<table>
<thead>
<tr>
<th><strong>Federal Agency</strong></th>
<th>U.S. Department of Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Federal Grant Number</strong></td>
<td>DTRT13-G-UTC33</td>
</tr>
<tr>
<td><strong>Project Title</strong></td>
<td>MID-ATLANTIC TRANSPORTATION SUSTAINABILITY UNIVERSITY TRANSPORTATION CENTER (UTC)</td>
</tr>
<tr>
<td><strong>Program Director Name, Title, and Contact Information</strong></td>
<td>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: <a href="mailto:briansmith@virginia.edu">briansmith@virginia.edu</a></td>
</tr>
<tr>
<td><strong>Name of Submitting Official, Title, and Contact Information</strong></td>
<td>Robert Merhige Director of Grants and Contracts University of Virginia <a href="mailto:ospnoa@virginia.edu">ospnoa@virginia.edu</a> 434-924-4270</td>
</tr>
<tr>
<td><strong>Submission Date</strong></td>
<td>October 2015</td>
</tr>
<tr>
<td><strong>DUNS/EIN Numbers</strong></td>
<td>065391526</td>
</tr>
<tr>
<td><strong>Recipient Organization (Name and Address)</strong></td>
<td>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</td>
</tr>
<tr>
<td><strong>Recipient Identifying Number, if any</strong></td>
<td>Federal Entity Number 54-6001796</td>
</tr>
<tr>
<td><strong>Project/Grant Period (Start Date, End Date)</strong></td>
<td>6/30/14 to 9/30/18</td>
</tr>
<tr>
<td><strong>Reporting Period End Date</strong></td>
<td>9/30/15</td>
</tr>
<tr>
<td><strong>Report Term or Frequency</strong></td>
<td>Six months</td>
</tr>
<tr>
<td><strong>Signature of Submitting Official</strong></td>
<td>[Signature] Digitally signed by Michael P. Ludwick Date: 2015.10.30 09:31:38 -04'00'</td>
</tr>
</tbody>
</table>
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.

We selected 12 mostly collaborative, multiple-university core projects during the proposal preparation process. Most of these projects started in Fall 2014 and have a May 2016 or earlier end date. We had six projects start between April and September 2015.

Table 1 Core Projects Utilizing Base Fund and Matching Fund Allocations

<table>
<thead>
<tr>
<th>Focus Area</th>
<th>Lead U</th>
<th>PI</th>
<th>Other Investigators</th>
<th>Other U</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR</td>
<td>ODU</td>
<td>Cetin</td>
<td>Ng, Talley, Park, Rakha</td>
<td>ODU, UVA, VT</td>
<td>Multimodal Freight Distribution to Support Increased Port Operations</td>
</tr>
<tr>
<td>IR</td>
<td>VT</td>
<td>Murray-Tuite</td>
<td>El-Shwarby, Rakha, Smith</td>
<td>VT, UVA</td>
<td>Infrastructure Resilience and Adaptation for Hurricanes in Coastal Areas</td>
</tr>
<tr>
<td>IR</td>
<td>UD</td>
<td>Attoh-Okine</td>
<td>Ivey-Burden</td>
<td>UVA</td>
<td>Multimodal Transportation Facility Resilience Index</td>
</tr>
<tr>
<td>IR</td>
<td>UVA</td>
<td>Harris</td>
<td>Ozbulut</td>
<td>UVA</td>
<td>Structural Enhancements to Adapt to Impacts of Climate Change</td>
</tr>
<tr>
<td>IR</td>
<td>UVA</td>
<td>Harris</td>
<td>Ozbulut</td>
<td>UVA</td>
<td>Accelerating Use of Sustainable Materials in Transportation Infrastructure</td>
</tr>
<tr>
<td>IR</td>
<td>UD</td>
<td>Maresca</td>
<td>Harris</td>
<td>UVA</td>
<td>Microbial Biomarkers for ASR-Damaged Concrete</td>
</tr>
</tbody>
</table>
Appendix A includes progress reports for the core projects.

We also held a competition in fall 2014 for competitive collaborative projects. These projects required participation from at least two universities and were limited to $150,000 in federal funding requiring full match. The proposals were reviewed by at least three external reviewers. Twenty-one proposals were submitted and five projects were awarded for the period: January 1, 2015-May 31, 2016. We expect another competitive collaborative competition in fall 2015.

Table 2  Competitive Collaborative Projects Awarded Fall 2014 (January 1, 2015-May 31, 2016 projects)

<table>
<thead>
<tr>
<th>Focus Area</th>
<th>Lead U</th>
<th>PI</th>
<th>Other Investigators</th>
<th>Other U</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>LU</td>
<td>VT</td>
<td>Hankey</td>
<td>Buehler, Mondschein</td>
<td>UVA</td>
<td>Designing a bicycle and pedestrian traffic count program to estimate performance measures on streets and sidewalks in Blacksburg, VA</td>
</tr>
<tr>
<td>WM</td>
<td>UD</td>
<td>Chiu</td>
<td>Imhoff, Culver</td>
<td>UVA</td>
<td>Simultaneous Removal of Nitrogen and Phosphorus from Stormwater by Zero-Valent Iron and Biochar in Bioretention Cells</td>
</tr>
<tr>
<td>IR</td>
<td>UVA</td>
<td>Goodall</td>
<td>Sridhar</td>
<td>VT</td>
<td>Impact of Climate Change and Sea Level Rise on Stormwater Design and Reoccurring Flooding Problems in the Hampton Roads Region</td>
</tr>
<tr>
<td>EU</td>
<td>ODU</td>
<td>Iftekharuddin</td>
<td>Cetin, Rakha</td>
<td>VT</td>
<td>LiDAR for Air Quality Measurement</td>
</tr>
<tr>
<td>EU</td>
<td>UD</td>
<td>Prasad</td>
<td>Advani, Shin</td>
<td>MSU</td>
<td>Connected Vehicle Technologies for Energy Efficient Urban Transportation</td>
</tr>
</tbody>
</table>
Appendix B includes progress reports for the five competitive collaborative projects awarded in Fall 2014 and started January 1, 2015.

