



SEMI-ANNUAL PROGRAM PROGRESS REPORT

FOR

UNIVERSITY TRANSPORTATION CENTERS

Project Title: **Center for Integrated Asset Management for Multimodal Transportation Infrastructure Systems (CIAMTIS)**

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Reporting Period: October 1, 2020 through March 31, 2021

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 focus 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 October 1, 2020 through March 31, 2021, which is the fifth reporting period for the regional center. The following center-wide 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 includes research project reports and technical briefs for several research projects that were completed during the reporting period. In addition to the CIAMTIS website, a website for the second annual TAIM conference was developed and updated regularly during the reporting period – this website can be found at the following link: <https://www.taim.psu.edu/>. The TAIM conference took place virtually on October 19-20, 2020.

The CIAMTIS 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>

CIAMTIS Newsletter

The CIAMTIS marketing and communications team completed contents for the fall/winter 2020 newsletter during the reporting period and distributed it to the TAIM stakeholder group during the reporting period. Contents for the fall/winter 2020 newsletter included: story about the 2nd annual TAIM conference; summaries/links to final research project reports; list of on-going projects with associated abstracts; education and outreach news; and highlights of a graduate student and post-doctoral scholar group that has been created among the CIAMTIS consortium. Content for the spring 2021 newsletter was also developed during the reporting period. Contents for this newsletter include the following: educational features from CIAMTIS activities, research project summaries, announcement of new research and educational project awards, and a summary of the new Transportation Infrastructure webinar series. The spring 2021 newsletter will be distributed in April 2021.

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

The second annual TAIM conference was held virtually on October 19-20, 2020 (<https://www.taim.psu.edu>). There was a total of 131 registered participants for the event, representing an 11 percent increase over the inaugural conference. The program consisted of the following activities:

- Two pre-conference workshops on Asset Management.
- Twelve (12) concurrent technical sessions on topics related to innovative materials and technologies, condition assessment and structural health monitoring, and infrastructure asset management.
- A graduate student research exhibition with “lighting” talks from several graduate students from universities in the CIAMTIS consortium.
- A keynote address by Leslie Richards, General Manager of the Southeastern Pennsylvania Transportation Authority (SEPTA) and former Pennsylvania Secretary of Transportation.

Planning for the 3rd annual conference began during the current reporting period. The conference will be held virtually in October 2021.

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 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 awarded on a competitive basis via response to an annual call for proposals.

Year 1 Funds

The competitive proposal process resulted in 14 projects being awarded using Year 1 competitive funds. These projects are summarized in Table 1 below. The rows that are shaded are projects that are complete, including 2 that were completed during the current reporting period. Final reports are posted on the CIAMTIS website and are distributed to various repositories per UTC grant deliverables requirements. It is anticipated that 2 additional projects will be completed during the next reporting period.

In addition to the competitive proposals awarded using Year 1 funds, a collection of research and educational activities using core funds were awarded. These 16 projects are shown in Table 2. The shaded rows identify projects that are complete, including 4 projects that were completed during the current reporting period. Final reports are posted on the CIAMTIS website and are distributed to various repositories per UTC grant deliverables requirements.

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	9/1/20	R
Fatigue Life Estimation of Bridges with Smart Mobile Sensing	Pakzad, Shamim N.	C	LU		3/1/19	12/21/20	R
Life Extension of Fatigue-Damaged Highway, Rail, and Transit Bridges	Sause, Richard	A, C	LU		3/1/19	12/31/20	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	9/1/20	R
Time-Based Modeling of Concrete Bridge Deck Deterioration Using Probabilistic Models	Guler, Ilgin	I	PSU		3/1/19	8/15/20	R
Railroad Track Performance Monitoring by Advanced Sensor Network & Big Data	Huang, Hai	C	PSU-Altoona	UDel	3/1/19	9/30/21	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	12/31/21	R
Improved Methods to Assess Corrosion Damage in Prestressed Concrete Beams	Roberts-Wollman, Carin	C	VT		3/1/19	12/20/21	R

Project	PI	Thrust Areas	PI Univ.	Partner Univ.	Performance Dates		Activity Type
Development of a Practical Risk Framework for Railway Bridge Stiffness Transition Maintenance and Upgrade	Palese, Joseph	C	UDel		3/1/19	8/25/20	R
Planning for the Inevitable: Readyng DOTs for Disaster Debris Management	McNeil, Sue	I	UDel		3/1/19	3/1/20	E, TT
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	5/21/21	R
Bridge Load Rating and Evaluation Using Digital Image Measurements	Head, Monique	C	UDel	GMU	3/1/19	12/31/21	R
Optimized Performance of UHPC Bridge Joints and Overlays	Mondal, Paramita	A	UDel	PSU	3/1/19	12/31/21	R
Development of Low-Cost Weigh-In-Motion (WIM) and Response Spectra Techniques: "Development of Cost-Effective Sensing System for Integrated Traffic and Pavement Response Monitoring in Support of Pavement Management"	Wang, Linbing	C	VT	WVU	3/1/19	12/1/21	R
Legend: Universities: GMU is George Mason University; LU is Lehigh University; MSU is Morgan State University; PSU is Penn State University; PSU-Altoona is Penn State-Altoona; UDel is University of Delaware; VT is Virginia Tech; WVU is West Virginia University Thrust Areas: A is application of innovative materials or technologies; C is condition assessment or structural health monitoring; I is infrastructure management and innovative financing Activity Type: R is research; E is education; TT is 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		4/1/19	3/31/20	R
The Impact of Accessing Public Credit Support on Public Private Partnerships	Gifford, Jonathan	I	GMU		1/25/19	9/24/20	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	7/20/23	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
Finite Element Model Updating for Bridge Deformation Measurements Extracted from Remote Sensing Data	Lattanzi, David	C	GMU		3/11/19	3/11/21	R

