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	4/30/17
Report Term or Frequency	Six months
Signature of Submitting Official	

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			Multifunctional 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, November 1, 2016 -April 30, 2017.

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 4 lists the eight projects awarded in January 2017. These projects are scheduled to begin May 2017. Progress reports for these projects are provided in Appendix D.

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

Table 4 Competitive Collaborative Projects Awarded January 2017 (May 1, 2017-May 1, 2018 projects)

Focus Area	Lead U	PI	Other Investigators	Other U	Title
IR	ODU	Cetin	Iftekharuddin , Goodall	ODU, UVA	Estimating Road Inundation Levels Due to Recurrent Flooding from Image Data
IR	ODU	Tahvildari	Cetin, Goodall, Murray-Tuite	ODU, UVA, VT	An Integrated Dynamic Modeling Approach for Flooding of Coastal Transportation Infrastructure: Assessment of Impacts on Emergency Operations

IR	MU	Zatar	Nguyen, Ozbulut	MU, UVA	Deployment of Ground Penetrating Radar and Ultrasonic Tomographer Non-Destructive Techniques for Assessment of Corrosion-Deteriorated Adjacent Prestressed Concrete Box Beams
EU	UVA	Chen	Paleti	ODU	Would You Consider a "Green" Vehicle? Anticipating Electric Vehicle Adoption Patterns and Emissions Impacts in Virginia with a Spatial Latent Choice Model
EU	VT	Buehler	Hankey, Mondschein	VT, UVA	Planning for Walking and Cycling in an Autonomous Vehicle Future
LU	MSU	Chavis	Barnes	UD	Bicycle Justice or Just Bicycles: Analyzing Equitable Access to Baltimore's Bike Sharing Program
WM	UD	Imhoff	Chiu, Culver	UD, UVA	Removing Nitrate from Stormwater with Biochar Amendment to Roadway Soils
SF	MU	Nichols	Cetin	ODU	Feasibility of Estimating Commodity Flows on Highways with Existing and Emerging Technologies

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 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 2017 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, 2017

Weeks	Topics
1 Aug 28 – Sep 1	**Overview**, Lindsay Ivey-Burden, University of Virginia
2 & 3	**Energy-Efficient Urban Transportation**, Hesham Rakha & Kyungho Ahn, VA Tech

Sept 4 – Sept 15	
4 & 5 Sep 18 – Sep 29	**Urban Freight**, Hyeon-Shic Shin, Morgan State University
6 & 7 Oct 2 – Oct 13	**Coastal Infrastructure Resiliency**, Navid Tahvildari, Old Dominion University
8 Oct 16–Oct 20	**Sustainable Materials**, Wael Zatar, Marshall University
9 & 10 Oct 23 – Nov 3	**Enhanced Water Quality Management**, Jonathan Goodall, University of Virginia
11&12 Nov 6– Nov 17	**Multimodal Transportation**, Andrew Mondschein, University of Virginia
Half Week Nov 20–Nov 22	**Re-usable Materials,** Ben Bowers, Virginia Transportation Research Council
14 & 15 Nov 27-Dec 8	**Land Use and Regional Planning Process**, Michael DuRoss, University of Delaware/ Delaware Department of Transportation
Half Week Dec. 11-13	**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 third offering of the graduate Transportation Sustainability class.

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 May 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 602 (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 publications for the reporting period include 13 papers accepted and presented at TRB 2017, and 9 additional external conference presentations, and published articles in Journal of Applied Energy, Big Data Conference, Materials and Structures, Transportation Research Part C, Geotechnical Frontiers Conference, and Advances in Science, Technology, and Engineering Systems. Additional papers are under review by Composite Structures, ASCE Journal of Infrastructure Systems, and the IEEE Conference. There was also a paper published in ASCE Special Publication No. 277. 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
Cathy McGhee	Interim 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, Chair	Executive Director	Wilmington Area Planning Council	Newark, DE

We had 30 external technical reviewers for the competitive collaborative proposals we received in November 2016. We also supplemented these technical reviews with scores of all of the proposals from our Advisory Board members.