1.1.3 Dissemination
The four research projects completed during the reporting period are presented in Table 3.

Table 3 Completed Projects as of Fall 2015 (Final Reports Submitted)

<table>
<thead>
<tr>
<th>Focus Area</th>
<th>Lead U</th>
<th>PI</th>
<th>Other Investigators</th>
<th>Other U</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR</td>
<td>MU</td>
<td>Shand</td>
<td>Corbett</td>
<td>UD</td>
<td>Alternative Fuels Usage in Maritime Transportation System</td>
</tr>
<tr>
<td>WM</td>
<td>UVA</td>
<td>Goodall</td>
<td>--</td>
<td>--</td>
<td>Design of a Decision Support Tool for Nutrient Credit Exchange Feasibility in Stormwater Regulatory Compliance</td>
</tr>
<tr>
<td>SL</td>
<td>UVA</td>
<td>Mondschein</td>
<td>--</td>
<td>--</td>
<td>Virginia Sustainable Travel Choices: Effects of Land Use and Location on Current and Future Travel Options</td>
</tr>
</tbody>
</table>

Appendix C includes partners, accomplishments, and products of these projects. The final research reports have been published to the MATS UTC website and 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 and starting a few new core projects. We anticipate another competitive collaborative solicitation in late Fall 2015. 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 has put a lot of effort into developing a semester long graduate course in Transportation Sustainability that is offered asynchronously at five of the six consortium universities in Fall 2015. We have developed nine one or two week module outlines for this course which are listed along with the instructor and their university in Table 4.
Table 4 Modules, Length, Instructor and University for the Semester-Long Graduate Course in Transportation Sustainability Offered August 31 – December 15, 2015

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Overview</strong>, Emily Parkany, University of Virginia</td>
</tr>
<tr>
<td>Aug 31 – Sept 4</td>
<td></td>
</tr>
<tr>
<td>2 &amp; 3</td>
<td><strong>Energy-Efficient Urban Transportation</strong>, Hesham Rakha &amp; Kyungho Ahn, VA Tech</td>
</tr>
<tr>
<td>Sept 7 – Sept 18</td>
<td></td>
</tr>
<tr>
<td>4 &amp; 5</td>
<td><strong>Urban Freight</strong>, Hyeon-Shic Shin, Morgan State University</td>
</tr>
<tr>
<td>Sept 21 – Oct 2</td>
<td></td>
</tr>
<tr>
<td>6 &amp; 7</td>
<td><strong>Coastal Infrastructure Resiliency</strong>, Navid Tahvidari, Old Dominion University</td>
</tr>
<tr>
<td>Oct 6 – Oct 16</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td><strong>Sustainable Materials</strong>, Wael Zatar, Marshall University</td>
</tr>
<tr>
<td>Oct 19 – Oct 23</td>
<td></td>
</tr>
<tr>
<td>9 &amp; 10</td>
<td><strong>Enhanced Water Quality Management</strong>, Jonathan Goodall, University of Virginia</td>
</tr>
<tr>
<td>Oct 26 – Nov 6</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td><strong>Land Use</strong>, Andrew Mondschein, University of Virginia</td>
</tr>
<tr>
<td>Nov 9 – Nov 13</td>
<td></td>
</tr>
<tr>
<td>12 &amp; 13</td>
<td><strong>Healthy Communities</strong>, Marcia Scott, University of Delaware</td>
</tr>
<tr>
<td>Nov 16 – Dec 1</td>
<td></td>
</tr>
<tr>
<td>14 &amp; 25</td>
<td><strong>Finance and Policy</strong>, Troy Mix, University of Delaware</td>
</tr>
<tr>
<td>Dec 2 – Dec 15</td>
<td></td>
</tr>
</tbody>
</table>

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). Morgan State University ran a Teacher Transportation Institute during the reporting period.

Morgan State ran a summer Teacher Transportation Institute for six middle and high school STEM teachers during July 2015.

MATS UTC developed two TTA workshops:
- Overview of Transportation Sustainability, April 14, Charlottesville
- Infrastructure Impacts of Sea-Level Rise, May 5, Virginia Beach
- Four-hour version of Infrastructure Impacts of Sea-Level Rise, August 7, Wilmington (optional activity during the MATS UTC Annual Meeting)

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 Program. A flyer was distributed at the end of February asking for March 20 applicants. We received 26 applicants from 13 universities, made 11 offers, and had 9 come for the nine-week summer research program at University of Virginia. Eight of the participants were women,
four of these came from underrepresented groups. The University of Delaware had two additional participants from underrepresented populations.

- The UVA USRP program included weekly meetings, Journal Club, several technical tours and an End of Summer Symposium where students presented a poster and an oral presentation of their research. The work of two students was included in a paper accepted for the 2016 TRB Annual Meeting.
- MSU Summer internships at MSHA. Maryland State Highway Administration selected and placed four junior and senior level students in headquarters and district offices for 10 weeks. Internship ranged from positions in civil engineering, finance, information systems, and communications. SHA and Morgan State, using UTC funds, shared the costs of the program.
- The MDOT/MSU Graduate Annual Internship Program selected 15 students as interns for the 2016 state fiscal year. The interns were assigned to modal administrations.
- MATS UTC has developed learning modules related to sustainable materials and structures testing to use for K-12 students visiting the University of Virginia. UVA is working with the UVA Chi Epsilon chapter to present these at local schools during the next reporting period.
- Promoting Careers in Transportation. We held our second webinar in this series on September 18 featuring two professors from the University of Alabama. A third webinar (with R.J. Porter from University of Utah) is scheduled on October 16.

### 1.2.4 Dissemination

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

### 1.2.5 Plans for Next Reporting Period

Student participation in the graduate sustainability class continues through the next reporting period. Additional sessions of the developed professional development workshops will be scheduled in accordance with participant demand. The Overview of Transportation Sustainability workshop will be presented with two instructors on November 12 in Arlington, VA.

### 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 and B 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:

- **Blue and Green Highways Sustainability Symposium**, May 6, Arlington, VA
- **MATS UTC Annual Meeting**, August 6-7, Wilmington, DE
- Transportation Sustainability Series including webinars from May 6 and August 6 along with additional sustainability-related webinars of regional interest [YouTube link]
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, email blasts to our list of over 405 (and growing) names, Facebook posts https://www.facebook.com/midatlantictransportationsustainability and Twitter feeds. 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.

Our quarterly E-Newsletter went out in April, July, and October 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.

Inspired by the tech transfer needs of University Transportation Centers, our Managing Director, Emily Parkany submitted a paper to the 2016 TRB Annual Meeting entitled, “Webinars, Advisory Boards, T2 Implementation Plans and other Examples of University Technical Transfer Best Practices”. The paper was accepted for presentation and publication.

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 started monthly Internal News communications for all of our researchers in October, 2015. 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 as shown in the Appendices. This includes 7 papers submitted to the 2016 TRB Annual Meeting (most were accepted); at least 8 other conference presentations, and at least one journal article (Transportation Research, Part C). 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 Additional project-related websites are provided in the Appendices.

2.3 Technologies
Nothing to report.
2.4 Inventions
Nothing to report.

2.5 Educational Products
We developed a semester-long graduate transportation sustainability course and two one-day professional development workshops as described in section 1.2.1 above.

