Awarding Federal Agency: University Transportation Centers Program, Office of The Assistant Secretary for Research and Technology, U.S. Department of Transportation

Federal Grant Number: 69A3551847101

Project Title: Transportation Infrastructure Durability Center (TIDC) at the University of Maine

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

Original Submission Date: 4/25/2019 **Revised Submission Date:** 9/4/2019

DUNS: 186875787

EIN: 016000769

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

Project/grant period: 6/5/2018 – 9/30/2023

Reporting Period end date: 3/31/2019

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 in this area tackles this issue through the development and implementation of novel strategies for the assessment and health monitoring of highway bridges, rail structures, pavements and foundations. The resulting picture of health of these vital elements of our transportation infrastructure will provide the information required to prioritize repair and replacement, while advanced assessment will allow structures to remain in service longer.
Thrust Area 2: New Materials for Longevity and Constructability	This thrust area investigates new materials and technologies to improve durability and extend the life of transportation infrastructure. The materials and technologies investigated will improve multi-modal transportation connections.
Thrust Area 3: New Systems for Longevity and Constructability	This thrust area focuses on evaluation, development, and application of engineering systems to improve the durability and longevity of new and existing transportation infrastructure. In these times of economic austerity, New England's transit networks face challenges related to cold weather, aging, deterioration, evolving load demands, and construction efficiencies. Addressing these issues, applicable to both roadway and railway modes of transit, will 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 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 will increase system performance, lower the costs of maintenance and provide more timely notification of assets that need immediate repair or replacement. Managing infrastructure for performance, capacity and maintenance with connected technologies will become the standard expectation of the future. This thrust area applies to all forms of infrastructure including highway and railroad bridges and other fixed assets including roadways and ramps.

TIDC will provide performance-based funding to each member university through base-funded projects. Additionally, competitive funding of $250,000 will be made available through an annual competitive RFP process.

Base and competitive funding are contingent upon performance, all funded activities must perform well against metrics identified in technology transfer, education and workforce development, and collaboration. Each member university will provide performance metrics information to UMaine through bi-monthly 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, undergraduates, graduate students, and/or post-docs) and peer monitoring. 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 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 institution; total number of classrooms reached by STEM Ambassadors, 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 goals: (1) develop new technologies, techniques, or methodologies; (2) conduct technical transfer through publications, conference papers, and policy papers that become references for practitioners for the modification of codes and standards for technology adoption; (3) deploy new technologies, techniques, or practices; (4) improve the processes, technologies, and techniques in addressing transportation issues; (5) workforce development; (6) adoption of technologies, techniques, or practices; and, (7) development of 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.

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.

Formal metrics to measure collaboration goals include presentations given at non-member universities, informal or formal conversations between TIDC and other UTCs, number of industrial partners and state DOTs who wish to participate in 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

TIDC's research focuses on efforts to improve the durability and extend the life of transportation infrastructure in New England and beyond through an integrated collaboration of universities, state DOTs, and Industry. Twenty-three research projects have been selected based on a rigorous review and revision process involving the TIDC Advisory Board, Research Area Leads, Principal Investigators, and Technical Champions (see section II for more information) as required by the TIDC project selection process. Collectively, these projects address TIDC's four research thrust areas; (1) transportation infrastructure monitoring and assessment for enhanced life, (2) new materials for longevity and constructability, (3) new systems for longevity and constructability, and (4) connectivity for enhanced asset and performance management.