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

Accomplishments:

- Collected converted water level time series data for condition 3 (storm surge + tide + one meter sea level rise) from the US army corps website and converted them into excel files (Dec 2016)
- Set up GIS files for doing the capacity analysis, and tested the algorithms (Dec 2016)
- Review all the time series datasets for 3 conditions; 20 million records. (Dec 2016)
- Designed data processing steps to deal with the big data for water level time series (Dec 2016- Jan 2017)
- Created the SQL database and coded the SQL script to generate data files containing water levels of all save points across the study area for many snapshots of the flooding event (Jan-Feb 2017)
- Modified the methodology and performed the GIS analysis for all of the scenarios as follows, (Feb-April 2017)

Generated raster water surfaces from water height layers for every snapshot of three conditions using Inverse distance weighted technique (IDW)

Calculated flooded areas, flood heights and figured out when to evacuate the area

Generated scenarios in time series to represent different snapshots of the flooded area between the peak and the time when the area would be flooded,

Identified flooded roads

- Performed the connectivity analysis for identifying isolated networks for all the scenarios, (Mar-April 2017)
- Calculated capacities for the whole network and did coding for the maximum flow algorithm for all scenarios (Mar-MAY 2017)
- Worked on the MATS report (Mar-May 2017)

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.

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:

- Finished final report, submitted to MATS

Products:

- Presented a Seminar at UVA
- Abstract submission to Big Data Conference – New York ' Big Data and Resilience Engineering
- Currently re-submitting journal publication based on work

Impact:

- The framework created for resilience will be extended to examine coastal areas and the interdependence of the systems within coastal areas.

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 was sequenced at the University of Delaware's Sequencing and Genotyping Center and the results are currently being analyzed. We have shown that the microbial communities in the two types of concrete were similar immediately after pouring (spring 2013), but very different from each other after 2.5 years outside (fall 2015). We are also analyzing the DNA extracted from the materials used to produce the concrete (course and fine aggregates, cement, and fly ash).

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. E.A. Kiledal[2]*, J.L. Keffer[3], J.A. Maresca. The Concrete Microbiome. Microbial Systems Symposium, February 2017. (Poster presentation)
  2. J.A. Maresca*. Urban geomicrobiology: Microbial communities in and on concrete. Geological Society of America Annual Meeting, September 2016. (Invited talk.)
  3. 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.)
  4. 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
  [2]graduate 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:
No current problems.

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)
- Sensors and data acquisition hardware were procured and installed on construction equipment
- Training of field personnel on the proper use of the smart equipment has been completed
- Preliminary data has been collected and is currently being analyzed

Products:
During the period of performance, the project team has published one peer-reviewed conference paper, and given five podium or poster presentations on preliminary results from the project, as follows:

Conference Paper Publication:
Baker, W. J. and Meehan, C. L. (2017). "Utilizing a Neighboring Weighted-Estimation Method for Anomaly Detection with a Continuous Compaction Control Data Set." Proc., Geotechnical Frontiers 2017: Transportation Facilities, Structures, and Site Investigation, Geotechnical Special Publication No. 277, Orlando, FL, March 12-15, 2017, ASCE, Reston, VA, 55-65. (doi:10.1061/9780784480441.007)
Presentations:
Baker, W. J. and Meehan, C. L. (2017). "Preliminary Continuous Compaction Control Data During US 301 Construction." Delaware Center for Transportation 2017 Research Showcase, Dover, DE, 5/3/17, (poster presentation).
Baker, W. J. and Meehan, C. L. (2017). "Preliminary Continuous Compaction Control Data During US 301 Construction." External Advisory Council Reception, University of Delaware, Newark, DE, 5/2/17, (poster presentation).
Baker, W. J. and Meehan, C. L. (2017). "Anomaly Detection Using a Neighboring-Weighed Approach for Continuous Compaction Control Data." Seventh Annual University of Delaware Graduate Research Forum, University of Delaware, Newark, DE, 4/13/17, (poster presentation).
Baker, W. J. and Meehan, C. L. (2017). "Anomaly Detection Using a Neighboring-Weighed Approach for Continuous Compaction Control Data." Delaware Valley Geo-Institute Meeting, Villanova University, Villanova, PA, 3/23/17, (poster presentation).
Baker, W. J. and Meehan, C. L. (2017). "Utilizing a Neighboring Weighted-Estimation Method for Anomaly Detection with a Continuous Compaction Control Data Set." Geotechnical Frontiers 2017: Innovation and Collaboration in Technology and Practice, ASCE Geo-Institute 2017 GeoCongress, Orlando, FL, 3/14/17.
At this time, we are not interested in making the data from this project available on a Dataverse site.
Impact:
The potential utility and effectiveness of this technology has been directly shared with employees of the Delaware Department of Transportation (DelDOT), and with the broader geotechnical engineering and construction QA/QC community through regional and national-level presentations at a variety of forums, as noted in the previous "Products" section.

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
- For Phase II of project MVA derived sample of all registered non-fleet vehicle owners in Maryland.
- MVA sent letters to vehicle owners directing them to online survey developed by PIs.
- Collected and analyzing survey data.

