



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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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, 2021 through March 31, 2022, which is the seventh reporting period for the regional center. The following center-wide activities have been accomplished during the reporting period.

Center Website

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, the website for the third annual TAIM conference was updated to reflect the conference program. The conference was held virtually on October 25-27, 2021.

CIAMTIS Newsletter

The CIAMTIS marketing and communications team distributed the fall 2021 newsletter in December 2021. The contents of the newsletter included: (1) a summary of the Transportation Asset and Infrastructure Management conference, (2) a mobile sensor technology feature from research being conducted by Lehigh University researchers, (3) a summary of research related to steel fin pile foundations by Penn State researchers, (4) and a summary of the CIAMTIS webinar series. Planning for the spring 2022 newsletter began during the current reporting period.

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

The third annual TAIM conference was organized by Penn State and delivered (virtually) during the reporting period, on October 25-27, 2021. There were 130 participants registered for the event. The program consisted of the following activities:

- Four 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 research exhibition, including posters from several graduate students representing universities in the CIAMTIS consortium.
- A graduate student panel session related to career opportunities in transportation infrastructure asset management.
- A keynote address by Peter Stephanos, Director, Office of Stewardship, Oversight, and Management, and Acting Chief Strategy Officer, Federal Highway Administration.

Planning for the fourth annual TAIM conference began in March 2022.

CIAMTIS Professional Development Webinar Series

The consortium developed and delivered a monthly seminar series during the 2021 calendar year. There were 12 speakers who presented research or state-of-the-industry topics on transportation infrastructure asset management. Penn State coordinated the series for CIAMTIS and provided participants with 1.2 continuing education units (CEUs) for attending the series (or 0.1 CEUs per webinar). Nearly 30 industry professionals and educators participated in the series. The series was completed in December 2021. Efforts are underway to repackage the series and the second phase will begin during the next reporting period.

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 can be used to support research, education, and technology transfer activities. 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.

Competitive and Core Funds: Years 1 and 2

The first competitive proposal process resulted in 14 research projects being awarded in March 2019. At the time of this semi-annual progress report, a total of 10 of 14 projects are complete with final reports posted on the CIAMTIS website and distributed to various repositories per UTC grant deliverables requirements. Three of the final project reports are expected in May 2022, while one project is anticipated to be completed in August 2022.

In addition to the competitive proposals awarded using Year 1 funds, a collection of research (11 projects) and educational (5 projects) activities using core funds were awarded in 2019. Of these 16 projects, 13 are complete, with final reports posted on the CIAMTIS website and distributed to various repositories per deliverables requirements. The remaining three projects will continue into the next reporting period.

Competitive and Core Funds: Years 2 and 3

Year 2 and 3 Federal funds were made available to the consortium in August 2019. A competitive call for proposals was issued in November 2019, with some of these funds used to award new projects in January 2020. Projects awarded via this competition (14 total) are shown in Table 1, while awards made in the core program are shown in Table 2. The projects that are shaded in Tables 1 and 2 are complete, while the remaining projects will continue into the next reporting period. A goal of the CIAMTIS consortium is to use competitive funds to work collaboratively on at least 25 percent of research projects – 6 of 14 competitive projects are collaborative, which exceeds the goal of the consortium. Another goal of the consortium is to conduct research on topics across all three focus areas – there are 4 competitive projects in the area of innovative materials and technologies, 8 competitive projects in the area of condition assessment and structural health monitoring, and 5 projects in the area of infrastructure management and innovative financing (several projects spanned more than one focus area).

Competitive and Core Funds: Years 3 and 4

A competitive call for proposals was made available to the consortium members in August 2020, to award additional projects using Year 3 funds and some Year 4 funds, which were made available to the consortium in August 2020. The peer review process was undertaken in November 2020 through January 2021. A total of 13 competitive projects were awarded during the spring 2021 semester, with 7 of the 13 projects being collaborative among at least two university partners in the consortium. A summary of these projects are shown in Table 3 – these projects are distributed across all three focus areas of CIAMTIS. Core projects were also awarded throughout 2021 – these are shown in Table 4. CIAMTIS partners will continue preparing proposals for core projects during the next reporting period.

Competitive and Core Funds: Years 4 and 5

A competitive call for proposals was made available to the consortium members in September 2021, to award projects using Year 4 and 5 funds. These projects are in the process of being awarded during the reporting period, with those awarded to date shown in Table 5 below. In addition, several core projects have been awarded during the reporting period, and these are shown in Table 6. All of these projects continue through the next reporting period (many are planned to

end in fall 2023). CIAMTIS partners will continue preparing proposals for core projects during the next reporting period.

