CIAMTIS
U.S. DOT Region 3 University Transportation Center

SEMI-ANNUAL PROGRAM PROGRESS REPORT

FOR

UNIVERSITY TRANSPORTATION CENTERS

Project Title:	**Center for Integrated Asset Management for Multi-Modal Transportation Infrastructure Systems (CIAMTIS)**
Submitted to:	U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology
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Center Partners:	Pennsylvania State University (lead), George Mason University, Lehigh University, Morgan State University, University of Delaware, Virginia Tech, and West Virginia University
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Recipient Organization:	Thomas D. Larson Pennsylvania Transportation Institute Pennsylvania State University 201 Transportation Research Building University Park, PA 16802
Reporting Period:	April 1, 2019 through September 30,2019

I. ACCOMPLISHMENTS

A. Major Goals of the Program

The vision of the Center for Integrated Asset Management for Multimodal Transportation Infrastructure Systems (CIAMTIS) Region 3 University Transportation Center (UTC) is to improve integrated asset management through research, education, and outreach activities that will enable transportation agencies to invest infrastructure funds when and where they are most critically needed. This will lead to improved ability of such agencies to deliver enhanced safe and cost-effective infrastructure management, and thereby gain the most benefit from available funds. The UTC activities will support multiple modes of transportation, including highways, rail, transit, air, maritime, and inter-modal transportation, with emphasis on highways and rail.

CIAMTIS addresses the following FAST Act priority area related to *Improving the Durability and Extending the Life of Transportation Infrastructure.* Within this priority area, CIAMTIS research, education, and outreach activities focuses on the following three thrust areas:

- **Application of Innovative Materials and Technologies,** including research on development and deployment of new materials and technologies with potential high impact on transportation infrastructure needs.
- **Condition Assessment and Health Monitoring,** including development of automated, remote access (e.g., using drones), and remote-controlled inspection and monitoring technologies, as well as novel imaging, nondestructive evaluation, and self-sensing and health monitoring techniques, to provide rapid, repeatable, and reliable assessment of the present condition and rate of degradation of aging infrastructure facilities.
- **Infrastructure Management and Innovative Financing,** to advance infrastructure asset management at the project, network, and system decision levels. The goal is to support informed collaborative and multi-objective decision making on investments and address societal needs for safe, reliable, and resilient transportation infrastructure systems.

B. Accomplishments During the Reporting Period

This semi-annual progress report covers the period of April 1, 2019 through September 30, 2019, which is the second reporting period for the regional center. The following activities have been accomplished during the reporting period.

Center Website and Social Networking

The CIAMTIS website (available at: https://r3utc.psu.edu) is regularly updated and now includes the quarterly newsletter, semi-annual progress reports, and a listing of all research projects. The website also redirects visitors to the inaugural Transportation Asset and Infrastructure Management website, which can be found at: https://www.taim.psu.edu/ A Google Analytics account was developed and is being used to compile statistics about the visitors to the CIAMTIS website.

In addition to the website, the Facebook and Twitter social networking accounts are regularly updated to communicate CIAMTIS activities to interested stakeholders. The Facebook site is: https://www.facebook.com/PSUR3UTC and the Twitter account is: https://twitter.com/psur3utc

Quarterly Newsletter

CIAMTIS developed and disseminated a quarterly newsletter during the reporting period. The fall 2019 issue featured the following content: background information about the CIAMTIS consortium and thrust areas, listing of on-going research and educational activities, and announcement regarding inaugural TAIM conference. The newsletter was disseminated to stakeholders throughout the mid-Atlantic region, including professional associations, state and federal transportation agencies, and academic institutions. The newsletter was made available in both on-line and in .pdf formats. The newsletter is posted on the CIAMTIS website.