Project	PI	Thrust Areas	PI Univ.	Partner Univ.	Performance Dates		Activity Type
					Beg.	End	
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	12/31/20	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	9/30/21	R
Evaluation, Beneficiation, and Implementation of Alternative Concrete Pozzolans for Transportation Infrastructure	Rajabipour, Farshad	A	PSU		3/11/19	6/1/20	R
A Semi-flexible Composite Trackbed Material for Stiffness Transition in Bridge Approaches and Its Application	Shen, Shihui	A	PSU-Altoona		3/11/19	10/6/20	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 WVDH IRI-based PSI and SCI Equations	Yoon, Yoojung	C	WVU		8/1/19	12/31/21	R
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Year 2 and 3 Funds

Year 2 and 3 Federal funds were made available to the consortium in August 2019. Projects awarded via the competitive program are shown in Table 3, while awards made in the core program are shown in Table 4. The 2 projects that are shaded in Table 3 (core funds) were completed during the current reporting period, while the remaining projects will continue into the next reporting period.

Year 4 Funds

During the reporting period, a competitive research project solicitation was developed and distributed in October 2020. A total of 27 proposals were received by CIAMTIS consortium members. A peer-review process was undertaken in November-December 2020. Table 5 is a summary of those projects that were awarded – several additional projects will also be awarded, following confirmation of matching funds. All Year 4 projects will continue into the subsequent

reporting period. Among the awarded projects, 50 percent are collaborative among at least two consortium members.

Table 3. Years 2 and 3 CIAMTIS Competitive Project Awards.

Project	PI	Thrust Areas	PI Univ.	Partner Univ.	Performance Dates		Activity Type
Decision Support Tools for Multi-objective, Multi-asset, Multi-modal Joint Maintenance Programming	McNeil, Sue	I	UDel	GMU, PSU	1/20/2020	1/19/22	R
Passive Strain Sensing Based on Changes in Retroreflectivity	Shenton, Harry	A, C	UDel		1/20/2020	1/20/22	R
Developing Equivalence Tools to Control Quality of Transportation Infrastructure Asset Management Data	Stoffels, Shelly	I	PSU		3/1/2020	4/30/21	R
AI-enabled fiscally constrained life-cycle asset management for infrastructure systems	Papakonstantinou, Kostas	I	PSU		1/20/2020	6/20/21	R
Smart Mobile Platform for Model Updating and Life Cycle Assessment of Bridges	Pakzad, Shamim	C	LU		1/20/2020	1/20/22	R
Artificial Intelligence for Advance Landslide Warning along Railroad Tracks in Pennsylvania and Delaware	Qiu, Tong	C	PSU	UDel	7/1/2020	6/30/22	R
Development of Turnout Rail Break Warning System Based on Distributed Optical Fiber Sensing Technologies	Huang, Hai	A, C	PSU-Altoona		1/1/2020	1/31/22	R
Evaluation of IoT-Enabled Pavement Response Monitoring for Transportation System Management	Wang, Linbing	C	VT	WVU	1/20/2020	7/19/21	R
Unmanned Aerial Vehicles for Inspection of Tack Coats and Ancillary Highway Structures	Dai, Fei	C	WVU	GMU, VT	1/20/2020	1/20/22	R
Durability Assessment of Externally Bonded Fiber-Reinforced Polymer (FRP) Composite Repairs in Bridge	Tatar, Jovan	A	UDel		2/1/2020	7/31/21	R
Extending Service Life of Rigid Pavement Joints with Self-Healing Sealants	Tatar, Jovan	A	UDel	VT	1/31/2020	1/31/22	R
Price Discovery for Strategic Compensation of Toll Road Operators to Relieve State Maintenance Impacts	Gifford, Jonathan	I	GMU	UDel	1/20/2020	1/31/22	R
Preparing the Next Generation of Undergraduate and Graduate Engineers in Autonomous Robotic System for Damage Detection	Efe, Steve	C	MSU		1/20/2020	1/20/22	E
Integration of traffic and structural health monitoring on the Varina-Enon Bridge via sensor fusion	Sarlo, Rodrigo	C, I	VT		1/20/2020	6/20/21	R
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Table 4. Years 2 and 3 CIAMTIS Core Project Awards.