Table 1. Competition 2 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	6/30/22	R
Passive Strain Sensing Based on Changes in Retroreflectivity	Shenton, Harry	A, C	UDel		1/20/2020	6/20/22	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	8/31/21	R
Smart Mobile Platform for Model Updating and Life Cycle Assessment of Bridges	Pakzad, Shamim	C	LU		1/20/2020	7/31/22	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	3/31/22	R
Unmanned Aerial Vehicles for Inspection of Tack Coats and Ancillary Highway Structures	Dai, Fei	C	WVU	GMU, VT	1/20/2020	8/15/22	R
Durability Assessment of Externally Bonded Fiber-Reinforced Polymer (FRP) Composite Repairs in Bridge	Tatar, Jovan	A	UDel		2/1/2020	7/31/22	R
Extending Service Life of Rigid Pavement Joints with Self-Healing Sealants	Tatar, Jovan	A	UDel	VT	1/31/2020	6/30/23	R
Price Discovery for Strategic Compensation of Toll Road Operators to Relieve State Maintenance Impacts	Gifford, Jonathan	I	GMU	UDel	1/20/2020	9/30/22	R
Preparing the Next Generation of Undergraduate and Graduate Engineers in Autonomous Robotic System for Damage Detection	Efe, Steve	C	MSU		1/20/2020	1/20/23	E
Integration of traffic and structural health monitoring on the Varina-Enon Bridge via sensor fusion	Sarlo, Rodrigo	C, I	VT		1/20/2020	9/20/21	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. Core Period 2 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
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	8/31/21	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	12/31/21	R
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Table 3. Competition 3 CIAMTIS 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							

Table 4. Core Period 3 Project Awards.

Project	PI	Thrust Areas	PI Univ.	Partner Univ.	Performance Dates		Activity Type
Stochastic Models for Incorporating Traffic Reliability Goals in Roadway Improvement Scheduling	Miller-Hooks, Elise	I	GMU		8/1/21	2/1/23	R
Investigation of self-healing characteristics of bacteria-based concrete	Shokouhian, Mehdi	A	MSU		10-01-2021	9-30-2022	R
A Direct Design Method of Hybrid High Strength Steel Web Tapered Members	Shokouhian, Mehdi	A	MSU		10-01-2021	9-30-2022	R
Development of a Fatigue Testing Protocol for Asphalt Mixture Using Hamburg Wheel Tracking Device	Solaimanian, Mansour	A	PSU		6-8-2021	6-7-2023	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; UDeI 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. Competition 4 CIAMTIS Projects.

Project	PI	Thrust Areas	PI Univ.	Partner Univ.	Performance Dates		Activity Type
Using Advance Refunding of Federal Loans to Support Transportation Infrastructure Asset Management and Delivery: Lessons from the Covid-19 Pandemic	Gifford, Jonathan	I	GMU		1-4-2022	7-5-2023	R
Roadway Rehabilitation, Improvement, and Protection with Equitable Services in a Future with Climate Change—AI-Based Learning and Optimization	Abbas, Monty	I	VTI	GMU	1-4-2022	7-4-2023	R
Multi-robot teaming for inspection of hydraulic structures	Lattanzi, David	C	GMU	UDEL	1-20-2022	7-20-2023	R
Field deployment and verification of an AI-based crowdsensing bridge condition assessment platform	Pakzad, Shamim Takac, Martin	C	LU		1-6-2022	7-5-2023	R
Reducing the Cost and Facilitating Broader Adoption of Ultra-High-Performance Concrete (UHPC) in Bridges	Rajabipour, Farshad	A	PSU	LU	12-8-2021	12-8-2023	R
Quantification of Railroad Ballast Performance Using Advanced Sensor Network & Big Data	Huang, Hai	C	PSU	UDEL	2-1-2022	8-31-2023	R
Ballast and Soil Performance Separation by Using Instrumented Geo-grid & Machine Learning	Huang, Hai	C	PSU		2-1-2022	8-31-2023	R
Field Demonstration of Advance Landslide Warning Index for Railroad Tracks on Amtrak's Harrisburg Line in Pennsylvania	Zarembski, Allan	C	UDEL	PSU	6-1-2022	12-31-2023	R
Quantifying the Impact of Data Unavailability, Inaccuracies and Uncertainty on Deterioration Modeling and Infrastructure Asset Management Policies	Papakonstantinou, Kostas	I	PSU		1-3-2022	2-3-2024	R
Beneficiation of High Sulfur Fly Ashes and Quarry Fines for Sustainable Ternary Concrete Mixtures	Brand, Alex	A	VTI	PSU	3-10-2022	9-9-2023	R
Improving Freeze-thaw Resistance and Fatigue Resistance of Recycled Aggregate Concrete	Radlinska, Aleksandra	A	PSU	MSU	1-3-2022	1-03-2024	R
Design of Anchors for Rapid and Durable Strengthening of Bridges with Externally	Tatar, Jovan	A	UDEL		1-4-2022	7-5-2023	R