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

- Webinar archives found on the MATS UTC YouTube site include the May 6 Green and Blue Highways Symposium presentations, Careers in Transportation webinars, and the emerging topics session with invited speakers at our August Annual Meeting.
- 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

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Affiliation</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jose Gomez, Chair</td>
<td>Director</td>
<td>Virginia Center for Transportation Innovation and Research</td>
<td>Charlottesville, VA</td>
</tr>
<tr>
<td>Damon Fordham</td>
<td>Principal</td>
<td>The Cadmus Group</td>
<td>Crozet, VA</td>
</tr>
<tr>
<td>Susan Handy</td>
<td>Director</td>
<td>National Center for Sustainable Transportation, University of CA, Davis</td>
<td>Davis, CA</td>
</tr>
<tr>
<td>Scott Hercik</td>
<td>Transportation and Trade Advisor</td>
<td>Appalachian Regional Commission</td>
<td>Washington D.C.</td>
</tr>
<tr>
<td>Camelia Ravanbakht</td>
<td>Interim Executive Director</td>
<td>Hampton Roads Transportation Planning Organization</td>
<td>Chesapeake, VA</td>
</tr>
<tr>
<td>Holly Rybinski</td>
<td>President</td>
<td>Rybinski Consulting</td>
<td>Wilmington, DE</td>
</tr>
<tr>
<td>Domini Scurti</td>
<td>Manager, Market Planning</td>
<td>Maryland Port Administration</td>
<td>Baltimore, MD</td>
</tr>
<tr>
<td>Donald Williams</td>
<td>Research and Special Studies</td>
<td>West Virginia DOT</td>
<td>Morgantown, WV</td>
</tr>
<tr>
<td>Tim Witten</td>
<td>ITS/Special Projects Manager</td>
<td>Blacksburg Transit</td>
<td>Blacksburg, VA</td>
</tr>
</tbody>
</table>
Our Advisory Board participated in person at our MATS UTC Annual Meeting August 6-7 in Wilmington, DE. They interacted with our researchers and suggested areas of interest during various brainstorming sessions.

Over 70 MATS UTC Advisory Board members, researchers including faculty and graduate students, and five invited speakers who responded to a call for young sustainability researchers attended the Annual Meeting which included a poster session of all of our projects, the emerging topics session, a tour of transportation vehicles on the UD campus, an outing to Longwood Gardens, a State of the Center presentation, eight brainstorming breakouts, and an optional training. A Meeting Summary was prepared.

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
- Hampton Roads Transportation Planning Organization; Hampton Roads Planning District Commission
- Maryland Motor Vehicle Administration
- Electric Vehicle Association-DC Chapter
- NASA Langley Research Center
- City of Charlottesville
- Ecosystem Services, LLC, VA;
- ReGenesis Global Solutions, LLC/Infinite Solutions L3C, PA

3.2.2 Presenters at MATS UTC Events
External presenters during this reporting period included:

- Table 6 Presenters at our May 6 Green and Blue Highways Symposium, Arlington, VA

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elise Barella</td>
<td>James Madison University</td>
<td>Facilitator and Event Organizer</td>
</tr>
</tbody>
</table>
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 are 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 Core Research 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@vti.vt.edu
Period of Performance: November 1, 2014 – April 30, 2016
Accomplishments:

- A literature review was conducted on studies on port and rail operations. Having determined what the state of the art is, a visit was also paid to the Virginia Inland Port in Front Royal, VA to see what operational problems related to rail exist. An important operational problem has been identified (the rail load planning problem) for which a mathematical model has been formulated to minimize (half)-empty rail cars that are nor cost-effective nor environmentally friendly.
- Developed fuel consumption models using truck data obtained from the University of California, Riverside.
- A mixed integer linear program formulation considering multi-modes and environmental sustainability was developed using a simple network having trucks, vessels and rail. This prototype can be expanded to model Hampton Roads multi-modal freight system and be able to provide optimal decisions for expanding hubs and/or mode capacity.

Products:

- A paper related to fuel consumption modeling to be presented at the 95th Transportation Research Board Annual Meeting in January 2016
- Ng, M.W., Talley, W.K., Cetin, M., Park, B., Hong, S., Rakha, H., Multimodal Freight Distribution for Environmental Sustainability, Presented at the MATS UTC Annual Meeting, August 6 12-2pm Wilmington, DE.
- Makahon, I, Cetin, M, Ng, M.W., Nguyen, D.T., Unloading and premarshalling algorithms with java computer animation for terminal yard operations, to be presented at and included in the Proceedings of the TRB Annual Meeting, Jan 2016.

Project: Infrastructure Resilience and Adaptation for Hurricanes in Coastal Areas

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


Other Participants and Collaborating Organizations:

- Willine Richardson – Undergraduate student, Morgan State University. Participant in MATS UTC Summer Research Experience Program (advised by Brian Smith)
- Aphisit Phoowarawutthipanich – Graduate student, Virginia Tech (advised by Pam Murray-Tuite)
- Dr. Jianhe Du – Sr. Research Associate, Virginia Tech
- Mohammed Aljamal – Graduate student, Virginia Tech (advised by Hesham Rakha)

Accomplishments:

- Completed on-site characterization of roadways to support microscopic modeling of the roadway network for the evacuation of a nuclear plant in the Knoxville area.
- Collected traffic signal timing data for major intersections from local traffic agencies.
- Developed detailed information on each roadway segment and a roadway system map that identifies node numbers and segments to develop the ETE.
- Constructed the INTEGRATION Roadway Network and incorporated roadway features.
- Completed report for effort entitled “An Investigation of Climate Change Adaptation: Case Study of the Hampton Boulevard Corridor in Norfolk, Virginia.” In this project, a geographic information systems (GIS) was used to study the topography and storm surge forecast of the area. As a result, potential adaptations were developed and explored - including Flood Barriers and Biotention Systems. The project illustrated that considering adaptation at a “project” level, as opposed to a regional level, is not desirable in that strategies simply “move” the problem to another regional location.
- Reviewed literature on Network Resilience and Vulnerability
- Reviewed Hampton Roads specific reports on sea level rise
- Gathered data on storm surge simulation from the Army Corps of Engineers
- Gathered population information for Hampton Roads area

Products:

- A poster presentation was made at the MATS UTC Annual Meeting in Wilmington, DE.
• USRP Project Report – 7/31/15 - An Investigation of Climate Change Adaptation: Case Study of the Hampton Boulevard Corridor in Norfolk, Virginia
• Poster and oral presentation for USRP End of Summer Symposium
Impact: Clearly demonstrated the limitations of considering adaptation at a local/project level when dealing with regional challenges.

Project: Multimodal Transportation Facility Resilience Index
Pls: 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:
• The background literature on multi-modal transportation facilities was conducted during this reporting period.
• Thus far, pervious studies and data has been gathered for the following transportation facilities: highways, seaports, and airports.
• The data gathered answers the following questions for each facility type: what aspect of the system should be resilient, what kind of change would the system be resilient to, what variables are changing and at what rate, and is the system resilient to external shocks or to technogenic disasters.