Center-wide Outreach and Technology Transfer Activities: Transportation Asset and Infrastructure Management Conference

Planning for the inaugural mid-Atlantic regional Transportation Asset and Infrastructure Management (TAIM) conference began in May 2019. A steering committee was formed to represent stakeholders from federal and state transportation agencies, industry, and academics from the CIAMTIS consortium. The steering committee worked with the conference planning team from Penn State to develop the conference program, which consists of 12 technical sessions, one pre-conference workshop, two technical tours, and more than 40 speakers. More than 110 participants were registered for the conference when this semi-annual progress report was prepared. The conference will take place on October 28-29, 2019, at the Penn Stater Hotel and Conference Center in State College, Pennsylvania.

Research and Education Activities

All research, education, and outreach activities undertaken by CIAMTIS consortium universities are allocated in two funding pools. Each partner university receives base or core funding that must support at least one education or technology transfer activity, as well as one or more research activities annually. This amounts to approximately one-half of the federal funds awarded to CIAMTIS. The remaining funds are available on a competitive basis via response to an annual call for proposals.

Year 1 Funds

The competitive proposal process used to award 14 projects using Year 1 funds was documented in the first semi-annual progress report. These projects are summarized in Table 1 below. All project Principal Investigators have completed quarterly progress reports for the projects shown in Table 1 – each of these projects will continue through the end of the period of performance noted.

In addition to the competitive proposals awarded using Year 1 funds, a collection of research and educational activities using core funds are on-going. These 16 projects are identified in Table 2. The project Principal Investigators have all documented their activities to date in quarterly progress reports – the projects will continue through the end of the period of performance noted in Table 2.

The following summarizes the distribution of projects currently underway using Year 1 funds:

- 13 projects are focused on the application of innovative materials and technologies;
- 13 projects are focused on condition assessment and structural health monitoring;
- 8 projects are focused on infrastructure management and innovative financing;
- 7 projects are focused on bridges;
- 14 projects are focused on pavements;
- 1 project is focused on railroads;
- 4 projects are focused on foundations, slopes, data analytics, infrastructure maintenance, or other general topics related to the CIAMTIS themes;
- 5 of 14 projects (36 percent) awarded in the competitive program were for multi-university collaborations among at least two CIAMTIS member institutions (goal is 25 percent of competitive awards to multi-university collaborations).

Table 1. Projects Funded in Year 1 Competitive Program.

Project	PI	Thrust Areas	PI Univ.	Partner Univ.	Performance Dates		Activity Type
Efficient Service Life Extension of Bridges through Risk-based Life-cycle Management and High-performance Construction Materials: Emphasis on Corrosion-resistant Steel	Frangopol, Dan	A	LU		3/1/19	3/1/20	R
Fatigue Life Estimation of Bridges with Smart Mobile Sensing	Pakzad, Shamim N.	C	LU		3/1/19	6/1/20	R
Life Extension of Fatigue-Damaged Highway, Rail, and Transit Bridges	Sause, Richard	A, C	LU		3/1/19	6/1/20	R
Numerical and Experimental Investigation of Efficient Geometric Arrangement of Metal Fin Tube Foundations for Transportation Applications	Qiu, Tong; Laman, Jeffrey	A	PSU		3/1/19	6/1/20	R
Time-Based Modeling of Concrete Bridge Deck Deterioration Using Probabilistic Models	Guler, Ilgin	I	PSU		3/1/19	2/1/20	R
Railroad Track Performance Monitoring by Advanced Sensor Network & Big Data	Huang, Hai	C	PSU-Altoona	UDel	3/1/19	3/1/21	R
Use of SmartRock Sensors to Monitor Pavement Performance for Supporting Rehabilitation Decision Making	Shen, Shihui; Wang, Linbing	A	PSU-Altoona, VT		3/1/19	3/1/21	R
Improved Methods to Assess Corrosion Damage in Prestressed Concrete Beams	Roberts-Wollman, Carin	C	VT		3/1/19	6/1/20	R
Development of a Practical Risk Framework for Railway Bridge Stiffness Transition Maintenance and Upgrade	Palese, Joseph	C	UDel		3/1/19	3/1/20	R
Planning for the Inevitable: Readying DOTs for Disaster Debris Management	McNeil, Sue	I	UDel		3/1/19	3/1/20	E, TT