Bonded Carbon Fiber Reinforced Polymer Composites—Phase 2							
Determination of Bridge Element Weights based on Data-driven Models	Yoon, Yoojung	C	WVU	UDEL	4-1-2022	9-30-2023	R
Multi-robot teaming for inspection of hydraulic structures	Lattanzi, David	C	GMU	UDEL	1-20-2022	7-20-2023	R
Developing Meta Data for State DOTs from Complex Optimization Problems to Support Asset Management	McNeil, Sue	I	UDEL		3-4-2022	10-3-2023	R
Development of a Rollable Polymer Pavement Overlay	Wang, Linbing	A	VTI		1-20-2022	7-20-2023	R
Roadway Rehabilitation, Improvement, and Protection with Equitable Services in a Future with Climate Change—AI-Based Learning and Optimization	Abbas, Monty	I	VTI	GMU	1-4-2022	7-3-2023	R
Prediction of Pavement Performance via Integrated Pavement Health and Traffic Monitoring with Deep Learning and Predictive Modeling	Wang, Linbing	C	VTI	WVU	1-20-2022	7-20-2023	R
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Table 6. Core Period 4 CIAMTIS Projects.

Project	PI	Thrust Areas	PI Univ.	Partner Univ.	Performance Dates		Activity Type
CIAMTIS Lehigh Research Experience for Undergraduates (REU) Program – Year 4	Sause, Richard/Kusko Chad	A	LU		3-15-2022	11-14-2022	E
MSU Outreach Activities	Shokouhian, Medhi	A	MSU		2-1-2022	1-31-2024	E
Artificial Intelligence (AI) for Building a Landslide Inventory & Advanced Landslide Warning System in Pennsylvania	Qiu, Tong	C	PSU		1-3-2022	8-3-2023	R
Economic Impacts of Transportation Infrastructure Investments	Guler, S. Ilgin	I	PSU		1-3-2022	6-3-2023	R
Continuously Enhancing Transportation Engineering Education in the Fundamentals of Engineering Program	Hensel, Robin	A	WVU		3-10-2022	3-9-2024	E
Holistic digital twins for transportation infrastructure	Lattanzi, David	C	GMU		3-22-2022	9-21-2023	R
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Other Administrative Activities of CIAMTIS

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

- CIAMTIS consortium members continued participating in monthly progress report meetings via virtual platform to discuss research and education activities, reporting requirements, and other matters of interest related to the Center.
- All new research projects shown in Tables 4 through 6 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.

University of Delaware

The University of Delaware developed a self-paced online course highlighting Building Information Modeling (BIM) as a supplemental tool for interpreting traditional transportation blueprints. The project team partnered with the Delaware Contractors Association (DCA) and recruited 20+ potential or new construction employees and conducted a comparative study using pre-course and post-course quizzes. The course was revised based on the comments from DCA and the participants. The preliminary results indicated that BIM can be used as a workforce training tool to assist with infrastructure plan reading, spatial recognition, and comprehension.

Morgan State University

Morgan State continued an educational activity focused on attracting undergraduate and graduate students from underrepresented groups and preparing them on topics related to autonomous robotic systems for damage detection. During this reporting period, the faculty demonstrated machine learning tools for damage prediction based on information collected by students. Students were trained to analyze color-coded maps on the Morgan State campus to identify weak spots and missing locations in infrastructure elements. Efforts are underway to recruit additional high school and undergraduate students in robotics training for summer 2022.

Morgan State University continued their work on a Fundamentals of Engineering (FE) and Principles of Practice of Engineering (PE) training activities during the current reporting period. A new set of FE questions on statics, surveying, transportation, and geotechnical engineering was programmed into the question pools to provide students with a broader array of questions in all subject areas. The training program will continue in summer 2022, build the competitiveness of the transportation infrastructure workforce from MSU campuses by impacting the ability of MSU students with skill deficiency to learn and utilize transportation engineering applications for road design. For the PE workforce development activity, this 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 engage best

practices or strategies efficiently and successfully 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 in future reporting periods.

Virginia Tech

Faculty at Virginia Tech are currently working to reimagine the way that infrastructure condition assessment and non-destructive analysis is taught in their curriculum. The existing curriculum is dated and does not reflect recent advances in the field, such as new non-destructive analysis techniques and the existence of asset management systems such as pavement management systems. To remedy these issues, the faculty continue developing new experiential learning opportunities for the course, including hands-on demonstrations and laboratory exercises. Additionally, final project topics have been re-designed to expose students to the current state of infrastructure practice, with a focus on new technologies and their implementation to contemporary civil engineering practice.

West Virginia University

Faculty at West Virginia University have developed a Fundamentals of Engineering review course – teaching modules from CIAMTIS projects have been implemented into the course, in order to offer instruction related to transportation infrastructure engineering.

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 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 research in October 2021; presentations at the CIAMTIS Transportation Infrastructure monthly webinar series; and dissemination of the semi-annual CIAMTIS newsletter.