Thrust Area 1: Transportation Infrastructure Monitoring and Assessment of Enhanced Life

- 1.1: Field Live Load Testing and Advanced Analysis of Concrete T-Beam Bridges to Extend Service Life, University of Maine
- 1.2: Condition/Health Monitoring of Railroad Bridges for Structural Safety, Integrity, and Durability, University of Connecticut

- 1.4: Electromagnetic Detection and Identification of Concrete Cracking in Highway Bridges, University of Massachusetts Lowell
- 1.5: Distributed Fiber Optic Sensing System for Bridge Monitoring, University of Massachusetts Lowell
- 1.6: Progressive Fault Identification and Prognosis of Railway Tracks Based on Intelligent Inference, University of Connecticut
- 1.8: Enhancing Intelligent Compaction with Passive Wireless Sensors, University of Vermont
- 1.11: Energy Harvesting and Advanced Technologies for Enhanced Life, University of Rhode Island
- C3.2018: Condition Assessment of Corroded Prestressed Concrete Bridge Girders, University of Massachusetts Lowell and Western New England University
- 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

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
- 2.3: Measuring Adhesion Between Binders and Aggregates Using Particle Probe Scanning Force Microscopy at Low Temperatures, University of Vermont
- 2.4: Thermoplastic Composites by 3D Printing and Automated Manufacturing, University of Maine
- 2.5: Development and testing of High/Ultra-High Early Strength Concrete for Durable Bridge Components and Connections, University of Connecticut
- 2.7: High Performance Concrete with Post-Tensioning Shrinking Fibers, University of Vermont
- 2.9: Carbonating Subgrade Materials for In Situ Soil Stabilization, University of Maine
- C7.2018: Alternative Cementitious Materials (ACMs) For Durable and Sustainable Transportation Infrastructures, University of Maine

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
- 3.5: Prevention of Stressed-Induced Failures of Prestressed Concrete Crossties of the Railroad Track Structure, Western New England University
- 3.8: Bridge Modal Identification via Video Processing and Quantification of Uncertainties, University of Massachusetts Lowell

Thrust Area 4: Connectivity for Enhanced Asset and Performance Management

- 4.1: Highly Automated Vehicles and Bridge Infrastructure, University of Maine

- 4.2: Future-Proof Transportation Infrastructure through Proactive, Intelligent, and Public-involved Planning and Management, University of Connecticut
- 4.3: Towards Quantitative Cybersecurity Risk Assessment in Transportation Infrastructure, University of Connecticut
- 4.4: Bridge-stream Network Assessments to Identify Sensitive Structural, Hydraulic, and Landscape Parameters for Planning Flood Mitigation, University of Vermont

The following accomplishments have been achieved during the reporting period:

Project 1.1: Field Live Load Testing and Advanced Analysis of Concrete T-Beam Bridges to Extend Service Life – Through live-load testing to date, three of five tested bridges had their live-load rating factors raised above 1.0, indicating their ability to carry modern loading (HL-93) without repairs, alterations, nor additional bolstering.

Project 1.2: Condition/Health Monitoring of Railroad Bridges for Structural Safety, Integrity, and Durability – Bridge members recently removed from the Cos Cob railroad bridge have been obtained and coupons are being cut from them for tensile and fatigue testing in order to develop a methodology for continuous structural health monitoring with a limited number of sensors. Performing testing on these recently retired railroad bridge members will provide information relating to the aging and degradation of members, and how their stress-strain condition is related to their fatigue life.

Project 1.4: Electromagnetic Detection and Identification or Concrete Cracking in Highway Bridges – To date, the team has manufactured laboratory concrete specimens with different sizes and types of cracks. The intact concrete panel concrete panel will be used for generating the background radar image for subtraction and the subsequent structural assessment of aging concrete bridges (reinforced and prestressed) in New England.

Project 3.4: Testing, Monitoring, and Analysis of FRP Girder with Concrete Deck – Activities to date are in direct support of the overarching project goal of assessing the constructability and design methodology for FRP bridge girder bridges. Shear stress distribution analysis has been performed to confirm that the assumptions made in the design of the girder were conservative. Lateral-torsional buckling analysis was also performed to assess the stability of girders during construction so as to anticipate premature failure. With these confirmations, design and construction can proceed as intended.

