Program Progress Performance Report (PPPR) No. 2 – Urban Mobility & Equity Center

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Project Title:	Urban Mobility & Equity Center
	Morgan State University (Lead Institution) *Virginia Polytechnic Institute and State University* *University of Maryland*
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Signature:

1. ACCOMPLISHMENTS

UMEC completed its first project during this reporting period and has 14 more underway, several of which are nearing completion. Meanwhile, selection of another round of projects using third-year funding is also in the final stages. The second year of summer programs aimed at workforce development successfully introduced middle schoolers, high school students and teachers to opportunities in transportation. Internships and fellowships created opportunities for critical learning for the next generation of the transportation workforce.

1.1 What are the major goals and objectives?

The Urban Mobility & Equity Center (UMEC) at Morgan State University's National Transportation Center (NTC) focuses its research on the urban mobility of people and goods while also identifying the ways in which mobility affects equity and sustainability. The research, which likely will influence public policy, also develops methods, such as algorithms, that create new efficiencies in transportation systems.

UMEC supports research centered on three themes:

- ♦ Transit, paratransit, and freight planning and operations to improve mobility, access and cost efficiency;
- ♦ Buyer acceptance, affordability and government promotion of connected and automated vehicles;
- ♦ Distribution of transportation costs and benefits, including equity of user fees and taxes that fund infrastructure and services.

UMEC provides utilizable technical assistance and nurtures the next generation of transportation professionals through educational and community outreach projects and programs.

1.2 What was accomplished under these goals?

Our research projects, listed in the chart below, dovetail with the four priorities cited in the U.S. Department of Transportation Strategic Plan for FY 2018-2022, namely, Safety, Infrastructure, Innovation and Accountability.

Project Name	Principle Investigator(s)	University	Subject Areas
Projects shaded in green are now complete. Projects shaded in blue have been added since the previous PPPR			
Developing an Eco-Cooperative Adaptive Cruise Control System for Electric Vehicles	Dr. Hao Chen Dr. Hesham Rakha	Virginia Tech Virginia Tech	Connected and Automated Vehicle, Connected Traffic Signal Control, Transit Signal Priority, Microscopic Traffic Simulation, Field Testing

	Dr. Cinzia Cirillo	University of Maryland	
E^3: Evaluating Equity in Evacuation: A Practical Tool and Two Case Studies	Dr. Cinzia Cirillo	University of Maryland	Evacuation, disaster management
Improving Public School Bus Operations: Boston Case Study	Dr. Youssef Bichiou Dr. Hesham Rakha Dr. Young-Jae Lee	Virginia Tech Virginia Tech Morgan State	
Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts	Dr. Celeste Chavis Dr. Cinzia Cirillo	Morgan State University of Maryland	High-speed bus lanes, bike lanes, shared bus-bike lanes, bike safety, bike-vehicle interactions
Managing the Impacts of Different CV/AV Penetration Rates on Recurrent Freeway Congestion from the Perspective of Traffic Management	Dr. Gang-Len Chang	University of Maryland	Freeway traffic control, autonomous vehicles
Sustainable Design of Concrete Bus Pads to Improve Mobility in Baltimore City	Dr. Monique Head Dr. Mehdi Shokouhian	Morgan State University Morgan State University	Concrete bus pads; sustainability; wheel axle loads; reinforcement; transportation; structural concrete design
Evaluating Equity Issue for Managed Lanes: Methods for	Dr. Cinzia Cirillo	University of Maryland	Road Pricing, Behavioral models for HOT and HOV lanes, Equity Measurements and Appraisal

Analysis and Empirical Results			
Drivers' Interactions with Advanced Vehicles in Various Traffic Mixes and Flows (autonomous and connected vehicles (ACVs) electric vehicles (EVs), V2X, trucks, bicycles, and pedestrians) – Phase I: Driver Behavior Study and Parameter Estimation	Dr. Mansoureh Jeihani	Morgan State University	Autonomous and connected vehicles, electric vehicles, Complete Streets, multimodal transportation, mobility, safety
Hands on Wheel, Eyes on Road	Dr. Mansoureh Jeihani	Morgan State University	Traffic safety, mobility, driver behavior, distracted driving
Innovative Methods for Delivering Fresh Foods to Underserved Populations (Collaborative Project)	Dr. Hyeon-Shic Shin Dr Young-Jae Lee Dr. Paul Schonfeld	Morgan State University Morgan State University University of Maryland	Last mile food delivery; Accessibility improvement for underserved population; social justice in transportation; Transportation planning and policy
Developing a Connected Vehicle Transit Signal Priority System (Collaborative Project)	Dr. Kyoungho Ahn Dr. Hesham Rakha Dr. Young-Jae Lee	Virginia Tech Virginia Tech Morgan State University	Connected and Automated Vehicle, Connected Traffic Signal Control, Transit Signal Priority, Microscopic Traffic Simulation, Field Testing
Developing and Testing an ECO-Cooperative Adaptive Cruise	Dr. Hesham Rakha Dr. Hao Chen	Virginia Tech Virginia	Connected and Automated Vehicle, Eco-Cooperative Adaptive Cruise Control, Energy Modeling, Hybrid Electric Bus, Diesel Bus, Microscopic