Project	PI	Thrust Areas	PI Univ.	Partner Univ.	Performance Dates		Activity Type
Strategic Prioritization and Planning of Transportation Infrastructure Maintenance, Rehabilitation, and Improvements Incorporating Continuously-Sensed Data	Miller-Hooks, Elise; Lattanzi, David	I	GMU	PSU, UDel	3/1/19	3/1/21	R
Bridge Load Rating and Evaluation Using Digital Image Measurements	Head, Monique	C	UDel	GMU	3/1/19	3/1/21	R
Optimized Performance of UHPC Bridge Joints and Overlays	Mondal, Paramita	A	UDel	PSU	3/1/19	3/1/21	R
Development of Low-Cost Weigh-In-Motion (WIM) and Response Spectra Techniques Phase I of "Development of a Cost-Effective Sensing System for Integrated Traffic and Pavement Response Monitoring in Support of Pavement Management"	Wang, Linbing	C	VT	WVU	3/1/19	3/1/21	R

Legend:

UNIVERSITIES:

GMU	George Mason University	**PSU-Altoona**	Penn State University - Altoona
LU	Lehigh University	**UDel**	University of Delaware
MSU	Morgan State University	**VT**	Virginia Tech
PSU	Penn State University	**WVU**	West Virginia University

THRUST AREAS:

- **A** Application of Innovative Materials and Technologies
- **C** Condition Assessment and Health Monitoring
- **I** Infrastructure Management and Innovative Financing

ACTIVITY TYPE:

- **R** Research
- **E** Education
- **TT** Technology Transfer

Table 2. Projects Funded in Core Program.

Project	PI	Thrust Areas	PI Univ.	Partner Univ.	Performance Dates		Activity Type
					Beg.	End	
Residual Compressive Strength of Partially Confined Concrete Column Retrofitted Using CFRP Wrap	Aslan, Kadir	A	MSU				R
The Impact of Accessing Public Credit Support on Public Private Partnerships	Gifford, Jonathan	I	GMU		1/25/19	3/24/20	R
Imagine the Future: Exercises on Conceptualizing Infrastructure Systems for an Interconnected World	Miller-Hooks, Elise	I	GMU		3/18/19	6/18/19	E
CIAMTIS Graduate Fellowship at University of Delaware	McNeil, Sue	A, C, I	UDel		1/1/19	8/31/20	E
Enhancing Fundamentals of Engineering Program	Zaniewski, John		WVU		3/1/19	3/1/20	E
Condition-based Inspection and Restoration Scheduling of Pavement and Bridge Systems for Improved Post-disaster Infrastructure Systems Recovery	Miller-Hooks, Elise	I	GMU		3/11/19	3/11/21	R

Project	PI	Thrust Areas	PI Univ.	Partner Univ.	Performance Dates		Activity Type
					Beg.	End	
Finite Element Model Updating for Bridge Deformation Measurements Extracted from Remote Sensing Data	Lattanzi, David	C	GMU		3/11/19	3/11/20	R
CIAMTIS Lehigh Research Experience for Undergraduates (REU) Program	Sause, Richard	A, C	LU		3/11/19	10/11/19	E
Road Pavement Condition Monitoring by Embedded Crowdsensing	Cheng, Liang	C	LU		3/11/19	5/31/20	R
Design of Anchors for Rapid and Durable Strengthening of Bridges with Externally Bonded Carbon Fiber Reinforced Polymers	Head, Monique	A	UDel		3/11/19	3/11/21	R
Evaluation, Beneficiation, and Implementation of Alternative Concrete Pozzolans for Transportation Infrastructure	Rajabipour, Farshad	A	PSU		3/11/19	3/11/20	R
A Novel Trackbed Material for Stiffness Transition in Bridge Approaches and Its Integration in Educational Outreach	Shen, Shihui	A	PSU-Altoona		3/11/19	3/11/20	R, E
Integration of Innovative Sensing Technology and Data Analytics in Transportation Asset Management	Wang, Linbing	C, I	VT		3/1/19	3/1/23	R
Evaluation of an Innovative Erosion Control on Road Embankment Using Synthetic Turf with Sand Infill	Xiao, Ming	A	PSU		3/18/19	3/18/20	R
Automated Path Tracking and Mapping for Economical, Real-Time, and Knowledge-Based Roller Control in Pavement Compaction Operations: Phase I: Algorithm Development	Dai, Fei	A	WVU		3/18/19	3/18/20	R
Calibration of WVDOH IRI-based PSI and SCI Equations	Yoon, Yoojung	C	WVU		8/1/19	1/1/21	R