Products:

- Presentation of descriptive statistics to Electric Vehicle Infrastructure Council and some of the research data was incorporated into Council's report of December 2016 to the legislature.
- Phase I report of analysis results from national data sets was completed and submitted to MATS UTC.

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.
- Additional chemical leaching tests using collected RCA samples were carried out. All results of organic chemical concentration in the RCA were BDL (Below Detection Limit). The result concluded that the RCA should have no potential for leaching hydrocarbon components into Chesapeake Bay watershed, if the RCA is used as a bottom conditioning material for oyster aquaculture.

Products:

- The final reports are completion and publication
  MATs UTC final report
  Mark M. Bundy, Anastasia E. M. Chirnside and **Dong Hee Kang**, "Evaluation of waste concrete road materials for use in oyster aquaculture-Phase III, Final Report, Published by Mid-Atlantic Transportation Sustainability Center, Charlottesville, VA, 2017.
  http://www.matsutc.org/wp-content/uploads/2014/07/Evaluation-of-Waste-Concrete-Road-Materials-for-Use-in-Oyster-Aquaculture.pdf
  SHA final report
  Mark M.Bundy and **Dong Hee Kang**, "Phase III evaluation of waste concrete road materials for use in oyster aquaculture, Final Report, Published by State Highway Administration, Baltimore, MD, 2016.
  https://ntl.bts.gov/lib/60000/60500/60545/MD-16-SHA-MSU-4-10_Oyster-Phase3_Report.pdf
- *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.
- *Paper Preparation*
  Dong Hee Kang, Anastasia E M Chirnside and Mark Bundy, "Evaluation of Waste Concrete Road Materials for Use in Oyster Aquaculture" manuscript in preparation for publication in professional journal.

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
- ALL THE CLIMATE CHANGE IMPACT RELATED TO SEA-LEVEL RISE HAVE BEEN DOCUMENTED AND MAPPED

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
- JOURNAL ARTICLES ARE CURRENTLY BEING REVIEWED. PRESENTATIONS WERE MADE AT UVA AND AT UD. MAKING DATA AVAILABLE IS OK WITH US.

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.
- RESEARCH DEALING WITH AND PREPARATION FOR THE IMPACT OF CLIMATE CHANGE ON NON-MOTORIZED TRANSPORTATION FACILITIES CAN BE EXCELLENT TEACHING, RESEARCH AS WELL AS TECHNOLOGY TRANSFER TOOLS.

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.
- Explores the use of GIS Story Maps as a public engagement tool to satisfy mandates for increased transparency, accountability, and public engagement in planning for transportation-efficient and 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.
- The final report, ***GIS Story Maps: A Tool to Empower and Engage Stakeholders in Planning Sustainable Places***, was published electronically in October, 2016.
- University of Delaware IPA produced 5 GIS Story Maps, which can be viewed on its online gallery at: http://arcg.is/25DcjGV
- Marshall University RTI won 3rd place in ERSI's 2016 contest 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
- IPA presented a poster at 96th Annual Meeting of the Transportation Research Board (TRB) Session 697, "Current Issues in Transportation Public." The 4' X 8' poster, entitled "GIS Story Maps Empower and Engage Stakeholders in Planning for Complete Communities in Delaware," was among the 25 selected for presentation by the TRB Committee on Public Involvement (ADA 60). Products:

Products:

Completion of Final Reports:

- **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

- Electronic publication of Phase II report in October 2016 on MATS UTC Final Report webpage: ***GIS Story Maps: A Tool to Empower and Engage Stakeholders in Planning Sustainable Places***. http://www.matsutc.org/wp-content/uploads/2014/07/gis-story-maps-Oct2016.pdf
- Dissemination of Phase I report via University of Delaware IPA publications website: http://www.ipa.udel.edu/publications/gis-story-maps-2016.pdf
-

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

Marcia Scott, Savannah Edwards, and Sarah Pragg. Transportation Research Board 96th Annual Meeting, January 10, 2017. Poster Presentation (4' x 8') on ***GIS Story Maps Empower and Engage Stakeholders in Planning for Complete Communities in Delaware***, TRB Session 697, "Current Issues in Transportation Public Involvement."