Project	PI	Thrust Areas	PI Univ.	Partner Univ.	Performance Dates		Activity Type
Automated Path Tracking and Mapping for Economical, Real-Time, and Knowledge Based Roller Control in Pavement Compaction Operations: Phase II: Prototyping and Validation	Dai, Fei	A	WVU		3/4/20	3/4/22	R
CIAMTIS Lehigh Research Experience for Undergraduates (REU) Program – Year 2	Sause, Richard	A, C	LU		3/4/20	10/31/20	E
Finite element model updating for bridge deformation measurements extracted from remote sensing data (Year 2 of a two-year project)	Lattanzi, David	C	GMU		3/1/20	2/28/21	R
Detecting Disruptions, Defining Causes and Understanding System Stability Restoration in Disrupted Traffic Networks	Miller-Hooks, Elise	I	GMU		3/4/20	12/3/21	R
Optimization Framework for Infrastructure Management Considering Traffic Safety Costs	Guler, S. Ilgin	I	PSU		6/1/20	12/1/21	R
Experimental and Numerical Investigation of Recycled Fiber Reinforced Concrete for Green Bus Pads	Shokouhian, Mehdi	A	MSU		3/4/20	4/29/22	R
Prioritization Framework of ITS Technologies in the context of Smart Cities	Yoon, Yoojung	I	WVU		5/3/20	11/3/21	R
Use of Machine Learning to Predict Long-Term Skid Resistant of Concrete Pavements	Rajabipour, Farshad	A	PSU		5/11/20	2/11/21	R
Optimization Framework for Infrastructure Management Considering Traffic Safety Costs	Guler, Ilgin	I	PSU		6/1/20	12/1/21	R
Transportation Infrastructure Readiness for Post-Pandemic Supply Chain Transformation for greater Resilience	Miller-Hooks, Elise	I	GMU		6/1/20	6/1/22	R
Smart Compaction for Infrastructure Materials	Shen, Shihui	A	PSU-Altoona		6/1/20	6/1/22	R
Railroad Engineering Education & Outreach	Shen, Shihui / Huang, Hai	A	PSU-Altoona		6/1/20	6/1/22	E
Life Extension of Fatigue-Damaged Highway, Rail, and Transit Bridges: Identifying Actual Crack Tip	Pessiki, S / Sause, R / Hodgson, Ian	A	LU		8/3/20	8/2/22	R
Video-Sensor Data Fusion for Enhanced Structural Monitoring	Lattanzi, David	C	GMU		9/1/20	8/31/21	R
Legend: Universities: GMU is George Mason University; LU is Lehigh University; MSU is Morgan State University; PSU is Penn State University; PSU-Altoona is Penn State-Altoona; UDel is University of Delaware; VT is Virginia Tech; WVU is West Virginia University Thrust Areas: A is application of innovative materials or technologies; C is condition assessment or structural health monitoring; I is infrastructure management and innovative financing Activity Type: R is research; E is education; TT is technology transfer							

Table 5. Years 4 CIAMTIS Competitive Project Awards.

Project	PI	Thrust Areas	PI Univ.	Partner Univ.	Performance Dates		Activity Type
Characterizing Fundamental Rutting Property of Asphalt Concrete from Multiscale Simulative Tests using an Inverse Approach	Wang, Linbing	A	VT	PSU Alt	3/3/21	3/2/23	R
Combined Structural Health and Traffic Monitoring using Fiber Optic Distributed Acoustic Sensing	Wang, Linbing	A	VT	WV	2/15/21	2/14/23	R
Deep reinforcement learning for multi-asset infrastructure management incorporating traffic operations adaptations and control	Papakonstantinou,K. and Shelley Stoffels	I	PSU	GMU	5/1/21	4/30/23	R
Developing Transportation Engineering Graduates for Industry	Efe, Steve	C	MSU		3/8/21	3/7/23	E
Implementing Waste Plastics in Asphalt Pavement for Both Engineering and Environmental Benefits	Shen, Shihui	A	PSU Alt	VT	3/8/21	3/7/23	R
In-situ Stiffening and Upgrading of Ballasted Rail Track Beds via Cement Grout Injection	Rajabipour, Farshad	I	PSU Alt		3/15/21	10/14/22	R
Strategic Prioritization and Planning for Multi-Asset Transportation Infrastructure Maintenance, Rehabilitation, and Improvements: Phase 2 - Data-driven Decisions from Continuous Monitoring	Miller-Hooks, Elise and Lattanzi, David	I	GMU	UDel / PSU	5/21/21	3/31/22	R
Mitigating Cracking in Ultra-High Performance Concrete (UHPC) Bridge Connections	Tatar, Jovan	A	UDel	PSU	3/8/21	3/7/23	R
Investigation of the Benefit of Using a Novel Corrosion Resistant Steel in New and Existing Steel Bridges in Pennsylvania	Frangopol, Dan	A	LU		3/1/21	6/1/22	R
Development of a Virtual Weigh-In-Motion System for Enhanced Pavement System Management	Dei, Fei; Wang, Linbing	C	WVU	VT	3/1/21	8/31/22	R
Workforce Development and Job Training Pilot	Na, Ri	A,C,I	UDel		6/1/21	5/31/22	E
Utilizing daily traffic as a sensor network for infrastructure health monitoring	Pakzad, Shamin	I	LU		3/1/21	12/30/22	R
Infrastructure Subsurface Damage Detection through Video-Based Imperceptible Vibration Measurement	Dai, Fei	C	WVU		8/31/20	8/31/22	R
Legend: Universities: GMU is George Mason University; LU is Lehigh University; MSU is Morgan State University; PSU is Penn State University; PSU-Altoona is Penn State-Altoona; UDel is University of Delaware; VT is Virginia Tech; WVU is West Virginia University Thrust Areas: A is application of innovative materials or technologies; C is condition assessment or structural health monitoring; I is infrastructure management and innovative financing Activity Type: R is research; E is education; TT is technology transfer							