Legend:

UNIVERSITIES:

GMU	George Mason University	**PSU-Altoona**	Penn State University - Altoona
LU	Lehigh University	**UDel**	University of Delaware
MSU	Morgan State University	**VT**	Virginia Tech
PSU	Penn State University	**WVU**	West Virginia University

THRUST AREAS:

- **A** Application of Innovative Materials and Technologies
- **C** Condition Assessment and Health Monitoring
- **I** Infrastructure Management and Innovative Financing

ACTIVITY TYPE:

- **R** Research
- **E** Education
- **TT** Technology Transfer

Year 2 and 3 Funds

Year 2 and 3 grant funds were made available to the consortium in August 2019. At that time, a call for competitive proposals was developed and distributed to the member universities. Proposals were due on October 14, 2019. A large proportion of the Year 1 awards focused on the application of innovative materials and technologies and on the condition assessment and health monitoring research thrust areas. In addition, a large proportion of the Year 1 awards focused on

brides. The year 2 and 3 call for competitive proposals therefore sought research ideas related to the infrastructure management and innovative financing research thrust, as well as on research applications related to pavements and rail transportation.

A total of 32 proposals were received in response to the call for proposals. The proposals will be reviewed during the next reporting period. In addition to awarding projects in the competitive program, core funds will also be allocated during the next reporting period.

Research Experience for Undergraduates at Lehigh University

Lehigh University, through its Institute for Cyber Physical Infrastructure and Energy (I-CPIE) and its Advanced Technology for Large Structural Systems (ATLSS) Engineering Research Center, ran a 10-week CIAMTIS Lehigh Research Experience for Undergraduates (REU) program. The REU program funded 4 students from Lehigh university to participate in a REU program. The program's focus included the assignment of each student to an active (Year 1) Lehigh University CIAMTIS research project under the direction of the project Principal Investigator and graduate student mentor to help the student navigate through the research project experience. Beyond the research experience, the program exposed the students to a well-rounded professional development experience. The program's activities included professional skills development workshops and seminars, onsite outreach activities, and offsite tours. The program culminated with a final report, poster, and presentation on the research findings.

Other Administrative Activities of CIAMTIS

The following other administrative activities have been completed during the current reporting period:

- CIAMTIS consortium members continue participating in monthly progress report meetings via teleconference to discuss research and education activities, reporting requirements, and other matters of interest related to the Center.

- All research projects shown in Tables 1 and 2 have been updated to the Transportation Research Board's (TRB) Research in Progress (RIP) database and documented on the CIAMTIS website.

C. How have the results been disseminated?

During the current reporting period, the following goals have been accomplished and disseminated:

- Two ArtsBridge students from the University of Delaware developed modules for elementary school students on climate change and the associated impacts on transportation infrastructure. The ArtsBridge students presented their work at the University of Delaware's 2019 Undergraduate Research and Service Scholar Celebratory Symposium in August 2019.

- Seven University of Delaware graduate students made presentations about their CIAMTIS research at the 15th Annual Interuniversity Symposium on Infrastructure Management held at the Center for Advanced Infrastructure and Transportation at Rutgers University in May 2019.

- The University of Delaware has used CIAMTIS funds to develop modules for an online version of a civil engineering graduate course (CIEG 655 "Civil Infrastructure Systems"). The new modules focus on Asset Management.

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

Core and Competitive Research and Educational Activities

The activities shown in Tables 1 and 2 will continue during the next reporting period. In addition, the Year 2 and 3 competitive project proposals will be peer-reviewed and awards will be made during the next reporting period. The Year 2 and 3 core projects will also be identified during the next reporting period. It is anticipated that several research projects will conclude during the next reporting period, so project Principal Investigators will begin publishing reports and technical briefs of their research during the 2020 calendar year.

