Federal Agency	U.S. Department of Transportation
Federal Grant Number	DTRT13-G-UTC33
Project Title	MID-ATLANTIC TRANSPORTATION SUSTAINABILITY UNIVERSITY TRANSPORTATION CENTER (UTC)
Program Director Name, Title, and Contact Information	Brian Smith, Ph.D., P.E. Professor and Chair, Civil and Environmental Engineering MATS UTC Director University of Virginia 351 McCormick Dr. P.O. Box 400742 Charlottesville, VA 22904-4742 Phone: 434-243-8585 Fax: 434-982-2951 Email: briansmith@virginia.edu
Name of Submitting Official, Title, and Contact Information	Brigette Pfister Director for Proposal and Award Management University of Virginia ospnoa@virginia.edu 434-924-4270
Submission Date	October 2016
DUNS/EIN Numbers	065391526
Recipient Organization (Name and Address)	University of Virginia Office of Sponsored Programs 1001 North Emmet Street P.O. Box 400195 Charlottesville, VA 22904-4195 Phone: 434-924-4270 Fax: 434-982-3096
Recipient Identifying Number, if any	Federal Entity Number 54-6001796
Project/Grant Period (Start Date, End Date)	6/30/14 to 9/30/18
Reporting Period End Date	9/30/16
Report Term or Frequency	Six months
Signature of Submitting Official	Michael P. Ludwick Associate Director for Grants and Contracts Digitally signed by Michael P. Ludwick 14 Date: 2016.10.31 09:36:37 -04'00'

1. Accomplishments

The Mid-Atlantic Transportation Sustainability University Transportation Center (MATS UTC) is a regional consortium of six universities led by the University of Virginia. Our consortium includes Marshall University, Morgan State University, University of Delaware, Old Dominion University, and Virginia Polytechnic and State University. The MATS UTC serves the region through applied research, education, workforce development, and technology transfer focused on environmental sustainability.

1.1 Research

MATS UTC strives to address research problems related to environmental sustainability and transportation.

1.1.1 Research Program Themes

Our research program is organized around five focus areas:

- Sustainable Freight Movement (SF)
- Coastal Infrastructure Resiliency (IR)
- Energy Efficient Urban Transportation (EU)
- Enhanced Water Quality Management (WM)
- Sustainable Land-Use Practices (LU)

We have core projects in all five of these focus areas. We have competitive collaborative projects in most of the focus areas.

1.1.2 Research Program Selection and Management

Our research program has two parts. Each university in the consortium has been allocated a base amount to spend on research, education, and outreach including technical transfer, diversity, and communications. This base money funds the core projects we select collaboratively as a center—guided by our advisory board.

Table 1 lists 32 projects funded with base and matching allocations. Many of these include researchers at multiple consortium universities as indicated. Fourteen projects have been completed since the inception of MATS UTC in July 2014. Projects with final reports have the title hyperlinked in Table 1. These hyperlinks take you to the Final Report.

Table 1 Projects Utilizing Base Fund and Matching Fund Allocations (Hyperlinks go to the final reports.)

Focus Area	Lead U	PI	Other Investigators	Other U	Title

FR	ODU	Raj Paleti	Mecit Cetin		Performance Measures for Freight Transport and General Traffic: Investigating Similarities & Differences Using Alternative Data Sources
FR	ODU	Mecit Cetin	ManWo Ng, Wayne Talley, Brian Park, Hesham Rakha	UVA, VT	Multimodal Freight Distribution to Support Increased Port Operations
FR	MU	Jennifer Shand	James Corbett	UD	Alternative Fuels Usage in Maritime Transportation System
IR	VT	Pamela Murray-Tuite	Ihab El-Shawarby, Hesham Rakha, Brian Smith	UVA	Infrastructure Resilience and Adaptation for Hurricanes in Coastal Areas
IR	UD	Nii Attoh Okine	Lindsay Ivey-Burden	UVA	Multimodal Transportation Facility Resilience Index
IR	UVA	Osman Ozbulut	Devin Harris		Structural Enhancements to Adapt to Impacts of Climate Change
IR	UD	Julie Maresca	Devin Harris	UVA	Microbial Biomarkers for ASR-Damaged Concrete
IR	UD	Chris Meehan	Dhruv Batra		Implementation of Smart Equipment in Field Construction
IR	UVA	Devin Harris	Osman Osbulut		Accelerating Use of Sustainable Materials in Transportation Infrastructure
IR	UVA	Devin Harris			Preserving Coastal Infrastructure through the Design and Implementation of Image-Based Structural Health Monitoring (iSHM)
IR	UVA	Osman Ozbulut			Development and Characterization of Nano Rei nforced Cement Composites using Graphene Nanoplatelets
IR	ODU	Navid Tahvildari	Mecit Cetin		Investigating the Vulnerability of the Transportation Infrastructure in Hampton Roads Region to Extreme Weather and Sea Level Rise
IR	UVA	Osman Ozbulut			Multifuntional Composites for Sustainable Civil Infrastructure Systems
EU	MU	Andrew Nichols	Brian Park, Hesham Rakha, Montasir Abbas	UVA, VT	Enhancing Traffic Control Systems to Reduce Emissions and Fuel Consumption
EU	VT	Hesham Rakha	Kyoungho Ahn, Mecit Cetin, Brian Park	ODU, UVA	Network-wide Impacts of Eco-routes and Route Choice Behavior/Evaluation of AERIS Applications
EU	MSU	Andrew Farkas	Hyeon-Shic Shin, Christine Risch, Kent Sowards, Jianhe Du	MU, VT	Environmental and Safety Attributes of Electric Vehicle Ownership and Commuting Behavior: Public Policy and Equity Considerations
EU	VT	Hesham Rakha	Ihab El-Shawarby		Develop and Test Connected Vehicle Freeway Speed Harmonization Systems
EU	ODU	Rajesh Paleti	Mecit Cetin		Investigating Relationship Between Driving Patterns and Traffic Safety Using Smartphones-Based Mobile Sensor Data
EU	ODU	Mecit Cetin			Exploring the use of LIDAR data from Autonomous Cars for Estimating Traffic Flow Parameters and Vehicle Trajectories
EU	VT	Hesham Rakha	Mohammed Elhenawy		Cluster Analysis Guidance and Pilot Test

EU	UD	Ardeshir Faghri	Hyeon-Shic Shin	MSU	Climate Change and Non-Motorized Transportation
EU	UVA	Devin Harris			Image-based Response Measurement for Reference-Free Deflection and Deformation Monitoring of Highway Structural Systems
EU	ODU	Rajesh Paleti	Mecit Cetin		Investigating Relationship between Driving Patterns and Traffic Safety using Smartphones Based Mobile Sensor Data
EU	VT	Hesham Rakha	Mohammed Elhenawy		Cluster Analysis Guidance and Pilot Test
EU	UVA	Brian Smith			Cybersecurity Analysis to Prepare VDOT Operat ions for Connected and Autonomous Vehicle A pplications
WM	UVA	Jon Goodall			Design of a Decision Support Tool for Nutrient Credit Exchange Feasibility in Stormwater Regulatory Compliance
WM	MSU	James Hunter	Dong Hee Kang		Mitigating Pollutants from Highway Infrastructure for Total Maximum Daily Load (TMDL) Compliance: Monitoring Efficacy of Best Management Practices and Advancing Decision Support
WM	UVA	Jon Goodall	Devin Harris, Brian Smith		Integrated Data for Improved Asset Management
WM	MSU	Dong Hee Kang	Anastasia E. M. Chirnside, Mark Bundy	UD	Evaluation of Waste Concrete Road Materials for Use in Oyster Aquaculture
LU	VT	Steve Hankey	Ralph Buehler		Multi-City, National-Scale Direct-Demand Models of Peak-Period Bicycle and Pedestrian Traffic
LU	UVA	Andrew Mondsche in			Virginia Sustainable Travel Choices: Effects of Land Use and Location on Current and Future Travel Options
LU	UD	Marcia Scott	Sinaya Dayan, Tuan Nguyen, Savannah Edwards and Jeff Cragle	MU	GIS Story Maps: A Tool to Empower and Engage Stakeholders in Planning Sustainable Places
LU	UVA	Andrew Mondsche in			Driver Education for New Multimodal Facilities

Appendix A includes progress reports for the active base and match funded projects including projects that ended during the current reporting period, April 1, 2016-September 30, 2016.

The other part of our research program are competitive collaborative projects. Table 2 lists the five projects awarded in Fall 2014. Hyperlinks lead to the project final reports. Progress reports for these projects are provided in Appendix B. Table 3 lists the six projects awarded in February 2016. Progress reports for these projects are provided in Appendix C.

Table 2 Competitive Collaborative Projects Awarded Fall 2014 (January 1, 2015-August 31, 2016 projects) (Hyperlinks go to the final reports.)

Focus Area	Lead U	PI	Other Investigators	Other U	Title
LU	VT	Hankey	Buehler, Mondschein	UVA	Designing a bicycle and pedestrian traffic count program to estimate performance measures on streets and sidewalks in Blacksburg, VA
WM	UD	Chiu	Imhoff, Culver	UVA	Simultaneous Removal of Nitrogen and Phosphorus from Stormwater by Zero-Valent Iron and Biochar in Bioretention Cells
IR	UVA	Goodall	Sridhar	VT	Impact of Climate Change and Sea Level Rise on Stormwater Design and Reoccurring Flooding Problems in the Hampton Roads Region
EU	ODU	Iftekharuddin	Cetin, Rakha	VT	LiDAR for Air Quality Measurement
EU	UD	Prasad	Advani, Shin	MSU	Connected Vehicle Technologies for Energy Efficient Urban Transportation

Table 3 Competitive Collaborative Projects Awarded Spring 2016 (May 1, 2016-October 31, 2017 projects)

Focus Area	Lead U	PI	Other Investigators	Other U	Title
IR	MU	Zatar	Nguyen, Ozbulut	UVA	Fiber-Reinforced Plastic (FRP) Wraps for Next Generation Sustainable and Cost-Effective Rehabilitation of Coastal Transportation Infrastructure in the Mid-Atlantic Region
IR	UVA	Murray-Tuite	Heaslip, Sridhar, Goodall	VT	Transportation Infrastructure Flooding: Sensing Water Levels and Clearing and Rerouting Traffic out of Danger
EU	MU	Nichols	Chou, Cetin, Abbas	ODU, VT	Leveraging Connected Vehicles to Enhance Traffic Responsive Traffic Signal Control
EU	MSU	Rakha	Chen, Jeihani, Chavis	VT	Eco-Speed Control for Hybrid Electric Vehicles and Buses in the Vicinity of Signalized Intersections
EU	ODU	Paleti	Cetin, Rakha	VT	Real-Time System Prediction & Optimal Rebalancing Strategies for Public Bike Sharing Systems
EU	MSU	Chavis	Jeihani, Rakha	VT	Quantifying the Impact of On-Street Parking Information on Congestion Mitigation

1.1.3 Dissemination

The final research reports have been published to the MATS UTC website and are linked to the tables above. Many of our results have been further disseminated in multiple ways including website updates and news posts, academic publications, project descriptions in quarterly newsletters, Facebook posts, Twitter tweets, monthly Internal News emails, MATS UTC webinars, and conference presentations.

1.1.4 Plans for Next Reporting Period

Plans for the next reporting period include continuing these projects. We anticipate another competitive collaborative solicitation in late Fall 2016. We will continue the dissemination and tech transfer of our research results.