Project 4.1: Highly Automated Vehicle and Bridge Infrastructure – To date, the research team has identified several applications for connected and autonomous vehicles, such as bridge collision avoidance, curve speed warning systems on highway ramps, road weather management systems and freight applications.

Education & Workforce Development

In an effort to ensure all education and workforce development goals are met, TIDC personnel have been working to finalize a Communications, Education, and Outreach Plan. The purpose of this plan is to provide clear guidelines and strategies to effectively achieve TIDC's goals and objectives for communicating research findings, providing opportunities for workforce development and K-12 outreach, and the expected and required acknowledgments for all reports. In addition, the process of creating toolkits to be used in K-12 classrooms and for the University of Maine 4-H Ambassador Program Cooperative Extension have begun. 4-H STEM Toolkits provide an experiential learning opportunity for youth by providing materials needed to successfully complete science-based activities. Groups and youth develop an interest in science through hands-on learning. TIDC will create transportation related toolkits to encourage youth to learn more about the transportation industry. Toolkits will be available to the K-12 school districts in Maine. The completion of the initial toolkits are expected to be completed in the fall of 2019, with the testing of the activities for the 4-H Ambassador program beginning in the spring of 2020. Copies of the toolkits and activities will be made available on the TIDC website.

Technology Transfer

TIDC Website and Social Media Accounts:

TIDC personnel have created the primary TIDC website (www.tidc-utc.org) and the required key personnel page (https://www.tidc-utc.org/about-us/key-personnel/). All of TIDC's selected projects have been posted on the TIDC website https://www.tidc-utc.org/research/tidc-funded-projects-and-reports/. The website has had 1839 views and 335 visitors in the reporting period. Traffic to the website has been driven from TIDC's Facebook and LinkedIn social media accounts, the TRB RiP and TRID databases, and through internet search engines like Google.

TIDC personnel have also created social media accounts on Twitter, Facebook, and LinkedIn that have been active for about three months. The TIDC Twitter account (https://twitter.com/TIDCatUMaine) has 8 followers and has made 717 impressions from its Tweets during the reporting period. The TIDC Facebook account (https://www.facebook.com/TIDCatUMaine/) has 10 page likes and the posts have reached 19 people during the reporting period. The TIDC LinkedIn account (https://www.linkedin.com/company/transportation-infrastructure-durability-center/) has 3 followers and has had 28 views during the reporting period.

Individual Research Project Websites:

Some TIDC researchers have created individual websites to share findings on their research projects to the general public in addition to the research pages on the TIDC Website. The following pages have been created: TIDC at UML (https://www.uml.edu/Research/tidc/), project 1.4 (https://www.uml.edu/Research/tidc/projects/electromagnetic-detection-identification-bridge-cracking.aspx), project 1.5 (https://www.uml.edu/Research/tidc/projects/distributed-sensing-textile-bridge.aspx), project 3.8 (https://www.uml.edu/Research/tidc/projects/bridge-modal-identification.aspx), and project C3.2018 (https://www.uml.edu/Research/tidc/projects/assessment-corroded-prestressed-bridge-girders.aspx).

Regional conferences and workshops:

TIDC researchers have participated in three conferences and workshops during the reporting period. The following table indicates the conferences and workshops attended by TIDC researchers during this reporting period.

Table 2: Conferences and Workshops			
Name of Conference/Workshop	**Activity**	**Location**	**Dates**
2019 SPIE Smart Structures (SS)/NDE Symposium	Presented 3 papers on the use of radar for subsurface sensing	Denver, Colorado	March 3-7, 2019
CUTC Annual Winter Meeting	Director's Meeting	Washington, DC	January 13, 2019
TIDC Project Proposal Workshop	Presentation of proposed TIDC projects	Portsmouth, New Hampshire	November 8-9, 2019

Published and Submitted Papers and Reports:

TIDC has published and submitted 3 papers and reports during the reporting period. The following table lists the publications that were submitted and/or accepted during the reporting period.