Technology Transfer and Outreach Activities

- Penn State will host the inaugural Transportation Asset and Infrastructure Management conference on October 28-29, 2019. At the conclusion of the conference, the steering committee will have a debriefing and begin efforts to plan for the 2nd annual conference.

- CIAMTIS will continue efforts to coordinate a consortium-level faculty and graduate student seminar series. This will involve use of a web-based conference tool so that consortia members may learn from research being done at various CIAMTIS member institutions. It is anticipated that graduate students will present the current status of research that they are performing to seek feedback about work while it is in progress. Because most of the Year 1 research activities will not be completed until June 2020, it is envisioned that one or two web-seminars will be offered during the next reporting cycle.

- CIAMTIS will continue efforts to coordinate an online professional development series for practitioners wishing to learn more about opportunities to implement Center activities into practice. It is envisioned that research projects shown in Tables 1 and 2 will have significant technology transfer components and these will be shared via one-hour webinars.

- CIAMTIS will continue disseminating quarterly newsletters during the next reporting period, highlighting progress from several research and educational activities, as well as summarizing planned Center events and activities.

II. PARTICIPANTS AND COLLABORATING ORGANIZATIONS

Below is a list of organizations who have been involved as CIAMTIS partners during the current reporting period. This includes state transportation agencies, materials suppliers, professional

trade organizations, and heavy highway contractors. Each partner organization's contribution to a particular activity is noted.

Organization Name:	Pennsylvania Department of Transportation
Location of Organization:	Harrisburg, PA
Partner's contribution(s) to the project:	PennDOT executed an intergovernmental agreement with Penn State to offer matching funds for research and educational activities undertaking by CIAMTIS faculty. The agreement ends on September 30, 2023 with a funding limit of $2.5 million. PennDOT, Penn State, and the FHWA division office will form a steering committee to identify projects that will be funded using resources from the agreement. The initial steering committee meeting is scheduled in November 2019. PennDOT is also collaborating on Lehigh University projects by assisting to identify bridges that can be used for case study research.

Organization Name:	Arcelor Mittal (in collaboration with Lehigh University for project "Efficient Service Life Extension of Bridges through Risk-based Life-cycle Management and High-performance Construction Materials: Emphasis on Corrosion-resistant Steel")
Location of Organization:	Coatesville, PA
Partner's contribution(s) to the project:	This partner is performing collaborative research with Lehigh University by offering staff support on the project, which includes cost and environmental impact data for ASTM A709-50CR steel.

Organization Name:	High Steel Structures (in collaboration with Lehigh University for project "Fatigue Life Estimation of Bridges with Smart Mobile Sensing")
Location of Organization:	Lancaster, PA
Partner's contribution(s) to the project:	This partner is performing collaborative research with Lehigh University by offering in-kind support of steel components for testing.

Organization Name:	Virginia Transportation Research Council
Location of Organization:	Charlottesville, VA
Partner's contribution(s) to the project:	This partner is working with Virginia Tech to offer matching funds on projects undertaken by Virginia Tech faculty.

Organization Name:	Watershed Geo
Location of Organization:	Atlanta, GA
Partner's contribution(s) to the project:	Dr. Bryan Scholl, an engineer at Watershed Geo, is working closely with the project team on the study "Evaluation of an Innovative Erosion Control on Road Embankment Using Synthetic Turf with Sand Infill." Watershed Geo is providing matching project funds to support flume construction, testing, and data analysis on the project.

Organization Name:	Schuylkill Energy Resources, Robindale Energy, Boral Resources, York Building Products.
Location of Organization: (if foreign, list country)	All organizations are Pennsylvania-based energy or materials suppliers.
Partner's contribution(s) to the project:	All have committed financial support (match) to Penn State for project "Evaluation, Beneficiation, and Implementation of Alternative Concrete Pozzolans for Transportation Infrastructure." They also provide routine feedback on the research results and assist with technology transfer and field implementation of the research products.