1.2 Education and Workforce Development

The MATS UTC education goal is to foster education and training to contribute to the development of the transportation workforce. Traditional discipline-based education and training is not sufficient for current and future workforce demands; our approach is multi-disciplinary, multimodal, and incorporates both passenger and freight. Under this grant we are developing a series of education activities, from K-12 to PhD and professionals. These programs build on the education and training programs available at all consortium universities.

1.2.1 New Activities Associated with Degree Programs

The MATS UTC Education Steering Committee put a lot of effort into developing a semester long graduate course in Transportation Sustainability that was offered asynchronously at five of the six consortium universities in Fall 2015. We will offer this course again in Fall 2016 with the 10 modules and 11 instructors listed in Table 4.

Table 4 Modules, Length, Instructor and University/Organization for the Semester-Long Graduate Course in Transportation Sustainability Offered August 29 – December 15, 2016

Weeks	Topics
1 Aug 29 – Sep 2	**Overview**, Emily Parkany, University of Virginia
2 & 3 Sept 5 – Sept 16	**Energy-Efficient Urban Transportation**, Hesham Rakha & Kyungho Ahn, VA Tech
4 & 5 Sep 19 – Sep 30	**Urban Freight**, Hyeon-Shic Shin, Morgan State University
6 & 7 Oct 3 – Oct 14	**Coastal Infrastructure Resiliency**, Navid Tahvildari, Old Dominion University
8 Oct 17–Oct 21	**Sustainable Materials**, Wael Zatar, Marshall University
9 & 10 Oct 24 – Nov 4	**Enhanced Water Quality Management**, Jonathan Goodall, University of Virginia
11&12 Nov 7– Nov 18	**Multimodal Transportation**, Andrew Mondschein, University of Virginia
Half Week Nov 21–Nov 23	**Re-usable Materials,** Ben Bowers, Virginia Transportation Research Council
14 & 15 Nov 28-Dec 9	**Land Use and Regional Planning Process**, Michael DuRoss, University of Delaware/ Delaware Department of Transportation
Half Week Dec. 12-14	**Sustainability Impacts of Connected/Automated Vehicles**, Mecit Cetin, Old Dominion University

1.2.2 Non-degree Programs

MATS UTC encompasses formal training programs for transportation professionals at the University of Virginia (Transportation Training Academy (TTA), Virginia's Local Technical Assistance Program (LTAP), Marshall University and the University of Delaware (Delaware's LTAP).

MATS UTC offered a workshop on Mobile, Wearable Sensing for Sustainable Systems at our Annual Meeting on August 5 in Charlottesville.

1.2.3 Attracting New Entrants to Transportation

MATS UTC has made a conscious effort to attract new entrants to transportation. This includes K-12 efforts and undergraduate efforts focused on transportation in general and specifically addressed to attract diverse audiences including women and underrepresented minorities.

Highlights of our activities in this area include:

- Undergraduate Summer Research Internship Program (USRIP). We had 11 students in our program from seven universities working at four consortium universities in Summer 2016. They participated jointly via weekly web meetings. All prepared and presented a final report, poster, and oral presentation. The reports and presentations are found here.
- Promoting Careers in Transportation. We have a Fall 2016 webinar series featuring three of our Advisory Board members.
- We participate in Career Fairs aimed at getting high schoolers excited about transportation careers and sponsored by the Virginia Department of Transportation in Northern Virginia (October 6) and Hampton Roads (November 2).

1.2.4 Dissemination

We use a variety of methods including email "blasts", website posts, Facebook posts, Twitter tweets, internal news distribution and a quarterly newsletter to disseminate information about our research and education and training activities.

1.2.5 Plans for Next Reporting Period

We are excited about our second offering of the graduate Transportation Sustainability class and the Fall 2016 Careers in Transportation webinar series.

1.3 Technology Transfer

The goal of the MATS UTC technology transfer program is to broaden our reach and effectively disseminate research results. Appendices A, B, and C include the technology transfer and outreach efforts of researchers affiliated with individual projects. These include seminars and conference poster/podium presentations about specific research projects.

In the section below, we describe our conducted and planned technology transfer and outreach events and media and communications efforts.

1.3.1 Technology Transfer/Outreach Events

MATS UTC Technology Transfer/Outreach Events in this reporting period include:

- A Spring Research Webinar Series from February-June 2016 (5 webinars) featuring 13 researchers and six of our projects.
- All of our webinars are archived on YouTube and we maintain a web page with a link to the archived recording and the presentations and additional information for each one. [YouTube link] List of MATS UTC webinars.
- Each of our research teams maintain a Technology Transfer Implementation Plan for each project. These were completed in July 2015 and updated in March 2016. We plan an update in March 2017.

1.3.2 Media and Communications

We have developed several outlets for disseminating MATS UTC research, education, diversity, and technology transfer activities. These include the MATS UTC website www.matsutc.org , external email

blasts to our list of over 530 (and growing) names, Facebook posts https://www.facebook.com/midatlantictransportationsustainability , a monthly internal news distributed to our advisory board and researchers, and Twitter feeds. This reporting period, we added our August 2016 Open House Participants to our mailing list. We also worked with our Advisory Board members to identify additional organizations that may be interested in our efforts. Each participating university posts once a week on Facebook and many of the posts are copied as posts to the MATS UTC website and to Twitter.

We have distributed a Quarterly newsletter since April 2015. The E-Newsletter includes a feature article, research spotlights for two projects, faculty and student spotlights, education and training updates, and news from consortium members. The newsletter is distributed to our MATS UTC email list and the articles are available on our website.

1.3.3 Disseminations

Dissemination of research results are achieved through the events, media, and communication channels described in sections 1.3.1 and 1.3.2 and in the Appendices.

1.3.4 Plans for Next Reporting Period

We will continue our communications and outreach efforts and continue to expand our email lists with new addresses of event attendees and other activity participants. We established a MATS UTC Dataverse to include data from our projects. We plan to include the data for six of our projects in fall 2016. Additional projects have indicated sharing their data in the Dataverse in the appendices. Technology transfer related to each individual research project will continue and likely increase as the projects mature.

2. Products

MATS UTC products specific to each of our research projects are provided in the Appendices. Here we describe general products related to our Center.

2.1 Publications

Despite our young Center, several related papers have been submitted to major conferences and published in journals as shown in the Appendices. Our current publications include 11 papers accepted for TRB 2017, 23 additional external conference presentations, and published articles in Journal of Applied Energy, Materials and Design, Materials and Structures, Transportation Research Part C. Additional papers are under review by the International Symposium of Transportation and Traffic Theory, ASCE Journal of Infrastructure Systems, ASCE Journal of Hydologic Engineering, Transportation Research Part C, Transportation Research Part D, and the Journal of Aerospace Information Systems. Our Center has also issued quarterly newsletters since April 2015.

Individual researchers are encouraged to submit papers related to their work to technical conferences and other avenues.

2.2 Websites

Our MATS UTC website was launched in August 2014: www.matsutc.org The MATS UTC Dataverse was established in June 2016.

2.3 Technologies

Much of our research leads to the development of technologies. Examples include:

- To measure aerosol vertical profiles, the research team retrofitted and calibrated a state-of-the-art elastic LiDAR donated to ODU by the NASA Langley Research Center and collected data at multiple sites.
- A decision support system for identifying nutrient credits for stormwater management.
- Development of a minimally destructive method to use microbial biomarkers to identify alkali-silica reaction damage in concrete.
- An optimal mix of biochar and zero valent iron to remove nitrogen and phosphorus from stormwater with a bioretention cell.
- Use of Shape Memory Alloys for bridge repairs.

2.4 Inventions

Nothing to report.

2.5 Educational Products

We developed a semester-long graduate transportation sustainability course, two one-day professional development workshops and a half-day workshop.

2.6 Other Products

Here are examples of additional products that have resulted from this grant:

- Webinar archives found on the MATS UTC You Tube site
- Website posts and Facebook posts of Center activities

3. Participants and Collaborating Organizations

MATS UTC is a consortium of six universities. In addition to these universities we collaborate with several match sources including state DOTs and local agencies. We also have an advisory board with 11 members from 11 different agencies and organizations covering multiple modes and our region.

3.1 Participants

MATS UTC participants include researchers, instructors and staff from the six universities; instructors and speakers for our workshops, seminars, and symposia; champions and other partners at our match funding agencies; and our 11 person advisory board.

Appendices A, B and C and the text in this report provide names of researchers, instructors, and other presenters affiliated with MATS UTC activities.

Table 5 presents the names, titles, affiliations, and location of our 11 advisory board members.

Table 5 MATS UTC Advisory Board Members

Name	Title	Affiliation	Location
Jose Gomez, Chair	Director	Virginia Transportation Research Council	Charlottesville, VA
Damon Fordham	Principal	The Cadmus Group	Crozet, VA
Susan Handy	Director	National Center for Sustainable Transportation, University of California, Davis	Davis, CA

Jason Wang	Senior Transportation Specialist	Appalachian Regional Commission	Washington D.C.
Camelia Ravanbakht	Interim Executive Director	Hampton Roads Transportation Planning Organization	Chesapeake, VA
Holly Rybinski	President	Rybinski Consulting	Wilmington, DE
Domini Scurti	Manager, Market Planning	Maryland Port Administration	Baltimore, MD
Donald Williams	Research and Special Studies	West Virginia DOT	Morgantown, WV
Tim Witten	ITS/Special Projects Manager	Blacksburg Transit	Blacksburg, VA
Hua Xiang	Office of Policy and Research	Maryland State Highway Administration	Hanover, MD
Tigist Zegeye	Executive Director	Wilmington Area Planning Council	Newark, DE

We expect to have 30 external technical reviewers for the competitive collaborative proposals we will receive in November 2016. We will supplement these technical reviews with scores of all of the proposals from our Advisory Board members.

August 4-5, 2016 we held an Annual Meeting and Open House in Charlottesville, VA. We had 60 full conference registrants (consortium members and Advisory Board members) and 25 Open House registrants (external to MATS UTC). All participated in our Poster Session featuring 31 projects, a leadership and ideas session featuring a junior faculty member from each of our universities, and a State of the Center presentation. After a dessert reception and historical tour of the UVA Grounds, the second day featured brainstorming sessions on ten topics with graduate student recording and reporting.

Representatives from all six consortium universities participate in the MATS UTC Executive Team teleconference held biweekly on Fridays.

3.2 Collaborating Organizations

In addition to the members of our advisory board, MATS UTC has collaborated with several individuals and organizations in conducting our research and other activities. These include research sponsors and presenters at MATS UTC events.

3.2.1 Research Sponsors

Our MATS UTC research sponsors and agency participants include:

- Virginia Transportation Research Council, Virginia Department of Transportation
- Virginia Statewide Bicycle and Pedestrian Committee
- Virginia Beach Department of Public Works
- Maryland State Highway Administration
- Maryland Department of Transportation
- Delaware Department of Transportation
- West Virginia Department of Transportation
- National Oceanic and Atmospheric Administration (NOAA)
- Delaware Department of Natural Resources and the Environment (DNREC)
- Hampton Roads Transportation Planning Organization; Hampton Roads Planning District Commission
- Maryland Motor Vehicle Administration

- Electric Vehicle Association-DC Chapter
- US Environmental Protection Agency
- NASA Langley Research Center
- City of Charlottesville
- City of Virginia Beach
- Ecosystem Services, LLC, VA;
- ReGenesis Global Solutions, LLC/Infinite Solutions L^3C, PA
- Town of Blacksburg, VA
- Blacksburg Transit
- Portland State University

3.2.2 Presenters at MATS UTC Events

During our Annual Meeting and our webinars (Spring and Fall) our presenters have been from our consortium universities or our Advisory Board (thus internal to MATS UTC). Please see the Spring Webinar Research Series and Fall Careers in Transportation Webinar Series sites and the Annual Meeting links for lists of presenters.