Products:
• The study premise has been presented via poster form at the 2015 MATS Annual Meeting and at the TRB International Conference for Sustainability in Transportation.
Impact: The goal of this project is to work use a cross-disciplinary approach (transportation engineering and data science) to formulate and develop a resilience index for multimodal transportation facilities. There will be cross training of graduate students in resilience engineering, sustainability science and large data analytics. This will open up a new direction in transportation engineering.

Project: Structural Enhancements to Adapt to Impacts of Climate Change
Pls: 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:
This project focuses on reducing the vulnerability of civil infrastructure systems by developing and integrating advanced composite materials into sustainable structural design. In this reporting period, following activities were conducted:

□ **Shape memory alloy fiber reinforced polymers:** The conventional fiber reinforced polymer (FRP) exhibits brittle failure, low toughness, limited fatigue strength, and relatively low ultimate tensile strains. This study explores the use of superelastic Shape memory alloy (SMA) fibers to reinforce a thermoset polymer matrix to produce a polymer composite with enhanced mechanical properties.
□ SMA-FRP coupons were fabricated and tested during the previous reporting period. The results of this tests indicated a better gripping is needed to prevent the premature failure of SMA-FRP coupons during tensile testing. Also, the tensile strength of the coupon was found to be low.
□ Another type of epoxy was ordered and considered as resin matrix. A mold was prepared to cast epoxy specimens for testing. To obtain mechanical properties of the epoxy, tensile test were conducted.
□ To prevent the failure of the SMA-FRP coupons, the new coupons were prepared to have a dog-bone shape. Also, CFRP sheets were obtained to cover the gripping region of the specimens.
□ To explore the effect of reinforcement ratio on the performance of SMA composite; the coupons with different SMA fiber ratios were prepared.
□ **Shape memory alloy fiber reinforced concrete:** As discussed in the previous report, five types of small-scale beam specimens were prepared. The testing of the specimens and the evaluation of the test results were carried out during this reporting period.
□ The crack development for each specimen was analyzed using Digital Image Correlation data.
- Acoustic Emission sensors were attached to the specimens during the testing to gather additional information on the performance of fiber-reinforced specimens. The results were synthesized in two conference papers.
- An undergraduate student was supervised for MATS UTC Summer Undergraduate program. The student prepared mortar specimens with SMA fibers and conducted cyclic flexural tests. The results showed that SMA-fiber reinforced cementitious composites exhibit self-centering behavior and reduce residual deformations.
- **Ultra high performance concrete (UHPC):** UHPC Represents one of the more recent evolutions in the design of cementitious materials used in infrastructure. The material is characterized by significantly higher compressive strength (order of magnitude), tensile strength beyond first cracking due to fiber reinforcement, and exceptional durability due to the tight particle packing, dense particle packing, and low permeability of the matrix. However, the application of UHPC has been slow due to the high cost of commercially available products and the lack of design standards. This investigation focuses on the latter with consideration of cost aspect.
- The initial study on this topic began during the summer of 2015 with an undergraduate student supervised for the MATS UTC Summer Undergraduate program. The student explored literature on the topic and adopted formulations that could be produced with locally available materials. The specimens were designed as a topping material to minimize usage and were tested for bond. The conclusions derived from this initial investigation confirmed that UHPCs could be produced using local materials and properties derived were approaching those cited in literature.
- The current focus of the investigation centers on characterizing the constitutive relationships of UHPC. In this focus, a recently hired graduate student is exploring strategies for modeling the constitutive relationships of UHPC so that designs can be tailored to specific applications. We anticipate developing modeling strategies, validated with experimental testing, that can be used to predict the behavior of UHPC in structural applications.

**Products:**

**Project: Accelerating Use of Sustainable Materials in Transportation Infrastructure**

Pls: 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:**
- An initial experimental program was developed to investigate the effect of graphene nanoplatelets (GNPs) on the mechanical and electrical properties of cementitious composites. Compared to other functional fillers such as carbon nanofiber (CNF), carbon black, and carbon nanotubes (CNTs) used in cement composites, GNPs are easier to completely disperse in a composite and are lower cost. They also have very thin but wide aspect ratio and, thus, provide more contact area with the host material.
- To conduct the experiment, four separate batches of mortar containing various levels of graphene nanoplatelets were mixed. GNP was added to mortar in 0.1%, 0.3% and 0.5% by weight cement.
- Type C Graphene with a surface area of 300 m2/g, obtained from XG Sciences, was used in preparation of the GNP reinforced mortar. In order to aid in dispersion of the GNP and to increase the workability of the GNP reinforced mortar, a surfactant, sodium deoxycholate was stirred into the mixing water by hand for 5
minutes. The measured GNP was then added to the mixture and the solution was ultrasonicated for 1 hour in a bath ultrasonicator. The solution was then mixed with the sand and cement and cast into six 50.8mm x 50.8 mm cubes and four 40mm x 40mm x 160 mm prisms, and tamped as per ASTM standards.

- The planned tests for each batch of mortar included compressive strength tests for the 6 cubic specimens, flexural strength tests for 3 prisms and electrical resistivity measurements for one prism specimen.
- The change in electrical resistivity of the mortar was negligible, leading to the conclusion that higher amounts of GNP are required to observe a change in the resistivity. Also, the mechanical properties of the mortar did not significantly increase as a result of the GNP.


Changes/Problems:
- After evaluation of the initial test results, the research team decided to pursue the use of GNPs to obtain self-sensing cementitious composites.
- The future work will include using higher amounts of GNP to observe a change in resistivity and ultimately developing a relationship between resistivity and damage in material. The effects of GNP content on the electrical properties and piezoresistive characteristics of mortar specimens will be explored.
- The resistivity meter was used in the initial testing to measure electrical properties. A four-probe method, which is a more reliable measurement technique, will be used in future tests.

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
Accomplishments:
- Reanalyzed samples to confirm the preliminary results
- Improved DNA extraction method (we now obtain cleaner DNA)
- Extracted DNA from 22 of 26 archived concrete cylinders.
- Currently drafting a manuscript describing the DNA extraction method
- Preparing to send the DNA extracted from the archived test cylinders for sequencing at a contract lab.

Products:
- Presentation at the Applied & Environmental Microbiology Gordon Research Conference (July 2015)

Impact:
- This work was presented at the MATS-UTC meeting in Wilmington in September 2015, and colleagues from several states offered to provide us with field samples next year, during the second phase of our project.
- We expect to obtain the data from the first phase of the project in the spring of 2016 and to complete the analysis by the summer.
- During summer 2016, we will collect field samples from Mid-Atlantic states, including Delaware, Maryland, and Virginia, extract DNA, and compare the field samples with our laboratory samples to identify patterns of microbial distribution.