C. 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 6 will continue during the next reporting period. It is anticipated that several 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. It is anticipated that the final competition for funds in the competitive pool will take place in late 2022, with awards made using Year 6 funds in early 2023.

CIAMTIS Technology Transfer and Outreach Activities

- Penn State began planning for the 4th annual Transportation Asset and Infrastructure Management (TAIM) conference during the reporting period. The conference is scheduled to take place on October 17-18, 2022, in State College, Pennsylvania. The planning committee consists of approximately 25 members from public and private sector agencies, as well as educational institutions in the consortium.
- CIAMTIS will implement the second installment of the transportation infrastructure webinar series during the next reporting period. Efforts to repackage the series were completed during the current period.
- 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.

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:	<p>PennDOT and CIAMTIS have identified six collaborative research projects – all are underway.</p> <p>PennDOT Engineering District 5-0 is collaborating on Lehigh University projects by providing access to the Gene Hartzell Memorial Bridge for instrumentation and data collection for the project entitled “Utilizing Daily Traffic as a Sensor Network for Infrastructure Health Monitoring.”</p> <p>PennDOT Engineering District 9-0 is collaborating with Penn State-Altoona researchers on pavement research projects, by permitting the research team to perform field tests on paving projects.</p>
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 test specimen fabrication for the project entitled “Life Extension of Fatigue-Damaged Highway, Rail, and Transit Bridges: Identifying Actual Crack Tip.”
Organization Name:	New Enterprise Stone and Lime Company
Location of Organization:	Roaring Springs, PA
Partner's contribution(s) to the project:	Penn State-Altoona researchers by providing materials (asphalt binder, aggregates, additives), and permitted the research team to embed SmartRock sensors into the pavement during paving operations. The contractor also provided staff and equipment support to measure compaction during construction.

Organization Name:	West Virginia Department of Highways
Location of Organization:	Charleston, West Virginia
Partner's contribution(s) to the project:	This partner is collaborating on research with West Virginia University on data collection activities, data sharing, facility access, project implementation guidance, and contractor access on four research projects.
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 with West Virginia University faculty to identify industry members to field test automated path tracking and mapping for roller control in pavement compaction operations.
Organization Name:	Delaware Contractor Association
Location of Organization:	Newark, DE
Partner's contribution(s) to project:	Partnered with the University of Delaware to provide advising and recruitment for professionals enrolled in the University's outreach program entitled "Workforce Development and Job Training Pilot."
Organization Name:	Avery Dennison and City of Newark, DE
Location of Organization:	Glendale, California
Partner's contribution(s) to project:	Avery Dennison donated 5 samples of different reflective sheeting materials for testing in the University of Delaware project entitled "Passive Strain Sensing based on Changes in Retroreflectivity." The City of Newark, Delaware lent the research team a retroreflectometer to record measurements of field tests to support the project.
Organization Name:	Delaware Department of Transportation
Location of Organization:	Dover, Delaware
Partner's contribution(s) to project:	The Delaware Department of Transportation offered in-kind support by performing diagnostic load tests and maintenance of traffic for field testing of bridge structures on the project entitled "Bridge Load Rating and Evaluation using Digital Image Measurements."
Organization Name:	Fyfe Co., LLC
Location of Organization:	San Diego, California
Partner's contribution(s) to project:	Offered in-kind support by providing materials, supplies, and staff time for the University of Delaware project entitled "Design of Anchors for Rapid and Durable Strengthening of Bridges with Externally-bonded Carbon Fiber Reinforced Polymers."
Organization Name:	Sentek Instruments
Location of Organization:	Blacksburg, VA
Partner's contribution(s) to project:	Sentek Instruments has provided in-kind support of fiber optic sensors for two projects by Virginia Tech.
Organization Name:	Northeast Prestressed Products
Location of Organization:	Pottsville, PA
Partner's contribution(s) to project:	Northeast Prestressed Products is producing a full-scale UHPC girder based on the materials and structural designs produced by a Penn State-Lehigh University research team. The girders will be tested at Lehigh University for the project entitled "Reducing the Cost and Facilitating Broader Adoption of Ultra-High-Performance Concrete (UHPC) in Bridges."
Organization Name:	Pennsylvania Asphalt Paving Association (PAPA), Eco Plastics of Delaware, and Struktol Company of America
Location of Organization:	Harrisburg, PA (PAPA), Wilmington, DE (Eco Plastics), Stow, OH (Struktol)

Partner's contribution(s) to project:	Penn State-Altoona faculty worked with PAPA to distribute survey questionnaires to paving contractors related to the waste plastics use in asphalt pavements. Eco Plastics provided waste plastic materials for the same project, while Struktol provided additives for the project.
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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)

CIAMTIS research produced the following outputs during the current semi-annual reporting period (annual performance metric is shown in parenthesis):

- 22 journal publications were submitted or published during the current semi-annual reporting period (annual performance metric is 30 journal papers).
- 25 conference presentations or other publications were accepted or delivered during the current semi-annual reporting period (annual performance metric is 40 presentations).
- 1 patent application (annual performance metric is 1 per year).
- 4,469 website views during the semi-annual reporting period (annual performance metric is 500 annually). This includes 1,503 users – more than 90 percent of the users were new during the reporting period.