4. Impact

Each of the projects summarized in the Appendices have included impacts in the principal discipline and some include impacts on other disciplines. In the sections below, we provide general impacts and describe how this Center has impacted the principal and other disciplines, human resources, resources at the University of Virginia and the other consortium universities, technology transfer, and society beyond science and technology.

4.1 Development of the Principal and Other Disciplines

MATS UTC researchers, instructors, and staff represent multiple disciplines including civil engineering (transportation, water resources, structures, and geotechnical engineering), electrical engineering, transportation planning, public policy, and business. Our emphasis on collaboration among universities and disciplines for all of our programs including research, education, and outreach leads to development of students, professionals and faculty in all of these disciplines.

Specific examples include:

- Cross-listing our graduate transportation sustainability course in engineering and public policy schools at University of Delaware; participants in the graduate class have been from five of six consortium universities and include civil engineering, urban planning, policy, energy engineering majors
- Researchers from at least six different academic departments involved in MATS UTC projects

4.2 Development of Human Resources

MATS UTC has directly impacted graduate students in terms of Graduate Student Research Assistantships, Fellowships, and our graduate course in transportation sustainability, undergraduate students applying for our summer undergrad research program and attending our Careers in Transportation series, professionals attending our workshop and symposium, and faculty at all six consortium universities involved in research and teaching our semester long graduate course.

4.3 Resources at University and Partner Institutions

MATS UTC resources have expanded the offerings at the University of Virginia, our consortium universities, and our match sources such as the Virginia Department of Transportation. Examples of activities directly enabled by MATS UTC include:

- Environmental sustainability research projects funded by federal funds and match funds that would not be possible without MATS UTC
- Professional development training workshops related to environmental sustainability
- MATS UTC summer undergraduate research program
- Graduate class in transportation sustainability offered at five of six consortium universities

4.4 Technology Transfer

We expect our research results and dissemination to continue after the period funded by the grant has elapsed. In the meantime, we intend to present preliminary and initial results during seminars, webinars, and conferences.

4.5 Society beyond Science and Technology

Sustainability issues will impact all of us. By promoting our activities, disseminating our results, and encouraging our match sources (such as regional DOTs) to spend resources on sustainability, we are increasing awareness of this nascent area.

5. Changes

There are no changes in the scope or objectives of this grant.

Individual projects may have changed a bit since inception as reported in the Appendices.

6. Special Reporting Requirements

No special reporting requirements. Nothing to report.

Appendix A Base-Funded Research Projects (Includes Match-Funded Non-Competitive Projects)

Project: Multimodal Freight Distribution to Support Increased Port Operations
PIs: Mecit Cetin, Old Dominion University, MCetin@odu.edu; Manwo Ng, Old Dominion University, mng@odu.edu; Wayne Talley, Old Dominion University, wktalley@odu.edu; Brian Park, University of Virginia, bpark@virginia.edu; Hesham Rakha, Virginia Tech, HRakha@vtti.vt.edu
Period of Performance: November 1, 2014 – September 31, 2016
Other participants and collaborating organizations: EPA, port authorities
Accomplishments:

- Virginia Tech Comprehensive Power-Based Fuel Consumption Model (VT-CPFM) was extended to predict Heavy-duty diesel vehicles (HDDVs) emissions for carbon monoxide (CO), hydrocarbons (HCs), and nitrogen oxides (NOx). The model accuracy is tested and it can be calibrated with publicly available data.
- A multimodal freight dispatching tool is developed that include environmental costs in addition to the transportation costs to support the environmentally conscious decisions.

- An optimization model is developed for the loading of containers on a double stack train at an inland port that is destined for a seaport. Particularly, the optimization model supports the assignment of containers to rail cars, in order to maximize the utilization of the available space on the train.

Products:

- Abdelmegeed M. and Rakha H. (2017), "Heavy Duty Diesel Truck Emission Modeling." Paper 17-00855. (Accepted for presentation at the TRB annual meeting in Jan. 2017 and under consideration for publication in Transportation Research Record)
- Hong, S., J. Hu, and B.B. Park, "Optimization of Multimodal Network System for Environmental Sustainability incorporating Economies of Scale," Accepted for presentation at the TRB annual meeting in Jan. 2017.
- Wang J. and Rakha H. (2016), "Fuel Consumption Model for Heavy Duty Diesel Trucks: Model Development and Testing" Accepted for publication in the Journal of Applied Energy.

Impact:

- Several papers are presented and published with the involvement of graduate students.
  New models are developed for emissions prediction, and for optimization of freight movement.

Project: Infrastructure Resilience and Adaptation for Hurricanes in Coastal Areas

PIs: Pamela Murray-Tuite, Virginia Tech, murraytu@vt.edu; Ihab El-Shawarby, Virginia Tech, IEl-Shawarby@vtti.vt.edu; Hesham Rakha, Virginia Tech, hrakha@vtti.vt.edu; Brian Smith, University of Virginia, briansmith@virginia.edu

Period of Performance: October 1, 2014 – August 31, 2016

Other Participants and Collaborating Organizations:

- Dr. Jianhe Du – Sr. Research Associate, Virginia Tech
- Mohammad Aljamal – Graduate student, Virginia Tech (advised by Hesham Rakha)
- Aphisit Phoowarawutthipanich, Graduate student, Virginia Tech (advised by Pamela Murray-Tuite) aphisit@vt.edu, Smart Urban Mobility Laboratory, Northern Virginia Center, Virginia Tech

Accomplishments:

- Completed the running of various evacuation scenarios using INTEGRATION.
- Completed the running of various evacuation scenarios using MATSIM.
- Finished the process of comparing the output results from INTEGRATION and MATSIM.
- Completed the final sub-report (Rakha and El-Shawarby).
- Collected and processed the latest datasets for both peak and time-series data for three storm surge scenarios based on storm tracks(1050 tracks), wind speeds, and pressure
- Modified the GIS steps as attached
- Located the flooded areas and determine how much they are inundated for base condition as shown in the sample results
- Processed the time series data for GIS analysis to find out when flooding happens in the area
- Set up the network dataset for doing the shortest path algorithm in GIS

Products:

- Aljamal, M., Rakha, H., Du, J., and El-shawarby, I. (2017) "Comparison of Microscopic and Mesoscopic Traffic Modeling Tools for Evacuation Analysis" Submitted for presentation at the 96th Transportation Research Board Annual Meeting, Washington DC, January 8-12.
- A poster for MATS UTC 2nd Annual Meeting

Impact:

- This project would account for the total influences of sea level rise, storm surge and high tides.
- The conceptual framework can be transferred to other coastal areas.

Changes/Problems:

- Delays in obtaining US Army Corps of Engineers data – caused subsequent analysis delays

Project: Multimodal Transportation Facility Resilience Index

PIs: Nii Attoh-Okine (UD) – email: okine@udel.edu; Lindsay Ivey-Burden (UVa) – email: lindsay.ivey@virginia.edu

Period of Performance: October 1, 2014 – December 31, 2016

Accomplishments:

- Attended a training of how to use Big Data paradigm in Resilience Engineering

Products:

- Presented a Seminar at UVA
- Abstract submission to Big Data Conference – New York ' Big Data and Resilience Engineering

Impact:

- Working with Dr. Ivey-Burden to advise a Master's Thesis at UVA

Project: Structural Enhancements to Adapt to Impacts of Climate Change

PIs: Osman Ozbulut, University of Virginia, ozbulut@virginia.edu; Devin Harris, University of Virginia, dharris@virginia.edu

Period of Performance: October 1, 2014 – May 31, 2016

Accomplishments:

- A final report that clearly and comprehensively document all aspects of the research program was prepared.

Products:

Journal Paper:

- Daghash, S., and Ozbulut, O. E. (2016). "Characterization of superelastic shape memory alloy fiber-reinforced polymer composites under tensile cyclic loading." Materials & Design, 111, 504-512, http://dx.doi.org/10.1016/j.matdes.2016.09.034

Conference Presentations:

- Sherif, M., Pavgi, R., Khakimova, E., Ozbulut, O. E., and Ozyildirim, H. C. (2016). "Characterization of mechanical and electrical properties of SMA-PVA fiber-reinforced cementitious composites." *Proceedings of ASCE Engineering Mechanics Institute (EMI) Conference 2016 & Probabilistic Mechanics & Reliability Conference 2016,* Nashville, TN, May 2016.
- Daghash, S., and Ozbulut, O. E. (2016). "Development of fiber-reinforced polymer composites with superelastic shape memory alloys." *Proceedings of ASCE Engineering Mechanics Institute (EMI) Conference 2016 & Probabilistic Mechanics & Reliability Conference 2016,* Nashville, TN, May 2016.
- Sherif, M., and Ozbulut, O. E. (2016). **"**Superelastic SMA fiber-reinforced polymer composites." *Proceedings of the ASME 2016 Smart Materials, Adaptive Structures and Intelligent Systems*, Stowe, VT, September 2016.
- Sherif, M., Ozbulut, O. E., and Tanks, J. "Investigations on cyclic flexural behavior of fiber reinforced cementitious composites using digital image correlation and acoustic emissions." *Proceedings of International Digital Image Correlation Society (iDICs) Conference*, Philadelphia, PA, November 2016.

Impact:

- Engaged one undergraduate student (from underrepresented groups) for summer research.
- Three graduate students involved in the study.

Project: Accelerating Use of Sustainable Materials in Transportation Infrastructure

PIs: Devin Harris, University of Virginia, dharris@virginia.edu; Osman Ozbulut, University of Virginia, ozbulut@virginia.edu

Period of Performance: August 1, 2015 – May 24, 2016

Accomplishments:

- A final report that clearly and comprehensively document all aspects of the research program was prepared.

Products:

Conference Proceedings:

- Pavgi, R., Jiang, Z., Ramniceanu, A., Ozbulut, O. E., and Harris, D. K. (2016). "Self-sensing cementitious composites with graphene nanoplatelets." Proceedings of *International Concrete Sustainability Conference 2016*, Washington, D.C., May 2016.
- Jiang, Z., Ozbulut, O. E., and Harris, D. K. (2016). "Graphene nanoplatelets-based self-sensing cementitious composites." *Proceedings of the ASME 2016 Smart Materials, Adaptive Structures and Intelligent Systems*, Stowe, VT, September 2016

- Jiang, Z., Ozbulut, O. E., and Harris, D. K. (2017). "Graphene nanoplatelets-based self-sensing mortar composites." *Proceedings of the TRB Annual Meeting 2017*, XX pages, Washington, D.C., January 2017.

Impact:

- Engaged one undergraduate student (from underrepresented groups) for summer research.
  One graduate student involved in the study.

