar offering. During the reporting period, researchers from UMaine have worked with the TIDC Senior Program Manager and the Advisory Board Chair to put together a Webinar series on FRP Composite Girders to be held in June 2022. Following the Webinar series, TIDC will be hosting an in-person workshop to continue training industry professionals on the application and use of the girders. Attendees will be visit the Grist Mill Bridge, the first installation of the girders. TIDC personnel also plans to bring back the Showcase Presentation Webinars featuring student presenters, holding the presentations two times each semester starting in January 2022. Having added two new members to the TIDC administrative team, TIDC is better suited to meet these goals in the next reporting period.

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. Professional development hours will continue to be made available to professionals who attend the TIDC Webinar Series, Annual Conference, and individualized trainings.

Technology Transfer

To accomplish TIDC's technology transfer objectives identified in Section I. a., Technology Transfer, the following venues and mechanisms will be and/or continue to be employed: (1) a TIDC website and social media accounts that promote findings and opportunities for collaboration directly to the public; (2) the expansion of the 2022 TIDC Annual Conference at the University of Maine, August 9-11, through early advertising and outreach activities in New England; (3) continued participation in regional transportation conferences; (4) a webinar series focused on sharing findings and engaging with industry professionals is scheduled to begin in June 2022 with a webinar series on FRP Composite Girders; and (5) promotion of all market-ready technology transfer opportunities through industry/trade publications, the TIDC website, and social media accounts.

TIDC will also use the webinars and symposiums mentioned in the above section as a form of Technology Transfer. Not only will these provide opportunities for professionals to receive profession development hours (PDH), but it will allow TIDC research findings to be presented to the public.

The new Center website will be launched in June 2022 to ensure information is more clearly available to the public, industry partners, and future collaborators. 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/AOT 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 Advisory Board will be meeting in May 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 2022 conference have been selected (a hybrid model is planned to allow for greater collaboration and attendance within the region and beyond).

II. PARTICIPANTS & COLLABORATING ORGANIZATIONS

a. What individuals have worked on the project?

In total, 54 principal investigators, faculty, administrators, and management team members and 116 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, Kathryn Ballingall, Dr. Keith Berube, James R. Bryce, Amanda Collamore, Dr. Bill Davids, Dr. Wilhelm Friess, Dr. Aaron Gallant, Dr. Per Garder, Dr. Douglas Gardner, Dr. Andrew Goupee, Dr. Yousoo Han, Dr. Hosain Haddad Kolour, Dr. Eric Landis, Dr. Roberto	Madison Ala, Nicholas Alvarez, Zahra Ameli, Yugandhar Aremanda, Alexander Baur, Drew Bennett*, Peter Bohrbacher*, Danilo Botero-Lopez, Sunil Bhandari, Sebastian Carvajal, Jacob Clark, Dominic Dangelo*, Nathan Godbout*, Sheldon Green*, Justin Harris, Jeffrey Hollstien, SK Belal Hossen, Braedon Kohler, Tanner Laflamme, Jack Leopold*, Ennis Marshall,