CIAMTIS Professional Development Webinar Series

During the current reporting period, CIAMTIS launched the Transportation Infrastructure monthly webinar series. One-hour webinars were delivered in February 2021 and March 2021 – speakers

included asset management professionals from the Federal Highway Administration and faculty from CIAMTIS. Planning for subsequent webinars is on-going, with speakers confirmed for April through June 2021. Continuing education credits are awarded for participation (0.1 credits per webinar) – a total of 25 participants are currently registered for the series – efforts are on-going to increase the number of registered participants.

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 new research projects shown in Table 5 have been added to the Transportation Research Board's (TRB) Research in Progress (RIP) database and documented on the CIAMTIS website.

Specific Education and Outreach Accomplishments of CIAMTIS Consortium Members

The following are some highlights of accomplishments from education and outreach projects during the reporting period for several CIAMTIS consortium members.

Penn State-Altoona

During the prior reporting period (March 2020 through September 2020), two rounds of the Women in Engineering Design Competition were held -- the third round of competition was held during the current reporting period (October 31, 2020). The competition held during the current reporting period focused on designing a solution to a highway-rail grade crossing problem, followed by a virtual presentation to a panel of judges.

In addition to the Women in Engineering Design Competition, the Penn State-Altoona faculty hosted virtual guest speakers from Norfolk Southern Railroad and CSX Railroad in October and November 2020, respectively, to discuss rail transportation engineering (RTE) topics with undergraduate students enrolled in the RTE program. In addition, faculty in the RTE program prepared a proposal to Metra Railroad for a virtual high school engineering summer camp during the reporting period.

University of Delaware

Faculty at the University of Delaware are working on several educational programs, including an ArtsBridge program, AISIM, Bootcamp, DRCIt! Debris Management, and summer Research Experience for Undergraduates (REU) program. During the current reporting period, dates have been set and instructors organized for a virtual infrastructure bootcamp for summer 2021, REU mentors were identified a project website (www.ciamtis-reu.com) developed and launched, and students are being recruited into the program. A collection of ArtsBridge activities have been developed for summer 2021.

Morgan State University faculty are working on a robotic training project, with the overall goal of training undergraduate and graduate students on autonomous road surface damage detection using a mobile robot. The project aims to assist in the creation of a strong, coherent and visible community of underrepresented scholars that will produce useful systems/designs and take-on pressing societal issues regarding the process of structural health monitoring and use of intelligent machines for damage detection.

The particular interest of this project is to develop the next generation of transportation engineers in supporting the Maryland Department of Transportation (MD-DOT) sustainable mobility initiative of automation technologies in infrastructure health monitoring. Current approaches for damage detection of roads such as visual inspection is time consuming, as difficulty in scanning larger surfaces of square miles, need for a spatially-referenced grid, and skilled operators are required. This project therefore seeks to train transportation engineering students on how to develop an autonomous robotic system to analyze roads distressed locations and provide surface damage detection using a convolutional neural network trained to characterize roads image-to-crack-label dataset. During the current reporting period, the Morgan State team prepared the training materials and, via collaboration with the Maryland Transportation Center, initiated the program for 8 undergraduate and 2 graduate students.

C. How have the results been disseminated?

During the current reporting period, several research and education project results have been disseminated. This includes completion of research reports, submission of journal publications, and presentations at conferences – these are highlighted below in section III Outputs below. In addition, other forums to disseminate results of research include the TAIM conference, where numerous faculty and graduate students presented their findings to more than 130 participants; presentations at the CIAMTIS Transportation Infrastructure monthly webinar series; and dissemination of the semi-annual CIAMTIS newsletter.

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

CIAMTIS Center-wide Core and Competitive Research and Educational Activities

The active projects shown in Tables 1 through 5 will continue during the next reporting period. It is anticipated that several research projects will conclude during the next reporting period, so project Principal Investigators be publishing final reports and technical briefs of their research. In addition, CIAMTIS partners will be encouraged to continue submitting research and education proposals for projects in the core program.

CIAMTIS Technology Transfer and Outreach Activities

- Penn State will continue planning for the 3rd annual Transportation Asset and Infrastructure Management (TAIM) conference during the next reporting period.

- CIAMTIS will continue scheduling speakers for the Transportation Infrastructure webinar series during the next reporting period and seek to increase participation in the series via increased marketing efforts to stakeholders throughout the mid-Atlantic region.
- CIAMTIS will continue disseminating newsletters during the next reporting period, highlighting progress from several research and educational activities, as well as summarizing planned Center events and activities.
- Rail Transportation Engineering (RTE) faculty at Penn State-Altoona will reconnect with schools to promote the “City-to-the-State” program, host a Kids College railroad engineering camp for 11-14 year old students during the summer of 2021, host a Railroad Engineering Summer camp for high school students during the summer of 2021, and begin planning for the next Railroad Industry Exchange conference (RRIX) – tentative date in Fall 2021.
- University of Delaware will deliver the ArtsBridge scholars program, Annual Interuniversity Symposium on Infrastructure Management (AISIM), and the Infrastructure Management “Bootcamp” in 2021, after postponing them in summer 2020.