- B. Publications, Conference Papers, and Presentations

Journal Publications

- Ghyabi, M., L. Timber, G. Jahangiri, D. Lattanzi, H. Shenton, M. Chajes, and M. Head. Vision-Based Measurements to Quantify Bridge Deformations. *Journal of Bridge Engineering*, submitted.
- Graves, W., K. Aminfar, and D. Lattanzi. Full-scale Highway Bridge Deformation Tracking Via Photogrammetry and Remote Sensing. *ISPRS Journal of Photogrammetry and Remote Sensing*, submitted.
- Palese, M., A. M. Zarembski, H. Huang, and J. Palese. Ballast Particle Dynamic Response as a Function of Subgrade Support Using Statistical Methods. *Construction and Building Materials*, March 2022, Vol. 325, 126772.
- McNeil, S., Q. Chen, P. Hu, Y. Liu, E. Miller-Hooks, and S. Stoffels. Performance Measures to Support Maintenance Decisions for Shared Auto, Bike and Pedestrian Facilities in the Context of the Lifecycle of a Socio-Technical System. *ASCE International Conference on Transportation & Development (ICTD 2022)*, Seattle, WA, May 2022. (accepted)
- Ghyabi, M. and D. Lattanzi. Applicability of Current Vision-Based Displacement Method in Lab-Scale Structural Experiments. *Proceedings of Structural Health Monitoring 2022*, Destech, 2022.

- Kamranfar, P., D. Lattanzi, A. Shehu, and S. Stoffels. Pavement Distress Recognition via Wavelet-Based Clustering of Smartphone Accelerometer Data. *Journal of Computing in Civil Engineering*, Vol. 36 (4), July 2022. (accepted)
- Zhou, W., E. Miller-Hooks, K. Papakonstantinou, S. Stoffels, and S. McNeil. A Bilevel and Stochastic Model for Multi-asset Roadway Improvement Scheduling Considering Traffic Impacts. *Journal of Infrastructure Systems*. (accepted)
- Shahverdi, B. and E. Miller-Hooks. Scheduling Inspection and Restoration Action in Post-Disaster Critical Lifeline Recovery through Stochastic Optimization with Endogenous Uncertainty. *ASCE Natural Hazards Review*. (under review)
- Chen, Q., E. Miller-Hooks, and E. Huang. Assessing Transportation Infrastructure Impacts from Supply Chain Restructuring for Increased Domestic Production of Critical Resources. *Computers and Industrial Engineering*. (under review)
- Liu, F. and L. Wang. UNet-based Model for Crack Detection Integrating Visual Explanation. *Construction and Building Materials*, Vol. 322, 2022. (accepted)
- Liu, F., J. Liu, and L. Wang. Asphalt Pavement Crack Detection based on Convolutional Neural Network and Infrared Thermography. *IEEE Transactions on Intelligent Transportation Systems*, 2022. (accepted)
- Liu, J., et al. Optimizing Asphalt Mix Design through Predicting Effective Asphalt Content and Absorbed Asphalt Cement using Machine Learning. *Construction and Building Materials*, Vol. 325, 2022. (accepted)
- Ye, Z., Y. Kai, K. Lu, D. Ildefonso, and L. Wang. Optimization of Embedded Sensor Packaging used in Rollpave Pavement based on Test and Simulation. *Materials*, Vol. 15(6), 2022. (accepted)
- Lee, J. and Y. Yoon. Hierarchy Table of Indicators and Measures for the Current Status Assessment of Urban Roads in Smart Cities. *Sustainable Cities and Society*, Vol. 77, February 2022, pp. 103532.
- Lee, J. and Y. Yoon. Indicators Development to Support Intelligent Road Infrastructure in Urban Cities. *Transport Policy*, Vol. 114, December 2021, pp. 252-265.
- Lu, L. and F. Dai. A Unified Normalization Method for Homography Estimation Using Combined Point and Line Correspondences. *Computer-Aided Civil and Infrastructure Engineering*. (accepted)
- Lu, L. and F. Dai. Automated Visual Surveying of Vehicle Heights to Help Measure the Risk of Overheight Collisions Using Deep Learning and View Geometry. *Computer-Aided Civil and Infrastructure Engineering*. (under review)
- Lee, J. and Y. Yoon. Prioritization of Advanced Systems Using a Distance-To-Target Weighting Method for Urban Infrastructure. *ASCE Journal of Infrastructure Systems*. (under review)
- Eshkevari, S.S., L. Cronin, and S. N. Pakzad. Input Estimation of Nonlinear Systems Using Probabilistic Neural Networks. *Mechanical Systems and Signal Processing*, 166, 2022, 108368. (accepted)
- Jafari, K., J. Yoon, R. Tokpatayeva, J. Olek, J., and F. Rajabipour. Surfactant-Assisted Purification of an Impure Kaolinite Clay to Improve Its Pozzolanic Reactivity in Concrete. *ASCE Journal of Materials in Civil Engineering*, Vol. 34(6), June 2022. (accepted)
- Andriotis, C. P. and K. G. Papakontantinou. 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>, 2022 (accepted)