	Lopez-Anido, Vu Phan, Dr. Jonathan Rubin, Dr. Ali Shirazi, and Gavin Wasson	Nicolas Michaud*, Sebastian Montoya, Peter O'Brien, Felipe Saavedra, Alanie Sawtelle, Andrew Schanck, Parry Seddiqi, Amirhossein Shahlaeegilan, Nicholas Tiner, Kelsey Weir, Emma White, and Bruce Wyatt
University of Connecticut	Dr. Shinae Jang, Dr. Ramesh Malla, Dr. Jiong Tang, Dr. Kay Wille, Dr. Jin Zhu, Dr. Song Han, Dr. Wei Zhang, and Dr. Nalini Ravishanker	Ethan Beattie, Chris Boisvert-Cotulio*, Sudipta Chowdhury, Hernan Cortez Jr., Cydney-Alexis Delarosa, Celso de Oliveira, Suvash Dhakal, Santosh Dhakal, William Hughes, David Jacobs, Donghyun Kim, Kaitlyn Kondos, Qin Lu, Dominic, Xiaolong Ma*, Parciasepe, Bijaya Rai, Jeet Rosa, Leana Santos, Andrew Schroder, Sachin Tripathi, Kelly Voong, Ting Wang, Matthew Wendland, Peng Wu, Yixin Yao, and Yang Zhang.
University of Massachusetts Lowell	Dr. Tzuyang Yu, Dr. Xingwei Wang, Dr. Susan Faraji, and Dr. Zhu Mao	Aiyad Alshimaysawee, Emi Aoki, Ronan Bates, Andres M. Biondi Vaccariello, Lidan Cao, Celso do Cabo, Tek Dhant*, Harsh Gandhi, Yaneliz Garcis Ruiz, Nimun nak Khun, Tiana Robinson, Mark Todisco, Nick Valente, Rui Wu, and Sophe Ying.
University of Rhode Island	Dr. Christopher Baxter, Dr. Aaron Bradshaw, Dr. Rebecca Brown, Dr. Sumanta Das, Dr. Mayrai Gindy, Dr. Joseph Goodwill, and Dr. Vinka Oyanedel-Craver	Pamela Franco*, Katie Marcil, Andrew Pariseault*, and Andrew Sheerin
University of Vermont	Dr. Arne Bomblies , Dr. Mandar Dewoolkar, Dr. Ehsan Ghazanfari, Dr. Eric Hernandez, Dr. Dryver Huston, Dr. David Novak, Dr. Hamid Ossareh, Dr. Donna Rizzo, Dr. Gregory Rowangould, Dr. Matthew Scarborough, James Sullivan, Dr. Ting Tan, Dr. Kristen Underwood, and Tian Xia	Joshua Allen, Lane Feldeisen*, Maziar Foroutan, Damien Garland, Ahmad Ghazanfari, Nick Giallombardo*, Diarmuid Gregory, Matt Kaplita, Bijay K-C, Sam Langeleh*, Eric Licho, Yi Liu, Zhuang Liu, Harrison Lucas, Ashlie Mercado*, Kyle Murphy*, Linh Nguyen*, Brandon Nimberger*, Fiona Nutbeam, Colin Palmer*, Rachel Seigel, Ryan van der Heijden and Reed Winter*
Western New England University	Dr. Moochul Shin and Dr. ChangHoon Lee	Evan Blake, Christa-Elizabeth Cicerone, Cameron Cox*, Daniel Doyle, Jacob Eberli, Adam Garstka, Brian Leclair, Andrew Masullo*, Nicholas Pantorno, Archer Parker, Tiana Robinson, Georgii Tifaniuk, and Tyler Yesu
Total	54	116

b. What organizations have been involved as partners?

TIDC has received continued commitments of support and matching funds from 45 collaborators during this reporting period. The type of support provided by the collaborators varies from in-kind, financial, equipment, personnel, to supplies. In addition, many collaborators provide direct personnel links in research through Technical Champions. See Table 5 on page 11 and Table 6 on page 13 for an overview of the collaborators on TIDC research projects and what they have contributed.

c. Have other collaborators or contacts been involved?

In addition to the collaborators and Technical Champions listed above, TIDC researchers have partnered with Shimadzu to receive trainings on technologies needed to conduct research efforts on project 3.15.

III. OUTPUTS

a. Publications, conference papers, and presentations:

The following table includes a list of some of the 47 accepted, submitted, and published papers, reports, and presentations given during the reporting period:

Table 8: Publications, Conference Papers, and Presentations

Type	Title/Citation	Date	Status
Conference Presentation	R. Malla. *Railroad Bridge Field Test Investigation of Live Load Impact as a Function of Train Speed.* 34th Rhode Island Transportation Forum. Kingston, RI. 2021.10.29.	10.29.2021	Presented
Conference Presentation	R. Lopez-Anido. *Large Scale 3D Printing for Precast Concrete Production and Culvert Outlet Diffusers*. Maine Transportation Conference. Virtual. 2021.12.02.	12.02.2021	Presented
Conference Presentation	K. Wille. *Development and Testing of High / Ultra-High Early Strength Concrete for Durable Bridge Components*. ACI Conference 2021. Virtual. 2021.10.17.	10.17.2021	Presented
Conference Paper and Presentation	R. Lopez-Anido. *Design and Manufacture of Precast Concrete Formwork Using Polymer Extrusion Based Large Scale Additive Manufacturing and Postprocessing*. ASTM International Conference on Additive Manufacturing. Anaheim, CA. 2021.11.01.	11.01.2021	Published and Presented
Conference Presentation	A. Gallant. *Lateral Spreading and the Stability of Embankments Supported on Unreinforced Rigid Columns*. Geo-Institute 6th Annual Web Conference. Virtual. 2021.12.09.	12.09.2021	Presented
Seminar Presentation	J. Zhu. *The Usage of Association Rule Mining towards Future-Proofed Transportation Infrastructure Planning.* 4th Annual CAMMSE Virtual Research Symposium. Virtual. 2021.11.05.	11.05.2021	Presented
Conference Paper and Presentation	T. Yu. A. Alzeyadi. *Interpretation of Synthetic Aperture Radar Images of Concrete by Combined Uses of Image Parameters*. SPIE SS/NDE Symposium, Conference 12047 *Nondestructive Characterization and Monitoring of Advanced Materials, Aerospace, Civil Infrastructure, and Transportation XVI.* Long Beach, CA. 2022.03.08	03.08.2022	Published and Presented
Conference Paper and Presentation	K. Raisi, N. N. Khun, T. Yu. *Application of Dual-frequency GPR for Subsurface Void Detection in Culverts*. SPIE SS/NDE Symposium, Conference 12047 *Nondestructive Characterization and Monitoring of Advanced Materials, Aerospace, Civil Infrastructure, and Transportation XVI*. Long Beach, CA. 2022.03.08	03.08.2022	Published and Presented
Conference Paper and Presentation	Gregory D, Worley II R, Allen J, Kaplita M, Huston D. (2022) "Chitosan-Based Shrinking Fibers for Post Cure Stressing to Increase Durability of Concrete" SPIE Smart	03.07.2022	Published and Presented

	Structures NDE 2022 Behavior of Mechanics of Multifunctional Material XVI		
Conference Paper & Presentation	Montoya-Vargas, S., Gallant, A., Davids, W.G. (2022). "Flexural Strength of Micropile Threaded Joints". Geo-Congress 2022.	03.01.2022 03.21.2022	Accepted Presented
Conference Abstract	de Oliveira, C., Dhakal, S., and Malla, R. B. , "Monitoring of Old Truss Railroad Bridge under Free and Service Vibration using Laser Doppler Vibrometers," 2022 International Bridge Conference, Pittsburgh, PA, July 17-20, 2022	10.18.2021	Submitted & Under Review
Conference Paper	Bhandari, S., Lopez-Anido, R.A., Anderson, J. and Mann, A. "*Large-scale extrusion-based 3D printing for highway culvert rehabilitation*," ANTEC 2021, Classic, SPE Inspiring Plastics Professionals, Hybrid Edition.	12.13.2021	Presented & received Best Paper Award.
Conference Paper	Ren, D., Fils, P. Jang, S., Malla, R. M. (2022). "Technical survey and literature review on bridge joint monitoring practices." American Society of Engineering Education Northeast Conference 2022	12.02.2021 12.17.2021 03.18.2022	Submitted Reviewed Accepted
Conference Paper	"Structural Damage Identification using Inverse Analysis through Optimization with Sparsity", 2022 SPIE Smart Structures & NDE Conference	02.10.2022	Submitted

b. Journal publications:

The following table includes some of the 11 TIDC journal publications and their status during the reporting period:

Table 9: Journal Articles and Publications

Title/Citation	Date	Status
Z. Ameli, Y. Aremanda, W. Friess, and E. N. Landis, "*Impact of UAV hardware options on bridge inspection mission capabilities*."	12.20.2021	Submitted & Under Review
Dhakal, S., Baniya, S., Jacobs, D., and Malla, R.B., "*Frequencies, Mode Shapes and Finite Element Model Verification of a Long Span Open Deck Through Truss Railroad Bridge from Field Tests*," ASCE J. of Bridge Engineering	10.01.2021	Submitted & Under Review
Remote Characterization of Chloride Content in Concrete Specimens Using Synthetic Aperture Radar Images. Construction and Building Materials, Volume 302, 124317, doi: 10.1016/j.conbuildmat.2021.124317	10.04.2021	Published
Bhandari, S., Lopez-Anido, R.A., Saavedra Rojas, F., and LeBihan, A. "*Design and Manufacture of Precast Concrete Formwork Using Polymer Extrusion-Based Large Scale Additive Manufacturing and Postprocessing*," STP1644 on ASTM International Conference on Additive Manufacturing (ICAM 2021).	12.01.2021 03.30.2022	Submitted Reviewed & Resubmitted
Gallant, Aaron, and Danilo Botero-Lopez. 2021. "Lateral Spreading of Embankments supported on Fractured Unreinforced high-modulus columns over Soft Soil." DFI Journal 15(2) 1-21	2021	Accepted
Ma, X., Zhang, W. (2022) "Dynamic Amplification Effects of Scour and Debris Impacts for Short Span Bridges", Engineering Structures, 252(1), February 2022, 113644 https://doi.org/10.1016/j.engstruct.2021.113644	02.01.2022	Published
T. Yu. "Electronic Detection of Concrete Cracking by Using Synthetic Aperture and Ground Penetrating Radar", NDT&E International.	12.20.2021 03.30.2022	Submitted & Under review Under Revision
Ameli Z, Aremanda Y, Friess WA, Landis EN. Impact of UAV Hardware Options on Bridge Inspection Mission Capabilities. Drones. 2022 Feb 28; 6(3):64	02.28.2022	Published

Biondi, A., Zhou, J., Guo, X., Wu, R., Tang, Q., Gandhi, H., Yu, T., Gopalan, B., Hanna, T., Ivey, J.,& Wang, X. (2022). Pipeline Structural Health Monitoring Using Distributed Fiber Optic Sensing Textile. Optical Fiber Techology, 70, 102876. https://doi.org/10.1016/j.yofte.2022.102876	03.26.2022	Published

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

TIDC's work was sited in two news articles.

- 01.31.2022 – Lowell Sun – *Pressure Builds to Address Rourke Bridge Concerns* - https://lowellsun.com/2022/01/30/pressure-builds-to-address-rourke-bridge-concerns/
- 01.19.2022 – Mass Ventures – *MassVentures Announces $195,000 in Seed Funding for Faculty Research Projects* - https://www.mass-ventures.com/acorn-jan2022-release

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, Presentations, and Meetings

Type	Title/Citation/Description	Date	Status
Meeting	A project kick-off meeting was held with the Connecticut DOT for Project 1.16	10/7/2021	Completed
Presentation	R. Malla. *Railroad Bridge: Basics, Eyebars, and Impacts: Why we don't see high speed rail in the US.* Presentation to URI Graduate seminar by UConn researchers.	11.12.2021	Presented
Presentation	B. Rai. *Development of Ultra-High Performance Concrete (UHPC) based on Locally Available Material*. STAM Seminar. UConn. Storrs, CT. 2021.10.27.	10.27.2021	Presented
Dissertation and Defense	S. Bhandari. *Thermal and Mechanical Numerical Modeling of Extrusion-Based 3D Printed Reinforced Polymers for Manufacturing Process Improvement*. Ph.D. Dissertation, Digital Commons, University of Maine, 2021.	10.20.2021	Accepted & Defended
Presentation	*Composite Bridge Systems and the Use of the Newest FRP Composite Girders in Recent Bridge Projects*. Presentation by Anthony Diba to UML Bridge Design Graduate Class.	11.29.2021	Presented
Presentation	Presentation given to Graduate Student life and professional experience seminar at the University of Hartford, CT.	03.28.2022	Presented
Master's Thesis and Defense	*Active Acoustic Technologies for Practical UAV-Based Condition Assessment of Underside Bridge Deck.* University of Vermont.	03.25.2022	Defended
Ph.D. Dissertation	Jacobs, David, *"Dynamic Impact Factors Produced by Trains on Long Span Open Deck Steel Truss Railroad Bridges,"* Ph.D. Dissertation (Advisor: R.B. Malla), University of Connecticut, Storrs, CT: Dec. 2021	12.01.2021	Accepted & Approved
Master's Thesis	B. Kohler. *Implementation of a Structural Health Monitoring System for Carbon Fiber Composite Strands in the Penobscot Narrows Bridge*. M.S. Thesis. Dept. of Mechanical Engineering. University of Maine, 2021.	12.15.2021	Submitted
Master's Thesis	*Chitosan-Based Shrinking Fibers for Post-Cure Stressing to Increase Durability of Concrete*. M.S. Thesis, Mechanical Engineering, University of Vermont	12.01.2021	Accepted