Organization Name:	Delaware Department of Transportation
Location of Organization: (if foreign, list country)	Dover, Delaware
Partner's contribution(s) to the project:	The Delaware Department of Transportation and Delaware Local Technical Assistance Program offer matching funds for University of Delaware projects, and provide technology transfer support for University of Delaware projects.

Organization Name:	American Concrete Institute
Location of Organization: (if foreign, list country)	Farmington Hills, Michigan
Partner's contribution(s) to the project:	ACI has committed financial support (match) to Penn State for project "Evaluation, Beneficiation, and Implementation of Alternative Concrete Pozzolans for Transportation Infrastructure." In addition, the University of Delaware is partnering with ACI Committee 440 to identify the experimental data test gaps to advance the knowledge and performance of repair and strengthening existing concrete bridges with fiber reinforced polymer (FRP) anchors. Specifically, ACI Committee 440-H is particularly interested in this topic as valid, appropriately scaled data with validated numerical models are needed to help direct design guidelines for ACI 440.2R-17 on the use of these FRP anchors for flexural strengthening of externally bonded systems. It is anticipated that the framework supported by this research may lead to design equations supported by experimental test data to be documented in ACI 440.2R-17.

Organization Name:	West Virginia Department of Highways
Location of Organization:	Charleston, West Virginia
Partner's contribution(s) to the project:	This partner is providing matching funds for projects undertaken by West Virginia

Organization Name:	Pennsylvania Infrastructure Technology Alliance
Location of Organization: (if foreign, list country)	Harrisburg, Pennsylvania
Partner's contribution(s) to the project:	The Pennsylvania Infrastructure Technology Alliance (PITA) is a collaboration of the Commonwealth of Pennsylvania, the Center for Advanced Technology for Large Structural Systems (ATLSS) at Lehigh University, and the Institute for Complex Engineered Systems at Carnegie Mellon University. PITA offers matching funds to competitive and core research projects conducted by Lehigh University.

Organization Name:	Norfolk Southern
Location of Organization: (if foreign, list country)	Atlanta, GA
Partner's contribution(s) to the project:	Offer in-kind access to rail track, material donations, on-track protection, and professional feedback on Penn State-Altoona projects.

Organization Name:	RTS
Location of Organization: (if foreign, list country)	Hollidaysburg, PA
Partner's contribution(s) to the project:	Provide SmartRock sensors for Penn State-Altoona research projects, offer quality assurance of sensor installation in field, assist with data analysis, and offer professional feedback on research projects.

Organization Name:	Mission Critical Solutions and Ben Franklin Technology Partners
Location of Organization: (if foreign, list country)	Both organizations are location in Pennsylvania
Partner's contribution(s) to the project:	Ben Franklin Technology Partners offer funding and business and technical expertise to early-stage technology firms to promote innovation. Mission Critical Solutions is working with the Ben Franklin Technology Partners to offer matching funds and in-kind technical support to Penn State for the project "Numerical and Experimental Investigation of Efficient Geometric Arrangement of Metal Fin Tube Foundations for Transportation Applications." Mission Critical Solutions is offering input on the numerical simulations and experimental design to enhance implementation and technology transfer opportunities within the industry.

III. OUTPUTS

A. List any outputs resulting from the program during the reporting period. (e.g., Publications, conference papers, and presentations; Policy Papers; Website(s) or other Internet site(s); New methodologies, technologies or techniques; Inventions, patents, and/or licenses; Other products, such as data or databases, physical collections, audio or video products, application software or NetWare, analytical models, educational aids, courses or curricula, instruments, equipment, or research material)

The CIAMTIS research performance metrics, goals, and targets are shown in Table 3, while the technology transfer performance metrics, goals, and targets are shown in Table 4. These targets will be assessed in subsequent semi-annual progress reports, as research and educational activities are completed.