Project: Microbial Biomarkers for ASR-Damaged Concrete

PIs: Julia Maresca, University of Delaware, jmaresca@udel.edu; Devin Harris, University of Virginia, dharris@virginia.edu

Period of Performance: June 1, 2015 – May 31, 2017

Other participants and collaborating organizations: Virginia and West Virginia Departments of Transportation

Accomplishments:

- Demonstrated and published the proof of concept: (1) DNA can be extracted from concrete; (2) we can extract enough DNA from concrete and at high enough concentrations to sequence; (3) the bacteria inside concrete are similar to those found in other dry, salty and alkaline environments. Further, we have extracted DNA from two sets of laboratory-prepared concrete cylinders. One set is highly susceptible to ASR (alkali-silica reaction) and one should be resistant. This DNA has been submitted to the University of Delaware's Sequencing and Genotyping Center for sequencing and we should have the results in January 2017. Products:

Products:

- **Publication:** J.A. Maresca, P. Moser[1], T. Schumacher. Bacterial communities in and on concrete. 2017. *Materials and Structures* 50: 25. doi:10.1617/s11527-016-0929-y
  [1]Denotes undergraduate student author
- **Invited seminars:** J.A. Maresca*. Towson University, Department of Physics, Astronomy, and Geosciences, Towson, MD. April 8, 2016. *Hard Microbiology: Bacteria in concrete.*
- **Conference presentations:**
  1. J.A. Maresca*. Urban geomicrobiology: Microbial communities in and on concrete. Geological Society of America Annual Meeting, September 2016. (Invited talk.)
  2. J.A. Maresca*, J.L. Keffer[3]. Microbial communities in concrete and their potential application in ASR-damaged concrete. Mid-Atlantic Transportation Sustainability Center – Region 3 University Transportation Center Annual Meeting, August 2016. (Poster presentation and invited talk.)
  3. A.K. Treglia[1*], J.L. Keffer[3], J.A. Maresca. Using Microbial Populations in Concrete as Bio-Indicators of Alkali-Silica Reaction. American Society of Microbiology General Meeting/Microbe, June 2016. (Poster presentation)

  [1]undergraduate student author
  [3]UD postdoctoral scholar
  *Presenting author.

Impact:

- **Education:** 1 MS student (Anders Kiledal) is now working on this project, as well as an undergraduate researcher (Alison Treglia). Both students have learned about the chemistry and physical structure of concrete, analytical techniques relevant to characterizing both concrete and the microbes inside it, and biological methods for analyzing the bacteria. Additionally, both students have presented their work at local symposia and Ms. Treglia has presented hers at a national conference, the American Society for Microbiology (see item 4 above).
- **Research:** Until our work, the only analysis of bacteria in the interior of concrete was focused on bacteria used for biorepair. We have shown that the microbial community inside concrete is small, but diverse, and that identification of bio-indicators for structural damage is theoretically possible.
- **Technology transfer:** I have discussed technology transfer with the University of Delaware College of Engineering intellectual property (IP) officer, who says that since any test focused on detection of specific bio-indicators would be based on existing molecular biology technology, it is unlikely to be patentable. We will continue to discuss our work with the IP office as the research continues.

Changes/Problems:

- I was originally funding a PhD student to do this work. However, she left the university for personal reasons in December 2015. Since April 2016, a research associate in my lab has been working on this project. Future research analyzing DNA from concrete samples collected from roadways by departments of transportation or associated contractors in the Mid-Atlantic region will be carried out by a new MS student in my research group, Anders Kiledal.

Project: Implementation of "Smart Equipment" in Field Construction
PIs: Christopher Meehan, University of Delaware, cmeehan@udel.edu, Dhruv Batra, Virginia Tech University, dbatra@vt.edu
Period of Performance: June 1, 2015 – May 31, 2017
Other Participants and Collaborating Organizations: Delaware Department of Transportation (DelDOT)
Accomplishments:

- DelDOT has secured funding for the equipment that is needed to begin fieldwork, and procured some of the equipment already (though not yet the most critical piece, the smart roller)
- Preliminary field studies have been conducted to explore the use of the in situ spot test equipment that will be used in the future field study, with a particular focus on the variability of results for the different QA/QC tests
- A group of undergraduate students and a high school student were mentored over the course of the past summer in conducting laboratory and field testing and running computer simulations related to the project (MATS-UTC summer program activities)

Products:

- During the MATS-UTC summer program, a group of undergraduate students and a high school student were trained about the use of "smart equipment" for field construction on transportation projects
- During the MATS-UTC summer program, undergraduate students were trained in the proper use of testing devices in the field

Changes/Problems:

- The equipment procurement process has taken longer than anticipated, largely due to DelDOT's fairly involved contracting and procurement requirements

Project: Enhancing Traffic Control Systems to Reduce Emissions and Fuel Consumption
PIs: Andrew Nichols, Marshall University, andrew.nichols@marshall.edu; Brian Park, University of Virginia, brianpark@virginia.edu; Hesham Rakha, Virginia Tech, hrakha@vtti.vt.edu; Montasir Abbas, Virginia Tech, abbas@vt.edu
Period of Performance: October 1, 2014 – March 31, 2016
Accomplishments:

- Matt Skiles, West Virginia Department of Transportation, would be interested in the metrics to audit the emergency vehicle preemption performance.
- Traffic engineers that are responsible for traffic signal control for any Department of Transportation would be possible champions.

Project: Network-wide Impacts of Eco-routes and Route Choice Behavior/Evaluation of AERIS Applications
PIs: Hesham Rakha, Virginia Tech, hrakha@vtti.vt.edu; Kyoungho Ahn, Virginia Tech, kahn@vtti.vt.edu; Mecit Cetin, Old Dominion University, mcetin@odu.edu; Brian Park, University of Virginia, bpark@virginia.edu
Period of Performance: November 1, 2014 – April 30, 2016
Accomplishments:

- The research team from ODU has developed methods to predict traffic volumes based on trajectory data from probe vehicles and the shockwave theory. Results will be presented at the EURO Working Group on Transportation Meeting in September 2016.
- VT researchers presented "Eco-routing: An Ant Colony based Approach" at the VEHITS 2016 : The 2nd International Conference on Vehicle Technology and Intelligent Transport Systems, 23 - 24 April, 2016, Rome, Italy

- UVA researchers developed "Route choice modeling with Support Vector Machine" and the study was accepted for presentation at the World Conference on Transportation Research, Shanghai, China, July 10-15, 2016
- ACO-ECO traffic assignment technique was developed which is inspired from the ant colony optimization algorithm. ACO-ECO attempts to enhance the SPF-ECO algorithm that is currently implemented in the INTEGRATION software.

Products:

- K. A. Anuar and M. Cetin, "Estimating Freeway Traffic Volume Using Shockwaves and Probe Vehicle Trajectory Data", Presented at the 19th EURO Working Group on Transportation Meeting (EWGT2016), Istanbul, Turkey, September 5-7, 2016 (also to be published in Transportation Research Procedia).
- Ahmed Elbery, Hesham Rakha, Mustafa Y. ElNainay , Wassim Drira, and Fethi Filali, Eco-routing: An Ant Colony based Approach, In Proceedings of the International Conference on Vehicle Technology and Intelligent Transport Systems, 31-38, 2016, Rome, Italy.
- F. Habtemichael, and M. Cetin, "Short-Term Traffic Flow Rate Forecasting Based on Identifying Similar Traffic Patterns" Transportation Research Part C, Volume 66, May 2016, Pages 61–78.
- Sun, B. and B. B. Park, "Route choice modeling with Support Vector Machine," Accepted for presentation at the World Conference on Transportation Research, Shanghai, China, July 10-15, 2016.

Impact:

- The team developed robust models that provide reliable travel-time or delay prediction under varying conditions using probe data from known bottleneck locations (e.g., bridges and tunnels).
- This research team also developed individual route choice behavior model which proposes a new perspective to address the heterogeneity issue by establishing individual route choice behavior model under traffic information provision for every driver.
- The team developed the Vehicular Net-work Integrated Simulator (VNetIntSim) as a new transportation network and VANET simulation tool by integrating transportation and VANET modelling. Specifically, it integrates the OPNET software, a communication network simulator, and the INTEGRATION software, a microscopic traffic simulation software.
- Finally, Eco-Cooperative Adaptive Cruise Control (Eco-CACC) systems were developed in an attempt to improve vehicle fuel efficiency in the vicinity of signalized intersections. These Eco-CACC systems utilize traffic Signal Phasing and Timing (SPaT) data received via Vehicle-to-Infrastructure (V2I) communication together with vehicle queue predictions to compute fuel-optimum vehicle trajectories that are continuously updated as the vehicle travels in the vicinity of signalized intersections.

Changes / problems:

- This project is completed and the final report was submitted to MATS UTC.

Project: Environmental and Safety Attributes of Electric Vehicle Ownership and Commuting Behavior: Public Policy and Equity Considerations

PIs: Z. Andrew Farkas, Morgan State University, andrew.farkas@morgan.edu; Hyeon-Shic Shin, Morgan State University, hyeonshic.shin@morgan.edu

Period of Performance: October 1, 2014 – September 30, 2016

Collaborating Organizations: Maryland Motor Vehicle Administration, Glen Burnie, MD; Maryland Electric Vehicle Infrastructure Council, BWI Airport, MD

Accomplishments:

- Continued to discuss logistics with MVA of deriving two large samples of registered vehicle owners in Maryland.
- Conducted survey distribution to various EV and conventional vehicle owners' forums.
- Collected and analyzed survey data.
- Preparing final technical report

Products:

- Poster presentation at MATS UTC Annual Meeting in Charlottesville, VA, August 4, 2016
- Poster presentation to Maryland Public Service Commission Meeting, July 14, 2016

Impact:

- Topics of electric vehicles and owner attitudes and commuting behaviors have been discussed in various transportation and planning classes.

Changes/problems:

- Scope of project has been enlarged to include national level survey data sets. National data will be used for stand-alone analyses and for comparisons with later derived state level data. So, phase 1 of 2 now nearing completion.

Project: Mitigating Pollutants from Highway Infrastructure for Total Maximum Daily Load (TMDL) Compliance: Monitoring Efficacy of Best Management Practices and Advancing Decision Support

PIs: James Hunter, Morgan State University, james.hunter@morgan.edu; Dong Hee Kang, Morgan State University, donghee.kang@morgan.edu

Period of Performance: October 1, 2014 – October 31, 2016

Other participants and collaborating organizations: Maryland State Highway Administration, Center for Watershed Protection

Accomplishments:

- Leveraging this research effort for a project with the Maryland State Highway Administration to focus on characterization of pollutants from inlet cleaning activities. Awarded March 2016, this project will start April 1, 2016 in partnership with the Center for Watershed Protection.
- In August, we have received SHA's Bay Restoration Viewer GIS data, this will be used with previous state wide analysis using the L-THIA methodology for long-term hydrologic impacts assessments and application of LID/Green Infrastructure BMPs.

Impact:

- This research will help highway agencies determine appropriate crediting of practices for TMDL compliance and to collect information that could support enhancements to the existing credit allowed.

Changes / problems:

- Project extension requested for October 31, 2016 to allow time for data acquisition from SHA, model analysis, and generate final report.

Project: Integrated Data for Improved Asset Management

PIs: Jonathan Goodall, University of Virginia, goodall@virginia.edu; Devin Harris, University of Virginia, dharris@virginia.edu; Brian Smith, University of Virginia, bls2z@virginia.edu

Period of Performance: August 1, 2015 – May 24, 2016

Other Participants and Collaborating Organizations: Drew Scott, District Hydraulic Engineer, VDOT, Hampton Roads District, VA; Steve Chase, Research Professor, UVA

Accomplishments:

- We used a bridge dataset from VDOT combined with digital terrain data, hydrologic data, and models to estimate the river stage at bridge locations during extreme (100, 200, and potentially 500 yr) storm events.
- The method provides a GIS-based approach for using available geospatial datasets to screen a large number of bridges to quickly and inexpensively estimate their risk for overtopping.
- The analysis resulted in identifying bridges within the study region that may be vulnerable to overtopping from different return period storms.
- These results were used along with transportation data on road classes and traffic to identify critical bridges that may be vulnerable to overtopping.