Table 3: Publication and Submitted Papers and Reports		
Publication Type	**Title**	**Status**
Conference Paper	"Towards the ontology development for smart transportation infrastructure planning via topic modeling"	Accepted by 36th International Symposium on Automation and Robotics in Construction
Report	Trueheart, M., Bomblies, A., Rizzo, D., Dewoolkar, M. (2019), "Identifying sensitive structural and hydraulic parameters in a bridge-stream network under flood conditions"	Submitted to Vermont Agency of Transportation, Report No. VTRC017-003
Report	Schanck, A. and Davids, W. (2018). "Live load testing and load rating of five skewed reinforced concrete T-beam bridges."	Submitted to MaineDOT, UMaine ASCC Report No. 19-09-1613

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.

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 evaluate 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.

During this reporting period, TIDC held an initial kick-off meeting, ten Management Team meetings, and the TIDC Proposal Review Workshop in Portsmouth, NH. The TIDC Proposal Review Workshop provided an opportunity for researchers to present their proposed projects to the Advisory Board, TIDC Thrust Area Leads, the Center Director, and fellow TIDC researchers. During the workshop, seven competitive projects were presented for possible additional funding. Upon completion of the presentations on day two of the workshop, the Advisory Board members met to discuss the presented projects and to provide their recommendations to the TIDC Management Team as to which projects they supported for competitive funding. The Advisory Board members also had an opportunity to provide feedback on all proposed base-funded projects.

The following table identifies active collaborations during the reporting period.

Table 4: Research Project Collaborators

Organization	Location	Contribution
ADAPT Corporation	Redwood City, California	In-kind
Advanced Infrastructure Technologies	Orono, Maine	In-kind, personnel, facilities
Amtrak	Philadelphia, Pennsylvania	In-kind, personnel
Argonne National Laboratory	Lemont, Illinois	In-kind, personnel
City of Lowell	Lowell, Massachusetts	In-kind, personnel
Connecticut Department of Transportation	Newington, Connecticut	In-kind, personnel
Intergraph Corporation	Madison, Alabama	In-kind
Maine Bureau of Motor Vehicles	Augusta, Maine	In-kind
Maine Department of Transportation	Augusta, Maine	In-kind, financial, personnel, equipment
Massachusetts Department of Transportation	Boston, Massachusetts	In-kind, personnel
Metro-North Railroad Company	New York City, New York	In-kind, personnel
New Hampshire Department of Transportation	Concord, New Hampshire	In-kind, personnel
Oak Ridge National Laboratory	Oak Ridge, Tennessee	In-kind, personnel, facilities
Precast/Prestressed Concrete Institute Northeast (PCINE)	CT, MA, ME, NH, NY, RI, VT	In-kind, personnel
Providence and Worcester Railroad Company	Stamford, Connecticut	In-kind, personnel
Rhode Island Department of Transportation	Providence, Rhode Island	In-kind, personnel

University of Connecticut	Storrs, Connecticut	In-kind, facilities, financial, personnel
University of Maine	Orono, Maine	In-kind, facilities, financial, personnel
University of Massachusetts Lowell	Lowell, Massachusetts	In-kind, facilities, financial, personnel
University of Rhode Island	Kingston, Rhode Island	In-kind, facilities, financial, personnel
University of Vermont	Burlington, Vermont	In-kind, facilities, financial, personnel
Vermont Agency of Natural Resources	Montpelier, Vermont	In-kind, personnel
Vermont Agency of Transportation	Montpelier, Vermont	In-kind, financial, personnel
Western New England University	Springfield, Massachusetts	In-kind, facilities, financial, personnel
XSEDE: University of Texas at Austin	Austin, Texas	In-kind, equipment

The following table identifies the 21 active Technical Champions involved in TIDC research projects during this reporting period.