- 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*, Vol. 2675(9), pp. 798-797, April 2022.

Other Publications, Conference Papers, and Presentations

Faculty and graduate students reported 25 presentations/conference proceedings during the reporting period. A sample of 15 are provided below.

- Cicek, D.M. Mante and J. Tatar. Fracture Characterization of Interfaces between Ultra-High-Performance Concrete and High-Performance Concrete. *American Concrete Institute Fall 2021 Virtual Convention*, Open Topic Presentations Session, October 20, 2021.
- Head, M. and L. Timber. Live Load Distribution of Slab-on-Girder Bridges Using Vision-Based Measurements. *American Concrete Institute Fall 2021 Convention*, October 17-21, 2021 (virtual)-->submitted for ACI special publication.
- Palese, M., T. Pei, and T. Qiu. Artificial Intelligence for Advance Landslide Warning along Railroad Tracks. *Presentation to Big Data in Railroad Maintenance Planning Conference*, December 2021, Newark DE.
- Withers, A., E. E. Lee, S. C. Lin and S. McNeil. Control, Monitor, and Inform: Lessons Learned from the 2014 Delaware I-495 Emergency Bridge Closure. *Presented at the Transportation Research Board Annual Meeting*, Washington, DC, January 2022.
- Na, R. and R. Webber. Transportation Blueprint Reading with BIM-A Transportation Construction Workforce Training Pilot. *Presented at the Transportation Research Board Annual Meeting*, January 2022, Washington D.C.
- Head, M. and L. Timber. Vision-based Measurement Techniques for Bridge Monitoring and Evaluation. *ASCE Structures Congress 2022*, Atlanta, GA, April 20-23, 2022. (Accepted)
- Manganaris, M., C. Gao, and J. Gifford. Accounting for Downtime Effects in Maintenance and Restoration Scheduling for Routine, Periodic, and Post-Disaster Events. *Transportation Research Board Annual Meeting*, Washington, DC, January 2022.
- Shahverdi, B. and E. Miller-Hooks. Joint Post-disaster Inspection and Restoration Prioritization in Roadway Networks through Stochastic Optimization with Endogenous Uncertainty. Presented at INFORMS, Anaheim, California, October 2021.
- Sujon, M. and F. Dai. Machine Learning-Enabled Automatic Vehicle Detection for Virtual Weigh-In-Motion Applications. *The 2022 ASCE Construction Research Congress (CRC 2022)*, March 9-12, 2022, pp. 967-976, Arlington, Virginia.
- Ntonifor, C., M. Adegoke, and M. Shokouhian. A Direct Design Method for Web Tapered Hybrid High Strength Steel Girders. *Structures Congress 2022*, Atlanta, Georgia, April 20-23, 2022. (accepted)
- Jafari, K., and F. Rajabipour. Pozzolanic Reactivity and Performance of Calcined Byproduct Clays of Various Kaolin Contents in Concrete Mixtures. *ACI Fall Convention*, Virtual, October 2021.

- Wang, X., V. V. Gayah, and S. I. Guler. Integration of Pavement Roughness into Safety Performance Functions of Two-Lane Rural Roads in Pennsylvania. Presented at the *101st Annual Meeting of the Transportation Research Board*, Washington, DC, January 2022.
- Yu, S. and S. Shen. Effect of WMA Additive on the Workability of Asphalt Mixture: from the Particle Perspective. *Presented at the Transportation Research Board Annual Meeting*, Washington, DC, January 2022.
- Ju, H., A.S. Brand, S.L. Abdelaziz, and G.M. Filz. Influence of Organic Matter on Strength Development of Cement-Water Slurry. *Geo-Congress 2022*, ASCE, Charlotte, NC, March 2022.
- Abi Aad, M. and M. Abbas. An Integrated Simulation-Optimization Framework for Assessing the Impact of I-66 Dynamic Toll Pricing on Pavement Deterioration and Maintenance Decisions. *Transportation Research Board Annual Meeting*, Washington, DC, January 2022.