Impact:

Transportation Education:

- Engaged 2 graduate students in Phase II research
- 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 - Newsletter Articles:

- MATS UTC Article, February 9, 2017. *IPA Presents Research Outcomes at 96th Annual TRB Meeting* http://www.matsutc.org/2017/02/ipa-presents-research-outcomes-at-96th-annual-trb-meeting/
- Delaware Complete Communities Toolbox news, March 10, 2017. *IPA Presents Research Outcomes at 96th Annual TRB Meeting.* http://sites.udel.edu/completecommunities/category/news/
- University of Delaware, Delaware Center for Transportation, TranSearch Winter 2017 newsletter article: *IPA Presents Research Outcomes at 96th Annual TRB Meeting.* https://sites.udel.edu/dct/files/2013/12/DCT-UTC-Newsletter-Winter-2017-Final-17g3zx1.pdf
- MATS UTC article, March 31, 2017. *IPA and Marshall University's RTI Partner on Research of Smart-Growth Evaluation Methods* http://www.matsutc.org/2017/03/ipa-and-marshall-universitys-rti-partner-on-research-of-smart-growth-evaluation-methods/
- University of Delaware IPA's poster, presented at TRB's 2017 96th Annual Meeting, Session 697, will be displayed on the TRB ADA Committee 60 website at: https://sites.google.com/site/trbcommitteeada60/home/resources/posters-1

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
- Presented research at 2017 Annual Meeting of the Transportation Research Board
- Published peer-reviewed paper: Mondschein, Andrew, Joel Lehman, Stephen Johnson, Peter Ohlms, and John Miller. 2017. "Road User Education and Multimodal Planning: Can Capability be a Part of the Process?" *Transportation Research Record: Journal of the Transportation Research Board*. 2654:20-28.

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), "Feedback Control Speed Harmonization Algorithm: Methodology and Preliminary Testing," *Transportation Research Part C*.
- Yang H. and Rakha H. (2017), "Reinforcement Learning Ramp Metering Control for Weaving Sections in a Connected Vehicle Environment," 96th Transportation Research Board Annual Meeting, Washington DC, January 7-12. [Paper # 17-03689].

Changes / problems:

- None.

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:

- Obtained bicycle and pedestrian count data from 20 MSAs across 15 years.
- Cleaned and aggregated all count data.
- Isolated peak hour counts.
- Tabulated land use, transportation, and weather predictor variables at all count locations.
- Assessed presence of bicycle facilities at count locations using Google Earth imagery.
- Developed a set of direct-demand models to estimate bicycle and pedestrian traffic volumes based on land use variables.

Products:

- Produced MATS UTC final report.
- Submitted abstracts for presentation at two conferences (Association of Collegiate Schools of Planning; International Society of Environmental Epidemiology).
- Created national scale database of bicycle and pedestrian traffic counts.

Impact:

- First national-scale direct-demand models of bicycle and pedestrian traffic for use in estimating spatial patterns of active travel.

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: November 1, 2016 - April 30, 2017

Accomplishments:

- The effect of different polycarboxylate-based superplasticizers on the dispersion of GNPs in cement composites were studied.
- The effect of silica fume on the mechanical and electrical properties of the cement composites were studied.
- Compression and piezoresistivity tests were conducted on the GNP-reinforced mortar specimens.

Products:

- Following paper was presented at 2017 TRB Annual Meeting and published in the proceedings:
  - Jiang, Z., Ozbulut, O. E., and Harris, D. K. (2017). "Effect of mixing method on piezoresistive behavior of self-sensing mortar composites with graphene nanoplatelets." Proceedings of the TRB Annual Meeting 2017, 16 pages, Washington, D.C., January 2017.
- Data obtained in this project can be shared with anyone on a Dataverse site.

Impact:

- One graduate student involved in the study.
- Four undergraduate students were supervised for their graduation project.

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:

- The Delft 3D hydrodynamic model was calibrated with local tide data. The model was then validated for storm surge simulation with the data on water surface elevation from Hurricane Irene (2011).
- A nested model was developed: In addition to regional grid (125 m resolution), two smaller scale grids (~30 m resolution and ~5 m resolution) were developed to capture storm surge flooding at high resolution at four critical spots in the regional transportation network.

Storm surge flooding for Irene-like hurricanes under future sea level conditions are being simulated. The sea level under low, medium, and high sea level rise scenarios for 2050 and 2100 are considered. Products:

- The primary product of the project so far is a developed hydrodynamic model that can simulate storm surge and tidal flooding at high spatial resolution at coastal areas of the Hampton Roads region, Virginia, in the present and current sea level condition.
- An abstract is submitted to the MTS/IEEE 2017 conference. If accepted, the conference paper will be submitted for publication in June 2017:

Castrucci, L., Tahvildari N., "Hydrodynamic Modeling of Storm Surge Flooding in the Transportation Infrastructure in Southeast Virginia", Proceedings of the MTS/IEEE Conference, Anchorage, Al

Impact:

- The developed model can be employed to simulate storm surge and tidal flooding of the transportation infrastructure in Hampton Roads, VA under different sea level rise scenarios.
- It is expected that the developed hydrodynamic model can be an important component in a real-time modeling framework for flood prediction in the regional transportation network.
- One MS student is working on the project.