Products:

- We submitted a journal manuscript based on the findings of this study to the ASCE Journal of Infrastructure Systems.
- We submitted a final report summarizing the research project to MATS UTC.

Impact:

- We presented our results to VDOT, specifically to Drew Scott Hampton Roads District Hydraulic Engineer and John Matthews, Assistant State Hydraulics Engineer.

Project: Evaluation of Waste Concrete Road Materials for Use in Oyster Aquaculture
PIs: Dong Hee Kang, Morgan State University, donghee.kang@morgan.edu; Anastasia E. M. Chirnside, University of Delaware, aemc@udel.edu; Mark Bundy, Morgan State University PEARL, mark.budy@morgan.edu
Period of Performance: August 1, 2015 – December 31, 2016
Collaborating Organization: Maryland State Highway Administration, Baltimore; SHA provide matching fund into MATs UTC project. SHA coordinated material sampling sites and also brought the cooperation from each company which is Flanigan & Sons, Inc. Machado Construction Co., Inc. and The Recycling Center.
Accomplishments:

- Additional chemicals leaching test using collected RCA samples were carried out. All results of organic chemical concentration in RCA were BDL (Below Detection Limit). The result concluded that RCA should give no concern for hydrocarbon components releasing into Chesapeake Bay waster shed, if RCA is used as a bottom conditioning material for oyster aquaculture.

Products:

- Submit the final report to SHA was revised and accepted by SHA.
- *Oral Presentations*
  Dong Hee Kang, "Evaluation of Waste Concrete Road Materials for Use in Oyster Aquaculture" TRB 2016 Summer Workshop Program, July 26-29 Asheville, NC.
- *Poster Presentations*
  Dong Hee Kang, "Evaluation of Waste Concrete Road Materials for Use in Oyster Aquaculture" MATS UTC Annual Meeting, Charlottesville, VA August 4-5, 2016.

Impact:

- Undergraduate students are involved in the process. Students are learning sample collection, preparation, and extraction methods. They also learned GC-MS operating skill.

Project: Climate Change and Non-Motorized Transportation
PIs: Ardeshir Faghri (Udel) faghri@udel.edu, Hyeon-Shic Shin (MSU) hyeonshic@udel.edu
Period of Performance: April 1, 2016 – September 30, 2016
Other participants and collaborating organizations:
Participants:

- Dr. Ardeshir Faghri, University of Delaware
- Dr. Hyeon-Shic Shin, Morgan State University

Champions

- National Oceanic and Atmospheric Administration (NOAA)
- Delaware Department of Natural Resources and the Environment (DNREC)
- Paul Moser – DelDOT

Accomplishments:

- A comprehensive literature review about the contribution of the transport sector in exacerbating global warming and climate change
- A comprehensive literature review on the climate change and climate change stressors specially in the Mid-Atlantic region
- Obtaining good knowledge of effects of climate change and global warming on civil infrastructure systems and transportation infrastructure
- Obtaining good knowledge of effects of climate change and global warming on pedestrians and bicyclists travel behavior
- Comprehensive literature review on the effects of climate change on human health
- Three climate change stressors (sea level rise, flooding and storm surges, and increases in mean temperature and heat waves) that have the most negative and adverse impacts on non-motorized transportation in Mid-Atlantic region were selected based on the literature review
- Geographic data including length, type, location and classification of non-motorized transportation facilities in particular for trails and bike routes in the state of Delaware have been obtained
- Sea level rise GIS model was obtained from NOAA which includes three different scenarios projecting 0.5, 1, or 1.5 meter of rise in the sea level at the end of the 21st century

- Based on the GIS model that was developed for both trails and bike routes, the location of the non-motorized facilities that are affected by sea level rise (each of the three scenarios) were identified
- Based on the GIS model, number of facilities that are affected by sea level rise were estimated
- Based on the GIS model, length of each facility that is going to be inundated is estimated under the three scenarios
- A literature review has been performed on the type of flooding (coastal, river, and others) that have more destructive effects on non-motorized facilities in the study area
- Literature review has been performed on changes to pedestrians and bicyclists travel behavior under meteorologically adverse conditions such as intense precipitation and heat waves
- Data on how climatic stressors, in particular precipitation and temperature are affecting bicyclist's travel behavior is being collected at the University of Delaware campus

Products:

- Presenting the results of the project at the MATS-UTC Annual Meeting, August 4th and 5th, 2016. Charlottesville, Virginia
- Presenting the results of the project at a poster session for External Advisory Council, May 2016, University of Delaware

Impact:

- Raising awareness especially among decision makers and planners that non-motorized transportation facilities are in serious danger in Delaware since Delaware's topography is flat and the vulnerability of facilities against sea level rise and flooding is amplified in comparison with other regions.
- Recommending a strong methodology to classify existing non-motorized transportation facilities based on their vulnerability against climate change stressors in order to allocate proper adaptation funds to save the facilities.

Changes / problems:

- The most considerable challenge in this research project so far has been distinguishing the flooding due to climate change and normal flooding that mostly occurs because of meteorological, lack of vegetation, topography, etc.

Project: Land Use Master Planning for Environmental Sustainability

PIs: Marcia Scott, University of Delaware, msscott@udel.edu; Mingxin Li, University of Delaware, lmx@udel.edu; Sinaya Dayan, Marshall University, dayans@njrati.org

Period of Performance: November 1, 2014 – August 31, 2016

Other participants and collaborating organizations: Delaware Department of Transportation (DelDOT), Delaware Office of State Planning Coordination, Delaware Office of the Governor, Delaware State Housing Authority

Accomplishments:

Completed:

- Completion and publication of Phase I report in June 2016: ***The Use of Smart Growth Scorecards/Assessment Tools to Advance Sustainable Land-Use Practices*** (http://www.ipa.udel.edu/publications/smart-growth-scorecards-2016.pdf)
- Completion of Phase II report in September 2016: ***GIS Story Maps: A Tool to Empower and Engage Stakeholders in Planning Sustainable Places***. Editing and final production is underway

Learned:

- **Phase I:** To provide a means for communities to measure the extent to which plans and policies achieve local sustainability goals, smart growth scorecards and other assessment tools have been developed. The results of this research reveal that both the concept of smart growth and the development and use of scorecards/assessment tools have co-evolved. Shifting state and federal legislation, leadership, political agendas, and funding have shaped the extent to which smart growth practices are implemented and evaluated at the local government level. The analysis indicates that a variety of contemporary assessment tools have been developed to provide either qualitative data and/or quantify performance on key indicators of sustainability. New assessment tools, scenario-planning techniques, and interactive visualization tools are being crafted to engage and educate the public on smart-growth-related topics and planning outcomes. Yet, measuring outcomes of smart growth remains challenging. Building local

government capacity, funding support, technical assistance, and an open environment for information sharing and education is needed.

- **Phase II:** Web-based, interactive visualization tools show promise to integrate high-tech (technology) with 'high-touch' (in-person) participatory processes. Online, digital formats offer a much-needed and dynamic platform with which to satisfy mandates for increased transparency, accountability, and public engagement. Because GIS technology has become more visual, interactive, and impactful it is being used to engage stakeholders in planning sustainable places. While GIS Story Maps are visually appealing, designed for non-technical audiences, and easily shared online, more research is needed to explore how new technologies—including GIS Story Maps—can impact citizen participation in democratic and decision-making processes.Products:

Products:

Completion of Phase I Final Report:

- **The Use of Smart-Growth Scorecards/Assessment Tools to Advance Sustainable Land-Use Practices**, June 2016, http://www.ipa.udel.edu/publications/smart-growth-scorecards-2016.pdf
- Dissemination of Phase I report via University of Delaware IPA publications website: http://www.ipa.udel.edu/publications/transportation.html

Poster Presentations:

- "Utilizing GIS Story Maps to Engage Citizens in Planning for Complete Communities in Delaware," Savannah Edwards, IPA Public Administration Fellow, 2016 DELMARVA GIS "Going Viral" Conference, Dover, DE, April 14, 2016
- "Utilizing GIS Story Maps to Engage Citizens in Planning for Complete Communities in Delaware," The Delaware Center for Transportation (DCT) 13th annual transportation research, University of Delaware Paradee Center, Dover, Delaware Thursday, May 12, 2016
- "GIS Story Maps: A Tool to Empower and Engage Stakeholders in Planning Sustainable Places," MATS UTC Annual Conference, August 4 – 5, 2016, Charlottesville, VA

Oral Presentation:

- "Utilizing GIS Story Maps to Engage Citizens in Planning for Complete Communities in Delaware," Savannah Edwards, IPA Public Administration Fellow, 2016 DELMARVA GIS Going Viral Conference, Dover, DE, April 14, 2016, http://degis.org/presentations/abstracts/

GIS Story Map Gallery:

- UD IPA GIS Story Map products may be viewed online at: http://tinyurl.com/zrbxos9

Impact:

Transportation Education:

- Engaged 2 graduate students in each research phase
- One non-GIS trained graduate student gained knowledge and proficiency developing GIS Story Maps

Research:

- Final Phase II research paper describes the value of GIS Story Map technology in visually conveying, communicating, and engaging stakeholders in planning for transportation sustainability

Technology Transfer:

- **2016 Delmarva GIS conference** – April 14 presentation/poster showcased outcomes of research on smart growth, support goals of regional GIS community, and improve the coordination of the use of GIS tools and spatial data in the Delmarva area.
- **Social media posts on GIS Story Map products via:**
  Complete Communities Delaware Twitter: https://twitter.com/CompCommunityDE
  Complete Communities Delaware Facebook: https://twitter.com/CompCommunityDE
  Delmarva GIS Twitter: https://twitter.com/DelmarvaGIS
- Delaware Downtown Development District GIS Story Map:
  1) Featured in Delaware Governor Markell's August 10, 2016 program expansion announcement: goo.gl/jVx3pb
  2) Featured on Delaware State Housing Authority website: http://www.destatehousing.com/Developers/dv_ddd.php
  3) Featured on Delaware Office of State Planning Coordination website: http://www.stateplanning.delaware.gov/ddd/

- **Article:**
  "Using GIS Story Maps to Engage Stakeholders in Sustainability Planning," MATS UTC web post, June 17, 2016:
  http://www.matsutc.org/category/sustainable-land-use-practices/
- **2016 Esri Storytelling with Maps Contest**
  Marshall University RTI won 3rd place in the Infrastructure, Planning, and Government category for its GIS Story Map on "Moving Towards Sustainability in Extraction Economies of Appalachia,"
  http://www.esri.com/landing-pages/story-maps/2016-contest-winners
  Featured in MATS UTC June 17, 2016 website post: http://www.matsutc.org/2016/06/marshall-university-gis-story-map-wins-3rd-place-in-esri-contest-2/
- An application to the **Transportation Research Board Public Involvement Poster Session** has been accepted by the TRB Committee on Public Involvement (ADA60). The poster, "GIS Story Maps: A Tool to Empower and Engage Stakeholders in Planning for Complete Communities in Delaware" will be presented at the January 2017 96th TRB Annual Meeting in January 2017 in Washington, D. C.