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:

- Virginia Tech faculty are using acoustic sensing techniques to monitor pavement condition and traffic – when fully developed, these sensing methods offer significant advantages over traditional sensing methods and, when combined with data analytics, can lead to improved pavement condition assessment.

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

US 17/536,418. Automatic Roller Path Tracking and Mapping for Pavement Compaction Using Infrared Thermography. Patent application filed by WVU with the U.S. Patent and Trademark Office, November 2021.

IV. OUTCOMES

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

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

- Dr. Tatar from the University of Delaware was tasked by ACI Committee 440 to lead a task group that will revise environmental durability factors for externally bonded fiber-reinforced polymers (FRP) based on the findings from CIAMTIS research entitled “Durability Assessment of Externally-bonded Fiber-reinforced Polymer Composite Repairs in Bridges.” The task group recommendations will be implemented in the next

version of the design guideline for concrete structures strengthened with externally-bonded FRP.

- University of Delaware researchers developed a training course for new and potential construction workforce. This course, which covers transportation blueprint reading topics, is designed for an online format with incorporated virtual reality elements. The pilot course can be modified and used as a template/prototype for future infrastructure asset management workforce training.
- Researchers at West Virginia University developed a vision-based vehicle height measurement technique that has been presented to the West Virginia Department of Transportation (WV DOT). The WV DOT is in the process of sharing IP access of state surveillance videos for a live evaluation of the technology. If the developed technology on vision-based on-road vehicle height measurement is thoroughly developed/evaluated/optimized and marketed to the over-height vehicle detection market, this technology has the potential to improve detection capabilities, as well as lower the costs associated with these devices.
- West Virginia University researchers have developed a virtual weigh-in-motion (WIM) system that has been demonstrated to the WV DOT – a live evaluation of the system is proposed, provided that access to state surveillance videos is granted. The developed virtual WIM is promising to inexpensively and continuously collect traffic data, which is currently missing in many state DOT inventories, but necessary, together with condition inspection data, to estimating pavement performance to inform maintenance and rehabilitation of pavements.
- Lehigh University is testing the efficacy of a proposed RNN-based algorithm that has been demonstrated through experimental studies. To further demonstrate the performance of the algorithms, the Gene Hartzell Memorial Bridge in Pennsylvania has been selected as a case study. The performance of the proposed algorithms will be demonstrated using sensed data from the bridge. On successful demonstration of the case study, the proposed algorithms can be readily employed by the Pennsylvania Department of Transportation as a part of their bridge life cycle assessment program. This outcome could potentially have significant impacts on the safety and reliability of transportation infrastructure and maintenance of bridges.
- A research team from Penn State and the University of Delaware are using video footage from Amtrak's track geometry inspection car to examine several segments of Amtrak's Harrisburg area right-of-way, which will allow for development of an artificial intelligence-based landslide risk index. The methodology is using these videos, along with other information sources, to develop a landslide warning for railroads.
- Penn State researchers are developing a hybrid experiment-modeling approach to validate predictions of a computational fluid dynamics model to determine optimal grout properties needed to facilitate proper filling and rehabilitation of railway ballasts.
- A team of researchers from Penn State and Lehigh University are developing low-cost, non-proprietary ultra-high performance concrete mix designs for several strength classes. Bridge girder structural design are being developed for implementation in Pennsylvania and use by PennDOT.
- Penn State researchers are conducting research to quantify the impact of transportation investments on economic activity at the county-level within the Commonwealth of Pennsylvania. Specifically, the project will identify optimal transportation investment

strategies that maximize the economic returns for the entire Mid-Atlantic region, considering both traditional and technological investments. The intended outcome of this project is to develop improved methods to allocate infrastructure investment decisions to obtain better economic returns of these investments.

- Penn State researchers are developing a multi-objective optimization for infrastructure management systems that can optimize maintenance, repair, and rehabilitation (MR&R) decisions while simultaneously considering agency costs, total vehicle operating costs, and costs associated with safety performance. The outcome of this project will optimize how transportation agencies can utilize existing budgets for infrastructure management, as well as potentially expand the budget for MR&R activities.
- Researchers at George Mason University are evaluating whether the financial health of transportation projects differs by financial structure during times of crisis. Three specific projects in Virginia were considered, including: Hampton Roads Bridge Tunnel (a publicly financed project), the Chesapeake Bay Bridge Tunnel Expansion (a revenue bond project), and Transform 66 Outside the Beltway (a P3 project). The first indicator examined was credit rating, which was stable for all three projects. The second indicator was credit spread, which changed for all three projects.
- Penn State-Altoona faculty used different cross-correlation methods to estimate vehicular speeds using the stress data collected from embedded sensors for a project in which SmartRock sensors were used to monitor pavement performance. The cross-correlation algorithms, along with the embedded SmartRock wireless sensors, were found to be a promising method for estimating the vehicle speeds in the field.
- The Morgan State project related to assessing infrastructure damage detection using robotics has resulted in development of a new course in the Civil Engineering program – the course proposal is currently under review for consideration in the curriculum.