Changes / Problems:

- One challenge that we faced was that using real atmospheric data as a boundary condition in the storm surge model resulted in underprediction of the storm surge when compared to the local tide gauge locations. While we made some improvements in the model and reduced this discrepancy, we decided to employ a different approach. In the different approach, which is commonly used, we use a parameterization to obtain hurricane wind and pressure field. This approach resulted in excellent agreement with the data from the tide gage.
- While the hydrodynamic and wave model can be run independently in parallel in a high performance computing environment (HPC), we realized using the coupled model in parallel is not straightforward. This is a well-known issue for this model. We don't expect that this issue will affect our results significantly based on earlier studies, we expect that the impact of waves on storm surge be small compared to other components which are already accounted for in the hydrodynamic model. Nevertheless, we are actively working to resolve this issue.

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:

- Completed tasks for first year.
- Wrote first draft of report summarizing work in first year.

Products:

- Clustering algorithm.
- Draft report of results of first year.

Impact:

One graduate student involved in the study

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:

Task 1. Review Connected and Automated Vehicle Data

The research team has completed a comprehensive review of the connected and automated vehicles data, including the Basic Safety Message (BSM), Probe Vehicle Message (PVM) and Service Request Message (SRM). In particular, the team has carefully reviewed progress of the Basic Infrastructure Message (BIM) work conducted by the Connected Vehicle Pooled Fund Study.

Task 2. Examine the Traffic Signal Systems of VDOT

The research team has examined deliverables from the Multi-Modal Intelligent Traffic Signal Systems project, funded by the Connected Vehicle Pooled Fund Study, to gain a better understanding of the upcoming CAV-enabled traffic signal systems.

Task 3. Identify the Functionality of CAV-Enabled Traffic Signal Systems

The team has identified and documented the desired functionalities of upcoming CAV-enabled traffic signal systems.

Task 4. Develop a High-Level Cybersecurity Plan for VDOT Traffic Signal Systems
The team has developed a draft plan to address cybersecurity issues while ensuring the desired functionalities. This plan includes existing and newly expected functionalities, expected cybersecurity issues, and high-level strategies to address those identified issues while ensuring functionalities.
Products:
The team has developed a draft cybersecurity plan for VDOT consideration. It is not ready for distribution.
Impact:
The results will impact VDOT practice and preparation for connected vehicles deployment.

Project: Multifunctional Composites for Sustainable Civil Infrastructure Systems
PIs: Osman Ozbulut (UVA) ozbulut@virginia.edu
Period of Performance: November 1, 2016 - April 30, 2017

Accomplishments:
- Planning for experimental testing of shape memory alloy-based cement composites was completed and test matrix was developed.
- Shape memory alloy fiber reinforced polymers with about %50 fiber ratio were fabricated and tensile testing was conducted.
- Additional specimens for shape memory alloy fiber reinforced polymers were fabricated for fatigue testing.
- Fatigue tests were completed for two specimens.

Products:
- Two journal papers were accepted for publication:
  - Sherif, M., Ozbulut, O. E., and Tanks, J. (2017). "Acoustic emission analysis of cyclically loaded SMA fiber reinforced mortar beams." Cement and Concrete Research, 95, 178-187.
  - Sherif, M., Khakimova, E., Ozbulut, O. E., Harris, D. K., and Ozyildirim, H. C. (2017). "Behavior of mortar beams with randomly distributed superelastic SMA fibers." Journal of Intelligent Material Systems and Structures, Accepted, In Press.
- One journal paper was submitted:
  - Sherif, M., Khakimova, E., Tanks, J., and Ozbulut, O. E. "Cyclic flexural behavior of hybrid SMA/steel fiber reinforced concrete analyzed by optical and acoustic techniques." Composite Structures, Under Review, Submitted in January 2017.
- Following paper was presented at International Digital Imaging Correlation Society and published in the proceedings:
  - Sherif, M., Ozbulut, O. E., and Tanks, J. (2017). "Investigations on cyclic flexural behavior of fiber reinforced cementitious composites using digital image correlation and acoustic emissions." In: Sutton M., Reu P. (eds) International Digital Imaging Correlation Society. Conference Proceedings of the Society for Experimental Mechanics Series, pp. 173-175, Philadelphia, PA, November 2016.
- Data obtained in this project can be shared with anyone on a Dataverse site.

Impact:
- Two graduate students involved in the study.