Project: Implementation of “Smart Equipment” in Field Construction
PIs: Christopher Meehan, University of Delaware, cmeehan@udel.edu
Other Participants and Collaborating Organizations: Dhruv Batra, Virginia Tech, Blacksburg, VA; Jim Pappas and Javier Torrijos, Delaware Department of Transportation, Dover, DE
Period of Performance: June 1, 2015 – May 31, 2017
Accomplishments:
- Initial meetings with the Delaware Department of Transportation (DelDOT) have been organized to assess collaboration needs for performing one or more field studies on active project sites
- Separate funding has been secured by the Delaware Department of Transportation for “smart equipment” modification kits for compaction equipment; this equipment will be beneficial for the field study we are currently planning
• Contact has been made with vendors regarding the purchase of project-specific “smart equipment”
• A literature review has been performed (and is ongoing) to understand the current capabilities of existing Smart Equipment utilized in Field Construction, with a particular focus on “Continuous Compaction Control” (CCC)
• Data analyses (i.e. regression, geospatial interpolation, etc.) have been performed on an existing CCC data set to better understand the nature of CCC data

Products:
• The end goal is to provide DelDOT with the necessary resources to implement their own Smart Construction Specification

An additional goal of this project to is to utilize Smart Equipment (i.e. Continuous Compaction Control) on an active project site in Delaware to showcase the benefits of this technology

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:
• Dr. Rakha’s team has completed an evaluation of the impact of cycle length, traffic demand, and signal lost time to determine the impact on delay, fuel consumption, and emissions. A model has been developed to produce better traffic signal timings (cycle length) to minimize these components.
• Dr. Park’s team has begun testing actuated controller settings that might affect environmental sustainability, including minimum green, maximum green, extension times, and simultaneous gap out.
• Dr. Abbas’ team has begun developing a simulation model that will be used to model various preemption setting and transition plans to be applied to the Morgantown, WV network.
• Dr. Nichols’ team has completed their development of performance measures to evaluate the impact of preemption on controller transition.

Products:
• A poster summarizing the project was prepared for the MATS Annual Meeting in Delaware.
• Two papers were submitted for presentation at the 2016 Transportation Research Board based on the work completed in this project. Acceptance decisions are forthcoming.

Impact: The results of the emergency vehicle preemption analysis in the traffic signal high resolution data have been shared with WVDOT for corrective action. Those same metrics have been shared with the vendor so that they can potentially investigate issues in other similar signal systems.

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, mctin@odu.edu; Brian Park, University of Virginia, bpark@virginia.edu
Period of Performance: November 1, 2014 – April 30, 2016
Accomplishments:
• The research team at UVA developed a route choice behavior model considering fuel cost, average travel time and travel time reliability was developed using Support Vector Machine and Artificial Neural Networks. The findings show that both ANN and SVM shows similar prediction accuracy but SVM required much less training times. A hypothetical network is developed to consider impacts of utilizing route choice behavior for environmental sustainability.
• The research team from ODU worked on developing forecasting algorithms to predict flow rates in the short term, e.g., 15 minutes in the future. A non-parametric and data-driven methodology is developed based on identifying similar traffic patterns using an optimized K-nearest neighbor (K-NN) algorithm. The proposed method was found to give more accurate results than competing advanced filtering and time-series methods. The results are published in Transportation Research Part C.
• The research team from ODU is working on developing methods to predict traffic volumes based on trajectory data from probe vehicles. The preliminary results are presented at the 18th International IEEE Conference on Intelligent Transportation Systems.
The research team at VT developed the VNetIntSim simulation tool that integrates the INTEGRATION software with the OPNET software to test alternative eco-routing strategies.

The VNetIntSim tool was used to evaluate the operation of an eco-routing system considering packet losses and delays within the communication system.

Products – the following publications were published/presented:


Impact:

- The research conducted under this project was presented by graduate students to students taking graduate-level transportation classes at ODU.
- The team at VT included a two-week module in a joint Sustainability class that covers the topics presented in this project.

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; Christine Risch, Marshall University, christine.risch@marshall.edu; Kent Sowards, Marshall University, sowardsk@njrati.org; Jianhe Du, Virginia Tech, jianedu@vt.edu

Period of Performance: October 1, 2014 – September 30, 2015

Collaborating Organizations: Maryland Motor Vehicle Administration, Glen Burnie, MD; Electric Vehicle Association-DC Chapter, Rockville, MD

Accomplishments:

- Discussed logistics with MVA of deriving two large samples of registered vehicle owners in Maryland.
- Conducted limited survey distribution to various EV and conventional vehicle owners’ forums.
- Tested survey questionnaires and collected and analyzed data preliminarily.
- Revised survey questionnaires based on survey responses and continued survey distribution.

Products:

- Poster presentation at MATS UTC Annual Meeting in Delaware, August 6, 2015
- Poster presentation to Maryland Electric Vehicle Infrastructure Council Meeting, Sept. 10, 2015

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

Changes/Problems:

- Non-disclosure Agreement between MSU and MVA has not been ratified because of legal issues between two state organizations; it may be that issue will be resolved soon.
- 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 state level data.


PIs: James Hunter, Morgan State University, james.hunter@morgan.edu; Dong Hee Kang, Morgan State University, donghee.kang@morgan.edu; Teresa Culver, University of Virginia, tculver@virginia.edu

Period of Performance: October 1, 2014 – May 31, 2016
Accomplishments:
During this period the Long-Term Hydrologic Impact Assessment model was used to assess the stormwater quantity and quality from storming from highway infrastructure using MS4 counties of Maryland as a case study. The work included literature review and model implemented within a spreadsheet interface.
We are also leveraging this research to address research questions posed by the Maryland State Highway Administration (SHA). SHA is interested in the characterization of their inlet cleaning practices for Total Maximum Daily Load (TMDL) Compliance. This project will have a duration of 24 months and will be done in partnership with the Center for Watershed Protection. MSU will lead the field sample and laboratory analysis on gross solid materials removed from highway inlets and catch basins.

Products:
A conference paper was submitted to for the TRB Conference entitled “Using the Long-Term Hydrologic Impact Assessment Method As A Tool for Stormwater Compliance”. A poster was also presented at the MATS UTC Annual Meeting.
Gary Wallace, a junior Civil Engineering student at Morgan State University, had a “Student Spotlight” feature on the MATS UTC website and gave presentations at several undergraduate research symposiums this summer on the highway stormwater research he performed at MS.
Impact: Under this area of research, at MSU now has 3 doctoral students and 2 undergraduate research assistants. Based on the research, 4 undergraduate students will be presenting senior design projects and proposals related to stormwater best management practice design, construction and maintenance.
Changes/Problems: We would welcome contributions from other researcher interested in studying what state highway agencies are doing to meet stormwater compliance issues.