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:	Central and District Offices
Partner’s contribution(s) to the project:	PennDOT and CIAMTIS continue collaborating to identify collaborative opportunities for matching on research projects. PennDOT Engineering District 5-0 is collaborating on Lehigh University projects by assisting to identify bridges that can be used for field research.
Organization Name:	American Concrete Institute
Location of Organization:	Farmington Hills, MI
Partner’s contribution to project:	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 and U wraps.
Organization Name:	High Steel Structures (in collaboration with Lehigh University)
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:	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 University and collaborating on the research.

Organization Name:	Asphalt Paving Association of West Virginia
Location of Organization:	Charleston, West Virginia
Partner's contribution(s) to the project:	This partner is working collaboratively on projects undertaken by West Virginia University faculty.
Organization Name:	Norfolk Southern Railroad
Location of Organization: (if foreign, list country)	Norfolk, VA
Partner's contribution(s) to the project:	Continued offering in-kind support for student educational projects. A locomotive gift is used by the Penn State-Altoona RTE program for teaching labs and for K-12 outreach activities. The SD60i locomotive gift enabled program faculty the opportunity to develop two new course modules for RTE courses taught in fall 2020.
Organization Name:	Sentek Instrument, LLC
Location of Organization: (if foreign, list country)	Blacksburg, VA
Partner's contribution(s) to the project:	Sentek is providing in-kind support and collaboration with Virginia Tech faculty on the project "Development of a Cost-Effective Sensing System for Integrated Traffic and Pavement Response Monitoring in Support of Pavement Management."
Organization Name:	Virginia Institute for Marine Science
Location of Organization:	Gloucester Point, VA
Partner's contribution(s) to the project:	George Mason University developed new partnership with Virginia Institute of Marine Sciences (VIMS) to expand capabilities from the CIAMTIS project, "Condition-based Inspection and Restoration Scheduling of Pavement and Bridge Systems for Improved Post-disaster Infrastructure Systems Recovery." This new work will create decision support for optimal preparedness investment and post-disaster roadway restoration scheduling for climate-related hazards, including sea level rise and flooding, where the key objectives are to prioritize those actions that will restore critical community services, such as power and water supply, as well as access, to needed facilities, such as hospitals, grocery stores, and fueling stations.
Organization Name:	NAVSEA Carderock
Location of Organization:	Bethesda, MD
Partner's contribution(s) to the project:	George Mason University developed partnership with the NAVSEA Carderock Ship Structures group as part of the project "Finite element model updating for bridge deformation measurements extracted from remote sensing data." NAVSEA researchers shared a series of structural test specimens that were used for experimental verification and algorithm testing. The new partnership will allow translation of research findings to the marine structures and transportation organizations that support NAVSEA research, such as the American Bureau of Shipping.

III. OUTPUTS

- A. List any outputs resulting from the program during the reporting period. (e.g., Publications, conference papers, and presentations; New methodologies, technologies or techniques; Inventions, patents, and/or licenses)

The CIAMTIS research performance metrics, goals, and targets are shown in Table 6, while the technology transfer performance metrics, goals, and targets are shown in Table 7. The following summarizes progress toward several of these targets during the current reporting period:

- 17 journal publications were submitted or published during the current semi-annual reporting period;
- 11 conference presentations or other publications were accepted or delivered during the current semi-annual reporting periods. In addition, several presentations that were planned for the previous reporting period have been postponed and are anticipated to be delivered during the next reporting period;
- One patent application was filed during the current reporting period;
- There were 1392 website visitors during the reporting period, up 103 percent from the previous reporting period. There were also 4949 pageviews on the website, up 108 percent from the previous reporting period.

Among the annual performance metrics shown in Table 6, considerable progress has been made toward the output and outcomes targets during the current semi-annual reporting period.

Table 6. 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 7. Performance Metrics for CIAMTIS Technology Transfer Activities

Performance Metric	Assessment Measure	Performance Targets
Partnership with Private and Public Entities	<ul style="list-style-type: none">✓ 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.	<ul style="list-style-type: none">✓ 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

- Andriotis, C. P. and K. G. Papakonstantinou. Deep Reinforcement Learning-driven Inspection and Maintenance Planning under Incomplete Information and Constraints. Reliability Engineering and System Safety arXiv Preprint <https://arxiv.org/abs/2007.01380> (Accepted Publication)
- Yu, S., S. Shen, H. Huang, and C. Zhang. Engineered Semi-flexible Composite Mixture and its Implementation Method for Mitigating Railroad Bridge Transition. *Transportation Research Record: Journal of the Transportation Research Board*, 2021. (Accepted Publication)
- Zhang, C., S. Shen, H. Huang, and L. Wang. Estimation of the Vehicle Speed using Cross-Correlation Algorithms and MEMS Wireless Sensors. *Sensors*, Vol. 21, Issue 5, March 2021.
- Yu, S., S. Shen, H. Huang, and C. Zhang. Engineered Semi-flexible Composite Mixture and Its Implementation Method for Mitigating Railroad Bridge Transition. *Proceedings of the 2021 Annual Meeting of the Transportation Research Board*, January 2021 (Also presented at TRB Annual Meeting).
- Zhang, C., S. Shen, B. Shi, H. Huang, and L. Sun. Estimation of the Vehicle Speed using Cross-Correlation Algorithms and MEMS Wireless Sensors. *Proceedings of the 2021 Annual Meeting of the Transportation Research Board*, January 2021 (Also presented at TRB Annual Meeting).
- Lee, N. and J. L. Gifford. MAP-21 to FAST Act: Did the Transportation Infrastructure Finance and Innovation Act (TIFIA) Program Better Support High-risk Transportation Infrastructure Projects? *Transportation Research Record: Journal of the Transportation Research Board*, 2021. (Accepted Publication)
- Sujon, M. and F. Dai. Application of Weigh-in-Motion Technologies for Pavement and Bridge Response Monitoring: State-of-the-Art Review. *Automation in Construction*, 2021. (Under Review)