Table 5: Technical Champions

Name and Title of Technical Champion	Organization	Contribution
Andrew Bardow, Director, Bridges and Structures	Massachusetts Department of Transportation	In-kind
Steven Cascione, Programming Services Officer	Rhode Island Department of Transportation	In-kind
Henry Chango, Contract Administrator	D'Ambra Construction Company, Inc.	In-kind
Brian Clang, Bridge Inspection Engineer	Massachusetts Department of Transportation	In-kind
Cassidy Cote, Hydraulics and Structures Engineer	Vermont Agency of Transportation	In-kind
Karen Gross, Geotechnical Engineer	Maine Department of Transportation	In-kind
Joshua Hasbrouck, Civil Engineer, Bridge Program	Maine Department of Transportation	In-kind
Garrett Kilfoyle, Assistant Engineer, Bridge Maintenance	Maine Department of Transportation	In-kind
Brandon Kipp, Project Manager, Pavement Management Section	Vermont Agency of Transportation	In-kind
John Kocur, Director of Engineering	Sperry Rail Service	In-kind

James Lacroix, P.E., State Bridge Design Engineer	Vermont Agency of Transportation	In-kind
Andrew Mrockowski, Transportation Engineer	Connecticut Department of Transportation	In-kind
Edmund (Ned) Newton, Civil Engineer	Massachusetts Department of Transportation	In-kind
Dale Peabody, Director, Transportation Research	Maine Department of Transportation	In-kind, equipment
Paul C. Petsching, P.E., Senior Civil Engineer	Rhode Island Department of Transportation	In-kind
Aaron Schwartz, Hot Mix Asphalt Engineer	Vermont Agency of Transportation	In-kind
Rite L. Seraderian, P.E., FPCI, LEED AP, Executive Director	Precast/Prestressed Concrete Institute Northeast	In-kind
Nick Ward, P.E., Hydraulics Engineer, Project Delivery Bureau, Structures	Vermont Agency of Transportation	In-kind
James Wild, Concrete Materials Manager	Vermont Agency of Transportation	In-kind
Dr. Kathleen Wilson, P.E., Chief Civil Engineer	Rhode Island Department of Transportation	In-kind
Hailing Yu, Civil Engineer	U.S. DOT Volpe Center	In-kind

c. How have the results been disseminated?

The results developed during this reporting period have been disseminated through each individual Project "*Semi-Annual Progress Report,*" which can be found at https://www.tidc-utc.org/research/tidc-funded-projects-and-reports/ on each research project's page.

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

Research

The following table indicates the anticipated activities for each research project during the next reporting period.

Table 6: Anticipated Activities for the Next Reporting Period	
Project No.	**Anticipated Activities for Next Reporting Period**
1.1	Continue developing linear FE Models. Compare Live Load results with FE Analysis. Continue to streamline nonlinear FE Modeling techniques.
1.2	Manufacture 5 fatigue and 5 tensile coupons. Continue gathering recently retired RR bridge components, and compile information.