Technical Report	Montoya-Vargas, S., Gallant, A., Davids, W.G. (2021). "Assessment of Micropile Supported Integral Abutment Bridges". Final Report, MaineDOT, Under review.	09.01.2022	Submitted & Under Review
Final Report	Gallant, Aaron, and Danilo Botero-Lopez. 2019. "Lateral Spreading and Basal Stability of Embankments and MSE Walls Supported on Unreinforced High-Modulus Columns." DFI final report.	2021	Submitted & Poster on DFI Webiste

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:

A number of technologies and/or technical innovations were developed during the reporting period:

- Researchers, under the leadership of Dr. Han, on project 4.3 developed a 6TiSCH Real-Time Wireless Mesh Network system.
- The project 1.4 research team created a new image processing algorithm (written in Mathlab) using the GPR B-Scan images collected during the reporting period.
- A new sensing textile was developed by the research team on project 1.5. The new technology will expand the textile's use beyond bridges to have a more broad application to other large infrastructure monitoring.
- The research team on project 2.4 designed and manufactured a large 3D-printed formwork system for a railroad bridge ballast retainer.
- Five sets of 3D-printed formworks using bio-based and conventional thermoplastic composite materials were designed and manufactured by the project 2.18 research team.
- Speeding models on interstates in Maine and Connecticut were created to understand the impact of the pandemic on speeding. The results of the models show that the odds of speeding during the pandemic were significantly increased in both states during the stay at home orders in 2020. This continued to hold true a year after the stay at home orders were lifted (using datasets from April and May of 2021).
- The researchers on project C9.2019 completed the creation of the Microsoft Excel tool. The tool is ready to use and will be made available to practitioners in the coming reporting period.
- A prototype acoustic sensor arm for UAVs to conduct testing on the underside of bridge decks was created, tested, and improved by the researchers working on project C20.2020. The prototype is equipped with signal processing algorithms.

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

Nothing to report.

IV. OUTCOMES

The TIDC has a number of outcomes to report as a result of the outputs from TIDC-funded research:

- The 6TiSCH Real-Time Wireless Mesh Network System developed by Dr. Han's team on project 4.3 is being utilized by Dr. Jang's team on project 1.16 in their work to develop a wireless joint monitoring system for highway bridges.
- The sensing textile developed under project 1.5 was installed on the Salmon River Bridge in New Hampshire and is being monitored.

- As a result of the work conducted on project 3.7, a new graduate level course was created and included in the Civil Engineering School at UML. The new course focuses on bridge designs with Integral Abutment Bridges (IABs).
- As a result of the successful installation of the 3D-printed culvert diffuser installed in Thorndike, ME, the New Hampshire DOT is working with the researchers on project 2.11 to have a 3D-printed diffuser installed in Exeter, NH this year.

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?

TIDC researchers have contributed to the body of scientific knowledge by publishing journal articles and presenting findings at conferences, webinars, seminars, and symposiums to transportation professionals.

d. What is the impact on transportation workforce development?

TIDC research findings have impacted workforce development through trainings and updates offered to transportation professionals at the city and state department/agency of transportations and industry organizations. Additionally, TIDC issued certificate of attendance certificates to 15 out of the 163 2021 TIDC Annual New England Railroad Symposium attendees.

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:

Nothing to report.

c. Changes that have a significant impact on expenditures:

Nothing to report.

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.