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, bsl2z@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; Greg Johnson, Stormwater Technical Services Engineer, Virginia Beach, Department of Public Works
Accomplishments:
- Built relationships with VDOT Hampton Roads District; Learned about their current efforts for creating a warning system for extreme event weather conditions, in particular the Regional River Severe Storm (R2S2) model
- Built relationships with municipalities, in particular Virginia Beach; Learned about their efforts for stormwater management and impacts of nuisance and extreme event flooding on transportation infrastructure managed by the city
- Continued refining a case study for extreme weather events as a demonstration for the need to integrate data across VDOT divisions and across federal and local governmental agencies. The case study could include VDOT road, bridge, and stormwater infrastructure data, local municipality road, bridge, and stormwater infrastructure data, and federal data on weather and river systems during extreme rainfall events.

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, Michigan State University PEARL, mark.budy@morgan.edu
Period of Performance: August 1, 2015-December 31, 2016
Collaborating Organization: Maryland State Highway Administration, Baltimore
Accomplishments:
Reclaimed concrete samples was collected from Flanigan & Sons Inc, which is the recycled material provider. Currently each project team prepares the first step of the laboratory experiment. And the literature reviews related to recycled materials especially reclaimed concrete materials are ongoing.
Impact: Undergraduate students are involved in the process. Students are also learning GC-MS operating skill.
Changes/Problems: To integrate our performance and get better result from this project, more communication between both research team is needed
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: September 1, 2014 – August 31, 2016
Accomplishments:
• Electronic survey on the current use of smart growth scorecards/assessment tools. The survey was distributed broadly to approximately 250 state, regional, and local land-use and transportation planning practitioners and smart growth advocates in the Mid-Atlantic region.
• Studied the EPA’s shift from its use of the Smart Growth INDEX® (SGI), a GIS sketch tool, to its current use of the Smart Location Database (SLD)
• Informational phone interviews with two separate regional planning organizations and a university-based policy institute that have an extensive, sophisticated digital presence and have developed tools to assess smart growth
• Literature review to gauge how new focuses of smart growth align with the contemporary use of smart growth assessment tools; matrix of contemporary smart growth scorecards/assessment tools.

Learned:
• The concept of smart growth and approaches to assess outcomes, via scorecards and assessment tools, has co-evolved in recent years.
• New tools offer both a tremendous potential to perform expected analyses, such as quantifying performance on key indicators of sustainability, and ability to better educate and engage the public.
• Interactive, web-based visualization tools offer a much needed, dynamic platform with which to satisfy mandates for increased transparency, accountability, and public engagement.
• While traditional transportation metrics have been applied to assess the outcomes of smart growth, these approaches are technically sophisticated and out-of-reach to small jurisdictions with limited resources, staff, and technical expertise.

Products:
• Article published – “DCT, IPA, MU Research Team Collaborate on MATS UTC Project,” Delaware Center for Transportation’s TranSearch Newsletter, Summer 2015 at https://sites.udel.edu/dct/files/2013/12/DCT-UTC-Newsletter-Summer-2015-279n2wk.pdf
• Poster Presentation, The Use of Smart Growth Scorecards/Assessment Tools to Advance Sustainable Land-Use Practices, MATS UTC Annual meeting, Wilmington, Delaware, August 6, 2015

Additional:
• Next research phase will involve preparation of prepare Geographic Information System (GIS) story map(s) to demonstrate how the combined use of geospatial data with photos, video, audio, and text can visually convey and communicate outcomes of smart growth plans, policies, and practices.
• Additional: Phase I report preparation is underway and expected to be completed by November 1, 2015.

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:
• Amy O’Leary, John Miller, Peter Ohlms, Virginia Center for Transportation Innovation and Research (VCTIR)
• Virginia Statewide Bicycle and Pedestrian Committee
Accomplishments:
• Literature review of research on driver education programs during installation of new infrastructure or as a part of safety initiatives.
• Review of driver education practices in Virginia, nationally, and globally both for new multimodal and traffic management facilities and infrastructure.
• Findings from the reviews include: Benefits of coordinated information and emotional appeals, importance of time scale of efforts
• Task: Practitioner interviews (begun in October 2015, 5% complete)
• Task: Driver survey (to begin January 2016, 0% complete)

Products:
• Presentation of literature review to VCTIR staff, August 2015
• Will present on-going progress to VDOT Transportation Planning Research Advisory Committee in November 2015

Appendix B Competitive Collaborative Projects

Project: Designing Bicycle and Pedestrian Traffic Count Program to Estimate Performance Measures on Streets and Sidewalks in Blacksburg, VA
Pls: Steve Hankey, Virginia Tech, hankey@vt.edu; Ralph Buehler, Virginia Tech, ralphbu@vt.edu; Andrew Mondschein, University of Virginia, mmondschein@virginia.edu
Collaborating Organization: Town of Blacksburg – town staff provides crews to divert traffic during installations. Town planning staff has helped with assessing count location feasibility.
Accomplishments:
• Completed manual validation counts of automated counters (n~240 hours).
• Developed correction equations for each automated counter based on manual counts.
• Continued collection of reference site data (total of ~6 months of counts at 4 locations).
• Collected 95/101 short-duration counts (i.e., 1-week counts) at each identified sampling location (remaining locations will be complete in the next 2 weeks).
• GIS-based land use data aggregated for ~90% of the count locations.

Products:
• Submitted quarterly memos to Town staff for review of trends at reference locations.
• Developed correction equations for each counter-type for adjusting automated counts of cyclists and pedestrians.

Impact:
• Correction equations (developed by students in a course taught by Dr. Hankey) can be used to correct any future counts using the counters in this project.
• Regular interaction with Town planning staff regarding transfer of bicycle and pedestrian counts for use in planning efforts.

Project: Simultaneous Removal of Nitrogen and Phosphorus from Stormwater by Zero-Valent Iron and Biochar in Bioretention Cells
Pls: Pei Chiu, University of Delaware, pei@udel.edu; Paul Imhoff, University of Delaware, imhoff@udel.edu; Teresa Culver, University of Virginia, tculver@virginia.edu
Other Participants and Collaborating Organizations: Dan Sweet and Kristel Riddervold, City of Charlottesville, VA; Kip Mumaw, Ecosystem Services, LLC, VA; Charles Hegberg, ReGenesis Global Solutions, LLC/Infinite Solutions L3C, PA
Accomplishments:
• Agreement Reached with City of Charlottesville to retrofit a bioinfiltration system with biochar and ZVI.
• Monitoring of seven storms performed between April and July of the system before retrofit.
• Design of retrofit completed.
• Installation of new system completed in July.
• Post-retrofit sampling of two storms completed.
• Comparison data collected for two storms at a nearby non-retrofitted facility.
• Experiments on biochar-promoted nitrate removal completed.
• Design of experiments on phosphate leaching and removal by ZVI completed.
• A manuscript on the mechanism of biochar-promoted nitrate removal completed.