1.4	Preparation of lab concrete specimens. Lab radar imaging of specimens. Preliminary field radar imaging of concrete bridges. Continue developing an EM database. Data analysis and image interpretation.
1.5	Modeling of the strain distribution on the bridge. Conduct field test on a bridge. Signal processing; compare field results with theoretical analysis.
1.6	Focus on tunable sensor optimization and fault identification algorithm development.
1.8	Evaluate sensitivity of passive sensing system to changes in density of geo-materials.
1.11	Investigate aspects of energy harvesting. Develop a perpetual pavement with embedded solar harvesting unit. Perform thermodynamic analysis of the pavement cooling system and solar harvesting unit to; a) ascertain the max benefit, and b) identify the most important sources of loss and inefficiencies within each system.
2.1	Develop the CRM mixtures with Evotherm and RAP. Conduct performance testing and review the results of asphalt binder on various RAP. Develop foamed asphalt mixtures containing RAP and CRM.
2.3	Prepare asphalt substrates and particle probes.
2.4	Identify applications for optimized bridge diaphragms using 3D printed formwork.
2.5	Conduct concrete mixing and material characterizations towards evaluating robustness of the suggested concrete mixtures.
2.7	Hire graduate students to work on experiments to develop the shrinking fiber for concrete and begin numerical studies of the mechanics of interactions of prestressed fibers in concrete.
2.9	Experiment with waste materials that may be used in decreasing cost of soil carbonate applications.
3.4	Begin manufacturing of girders and construction of the bridge, with testing and monitoring to follow.
3.5	Conduct a series of "pull-out" tests for prestressing wires of varying indentations to characterize differing bond-mechanisms.
3.8	Collect video data from a better point of observation.
4.1	Complete literature review. Continue to develop a test of connected bridge technology while focusing on the development of a concept of operations and stakeholders needs.
4.2	Refine preliminary ontology by incorporating more documents and different types of data into the analysis. Validate the ontology with subject-matter experts. Implement the ontology into a case study.
4.3	Extend literature studies. Survey existing V2X technologies. Select problems for in-depth studies. Continue collaboration efforts with stakeholders.
4.4	Select two additional sites and develop transient hydrologic models (HECRAS 2D) using existing LiDAR data and supplemental bathymetry data.

C3.2018	Field Inspections and measurements. Development of macro-scale mechanical damage model due to corrosion. Development of capacity reduction model for PC bridges due to corrosion.

Education & Workforce Development

TIDC will hold the first Annual TIDC Conference June 6th-7th, 2019 at the University of Maine. TIDC Personnel are working to finalize the schedule of events and create a webpage to advertise the conference on the TIDC website and through social media.

TIDC personnel will be attending K-12 STEM activities including: (1) 4-H at UMaine on June 1st, 2019, and (2) 2019 Maine 4-H Days, July 20th-21st, 2019. In addition, TIDC personnel will work with UMaine 4-H Cooperative Extension to create six activities that will be include in the 4-H Ambassador Toolkit while working to create an internal activity toolkit to be used at workshops, science fairs and festivals, and K-12 STEM activities offered on member university campuses.

TIDC faculty and principal investigators will be hiring additional students to work on the research projects as research accelerates in the coming summer and academic year.

Technology Transfer

To accomplish TIDC's technology transfer objectives identified in Section I. a., Technology Transfer (pg. 3), 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; (3) a TIDC Annual Conference; (4) participation in regional transportation conferences (i.e. the Maine Transportation Conference hosted by the Maine DOT); and (5) promotion of all market-ready technology transfer opportunities through industry/trade publications, the TIDC website and social media accounts, and member university on-campus publications and postings.

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. Technical Champions will receive bi-monthly progress reports for the research projects they are actively supporting. Additionally, all TIDC project will have at least one Technical Champion assigned to support the Principal Investigator. Monthly management team meeting will continue and the Program Manager will visit each member university on a quarterly basis. TIDC's 1st Annual conference is scheduled to be held in June 2019. An Advisory Board meeting will be held after the completion of the conference to discuss the progress of the research projects, goals and needs of the industry, and suggestions for the success of TIDC.

II. PARTICIPANTS & COLLABORATING ORGANIZATIONS

a. What individuals have worked on the project?

In total, 39 principal investigators, faculty, administrators, and management team members and 26 students who participated in TIDC research projects during the reporting period. As the projects progress, more student researchers will be added. The TIDC management team members, principal investigators, faculty, administrators, and students who are currently active are listed in the table below.