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?]

A. Impact:

The expected impact of a Leigh University project is more reliable fatigue crack-arrest holes. The development of fatigue cracks in steel highway bridges is a critical problem, particularly on steel bridges constructed before the 1970's. 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. The potential impact of this research is more reliable repair of fatigue cracks, resulting in fewer instances where a previously-repaired bridge needs to be fully or partially closed as additional expensive emergency repairs are made.

Researchers from Penn State-Altoona are using SmartRock sensor technology and its related models and programs to improve the quality of compaction and the durability of pavements. High-quality compaction can lead to extended service life, better life cycle cost and sustainability, and reduced premature failure. In addition, the smart sensing technology and the associated pavement prediction models can reduce the labor and other costs needed to survey

pavement conditions and enable more reliable and data-informed decision-making for pavement maintenance.

Penn State-Altoona researchers are also investigating the use of waste plastics in asphalt industry, which can provide environmental benefits, and potentially be a substitute for more expensive polymer additives in asphalt materials for performance improvement.

The Morgan State FE exam activity has resulted in one student taking and passing the exam during the reporting period. Efforts are underway to train and encourage additional students to take the exam in future reporting periods.

Researchers at Virginia Tech are working on a collection of research activities to investigate methods to integrate traffic monitoring into pavement performance assessments. These technologies will have significant impacts on safety, maintenance costs, and understanding the material deterioration process, which will provide feedback on material design for more durable materials.

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

Research being conducted by universities in the CIAMTIS consortium are focused on the application of innovative materials and technologies; condition assessment and structural health monitoring; and infrastructure management and innovative financing. The current research portfolio of the Center includes a well-balanced collection of projects addressing these three topics. For example, several researchers are investigating the application of ultra high-performance concrete (UHPC) in bridges. The anticipated results of the research could lead to greater adoption of this innovative material in precast concrete applications, improve the reliability of structures by mitigating interfacial and cohesive cracking, and optimize UHPC mixtures using low-cost materials, leading to improved durability of bridges.

Researchers are also applying advanced technologies to assess the performance of pavements and bridges. Examples include smart mobile platforms, artificial intelligence methods, unmanned aerial vehicles, video sensor-fusion data, and digital twinning. Collectively, these technologies may automate condition assessment and structural health monitoring of infrastructure systems, and offer opportunities to quantitatively assess these systems using advanced computational and vision-based methods. This may lead to more efficient inspection and improved life-cycle assessment of infrastructure elements.

A variety of infrastructure management and innovative financing projects are also being undertaken by CIAMTIS researchers. Examples include multi-objective optimization methods to support asset management decision-making; quantifying the impacts of data unavailability and uncertainty on deterioration modeling and infrastructure asset management policies; and strategic prioritization of infrastructure maintenance and rehabilitation. These projects will lead to models that transportation agencies can apply to manage infrastructure assets and to identify when to make maintenance and rehabilitation investment decisions.

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?

Many researchers in the CIAMTIS consortium are working on research projects that impact the scientific body of knowledge, including use of fiber-reinforced polymers in infrastructure

materials, machine learning-artificial intelligence applications, life-cycle modeling, collection and analysis of various sensor data, and use of unmanned aerial systems to monitor the condition of the transportation infrastructure. Collectively, the use of innovative materials and technologies, new methods to monitor the condition and the health of the transportation, and application of methods to manage and finance transportation infrastructure will enable owners to extend the life of bridges, pavements, and railroads in the mid-Atlantic region. Researchers in the CIAMTIS consortium are actively transferring their research to the scientific community via journal publications, conference proceedings, and presentations at technical conferences.

E. What is the impact on transportation workforce development?

The Transportation Asset and Infrastructure Management (TAIM) conference and transportation infrastructure webinar series both provide forums for researchers and practitioners to learn more about CIAMTIS research and to identify opportunities to implement the results of research into practice. These activities will both continued in subsequent reporting periods. The CIAMTIS transportation infrastructure webinar series offers continuing education credits to fulfill professional development requirements to remain registered professional engineers.

Morgan State outreach activities continue training working professionals for the PE exam. West Virginia and Morgan programs continue developing improved FE materials for students seeking the fundamentals of engineering certification. Research experiences for undergraduate students at Lehigh University and the University of Delaware seek to interest current students in transportation infrastructure careers.

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 continued to delay experimental and field research during the reporting period. For example, one university reported that supply chain issues have caused delays in securing polysulfides for research related to self-healing sealants in rigid pavements.

Several universities in the CIAMTIS consortium have also reported delays to field work and graduate student recruitment. For example, one university has reported that a bridge loading project was originally intended to consider structures in two states within the region; however, issues associated with field work support by one state has resulted in the field work shifting to another state within the region.

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.