- Lu, L. and F. Dai. A Unified Normalization Method for Homography Estimation using Combined Point and Line Correspondences. *Computer-Aided Civil and Infrastructure Engineering*, 2021 (Under Review)
- Lee, J. and Y. Yoon. Indicators Development to Support Intelligent Road Infrastructure in Urban Cities. *Transport Policy*, 2021. (Under Review)
- Efe, S., M. Shokouhian, and K. Aslan. Surface Crack Detection in Concrete using Mobile Robot. *Journal of Engineering Education*, 2020. (Under Review)
- Shokouhian, M. and T. Tsegaye. Recycled Fiber Reinforced Concrete for Green Bus Pads. Submitted to *Structures Congress 2022*. (Under Review)
- Efe, S., M. Shokouhian, and K. Aslan. Evaluation of the Principles and Practice of Engineering (PE) Exam Training Program for At-risk Engineers. *Journal of Engineering Education*, 2020 (Under Review).
- Sadeghi Eshkevari, S., M. Takac, S. Pakzad, and M. Jahani. DynNet: Physics-based Neural Architecture Design for Nonlinear Structural Response Modeling and Response. *Engineering Structures*, Vol. 229, pp. 111582, 2021.
- Gulgec, N. S., M. Takac, and S. N. Pakzad. Structural Sensing with Deep Learning: Strain Estimation from Acceleration Data for Fatigue Assessment. *Journal of Computer-aided Civil and Infrastructure Engineering*, Vol. 35(12), 2020, pp. 1349-1364..
- Lu, L., F. Dai, and J. Zanewski. Automatic roller path tracking and mapping for pavement compaction using infrared thermography. *Computer-aided Civil and Infrastructure Engineering*, 2021. (Awaiting publication)
- Tatar, J. and S. Milev. Durability of Externally Bonded Fiber-Reinforced Polymer Composites in Concrete Structures: A Critical Review. *Polymers*, 13(5), 765, 2021.
- Wang, Z., D. Ildefonso, M. Abbas, and L. Wang. Pavement Fatigue Crack Detection and Severity Classification based on Deep Convolutional Neural Network. *Journal of Pavement Research and Technology*, 2021. (In review)

Other Publications, Conference Papers, and Presentations

- Andriotis, C. P. and K. G. Papakonstantinou. Deep reinforcement learning approach to structural inspection and maintenance policy optimization subject to life-cycle reliability constraints. Proceedings of the 14th International Conference on Evolutionary and Deterministic Methods for Design, Optimization and Control (EUROGEN 2021) – abstract accepted; presentation in June 2021.
- Andriotis, C. P. and K. G. Papakonstantinou. Partially observable Markov decision processes for life-cycle inspection and maintenance planning under constraints. Proceedings of the Engineering Mechanics Institute (ASCE) and Probabilistic Mechanics and Reliability Conference – abstract accepted; presentation in May 2021.
- Begany, M., J. Ambrosino, and B. Schlake. Railroad Trespassing – on Rising Fatalities and Potential Solutions. Accepted for presentation at the *Joint Rail Conference*, Virtual, April 2021.
- Lu, L. and F. Dai. A Thermal-based Technology for Roller Path Tracking and Mapping in Pavement Compaction Operations. *Proceedings of the 2020 Winter Simulation Conference*, IEEE. December 14-18, 2020, Orlando, Florida, USA.
- Efe, S., M. Shokouhian, and K. Aslan. Training on Surface Crack Detection using Deep Learning. *American Society of Engineering Education*, 2021. (Under Review)

- Tatar, J., C. Viniarski, and M. Head. Experimental Assessment of U-wrap Anchorage in Reinforced Concrete Girders Strengthened with Flexural CFRP. *ACI Virtual Convention*, March 28-April 1 2021, Committee 440D presentation. (Accepted)
- Palese, J. Using Autonomously Collected Track Deflection Data to Characterize Track Stiffness Transitions. To be presented at the virtual AREMA Conference, September 2021. (Accepted)
- Milev, S. and J. Tatar. Durability Assessment of Fiber-reinforced Polymers Composites Externally Bonded to a Concrete Bridge after 26-year Exposure. *Proceedings of the 8th International Conference on Advanced Composite Materials in Bridges and Structures (ACMBC VIII) Virtual Conference*, August 5-7, 2021. (Accepted)
- Efe, S., M. Shokouhian, and K. Aslan. Evaluation of The Principles and Practice of Engineering (PE) Exam Training Program for At-Risk-Engineers. American Society of Engineering Education Conference, 2021. (Submitted)
- Lee, N., J. Gifford, et al. P3 Toll Adjustments to Relieve Maintenance Impacts of Adjacent Facilities: A Repeated Game Analysis, 53rd Annual Meeting of the University Transport Study Group (UTSG), July 2021 (Accepted)
- Zhou, W. and E. Miller-Hooks. Optimizing Multi-asset Roadway Improvement Scheduling Considering Traffic Delays. Presented at INFORMS, National Harbor, Maryland, November 2020.