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

Institution	Principal Investigators, Faculty, Administrators, and Management Team Members	Students
University of Maine	Dr. Habib Dagher, Bruce Knox, Dr. Bill Davids, Dr. Roberto Lopez-Anido, James Anderson, Dr. Douglas Gardner, Dr. Yousoo Han, Dr. Aaron Gallant, Dr. Warda Ashraf, Dr. Jonathan Rubin, Kathryn Ballingall, Vu Phan, and Amanda Collamore	Andrew Schanck, Sunil Bhandari, SK Belal Hossen, and Nicholas Alvarez.
University of Connecticut	Dr. Ramesh Malla, Dr. Jiong Tang, Dr. Kay Wille, Dr. Jin Zhu, and Dr. Song Han	Sudipta Chowdhury, Gang Wang, Areej Althubaity, Mark Castaldi, David Jacobs, Suvash Dhakal, Francis Almonte, Stephanie Kreitler, Sean Doolittle, Liam Gerety, Yixin Yao, and Bijaya Rai.
University of Massachusetts Lowell	Dr. Tzuyang Yu, Dr. Xingwei Wang, Dr. Susan Faraji, and Dr. Zhu Mao	Ahmed Alzeyadi, Harsh Gandhi, Sanjana Vinayaka, Ruben Diaz, Jade Man, Hao Peng, Aral Sarrafi, Mark Todisco, and Brett Daniels
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	Neha Shrestha, David Schumacher, and Mason Hyde
University of Vermont	Dr. Mandar Dewoolkar, Dr. Ehsan Ghazanfari, Dr. Ting Tan, Dr. Dryver Huston, Dr. Donna Rizzo, Dr. Arne Bomblies, and Dr. Kristen Underwood	Maziar Foroutan, Zhuang Liu, and Matthew Trueheart

Western New England University	Dr. Moochul Shin and Dr. ChangHoon Lee	Cy Riding, Isaiah Colombani, Cameron Cox, and Nicholas Pantorno

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 22 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 for an overview of the collaborators on TIDC research projects and what they have contributed.

c. Have other collaborators or contacts been involved?

University of Connecticut's machine shop is advising and training researchers to make coupons. In future months, the machine shop will be training student researchers to use plasma and arc cutters, manual mills and lathes, and a CNC mill.

III. OUTPUTS

a. Publications, conference papers, and presentations:

The following table includes a list of accepted and submitted papers and reports:

Table 8: Publication and Submitted Papers and Reports		
Publication Type	**Title**	**Status**
Conference Paper	"Towards the ontology development for smart transportation infrastructure planning via topic modeling"	Accepted by 36th International Symposium on Automation and Robotics in Construction
Report	Trueheart, M., Bomblies, A., Rizzo, D., Dewoolkar, M. (2019), "Identifying sensitive structural and hydraulic parameters in a bridge-stream network under flood conditions"	Submitted to Vermont Agency of Transportation, Report No. VTRC017-003
Report	Schanck, A. and Davids, W. (2018). "Live load testing and load rating of five skewed reinforced concrete T-beam bridges."	Submitted to MaineDOT, UMaine ASCC Report No. 19-09-1613

b. Journal publications:

Nothing to report.

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

Nothing to report.

d. Other publications, conference papers, and presentation:

Nothing to report.

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

The TIDC website and social media accounts increase the awareness of transportation issues through postings of news articles and research projects. During the reporting period, the TIDC website has received 1839 views and 335 visitors. Social Media posts have reached 764 people.

The following are active websites for TIDC research.

TIDC Website: www.tidc-utc.org, TIDC at UML Website: https://www.uml.edu/Research/tidc/, Project 1.4 Website: https://www.uml.edu/Research/tidc/projects/electromagnetic-detection-identification-bridge-cracking.aspx, Project 1.5 Website: https://www.uml.edu/Research/tidc/projects/distributed-sensing-textile-bridge.aspx, Project 3.8 Website: https://www.uml.edu/Research/tidc/projects/bridge-modal-identification.aspx, and Project C3.2018: https://www.uml.edu/Research/tidc/projects/assessment-corroded-prestressed-bridge-girders.aspx.

f. Technologies or techniques:

Nothing to report.

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

Nothing to report.

IV. OUTCOMES

Nothing to report.

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:

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.