Changes / Problems: Phase II report editing/publication delay (Sinaya Dayan resigned from Marshall University RTI in May 2016). Final editing and production is now underway of final report of: *GIS Story Maps: A Tool to Empower and Engage Stakeholders in Planning Sustainable Places*

Project: Driver Education for New Street Facilities and Operations: Multimodal and Traffic Management
PIs: Andrew Mondschein, University of Virginia, mondschein@virginia.edu
Period of Performance: August 1, 2015 – May 24, 2016
Other Participants and Collaborating Organizations: Peter Ohlms, John Miller, and Amy O'Leary, Virginia Transportation Research Council, Charlottesville, VA
Accomplishments:

- Assembled review of literature on driver education practices for new multimodal infrastructure
- Assembled database of driver education materials
- Conducted and transcribed in-depth interviews with professional regardless the implementation and effectiveness of current driver education practices
- Key findings: Relationship of education and outreach to multimodal planning and design practice, categorization of driver education practices by type of infrastructure, geographic scale, medium, content, actors, financial commitment, and other factors, barriers to implementation of driver education

Products:

- Final Report submitted May 2016
- Academic paper submitted to the Journal of the Transportation Research board (recommended acceptance with minor revisions as of October 2016).

Impact:

- Engaged 2 graduate planning students and one undergraduate in the research
- Supplied findings to VDOT on driver education best practices in Final Report
- Findings presented to VDOT planning research committee, will present to Virginia Statewide Bike/Ped Committee (October 2016) and Transportation Research Board (January 2017)

Project: Develop and Test Connected Vehicle Freeway Speed Harmonization Systems
PIs: Hesham Rakha, Virginia Tech, hrakha@vtti.vt.edu; Ihab El-Shawarby, Virginia Tech, shawarby@vtti.vt.edu
Period of Performance: July 1, 2015 – June 30, 2017
Other participants and collaborating organizations: Dr. Hao Yang – Postdoctoral Fellow, Virginia Tech Transportation Institute; Virginia Transportation Research Council (VTRC).
Accomplishments:

- Tested the speed harmonization algorithm using reinforcement learning on a section of I-66.
- Applied the speed harmonization algorithm using bang-bang control and tested on a section of I-66.

Products:

- Yang, H. and Rakha, H. (2017) "Ramp Metering Control to Improve Weaving Capacity Based on Reinforcement Learning" Accepted for presentation at the 96th Transportation Research Board Annual Meeting, Washington DC, January 8-12.

- Another paper is under review in the Transportation Research Part C.

Project: Exploring the use of LIDAR data from Autonomous Cars for Estimating Traffic Flow Parameters and Vehicle Trajectories
PIs: Mecit Cetin, Old Dominion University, MCetin@odu.edu
Period of Performance: October 1, 2015 – September 30, 2017
Accomplishments:

- Additional field data collected with Velodyne VLP-16 mounted on a sedan vehicle driven on arterial and freeway segments for about 30 minutes.
- Algorithms are developed to identify and track vehicles so that their trajectories can be constructed from the point cloud data collected by Velodyne LIDAR.
- Different car following models such as Newell, Gipps and IDM are calibrated and validated based the vehicle trajectory data. These models will be used to complete trajectories when there is missing data.

Products:

- Presented a poster at 2016 MATS UTC annual meeting
- Point cloud data can be made available on the Dataserve site

Impact:

- 2 PhD students are working on this project

Project: Multi-City, National-Scale Direct-Demand Models of Peak-Period Bicycle and Pedestrian Traffic
PIs: Steve Hankey (VT) hankey@vt.edu, Ralph Buehler (VT) ralphbu@vt.edu
Period of Performance: June 1, 2016 – May 31, 2017
Other Participants and Collaborating Organizations:

- Portland State University (aggregation of a portion of the bicycle and pedestrian count database)

Accomplishments:

- Identified ~40 cities with available bicycle and pedestrian count data
- Obtained count data from those jurisdictions
- ~50% complete in cleaning and aggregating the count data

Products:

- A partial database (to be completed in the next 3 months) has been assembled from the bicycle and pedestrian data in each city

Impact:

- We have spoken with many planners in the cities with count data. There has been interest in our models and we plan to disseminate our results to the interested individuals

Project: Preserving Coastal Infrastructure through the Design and Implementation of Image-Based Structural Health Monitoring (iSHM)
PIs: Devin K. Harris (UVA) dharris@virginia.edu
Period of Performance: August 1, 2016 – May 24, 2017
Other Participants and Collaborating Organizations: Michael Brown and Bernie Kassner – Virginia Transportation Research Council
Accomplishments:

- This project has just been initiated at the end of this performance period. During the initial stages of the project, the PI has organized the research team which includes a partially supported PhD student and an undergraduate research assistant. The students involved will be working on complementary, but separate aspects of the project.
- PhD student will focus efforts on image-based model updating strategies
- Undergraduate researcher will focus on condition quantification using image and vision based approaches

Products:

- No products have been developed to date, however, the PI will be presenting some preliminary work on the topic of model updating with digital image correlation at the International Digital Image Correlation

Society Conference and Workshop/SEM Fall Conference (see: http://idics.org/idics-2016/). We also anticipate translating this work into a technical publication in the near future.

Impact:

- This work represents a new area of research that is expected to provide a foundation for image-based measurement and characterization integration into the structural health monitoring framework.

Project: Development and Characterization of Nano Reinforced Cement Composites using Graphene Nanoplatelets

PIs: Osman Ozbulut (UVa) ozbulut@virginia.edu

Period of Performance: August 1, 2016 – September 31, 2016

Accomplishments:

- To better assess the dispersant quality of different mixing methods used to prepare GNP-reinforced mortars, SEM images were obtained for the specimens with 7.5% GNP ratio.
- New specimens with 10% GNP ratio were prepared.
- Additional piezoresistive tests were conducted for the specimens with 7.5% GNP ratio.

Products:

- Following paper was accepted for presentation in TRB.
- Jiang, Z., Ozbulut, O. E., and Harris, D. K. (2017). "Graphene nanoplatelets-based self-sensing mortar composites." *Proceedings of the TRB Annual Meeting 2017*, XX pages, Washington, D.C., January 2017.
- Data obtained in this project can be shared with anyone on a Dataverse site.

Impact:

- One graduate student (from underrepresented groups) involved in the study.

Project: Investigating the Vulnerability of the Transportation Infrastructure in Hampton Roads Region to Extreme Weather and Sea Level Rise

PIs: Navid Tahvildari, Old Dominion University, ntahvild@odu.edu, Mecit Cetin, Old Dominion University, mcetin@odu.edu

Period of Performance: July 1, 2016 – May 22, 2017

Other Participants and Collaborating Organizations: Active agency champion – [Robert Morgan, Ph.D., PE, VDOT Hampton Roads office; Scott Smith, PE, Coastal Resiliency Officer, City of Norfolk]; Potential additional agency champion – [Andrew Scott, PE, Hydraulic Engineer, City of Virginia Beach]

Accomplishments:

- Data for bathymetry, topography, and land boundaries was obtained from the Digital Elevation Model (DEM) provided by the City of Norfolk.
- The hydrodynamic model, Delft 3D Flow, is set up and a regional computational grid is generated. Appropriate boundary conditions were specified using DEM, data from NOAA, and the ADCIRC tidal database.
- Simulation of tidal flooding in the present day sea level condition was conducted.

Products:

- The primary product of the project so far is a developed hydrodynamic model that can predict tidal elevation at high spatial resolution at coastal areas of the Hampton Roads region, Virginia, in the present and current sea level condition. The domain of the model includes the cities of Virginia Beach, Norfolk, Hampton and Portsmouth and Chesapeake.

Impact:

- The developed model can be used for predicting tidal flooding elevation under different sea level rise scenarios. The model once completed will provide combined storm surge and tidal floods estimations in Hampton Roads.
- The project has resulted in training of a graduate student in civil engineering. The eventual goal of the research is assessing the impacts of extreme weather events on transportation assets.
- Dr. Tahvildari is the instructor of the Coastal Infrastructure Resiliency module in the Transportation Sustainability course that is offered by the universities partnered in MATS UTC. In the recent offering of the module, the state-of-the-practice in modeling storm impacts on transportation assets were discussed. The material was related to the research conducted in this project.

Changes / Problems:

- We expect some challenge in setting up the gird suitable for modeling storm surge as the simulations will need to be conducted in higher resolution and the domain should be larger than the existing one. This may create a challenge in terms of memory required to load the computational grid in the hydrodynamic model. One potential solution for this challenge is to alter the type of grid used in the model. Delft 3D has recently been updated to allow for flexible mesh, i.e. the model allows for a mesh that is refined at the coast but is coarse further offshore where high resolution is not required. This may address this potential challenge.

Project: Image-Based Response Measurement for Reference Free Deflection and Deformation Monitoring of Highway Structural Systems

PIs Devin Harris, Univeristy of Virginia, dharris@virginia.edu
Period of Performance: August 1, 2016 – May 24, 2017
Collaborating Organization: Michael Brown and Bernie Kassner – Virginia Transportation Research Council
Accomplishments:

- This project has just been initiated at the end of this performance period. During the initial stages of the project, the PI has organized the research team which includes a partially supported PhD student and an undergraduate research assistant.

Products:

- No products have been developed to date, however, the PI is expected to give a presentation at the Fall 2016 American Concrete Institute Convention related to this topic in collaboration with Dr. Thomas Schummacher from Portland State University (see: https://www.concrete.org/events/conventions/currentconvention/sessionsandevents.aspx?m=pschedule&EventId=ZSESS11)

Impact:

- This work builds from a preliminary study on the topic of reference-free deflection measurements for load testing of bridges. The expected impact of this work will a non-invansive approach for implementation in live load testing and structural health monitoring experimetns in the future.

Project: Investigating Relationship between Driving Patterns and Traffic Safety using Smartphones Based Mobile Sensor Data

PIs: Rajesh Paleti (ODU) rpaleti@odu.edu, Mecit Cetin (ODU) mcetin@odu.edu
Period of Performance: May 1, 2015 – May 22, 2016
Other participants and collaborating organizations: Virginia Department of Transportation (VDOT)
Accomplishments:

- Sensor data collected using smartphones was used to characterize driving patterns and explore the relationship between these patterns and crash occurrences.
- Microscopic traffic measures describing speed and acceleration patterns enhance the crash frequencies models considerably.
- Not only does the statistical fit improve but also the magnitude of elasticity effects of these microscopic measures was found to be larger than standard variables such as traffic exposure.
- Results also suggest strong spatial dependency effects whereby the crash risk on a segment depends on the acceleration patterns of segments in close proximity in addition to acceleration patterns on the same segment.

Products:

- The study methodology and findings are documented in a final report. Also, the study findings were presented at following conferences:
- 2016 North American Travel Monitoring Exposition and Conference (NATMEC) in Miami, FL
- 2017 Transportation Research Board Meeting in Washington DC (accepted for presentation)
- The research paper from this study is currently under review for presentation and publication at the 22nd International Symposium on Transportation and Traffic Theory (*ISTTT*).