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:

CIAMTIS researchers are developing the following technologies or techniques as part of research projects:

- Penn State researchers are applying a novel Deep Reinforcement Learning (DLR) constrained optimization framework for life-cycle asset management.
- West Virginia researchers developed a new technology for data normalization in homography estimation for computer vision-based structural displacement measurement using combined line and point correspondences. Such technology allows for more accurate homography estimation and displacement measurement.
- Virginia Tech researchers developed a machine-learning based classifier of pavement crack severity based on cell phone acquired images. The classifier provides a simple and convenient approach for agency engineers to assess the distress severity in real-time.

Inventions, Patent Application, and/or Licenses (include date, and/or licenses that have resulted from the research):

Patent Application. Invention description: Automatic Roller Path Tracking and Mapping for Pavement Compaction Using Infrared Thermography. Provisional Application Filed, 12-11-2020. Application Number: 63124120.

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?

Examples of outcomes produced during the current reporting include the following:

- Penn State researchers are developing an AI data-based model that can be used to predict deterioration of bridge decks, as well as a constrained optimization Deep Reinforcement Learning algorithm that can be used for large-scale infrastructure asset management. The results of this research will help improve inspection, maintenance, repair, and reconstruction decisions, such that existing budgets can be optimally-allocated under constraints and risk considerations.
- Penn State researchers are testing and demonstrating statistical equivalence and non-inferiority methodologies for the purpose of comparing and evaluating infrastructure condition assessment techniques, equipment, and vendors. This will enable agencies to make informed investment decisions as to the timing for implementation of technology advances and comparative choices for purchases and data collection contracts.
- During the current reporting period, Penn State-Altoona RTE faculty completed the third phase of a Women in Engineering Design Competition, which introduced more than 40 women engineering students to rail transportation engineering.
- Morgan State University faculty are training current students on topics related to process automation in structural health monitoring, including the use of intelligent machines for damage detection.
- Morgan State University faculty are investigating the cause of bus pad cracking and developing a more sustainable design and monitoring approach. This will lead to less frequent reconstruction, thereby reducing costs to maintain transit bus pads. Use of recycled fiber extracted from used tires will also lead to reduced environmental impacts as a result of the research.
- West Virginia University developed an algorithm of a thermal image-based intelligent compaction technology has been implemented into a prototype and tested in the lab. This cost-effective technology will help the paving industry better control the quality of asphalt paving operations.
- West Virginia University developed and implemented a new normalization method for homography estimation in structural displacement measurement using computer vision. This method will help collect more accurate structural displacements using combined line and point features that commonly exist in civil infrastructure scenes.
- Lehigh University researchers are developing distortion-induced fatigue crack NDE guidelines in the form of draft specifications for owners to adopt for their projects to maintain steel bridges within rail and highway systems.
- University of Delaware faculty are voting members of the American Concrete Institute Committee 440L which deals with the durability of FRP reinforcement in concrete structures. Professor Tatar will work with the committee to implement findings from the project entitled “Durability Assessment of Externally Bonded Fiber-Reinforced Polymer (FRP) Composite Repairs in Bridges.”

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:

The Penn State project entitled “AI-enabled fiscally constrained life-cycle asset management for infrastructure systems” will produce improved predictive models and optimization capabilities that can substantially reduce life-cycle costs, while increasing safety and reliability, of the transportation system.

Morgan State University are training undergraduate and graduate students on automated crack identification and visualization using computer vision. With an aging infrastructure, manual inspection is not efficient at identifying deterioration in order to facilitate implementation of appropriate maintenance or rehabilitation procedures. Training programs will produce opportunities to implement autonomous mobile robotic system for inspection and evaluation of transportation infrastructure.

Morgan State University research will improve the safety, reliability, and durability of bus pads served by the Maryland Transit Administration transit system. Maintaining a durable infrastructure is critical to the operation of the system, which is served by 80 bus lines and 840 buses. The research findings will provide recommendations to improve the mechanical properties of concrete mix designs.

One of the main challenges facing bridge owners is allocation of scarce resources for repair and maintenance of aging structures. Since the main problem in many bridges relates to the issue of fatigue, the availability of life-cycle information could provide very important tools for allocation of these resources for an effective management of transportation assets. Research by Lehigh University, which is using Machine Learning algorithms to substitute strain signal recordings with acceleration data in the field, will provide opportunity to monitor the performance of bridges, leading to more efficient allocation of resources when making funding and repair decisions. A mobile application is being developed, which can synchronize with a centralized server to store acceleration data collected in the field.