Project: Exploring the use of LIDAR data from Autonomous Cars for Estimating Traffic Flow Parameters and Vehicle Trajectories
PIs: Mecit Cetin (ODU)
Period of Performance: October 1, 2015 – September 30, 2017
Accomplishments:
- Algorithms were enhanced for identifying and tracking 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:

- The following two IEEE conference papers were prepared/submitted and got accepted:
  - C. Sazara, R. Vatani Nezafat, and M. Cetin, "Offline Reconstruction of Missing Vehicle Trajectory Data from 3D LIDAR" To be presented at the *IEEE Intelligent Vehicle Symposium*, Redondo Beach CA, June 11-14, 2017.
  - M. Cetin and K.A. Anuar, "Using Probe Vehicle Trajectories in Stop-and-Go Waves for Inferring Unobserved Vehicles" To be presented at the *5th IEEE International Conference on Models and Technologies for ITS*, Naples, Italy, June 26-28 2017.

Impact:

- 2 PhD students are working on this project

Project: Developing Multi-modal Eco-routing and Eco-CACC Systems
PIs: Hesham Rakha, Virginia Tech, hrakha@vtti.vt.edu; Kyoungho Ahn, Virginia Tech, kahn@vtti.vt.edu
Period of Performance: May 1, 2016 – April 30, 2018
Accomplishments:

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Products:

- Yang H., Rakha H., and Venkat Ala M. (2016), "Eco-Cooperative Adaptive Cruise Control at Signalized Intersections Considering Queue Effects," IEEE Transactions on Intelligent Transportation Systems. DOI: 10.1109/TITS.2016.2613740.
- Elhenawy M. and Rakha H. (2016), "Stretch-Wide Traffic State Prediction Using Discriminatively Pre-Trained Deep Neural Networks," 19th IEEE Intelligent Transportation Systems Conference, Rio de Janeiro, Brazil, Nov. 1-4.
- Elhenawy M. and Rakha H. (2017), "Spatiotemporal Traffic State Prediction Based on Discriminatively Pre-trained Deep Neural Networks," *Advances in Science, Technology and Engineering Systems Journal*.
- Fiori C., Ahn K. and Rakha H. (2017), "Effect of Route Choice on Battery Electric Vehicle Energy Consumption," 96th Transportation Research Board Annual Meeting, Washington DC, January 7-12. [Paper # 17-00199].
- Almannaa M., Chen H., Rakha H., Loulizi A. and El-Shawarby I. (2017), "Controlled-Field Evaluation of Effectiveness of Infrastructure-to-Vehicle Communication in Reducing Vehicle Fuel Consumption and Delay at Signalized Intersections," Transportation Research Record: Journal of the Transportation Research Board, No. 2621. DOI: 10.3141/2621-02.
- Abdelmegeed M. and Rakha H. (2017), "Heavy-Duty Diesel Truck Emission Modeling," Transportation Research Record: Journal of the Transportation Research Board, No. 2627. DOI: 10.3141/2627-04.
- Wang J. and Rakha H. (2017), "Convex Fuel Consumption Model for Diesel and Hybrid Buses," Transportation Research Record: Journal of the Transportation Research Board, No. 2647. DOI: 10.3141/2647-07.
- Wang J. and Rakha H. (2017), "Electric Train Energy Consumption Modeling," Journal of Applied Energy. DOI: 10.1016/j.apenergy.2017.02.058.

Impact:

- 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 Network 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. These systems are currently being tested in a simulation environment and along the Smart Road test facility.

Changes / problems:

- None.

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), "Feedback Control Speed Harmonization Algorithm: Methodology and Preliminary Testing," *Transportation Research Part C*.
- Yang H. and Rakha H. (2017), "Reinforcement Learning Ramp Metering Control for Weaving Sections in a Connected Vehicle Environment," 96th Transportation Research Board Annual Meeting, Washington DC, January 7-12. [Paper # 17-03689].

Changes / problems:

- None.

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:

- Completed tasks for first year.
- Wrote first draft of report summarizing work in first year.

Products:

- Clustering algorithm.
- Draft report of results of first year.

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.
- One graduate student is working on his D. Eng thesis on this project. He is expected to finish in December 2017.

Products:

- Presentation in MATS - UTC webinar series, 2016
- A poster presentation in the MATS - UTC annual meeting, 2016.
- A paper published at SPIE annual conference: M. I. Elbakary, K. M. Iftekharuddin, R. De Young, and K. Afrifa, "Aerosol Detection Methods in Lidar-Based Atmospheric Profiling", SPIE International Conference on Optics and Photonics for Information Processing X, San Diego, August 2016.
- Another paper has been accepted at SPIE annual conference, to be presented in August 2017.
- A paper titled "A Comparison of Three Approaches to Atmospheric Source Localization" is under revision for submission to the journal Applied Optics.
- One D. Eng. thesis by December 2017.