Impact:

- Currently, most of the Safety Performance Functions (SPFs) are only sensitive to aggregate variables such as traffic exposure and geometric attributes (e.g.: presence of shoulder). Federal safety agencies and state DOTs would benefit immensely by updating these SPFs using microscopic traffic measures so that the predictions are more accurate and these models can also be used to evaluate countermeasures that primarily affect driving behavior (*e.g.,* variable speed limits).
- Currently, most of the SPFs in the HSM are either Poisson or Negative Binomial models. However, there is considerable scope for improving these models without adding significant computational complexity. Specifically, the Heterogeneous Dispersion (HD) and Generalized Ordered Response (GOR) variants of the NB model are relatively easy to estimate and were found to improve the statistical fit significantly.

Changes / problems:

- The interstates must be split into smaller segments that constitute the unit of analysis. However, this decision cannot be made arbitrarily because the availability of roadway inventory data and the homogeneity of resulting segments are critical to developing an accurate crash frequency model. So, several segment definitions were explored prior to choosing the spatial unit of analysis.
- Based on the relative merits of three different segment definitions, this study adopted the VDOT segment definition as the spatial unit of analysis

Project: Cluster Analysis Guidance and Pilot Test

PIs: Hesham Rakha, Virginia Tech, hrakha@vtti.vt.edu, Mohammed Elhenawy, Virginia Tech, elhenawy@vt.edu

Period of Performance: September 1, 2016 – June 30, 2017

Other participants and collaborating organizations: Virginia Transportation Research Council

Accomplishments:

- Started literature review.
- Preprocessing the traffic and weather data.

Project: Cybersecurity Analysis to Prepare VDOT Operations for Connected and Autonomous Vehicle Applications

PIs: Brian Smith (UVa) briansmith@virginia.edu

Period of performance: August 1, 2016 – May 24, 2017

Other participants and collaborating organizations: Kamal Sulliman, Virginia Department of Transportation

Accomplishments:

- Background reading on VDOT operations systems
- Background reading on cybersecurity
- Initial system monitoring concept documented.

Project: Multifunctional Composites for Sustainable Civil Infrastructure Systems

PIs: Osman Ozbulut (UVA) ozbulut@virginia.edu

Period of Performance: August 1, 2016 – September 31, 2016

Accomplishments:

- Shape memory alloy fibers with a length of 20 mm and diameter of 0.20 mm were obtained.
- Before any experimental testing, preliminary analytical studies were conducted to design SMA-based multifunctional composites using a micromechanics-based approach.
- A test set up and fixtures were designed for direct tensile testing of cementitious composites.

Products:

- Data obtained in this project can be shared with anyone on a Dataverse site.

Impact:

- One graduate student involved in the study.

Appendix B Competitive Collaborative Projects (Awarded in 2015)

Project: Designing Bicycle and Pedestrian Traffic Count Program to Estimate Performance Measures on Streets and Sidewalks in Blacksburg, VA

PIs: Steve Hankey, Virginia Tech, hankey@vt.edu; Ralph Buehler, Virginia Tech, ralphbu@vt.edu; Andrew Mondschein, University of Virginia, mondschein@virginia.edu

Period of Performance: January 1, 2015 – May 31, 2016

Collaborating Organization: Town of Blacksburg staff and committees, Virginia Tech Alternative Transportation Office

Accomplishments:

- Cleaned and adjusted all count data
- Developed scaling factors based on the reference site data
- Estimated bicycle and pedestrian AADT for all count sites
- Developed direct demand models of bicycle and pedestrian traffic in Blacksburg, VA
- Estimated bicycle and pedestrian AADT for all road and trail segments in Blacksburg, VA

Products:

- Submitted two papers to TRB for presentation
- Prepared two papers to be submitted to Transportation Research Part D
- Prepared MATS UTC report

Impact:

- Prepared webinar for MATS UTC
- Disseminated count data to Town of Blacksburg staff and Virginia Tech planning department

Project: Simultaneous Removal of Nitrogen and Phosphorus from Stormwater by Zero-Valent Iron and Biochar in Bioretention Cells

PIs: Pei Chiu, University of Delaware, pei@udel.edu; Paul Imhoff, University of Delaware, imhoff@udel.edu; Teresa Culver, University of Virginia, tculver@virginia.edu

Period of Performance: January 1, 2015 – November 1, 2016

Other Participants and Collaborating Organizations: City of Charlottesville, VA (Dan Sweet and Kristel Riddervold)

- Ecosystem Services, LLC, VA (Kip Mumaw)
- ReGenesis Global Solutions, LLC/Infinite Solutions L^{3}C, PA (Charles Hegberg)

In addition, the following individual/agency are aware of our work and are supporters of this research and its potential benefits to the transportation sector.

- Kenneth Pantuck, Senior Environmental Scientist, Innovative Technologies Practice Leader
- U.S. Environmental Protection Agency, Water Protection Division (3WP50), Office of Infrastructure and Assistance, 1650 Arch Street, Philadelphia, PA 19103

Accomplishments:

Field work continued through the summer and the fall. New flumes were installed at the enhanced bioretention facility. Data and samples were collected for several storms in the summer and fall. Total nitrogen, total phosphorus, nitrate, phosphate and total suspended sediment concentrations and loads were determined from this information. Preliminary results suggest that the system is removing total phosphorus and total nitrogen, but the levels of enhanced removal may be below anticipated level. Final report part 2 will be submitted in November.

Products:

Conference Presentations:

08/16 The 252nd American Chemical Society (ACS) Fall National Meeting, Philadelphia, PA. Platform presentation. "Mechanisms and Applications of Black Carbon-Supported Microbial Nitrate Reduction."

08/16 Biochar 2016 – The Synergy of Science and Industry: Biochar's Connection to Ecology, Soil, Food, and Energy, Corvallis, OR. Platform presentation. "Biochar Addition to Stormwater Treatment Media for Enhanced Nitrogen Removal and Hydraulic Performance."

08/16 MATS-UTC Annual Meeting, Charlottesville, VA. Poster presentation. "Removal of Nitrogen and Phosphorus from Stormwater in Bioretention Cells Using Zero-Valent Iron and Biochar"

05/16 World Environmental and Water Resources Congress 2016, EWRI, West Palm Beach, FL. Platform presentation. "Field Performance of a Bioinfiltration System with Biochar and Zero-Valent Iron."
05/16 Delaware Center for Transportation Research Showcase, Dover, DE. Poster presentation. "Using Biochar to Reduce Nitrogen Load to Chesapeake Bay."
05/16 Delaware Center for Transportation Research Showcase, Dover, DE. Poster presentation. "Phosphorus Removal from Stormwater Using Zero-Valent Iron."
Invited Talks:
05/16 Industrial Technology Research Institute, Hsinchu, Taiwan. "Biochar as a Reversible Electron Storage Medium to Enhance Stormwater Bioremediation."
04/16 MATS UTC Research Webinar Series. "Simultaneous Removal of Nitrogen and Phosphorus from Stormwater by Zero-Valent Iron and Biochar in Bioretention Cells."
Report:
05/16 Project Final Report Part I submitted.

Impact:

- U of DE: 1 undergraduate, 1 graduate student, and 1 postdoc were involved in this study.
- UVa: In addition to the graduate assistant on this project, a summer MATS-UTC undergraduate research fellow participated in the project, plus 5 undergraduate students are basing their undergraduate theses on various aspects of this project, and thus expanding the goals of the project.
- This work is helping to assess the potential of an innovative approach to nutrient removal from runoff from transportation surfaces.
- In addition, results were disseminated in a presentation to EPA scientists in USEPA Region 3 in July, 2016, and at a joint meeting of stormwater professionals from the Delaware Department of Transportation and the Delaware Department of Natural Resources and Environmental Control in August, 2016. During these meetings we summarized our work on use of biochar and zero-valent iron for removing nutrients in transportation stormwater facilities and discussed where it might be appropriate to begin field implementation.

Project: Impact of Climate Change and Sea Level Rise on Stormwater Design and Reoccurring Flooding Problems in the Hampton Roads Region

PIs: Jonathon Goodall, University of Virginia, goodall@virginia.edu; Venkat Sridhar, Virginia Tech, vsri@vt.edu
Period of Performance: January 1, 2015 – June 30, 2016
Other Participants and Collaborating Organizations: Hampton Roads Planning District Commission, Greg Johnson, Stormwater Technical Services Engineer, Virginia Beach, Department of Public Works
Accomplishments:

- We analyzed existing rainfall data within Virginia Beach to determine the relationship between the distance a rainfall gauge is from a flooding hotspot and how representative that observed rainfall is to the actual rain that fell at that flooding hotspot. The result of this analysis is that rain gauges must be at least within 1km of the flooding hotspot to be representative for rainfall on a 15-minute time interval.
- We analyzed existing roadway elevations using LiDAR data for the region to determine which roads are most vulnerable to flooding. We did this for different scenarios: mean high tide, king high tide (99 percentile), and 100-year storm surge. We then analyzed the impact of projected relative sea level rise (RSLR) on roadway flooding for these three scenarios. We then included traffic data to identify when high-traffic roads may begin to experience flooding from these three scenarios as RSLR continues to increase.
- We analyzed weather and climate models to determine the potential impact of climate change on rainfall patterns in the region. This data was dynamically downscaled using a local Weather Research and Forecasting (WRF) model and showed potential changes in rainfall within the Hampton Roads region.

Products:

- We submitted two journal papers based on this work. One is in revision for the ASCE Journal of Infrastructure Systems and the second is in review for the ASCE Journal of Hydrologic Engineering. Other journal articles are planned based on the research outcomes.
- We submitted our final report for the project outlining our accomplishments.

Impact:

- We are planning to do additional TTA workshops on sea level rise impacts to transportation infrastructure that will include some of the research completed in this project.

Project: LiDAR for Air Quality Measurement

PIs: Khan Iftekharuddin, Old Dominion University, iftekhar@odu.edu; Mecit Cetin, Old Dominion University, MCetin@odu.edu; Hesham Rakha, Virginia Tech, hrakha@vtti.vt.edu

Period of Performance: April 1, 2015 – November 30, 2016

Collaborating Organization: Potential user of the LIDAR technology – EPA

Accomplishments:

- Offered a presentation in MATS - UTC webinar series in July 2016
- Presented a poster in the annual meeting
- Published a paper in Optics and Photonics for Information Processing X, part of SPIE Optical Engineering + Applications, August 2016
- Collected data at multiple locations at the campus of Old Dominion University
- Placed an order to a new pump for the cooling system of the laser unit
- Developed algorithms to detect the pollutants of interest in the collected data from Lidar
- ODU is working with VT to employ the collected data for their tracking algorithm
- Turbulent wind field was generated using the openly available software "TurbSim".
- A concentration field was created by advection and diffusion of the contaminant from its source.
- A recursive Bayesian estimation approach was compared with a gradient descent algorithm and an extended Kalman filter, for finding the source of an airborne contaminant in a turbulent wind field.
- By comparison, Bayesian estimation requires relatively weak modeling assumptions and simulation results suggest this approach is less sensitive to error in the initial state.

Products:

- Presentation in MATS - UTC webinar series
- A poster presentation in the annual meeting
- A paper published at SPIE conference
- A paper titled "A Comparison of Three Approaches to Atmospheric Source Localization" had been submitted to the Journal of Aerospace Information Systems

Impact:

- The end goal of the project is to improve the LiDAR capability in profiling the aerosol in Hampton Roads area. The new capability for the instrument to measure the depolarization ratio, in addition to the color ratio, such that the new acquired measurements will be an excellent source for analyzing the air quality and identifying the sources of aerosols in the area of study.