Products:
• An abstract with respect to the field monitoring of this field was submitted to the EWRI Congress to be held in May 2016.
• Invited talk at Penn State, "Microbial Nitrate Reduction Promoted by Biochar and Zero-Valent Iron", Pei Chiu (April, 2015).
• Poster presentation at the Delaware Center for Transportation Research Showcase in Dover, DE (May 2015).
• Poster presentation at the MATS-UTC Annual Meeting in Wilmington, DE (August 2015).
• Poster presentation at the 25th Goldschmidt Conference in Prague, Czech Republic (August 2015).

Impact:
• Seven undergraduates and one graduate student engaged in the study at UVA.
• Three undergraduates, two graduate students, and one postdoc involved in the study at U of DE.
• Biochar-enhanced nitrate biodegradation is experimentally confirmed and the mechanism understood. This understanding will translate into specific strategies to improve bioretention system performance.
• PI Imhoff and collaborator Charles Hegberg (reGenesis Global Solutions, LLC) participated in the Seventh Annual Bay-Wide Stormwater Retreat (April 2015). They discussed biochar application with practitioners developing innovative stormwater BMPs to reduce nutrients fluxes, including representatives from USEPA and environmental regulators from Delaware, Maryland, New York, Virginia, and West Virginia.

Changes/Problems: Sampling has been complicated by unusual weather patterns. The six-week period immediately after retrofit was extremely dry, followed by September with multiple extreme events, including over 3” of rain in a single day and a week with over 7” of rain. These extreme events were well beyond the design capacity of the facility.

Project: Impact of Climate Change and Sea Level Rise on Stormwater Design and Reoccurring Flooding Problems in the Hampton Roads Region
Pls: Jonathon Goodall, University of Virginia, goodall@virginia.edu; Venkat Sridhar, Virginia Tech, vsri@vt.edu
Collaborating Organization: Hampton Roads Planning District Commission
Accomplishments:
• Historic analysis of climate extremes using National Climatic Data Center (NCDC) is done for the period between 1950 and 2015. The stations for our analysis include Williamsburg, Elizabeth City, Norfolk, Richmond and Wakefield and these are located in the vicinity of Coastal Virginia. This step is verified with the downscaled CMIP5 General Circulation Model (GCM) scenarios. The locations for GCM verification are selected in such a way that each NCDC station remains within the corresponding grid cell of the downscaled (1/16th of a degree) data. The fifteen climate models are: bcc-csm1-1, bcc-csm1-1-1, BNU-ESM, CanESM2, CCSM4, CNRM-CM5, CSIRO-Mk3-6-0, GFDL-ESM2G, GFDL-ESM2M, inmcm4, IPSL-CM5A-LR, IPSL-CM5A-MR, IPSL-CM5B-LR, MIROC5, and MIROC-ESM.
• We have set up the Weather Research and Forecasting (WRF) model to dynamically downscale North American Regional Reanalysis (NARR) data from 32 km to 4 km resolution for the period of 1980 – 2015 and the results will be available in Dec.
• Downloaded and processing LiDAR data and other relevant geospatial data layers for the county.
• Began development of a simple surface hydrology model for identifying flood prone areas in Hampton Roads.
What we have learned so far is that station-based observed precipitation data for Intensity, Frequency, and Duration analysis trends show that there is an increase in IDF in the past 30 years.

Projects:
- A conference presentation at the National Capital Region American Water Resources Association in Washington D.C was made in April 2015 (Valayamkunnath, P., M. Billah and V. Sridhar (2015) Design storm and climate change analysis in Eastern Virginia)
- Presented poster on research results to date at the MATS UTC Annual Meeting in Wilmington, DE, Aug 2015

Impact:
- Conducted workshop on sea level rise and infrastructure vulnerability held in May 2015 at Virginia Beach, VA
- Presented preliminary results at the Hampton Roads Planning District Commission monthly meeting of stormwater engineers

**Project: LiDAR for Air Quality Measurement**

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


Collaborating Organization: NASA Langley, Hampton VA

Accomplishments:
- Installed High-speed digitizer to increase the LiDAR’s data resolution. Installing the new digitizer required development of the embedded software applications that run the LiDAR which was beyond the scope of this project (since the company did not support this card) with limited improvement in LiDAR performance. So, decision was made to uninstall the new digitizer to address this technical issue and change the plan to stay with the same resolution for LiDAR.
- Restored the software of the LiDAR after it was corrupted by installing and uninstalling the new digitizer.
- Worked on the algorithm to obtain LiDAR backscatter ratio.
- Obtained optical polarizers through our collaboration with NASA Langley.
- Installed polarizer on the LiDAR and currently working to obtain depolarization ratio measurements.
- Developed a Bayesian-based approach to identify the location of the source of an air pollutant. The proposed approach is demonstrated to be better than an approach presented in the literature.

Products:
- Poster presentation at MATS UTC Annual Meeting
- Published a Research Spotlight news item for MATS UTC Newsletter (http://www.matsutc.org/2015/09/research-spotlight-lidar-for-air-quality-measurement/)

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 such that the new acquired measurements will be excellent source for analyzing the air quality and the identifying the sources of the aerosol in the area of study.

Changes/Problems: Change of plan for installing high-speed digitizer after a thorough evaluation over four months as discussed above.

**Project: Connected Vehicle Technologies for Energy Efficient Urban Transportation**

Pls: 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


Accomplishments:
- The original LFM (Light, Fast and Modifiable) simulation model of the hybrid fuel cell bus system (based on Matlab/Simulink) has been modified for the purpose of optimization. Dynamic programming was used to determine the optimal power management strategy for the hybrid system based on a predicted velocity profile which is dependent on traffic conditions.
• Historical velocity profiles of the current bus route were extracted and used as a starting point for preliminary research; real time traffic information can be easily incorporated into the optimization algorithm in the future.

• Preliminary results have shown that an optimal power management strategy can reduce hydrogen consumption by 9% compared to the most sub-optimal strategy (Figure 1), and by 5.6% compared to a simple rule-based strategy which only turns on the fuel cell when the battery state-of-charge drops below a threshold value.

• Due to the computationally-intensive nature of the dynamic programming algorithm, realtime implementation with high resolution might not be feasible. A less computationally-intensive neural-network based machine learning algorithm is under development to achieve faster realtime implementation. The neural network will learn to control the workload of the fuel cell to achieve the best fuel efficiency based on the optimal power management strategies provided by the dynamic programming optimization model which is computed offline for a large set of drive cycles with different traffic modes (combined highway and urban).