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 was replaced and data was collected. We are planning to collect more data in response to reviews of the paper that was submitted in a journal.

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:

- Weather data assimilation is promising but improvement is required.
- Precipitation analysis for Jan –Dec 2016 is completed.
- Simulation results of a few observation stations were compared and found the model was underestimating the cumulative precipitation.
- Hourly precipitation was tested for improvements with additional simulation runs by assimilating direct observations for three locations (MMPS-004, MMPS-036 and MMPS-0922)
- WRF HYDRO is being set up to assess the stream network for flooding.
- Street flooding data from Norfolk City was gathered. The data is a record of flooding of over 1000 locations which flooded from more than 40 events
- Geographic data has also been gathered and processed including 1m DEM and 1m land use data which is available in the area.
- Rainfall, tide, groundwater, and wind data have been collected at various sites in and around Norfolk as input for the model.
- Various machine-learning models have been produced to predict street flooding events (from the data obtained from Norfolk City) given a set of environmental and geographic conditions.
- Preliminary results show that total daily rainfall is by far the best indicator of street flooding and that other factors such as tide and groundwater levels have a less significant effect.
- Finalized the construction of the two VISSIM Networks to model the two case study locations of interest
- Finalized the input of signal timings for signalized intersections in the both VISSIM networks

- Developed an approach for node consideration for the VISSIM Networks, as VISSIM output does not consider nodes and works only with "links" and "connectors". The nodes are inserted in an external step after the VISSIM Network is finalized
- Tested different visualization strategies for the VISSIM Networks considering the inclusion of nodes
- Finalized a Visual Basic Script (VBScript) enabling continuous simulation and gradual loading of vehicles to obtain link specific flow rates & their respective travel time estimates
- Developed an approach in Excel & later refined it in R-Studio, of arranging the VISSIM Network data and preparing it for travel time function analysis
- Tested different forms of linear and non-linear travel time functions
- Developed an R-Studio script to perform the regression procedure in bulk (for all links & connectors) and extract the travel time functions in csv format
- Framework for the routing of affected vehicles (flowchart)
- Adjustement of the Hyperstar script
- Coding the Partitioning shortest path algorithm on java to obtain potentials at nodes
- Developing a code (VehicleInput_generation.java) that reads the VehicleRawData file from VISSIM and generates an output file (Output_Vehicles.txt) that includes for each vehicle its origin, destination, start time and group.
- Developing a code (Process.java) that reads the Output_Vehicles.txt file and finds the route for each vehicle along with the corresponding computational time in java
- Testing of the java scripts on a subnetwork from VISSIM

Products:

- VISSIM Networks & traffic travel time estimate data
- VBScript for multiple simulation & gradual loading
- R-Studio script for preparation of raw VISSIM data
- R-Studio script for regression procedure and output of travel time functions
- Java scripts (Hyperstar, Partitioning, Process, VehicleInput_generation)
- 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 (1Km2) 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:

- The Econolite Traffic Responsive algorithm has been replicated in VISSIM to enable the simulation of various conditions and TR parameters. Delay, queue length, and detector data is written to a database for analysis.
- 10 timing plans have been developed for the Morgantown network and simulations run to produce performance metrics that will be used in the state estimation task

Impact

Through the course of replicating the Econolite TR algorithm and truly understanding the decisions it is making, it is clear that the algorithm and parameters could be improved. We will be in a position to provide recommendations to Econolite to improve their algorithm implementation and hopefully gain subsequent funding to develop software applications to facilitate the analysis.

Changes / problems:

- A desired goal of this project is to analyze high resolution data generated by the simulated controllers. The newest versions of the Econolite firmware are not compatible with VISSIM 9, so we are using older firmware. The HRD has been generated, but the files cannot be read. We are working with Econolite to identify a compatible version of their Translator program. If it isn't resolved, it won't affect planned outcomes of this project.

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:

- Individual trip and bike sharing station data was archived at 15-minutes resolution for past one year from the Capital Bike Sharing website
- Seasonal, daily, and hourly demand patterns of bike arrivals and departures was analyzed
- Daily weather information along with socio-demographics, land-use, and transportation infrastructure data around bike stations was collected from several secondary data sources
- Two modeling methods – machine learning and econometric modeling, are currently adopted to model the bicycle arrival and departure patterns at stations.
- Deferred acceptance based heuristic algorithms are being developed for rebalancing bike sharing systems.

Products:

- Elhenawy M. and Rakha H. (2017), "A Heuristic for Rebalancing Bike Sharing Systems based on Deferred Acceptance Algorithm," Accepted for presentation at the 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems, Napoli, Italy, June 26-28.
- Ashqar H., Elhenawy M., Almannaa M., Ghanem A., Rakha H. and House L. (2017), "Modeling Bike Sharing Availability using Machine Learning," Accepted for presentation at the 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems, Napoli, Italy, June 26-28.
- The bike sharing system demand patterns and study approach were presented in a poster presentation at the 2016 MATS UTC Annual Meeting in Charlottesville.