Changes/Problems:

- The cooling pump for the laser in LIDAR broke down. It is ordered now and expected to be in about two weeks.

Project: Connected Vehicle Technologies for Energy Efficient Urban Transportation

PIs: Ajay Prasad, University of Delaware, prasad@udel.edu; Suresh Advani, University of Delaware, advani@udel.edu; Hyeon-Shic Shin, Morgan State University, hyeonshic.shin@morgan.edu

Period of Performance: January 1, 2015 – August 31, 2016

Accomplishments:

- A two-way communication system between the University of Delaware's newest fuel cell bus and a server residing in our laboratory has been implemented using a Raspberry Pi computer installed on the bus. The Pi computer communicates with our lab server through the cellular network in real-time and transmits vehicle velocity, energy consumption and other detailed operating data to the server where they are logged into the database. The Pi computer is also designed to be able to receive traffic information from our server in real time for possible route optimization. Traffic data can be in the form of real-time information from stationary sensors or from other connected vehicles; in the absence of realtime traffic information, historical traffic data would be used for testing purposes.

- A CAN bus interface has also been added to the Pi computer to communicate with the control system on bus. A program was developed and implemented to send power commands through the CAN bus network to the fuel cell stack on the new bus. This completes the portion of our project related to optimal power management which adjusts power management based on traffic information in real time. The whole system has been under routine testing for almost two months with all testing data logged on the server. We have also devoted time and effort to improving the reliability of the software system and fixing some mechanical issues with the bus. The system will soon be ready for field tests to validate its effectiveness

Appendix C Competitive Collaborative Projects (Awarded in 2016)

Project: Transportation Infrastructure Flooding: Sensing Water Levels and Clearing and Rerouting Traffic out of Danger

PIs: Pamela Murray-Tuite, Virginia Tech University, murraytu@vt.edu, Keven Heaslip, Virginia Tech University – kheaslip@vt.edu, Venkataramana Sridhar, Virginia Tech University – vsri@vt.edu, Jon Goodall, University of Virginia, goodall@virginia.edu

Period of Performance: May 10, 2016 – August 30, 2017

Other participants and collaborating organizations: Greg Johnson (stormwater) and Steve McLaughlin (transportation), both with the City of Virginia Beach

Accomplishments:

- We've begun a literature review regarding data-driven hydrologic modeling for flood warning applications
- We've obtained more information about sites monitoring the groundwater table sponsored by the USGS and the Hampton Roads Sanitation District.
- We've started to obtain groundwater and tide data as inputs for predicting flooding
- We attended a sea level rise symposium sponsored by the USGS to gain local perspective of the flooding issues, increase research network, and understand what data are available
- An extensive literature review was done based on 3D-Var data assimilation into WRF for precipitation data quality.
- The WRF model (Version 3.8.1) is configured over Hampton Roads. The model validation includes comparing WRF_{Obs} and WRF_{Radar} precipitation products with Stage IV precipitation data and GPM data for near-past.
- The Global Forecast System (GFS) forecast is used to drive initial and boundary condition of the model. The WRF consists four domains 27 Km, 9Km, 3km and, 1km centered over Hampton Roads region.
- All the datasets are downloaded and processed for the simulation considering its quality flags.
- The radar data assimilated into the model includes radial velocity and radar reflectivity accessed from NEXRAD.
- The US National Center of Atmospheric Research (NCAR) archived operational global meteorological observations like surface and upper-air data assimilated in to the WRF_{Obs} case are obtained from the NCAR Research Data Archive as "ds353.4" and "ds464.0" datasets. These datasets contain the surface and upper-air measurements of pressure, temperature, humidity and wind from fixed and mobile land/sea stations. These downloaded ADP format data then converted to WRF LITTLE-R format before they are assimilated in the 3D-Var system.
- The two networks for the Virginia Beach have been in construction for the two case study locations of interest
- It has been learned that the construction of the networks in VISSIM is a very detailed task that requires a lot of time
- Obtaining the traffic signal timing plans was an accomplishment, we are now looking at inputting the information into VISSIM, there are 23 intersections signal timings for the northern network of Shore Dr and 60 intersection signal timings for the resort area in the eastern network of the resort area

- Coding the Hyperstar algorithm on java. First, the variables were considered static and the code was implemented on different sample networks to test it. Then, the code was modified in a way to incorporate the variability of the data with time.
- Working on how to obtain and/or generate the code's input data of the Virginia Beach network

Products:

- Will produce collection of input and output data for predicting flooding which can be made available on the UVA dataverse repository.
- We plan to write a journal paper on the flood forecasting application.
- Our effort will provide high resolution (1Km^2) precipitation forecast in hourly basis for Hampton Roads region. Later the project will target generating surface runoff information (spatial information about depth of overland flow and road submergence) for instant flood warnings. But this step is in its development stage and will operational as we finish WRF validation. We will communicate the precipitation analysis in a peer-reviewed journal.
- Articles are planned regarding the transportation routing and simulation

Impact:

- It is expected to provide insights into precipitation intensities and potential inundation of urban neighborhoods.

Project: Leveraging Connected Vehicles to Enhance Traffic Responsive Traffic Signal Control

PIs: Andrew Nichols (MU) andrew.nichols@marshall.edu, Chih-Sheng Chou (MU) chouj@njrati.org, Mecit Cetin (ODU) mcetin@odu.edu, Montasir Abbas (VT) abbas@vt.edu

Period of Performance: May 1, 2016 – October 31, 2017

Other Participants and Collaborators: The main champion for this project at this point would be Econolite Control Products, who produces the traffic signal controllers and the current Traffic Responsive algorithm. If they can implement the product developed by this project, then agencies would have access to it. Econolite is providing matching funds for this project.

Accomplishments:

- Marshall University is in the process of replicating the traffic responsive algorithm in the VISSIM environment. MU is also in the process of converting the study network to the current version of VISSIM for distribution to other partners.
- VT has begun working on methods to fuse the system detector information with the mobile vehicle information.

Changes / problems:

- We were planning to use VISSIM version 8, but are considering switching to V9 which was recently released due to the bugs in V8. We are exploring this now.

Project: Real-time System Prediction and Optimal Rebalancing Strategies for Public Bike Sharing Systems

PIs: Rajesh Paleti (ODU) rpaleti@odu.edu

Period of Performance: May 1, 2016 – October 31, 2017

Other participants and collaborating organizations: Capital Bikeshare, Washington DC (https://www.capitalbikeshare.com/)

Accomplishments:

- Bike station data is continuously archived at 5 minutes resolution from the Capital Bike Sharing website
- Seasonal trip data that tracks each individual bike is also downloaded and is currently analyzed
- Seasonal, daily, and hourly demand patterns of bike arrivals and departure is being analyzed
- Work is underway to fuse station and trip data to identify rebalancing trips by trucks (as opposed to customers using bikes).

Products:

- The bike sharing system demand patterns and study approach were presented in a poster presentation at the 2016 MATS UTC Annual Meeting in Charlottesville.

Project: Fiber-Reinforced Plastic (FRP) Wraps for Next Generation Sustainable and Cost-Effective Rehabilitation of Coastal Transportation Infrastructure in the Mid-Atlantic Region

PIs: Wael Zatar, Marshall, zatar@marshall.edu, Hai Nguyen, Marshall, nguyenhai@marshall.edu, Osman Ozbulut, UVA, ozbulut@virginia.edu

Period of Performance: May 1, 2015 – October 31, 2017

Other Participants and Collaborating Organizations: Donny Williams, West Virginia Department of Transportation, would be interested in the increased knowledge of the use of FRP to sustain, repair and retrofit deteriorating bridge structures.

Accomplishments:

- The project is just getting underway.
- Marshall University is performing critical review of FRP literature for FRP-retrofitted projects in West Virginia.
- Marshall University is evaluating the acceptance levels of FRP-retrofitted projects.
- University and Virginia and Marshall University are identifying structures/elements suitable for FRP retrofit.

Project: Quantifying the Impact of On-Street Parking Information on Congestion Mitigation

PIs: Celeste Chavis (MSU) celeste.chavis@morgan.edu, Mansoureh Jeihani (MSU) mansoureh.jeihani@morgan.edu, Hesham Rakha (Virginia Tech) hrakha@vtti.vt.edu

Period of Performance: June 1, 2016 – August 20, 2017

Other participants and collaborating organizations: District Department of Transportation (DDOT) – Planning & Sustainability Administration

Accomplishments:

The following has been completed:

- IRB forms submitted for review
- Three surveys for participants developed (Survey #1: Sociodemographic information and parking information questionnaire, Survey #2: questionnaire on study site familiarity and tradeoff between walk times and parking costs, Survey #3: questionnaire on experience while driving the simulator and parking information presentation and use)
- Literature review

The following is in progress:

- Building the network in driving simulator – Streets and intersections have been constructed. Graphics such as building faces, street markings and signage are currently being added to the network. Products:

Impact:

Many jurisdictions have turned to innovative parking management strategies as a way to address congestion in urban areas since the time spent circling for on-street parking increases congestion and emissions. By decoupling pricing from parking information, this project develops a methodology that uses parking turnover and occupancy data to provide drivers with information about available on-street spaces. The parking availability information will be broadcasted via dynamic on-street wayfinding as well as mobile apps. On-street information allows the drivers to find available parking without taking their eyes off the road to use a mobile device; however, mobile apps are beneficial for trip planning and also when drivers can rely on passengers to safely disseminate information or when information is provided via voice commands. On-street parking information has the added benefit of being more equitable as it does not rely on the adoption of smartphone technology.

This study can provide agencies with the tools necessary to incorporate parking information into curbside management best practices.

Changes / problems:

- Despite the relatively small study area (10 blocks by 10 blocks), we have run into storage limitations. The high number of intersections has resulted in a network over 3 gigabytes.

Project: Eco-Speed Control for Hybrid Electric Vehicles and Buses in the Vicinity of Signalized Intersections
PIs: Hesham Rakha (VT) hrakha@vt.edu, Hao Chen (VT) hchen@vt.edu, Mansoureh Jeihani (MSU) mansoureh.jeihani@morgan.edu, Celeste Chavis (MSU) celeste.chavis@morgan.edu
Period of Performance: May 1, 2016 – October 31, 2017
Other participants and collaborating organizations: Blacksburg Transit, Blacksburg, VA
Accomplishments:

- The research team from VT Listed all the input and output variables for the Eco-Speed Control algorithm, provided such information for the MSU team so that they can prepare the needed variables in the Delphi code.
- Discussed with the MSU to write codes together for testing the Eco-Speed Control algorithm in the driving simulator. Considering the algorithm was originally written and tested in C/C++ code, the VT team decided to re-write the algorithm as a function using Delphi programming language, and this function will be provided to the MSU for testing in the simulator.
- Discussed with Blacksburg Transit to plan the testing, and Blacksburg Transit agreed to provide buses and drivers for the field test on the smart road.
- The research team from MSU prepared survey questionnaire for the participants before and after the experiment.
- Applied for IRB approval for human subject.
- Extracted real time speed and position of the driver's vehicle as well as traffic light information, the phase, the time left to change the phase, and the distance of the vehicle to the intersection. Purchased a plugin from the driving simulator vendor (Forum8) and writing codes in Delphi. The real-time plugin sends the information to TCP/IP protocol and we wrote a server to listen to the TCP/IP protocol and extract the aforementioned data, which can be used as the input for the Eco-Speed Control algorithm.