The expected impact of other Lehigh University research is more reliable fatigue crack-arrest holes. The development of fatigue cracks in steel highway bridges is a critical problem. Tens of thousands of steel bridges constructed in the 1960’s and 1970’s (or earlier) are critical components of transportation systems. These older steel bridges have welded steel details that develop fatigue cracks during their service life. If not repaired, these fatigue cracks have the potential to cause brittle fracture and bridge collapse. Crack-arrest holes are commonly used as the repair method. Current practice uses visual inspection to determine the crack geometry and to drill crack-arrest holes. Field experience, however, suggests that cracks have the potential to “re-initiate” at weld toes near these holes. The potential impact of more reliable repair of fatigue cracks is fewer instances where a previously-repaired bridge needs to be fully or partially closed as additional expensive emergency repairs are made.

Virginia Tech researchers are using novel sensors and sensing techniques, including distributed array and roadway surface-mounted sensors, to collect traffic and pavement response information. The data processing that is currently in progress has the potential to yield results that can change the design and management of roadway pavements; a data-rich environment is more desirable for decision-making. Further, these technologies will contribute to the promotion of connected transportation infrastructure systems, which will lead to more informed design and operations and maintenance decisions for pavements.

Morgan State University developed a simulated exam environment for the diagnostic test for the morning and afternoon sessions of the Principles and Practice of Engineering (PE) exam. The diagnostic exam will send the collected user input to be stored in a database which can then be examined for validity and retrieved for evaluation purposes.

West Virginia University is developing a new, inexpensive compaction technology which will help control the quality of asphalt concrete pavements being constructed. This will make intelligent compaction more affordable, potentially leading to wider adoption and, therefore, enhancing reliability and durability of newly-constructed asphalt concrete pavements.

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

Several research projects currently on-going in CIAMTIS involve fiber reinforced polymers, which are used in the construction or reconstruction of transportation structures. It anticipated that this research will enable updates to existing design and construction guidelines in order to make bridge construction or repairs more efficient and durable.

Other research related to bridge structures in the CIAMTIS consortium will have considerable impact on the life-cycle of this critical infrastructure element. For example, there are projects focused on the application of new materials (e.g., corrosion-resistant steel); use of innovative sensing technologies (e.g., mobile sensors); and improved infrastructure management methods (e.g., probabilistic modeling, optimization of repair and rehabilitation strategies) that will collectively enable transportation agencies to improve the durability of bridges while using data to make informed construction and maintenance decisions.

In addition to bridges, there are a number of projects focused on pavements in the CIAMTIS consortium. These projects also consider the three thrusts areas of the Center, including the application of new materials and technologies (e.g., waste plastics in asphalt pavements and pozzolans in concrete pavements), condition and structural health monitoring technologies (e.g., crowd sensing to collect condition data), and infrastructure management (e.g., smart compaction during construction and optimization strategies for maintenance and rehabilitation).

Other CIAMTIS research focuses on rail transportation engineering applications (e.g., use of sensors to assess the condition of the rail infrastructure), landslide prediction methodologies in the areas of transportation assets, and use of unmanned aerial systems to assess the condition of roadside hardware and other transportation infrastructure systems.

Collectively, the research, education, and workforce development programs will improve the durability and extend the life of the transportation infrastructure.

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?

Novel data driven artificial intelligent (AI)-based predictive models for bridge deck deterioration are being used by research at Penn State, including the first-ever deep reinforcement learning constrained optimization framework. The framework appears to significantly outperform currently used asset management standard policies.

E. What is the impact on transportation workforce development?

Morgan State University continued their work on a Principles and Practice of Engineering (PE) exam workforce development activity during the current reporting period. The program is aimed at building the competitiveness of the transportation infrastructure workforce in the region by impacting the ability of “at risk” engineers and other participants in the training to learn how to efficiently and successfully engage best practices or strategies for the PE exam through an active learning approach. The structured PE training course and assessment will be used to measure the changes in the pre-training and post-training performance of the test takers. Based on responses, the PE certification training program was effective in preparing

license applicants for the NCEES standards examination as there was more than a significant general improvement in pre-test scores considering the evaluated final morning and afternoon exams.

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:

The COVID-19 pandemic has resulted in delays to experimental research. Several universities in the CIAMTIS consortium issued directives to reduce research activities in laboratories during previous reporting periods, and this continued into the current reporting period. Most laboratory research by CIAMTIS consortium members restarted during the previous reporting period (May-August 2020 timeframe), but with reduced capacities. The COVID-19 temporary lab closures, as well as reduced laboratory capacities, have resulted in delays to several active research projects.

Several universities in the CIAMTIS consortium have also reported delays to field work associated with travel restrictions during past and current reporting periods. While some travel has been approved, several research projects involving field instrumentation have been delayed.

Several CIAMTIS universities have reported that graduate student recruitment has been impacted by COVID-19, resulting in students having to delay the start of their graduate program until the fall 2021 semester.

The projects entitled *Use of SmartRock Sensors to Monitor Pavement Performance for Supporting Rehabilitation Decision Making* and *Development of a Cost-Effective Sensing System for Integrated Traffic and Pavement Response Monitoring in Support of Pavement Management* both included some field experimentation using human participants. Due to the COVID-19 pandemic, these field trials have been cancelled.

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.