Impact:

- A database that fuses several alternate data sources including weather information, socio-demographics and land-use data, and transportation infrastructure was developed for all bike stations under the Capital Bike Sharing system.
- State-of-the-art econometric and data mining models that account for spatial and temporal correlations of bike sharing demand are under development.

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: Nov. 1, 2016 – April 30, 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 team has been working on tasks for the project.
- Marshall University has completed critical review of literature for FRP-retrofitted projects in West Virginia and is currently evaluating the acceptance levels of FRP-retrofitted projects.
- University of Virginia and Marshall University are identifying structures/elements suitable for FRP retrofit and are taking the steps to complete the tasks of the project.

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 during the reporting period:

- IRB approval received
- Completed building and testing the network in the driving simulator
- 25 participants drove the driving simulator and completed the survey
- Designed prototype signs and developed test procedures for the driver acceptance test
- Completed running 76 test participants for the driver acceptance test

The following is in progress:

- Completing the data collect for the driving simulator
- Preliminary data analysis
- TRB Annual Meeting paper

Products: None Yet
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 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.

Products:

- Implemented the algorithm in the MSU driving simulator.
- Completed the IRB for field tests on the Smart Road.
- Currently implementing the system on Blacksburg Transit buses.

Problems:

- None.

Appendix D Competitive Collaborative Projects (Awarded in Jan 2017 – will not start until May 31, 2017)

Project: Estimating Road Inundation Levels Due to Recurrent Flooding from Image Data
PIs: Cetin (ODU), Iftekharuddi (ODU), Goodall (UVA)
Period of Performance: May 31, 2017- May 31, 2018
Other Participants and collaborating organizations:
Accomplishments:
None
Products:
None
Impacts:
None
Problems/Changes:
None

Project: An Integrated Dynamic Modeling Approach for Flooding of Coastal Transportation Infrastructure Assessment of Impacts on Emergency Operations
PIs: Tahvildari (ODU), Cetin (ODU), Goodall (UVA), Murray-Tuite (VT)
Period of Performance: May 31, 2017- May 31, 2018
Other Participants and collaborating organizations:
Accomplishments:
None
Products:

None
Impacts:
None
Problems/Changes:
None

Project: Deployment of Ground Penetrating Radar and Ultrasonic Tomographer Non-Destructive Techniques for Assessment of Corrosion-Deteriorated Adjacent Prestressed Concrete Box Beams
PIs: Zatar (MU), Nguyen (MU), Ozbulut (UVA)
Period of Performance: May 31, 2017- May 31, 2018
Other Participants and collaborating organizations:
Accomplishments:
None
Products:
None
Impacts:
None
Problems/Changes:
None

Project: Would You Consider a "Green" Vehicle?
PIs: Chen (UVA), Paleti (ODU)
Period of Performance: May 31, 2017- May 31, 2018
Other Participants and collaborating organizations:
Accomplishments:
None
Products:
None
Impacts:
None
Problems/Changes:
None

Project: Removing Nitrate from Stormwater with Biochar Amendment to Roadway Soils
PIs: Imhoff (UD), Chiu (UD), Culver (UVA)
Period of Performance: May 31, 2017- May 31, 2018
Other Participants and collaborating organizations:
Accomplishments:
None
Products:
None
Impacts:
None
Problems/Changes:
None

Project: Bicycle Justice or Just Bicycles: Analyzing Equitable Access to Baltimore's Bike Sharing Program
PIs: Chavis (MSU), Barnes (UD)
Period of Performance: May 31, 2017- May 31, 2018
Other Participants and collaborating organizations:
Accomplishments:
None
Products:
None

Impacts:
None
Problems/Changes:
None

Project: Preserving Coastal Infrastructure through the Design and Implementation of Image-Based Structural Health Monitoring (iSHM)
PIs Nichols (MU), Cetin (ODU)
Period of Performance: May 31, 2017- May 31, 2018
Other Participants and collaborating organizations:
Accomplishments:
None
Products:
None
Impacts:
None
Problems/Changes:
None

Project: Planning for Walking and Cycling in an Autonomous Vehicle Future
PIs: Buehler (VT), Hankey (VT), Mondschein (UVA)
Period of Performance: May 31, 2017- May 31, 2018
Other Participants and collaborating organizations:
Accomplishments:
None
Products:
None
Impacts:
None
Problems/Changes:
None