Table 3. Research Performance Metrics

Output, Outcome, or Impact	Performance Measure	Target
Output #1	Annual number of journal publications	30
Output #2	Annual number of conference presentations	40
Outcome #1	Annual number of times research changes a standard practice, guideline, or specification	2
Outcome #2	Annual number of media stories referencing CIAMTIS research, faculty, or students	12
Impact #1	Percentage of research projects that extend infrastructure asset life by 10%	20%
Impact #2	Percentage of research projects that reduce repair, maintenance, and rehabilitation costs by 10%	20%

Table 4. Performance Metrics for CIAMTIS Technology Transfer Activities

Performance Metric	Assessment Measure	Performance Targets
Partnership with Private and Public Entities	✓ Number of technologies advanced to State Transportation Innovation Councils (STIC) in each state or nominated for Every Day Counts (EDC) and Accelerated Innovation Deployment (AID) programs. ✓ Number of adopted technologies or programs.	✓ One STIC technology innovation annually. ✓ One adopted technology or program annually.
Patents and Commercialization	✓ Number of invention disclosures, patents, and copyright applications. ✓ Number of license agreements.	✓ One invention disclosure, patent, or copyright application annually. ✓ One license agreement annually.
Publications and Presentations	Number of publications and presentations per project and per thrust area.	One publication and presentation per project per year.
Information Exchange	Number of website visitors, news reports, and tech-briefs.	500 website visitors annually, seven news reports annually, and seven technical briefs annually.
Continuing Education Courses	✓ Number of courses offered annually. ✓ Number of participants.	✓ Three continuing education courses offered annually with at least 25 participants per course.
Number of students supported	✓ Number of undergraduate and graduate students supported annually by CIAMTIS	✓ Support at least 20 undergraduate and 20 graduate students annually.

B. Publications, Conference Papers, and Presentations

Journal Publications

- Yang, D. Y. and D. M. Frangopol. Life-cycle Management of Deteriorating Bridge Networks with Network-level Risk Bounds and System Reliability Analysis. Submitted for review to *Structural Safety*.

- Gulgec, N. S., M. Takac, and S. N. Pakzad. Structural Sensing with Deep Learning: Strain Estimation from Acceleration Data for Fatigue Assessment. Submitted to *Computer-aided Structure and Infrastructure Engineering*.

- Zahedi, M., and F. Rajabipour. Fluidized bed combustion (FBC) fly ash and its performance in concrete. *ACI Materials Journal*, 116(4), 2019.

Books or Other Non-Periodical, One-Time Publications: Nothing to report this period

Other Publications, Conference Papers and Presentations

- Alkhatib, K. and J. McCray. Climate Change Movement: Teaching Climate Change through Dance. Presented at *2019 Undergraduate Research and Service Scholar Celebratory Symposium*, University of Delaware.

- Curnyn, A. and J. McCray. Arts Integrated Science Lessons: Learning about Climate Change through Dance. Presented at *2019 Undergraduate Research and Service Scholar Celebratory Symposium*, University of Delaware.

- Alenzi, A., G. Upton, M. Adegoke, M. Shokouhian, and M. Head. Experimental Investigation of Residual Compressive Strength of Partially Confined Column Retrofitted using CFRP Wrap. Presented at the *ASCE-SEI Structures Congress 2019*, Orlando, FL, April 24-27, 2019.

- Yang, D. Y. and D. M. Frangopol. Comparison of Different Risk-based Inspection Planning Methods for Life-cycle Maintenance Optimization. Presented at *ASCE-SEI Structures Congress 2019*, Orlando, FL, April 24-27, 2019.

- Childress, E. and J. Gifford. Measuring the Impact of Federal Credit Support Programs. Presented at the *American Road and Transportation Builders Association Public Private Partnership Conference*, Washington, DC, July 2019.

- Gulgec, N. S., M. Takac, and S. N. Pakzad. Innovative Sensing by Using Deep Learning. *Dynamics of Civil Structures*, Vol. 2, pp. 293-300, Springer, 2019.

- Eshkevar, S. S. and S. N. Pakzad. Innovative Sensing by Using Deep Learning Framework. *Topics in Modal Analysis and Testing*, Vol. 8, pp. 61-75, Springer, 2020.

- Pei, T., T. Qiu, and J. A. Laman. Parametric Study of Steel Fin Pile Foundations. Report submitted to Mission Critical Solutions, LLC., LTI 2020-02, 2019, 82 pp.