Products:
• A dynamic programming-based optimization simulation model of the power management system for the hybrid fuel cell bus has been developed.
• One poster was presented at the 2015 MATS UTC Annual Meeting during August 6-7, 2015 in Wilmington, DE.

Changes/Problems: The delivery of our Phase 3 fuel cell bus has been delayed. Therefore, the two-way communication system will be developed and tested upon its delivery by the end of October 2015.

Appendix C Completed Projects

Project: Performance Measures for Freight Transport and General Traffic: Investigating Similarities and Differences Using Alternative Data Sources
Pls: Rajesh Paleti, Old Dominion University, rpaleti@odu.edu; Mecit Cetin, Old Dominion University, mctein@odu.edu
Period of Performance: February 6, 2015 – May 24, 2015
Accomplishments:
• Developed a framework for visualizing, computing, and comparing performance measures of freight and general traffic using three different probe vehicle data sources – INRIX, HERE, & ATRI GPS data.
• The study results indicate that while average traffic conditions of freight and general traffic are similar, there can be significant differences in the extent of variation about the average conditions.
• The research quantified the magnitude of differences and identified spatial locations where these differences are pronounced.

Products:
• The study details including the description of different data sources, analytical methods, and final results/findings were compiled in a project report that was submitted to Virginia Department of Transportation.
• The study findings were presented in the First Annual MATS UTC Annual Meeting in Delaware.

Impact:
• One of main findings of the study was that, in the absence of freight-specific data, planning agencies can use general traffic data as a surrogate at most locations and purchase freight-specific data only for locations or corridors with significant differences. This can result in direct cost savings for planning agencies.
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- The visualizations methods and reliability metrics used in this study are easy to implement and in accordance with the recommendations of the Federal Highway Administration. So, the methods are easily transferable and the results may be compared across different regions.

Changes/Problems:
- While the study uncovered important differences between freight and general traffic conditions, predictive models of these differences could not be developed due to the relatively short time span of the project.
- The research team is currently evaluating advanced modeling methods such as bivariate copula models for analyzing dependencies between freight and general traffic conditions. Once developed, these predictive models can be used to infer freight traffic conditions based on general traffic PMs.

Project: Alternative Fuels Usage in Maritime Transportation System
Pls: Jennifer Shand, Marshall University, shandj@cbemu.org; James Corbett, University of Delaware, jcorbett@udel.edu
Period of Performance: January 1, 2015 – July 31, 2015
Accomplishments:
- Research was completed. Market analysis indicated that while the supply of natural gas is abundant within the region due to the Marcellus shale activities, existing LNG supplies may be insufficient to support long term growth. In addition to competing uses for natural gas, which serves chemical manufacturing and energy industries, a critical condition for the use of LNG as an alternative fuel is complementary refueling infrastructure, which is largely absent at current.
- Further analysis of technological conversion for inland fleet indicate that switching to LNG would reduce emissions from GHGs except CO. High capital costs of conversion and age of current fleet suggest gradual phase in of technology may be preferred among operators. Within Region 3, West Virginia merits additional study as an option for investing in LNG infrastructure based on vessel age, activity and emissions.

Products:
- A combined report consisting of two papers – the market analysis (supply considerations) and the vessel technology analysis (demand) has been submitted to UVA.
- Additionally, collaborators from UD presented at the MATS conference in August.
- Paper/presentation at TRB 2016 for technology analysis.

Impact: The research highlights economic issues and considerations associated with large scale fleet conversions for using LNG as an alternative fuel in inland maritime for Region 3. While conversion may produce some emission reductions, critical issues include capital costs of retrofitting or new vessels as well as the lack of complementary refueling infrastructure within Region 3. While natural gas supply is currently abundant due to Marcellus shale activities, this supply is used in several industries such as power generation and chemical manufacturing, in addition to transportation.

Changes/Problems: Communication challenges and unique expertise between project partners necessitated separately pursuing scopes of work, producing two separate papers which constituted the final report. Potential for future integration of work exists.

Project: Design of a Decision Support Tool for Nutrient Credit Exchange Feasibility in Stormwater Regulatory Compliance
Pls: Jon Goodall, University of Virginia, goodall@virginia.edu
Period of Performance: October 1, 2014 – May 31, 2016
Other Participants and Collaborating Organizations: Stuart F. Sheffield, University of Virginia, sfs8cq@virginia.edu; G. Michael Fitch, Virginia Center for Transportation Innovation and Research, Michael.Fitch@vdot.virginia.gov; Roy T. Mills, Virginia Department of Transportation, Roy.Mills@vdot.virginia.edu; John D. Olenik, Virginia Department of Transportation, John.Olenik@vdot.virginia.edu
Accomplishments:
- Located information required by project managers to make informed decisions on nutrient credit exchange participation
- Designed a prototype web-based application to gather the required information from several different sources and provide useful feedback to the project manager
- Leveraged EPA web services to obtain useful hydrologic information
- A web-based application allows for the use of real-time data and can reduce user input, which, ideally, would improve estimation accuracy

Products:
- Sheffield, S., Goodall, J. (2015, August). Design of Decision Support Tool for Nutrient Credit Exchange Feasibility in Stormwater Regulatory Compliance. Poster session at the annual meeting of the Mid-Atlantic Transportation Sustainability Center, Wilmington, DE.
- Prototype website (still in development stages)
- VCTIR Report submitted last May.

Project: Virginia Sustainable Travel Choices: Effects of Land Use and Location on Current and Future Travel Options
PLs: Andrew Mondschein, University of Virginia, mondschein@virginia.edu
Period of Performance: October 1, 2014 – August 31, 2015
Other Participants and Collaborating Organizations: Marcia Scott, Project Advisor, University of Delaware, Newark, DE; Peter Ohlms, Project Advisor, Virginia Center for Transportation Innovation and Research, Charlottesville, VA

Accomplishments:
- Assembled Virginia-wide neighborhood scale data (block, census, or zip code level) on commute patterns, vehicle registrations by year, make, and model, transit use, and additional travel and socio-demographic variables.
- Assembled Northern Virginia data on bike share stations and usage and land use patterns.
- GIS-based analysis of relationships between commute length and vehicle emissions by location across VA between 2006 and 2012.
- Change analysis in bike share station deployment by land use density measures.
- Key findings: Identification and characteristics of commute/emissions clusters including “sweet spots,” where commute lengths and vehicle emissions are lower, policy recommendations based on cluster membership.

Products:
- Presentation to VDOT Transportation Planning Research Advisory Committee (April 2015)
- Presentation to MATS UTC Annual Meeting (August 2015)

Impact:
- Engaged 4 graduate planning students in the research
- Supplied findings to VDOT to contribute to long-range planning efforts in Virginia