- Pei, T., T. Qiu, and J. A. Laman. A Numerical Investigation of Laterally Loaded Steel Fin Pile Foundations. Accepted for publication in the *Proceedings of the 2020 ASME Joint Rail Conference*, April 19-22, 2020, St. Louis, MO, USA, accepted for presentation.

- Gifford, J. Putting P3 Research into Action. Presented at the *31st Annual American Road and Transportation Builders Association (ARTBA) P3s in Transportation Conference*, Washington D.C., July 17-19, 2019.

- Jafari, K., and F. Rajabipour. The performance of impure calcined clay as a pozzolan in concrete. Accepted for presentation at the *2020 Transportation Research Board Annual Meeting*. Currently in review for publication in Transportation Research Record: Journal of the Transportation Research Board.

Website(s) or Other Internet Site(s) (Not necessary to include the publications already specified above in this section.): Nothing to report this period

Technologies or Techniques: Nothing to report this period

Inventions, Patent Application, and/or Licenses *(include date, and/or licenses that have resulted from the research):* Nothing to report this period

IV. OUTCOMES *[WHAT OUTCOMES HAS THE PROGRAM PRODUCED? HOW ARE THE RESEARCH OUTPUTS DESCRIBED IN SECTION (III) ABOVE BEING USED TO CREATE OUTCOMES?]*

A. What outcomes has the program produced? How are the research outputs being used to create outcomes?

Programmatic outcomes will be measured after the first collection of research projects (see Tables 3 and 4) are completed. Examples of expected outcomes include the following:

- Development of a crowdsensing system allowing for pavement condition monitoring in a low-cost, reliable and rapid manner. The number of targeted users is 100.
- Development of a novel method to select bridges in a transportation network for potential rehabilitation actions. The proposed method will select critical bridges for rehabilitation endeavors to minimize network-level risks associated with deterioration-induced bridge failure.
- The program proposes to develop a mobile phone application that collects acceleration data from bridges. This app will send the collected acceleration data to the servers to convert it to rain-flow counting histograms to be used in fatigue life assessment.
- Crack-arrest-hole recommendations in the form of draft specifications for owners to adopt for their projects to maintain steel bridges within rail and highway systems.
- The anticipated findings from innovate financing research can help policy makers accurately assess the current status of the TIFIA program and make better policy designs in further enhancing the TIFIA credit program. The analysis also aims to help concessionaires better approach the credit support program.
- The proposed research has the potential to improve the condition assessment of bridges using remote sensing-based measurements. The program will address key challenges that engineers face when evaluating the impact of geometric distortions on structural performance. Two practical applications of explicit interest to stakeholders are (1) the quantification of truck collision damage on bridge capacity and (2) quantification of web crippling impacts on bridge bearing capacity.

B. Discuss the performance measures (a minimum of two) for research outcome and the targets (goals) for each measure

Nothing to report this period

V. IMPACTS *[WHAT IS THE IMPACT OF THE PROGRAM? HOW HAS IT CONTRIBUTED TO IMPROVE THE TRANSPORTATION SYSTEM: SAFETY, RELIABILITY, DURABILITY, ETC.; TRANSPORTATION EDUCATION; AND THE WORKFORCE?]*

A. Impact: Nothing to report this period

B. What is the impact on the effectiveness of the transportation system? Nothing to report this period

C. 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 this period

D. What is the impact on the body of scientific knowledge? Nothing to report this period

E. What is the impact on transportation workforce development? Nothing to report this period

VI. CHANGES/PROBLEMS

A. Changes in approach and reasons for change: Nothing to report this period

B. Actual or anticipated problems or delays and actions or plans to resolve them: Nothing to report this period

C. Changes that have a significant impact on expenditures: Nothing to report this period

D. Significant changes in use or care of human subjects, vertebrate animals, and/or biohazards: Nothing to report this period

E. Change of primary performance site location from that originally proposed: Nothing to report this period

VII. SPECIAL REPORTING REQUIREMENTS

None to report this period.