Control System for Buses (Collaborative Project)	Dr. Mansoureh Jeihani	Tech Morgan State University	Traffic Simulation
Optimization of Emergency Traffic Patrols (ETP) Operations (Collaborative Project)	Dr. Ali Haghani Dr. Mansoureh Jeihani	University of Maryland Morgan State University	Incident response and management
Development of Multimodal Traffic Signal Control	Dr. Hesham Rakha Dr. Kyoungho Ahn	Virginia Tech Virginia Tech	Traffic Signal Control
Traffic State Prediction: A Traveler Equity and Multi-model Perspective	Dr. Hesham Rakha	Virginia Tech	Multimodal Transportation System, Transit Passenger Demand Prediction, Bike Share System, Travel Time Prediction
Optimized Development of Urban Transportation Networks	Dr. Paul Schonfeld	University of Maryland	Transportation Network Evaluation, Traffic In Road Networks, Project Scheduling, Optimization, Economic Analysis
Understanding Access to Grocery Stores in Food Deserts in Baltimore City	Dr. Celeste Chavis Anita Jones, M.S.	Morgan State University Morgan State University	Food deserts, Access to Transportation, Public Transportation
Optimal Automated Demand Responsive Feeder Transit Operation and Its Impact	Dr. Young-Jae Lee	Morgan State University	Automated Vehicles, Transit, Ridesharing
Dynamic Vehicle Routing with Route Guidance	Dr. Ali Haghani	University of Maryland	Freight Mobility, Logistics

for Urban Pickup and Delivery

Our goals of community outreach and technical assistance also played a prominent role during the last six months.

- The Second Annual Transportation Summit, open to the public and attended by nearly 200 people, was a lively success. Speakers included Robbyn Lewis, Maryland State Delegate, District 46, and Ryan Dorsey, Baltimore City Council, District 3. Additional panelists include Mike Heslin, Market Manager at Lyft, and David McClure, President, Amalgamated Transit Union Local 1300. The event took place in the Center for the Built Environment and Infrastructure Studies (CBEIS) Building on April 18. Noting that some 33 percent of households in Baltimore City don't have access to a car, Councilman Dorsey said, "An opportunity that you can't get to might as well not exist." Ironically, Delegate Lewis, the only state delegate who doesn't use a car, was late to the event due to delays with the bus system.

The Second Annual Transportation Summit

- UMEC faculty member Dr. Celeste Chavis has been appointed to the Central Maryland Transportation Alliance Board; she is also a member of the Greater Washington Partnership Equitable Access Workgroup and the Baltimore City Department of Transportation Complete Streets Equity Workgroup. On April 25, 2018, she served as an expert panelist at the Complete Streets Hearing before the Baltimore City Council. She also organized a workshop, the Youth Symposium, at the Conference of Minority Transportation Officials Annual Meeting in July 2018.
- UMEC director Dr. Andrew Farkas continues to serve on Maryland's Electric Vehicle Infrastructure Council, established by the state legislature. At a recent

meeting, he presented research conducted at the National Transportation Center that gave critical insights into the commuting habits and purchasing motivations of electric vehicle owners. The information from this ground-breaking research is expected to influence state policies aimed at promoting EV adoption.

- UMEC helped sponsor Transportation Camp Baltimore 2018 on May 12 at the University of Baltimore. It was an unconference, a format in which attendees decide on session topics and lead the sessions. It was well attended by transportation professionals and interested citizens.
- The Safety and Behavioral Analysis (SABA) Center, which has two driving simulators, moved to larger quarters that will allow for expanded research and the future addition of a bicycle simulator.
- Faculty and staff from UMEC met with representatives from both BIRD and SPIN, companies that provide electric scooters and electric bikes for sharing through apps. The companies were interested in obtaining a contract with the university; UMEC faculty and staff enjoyed a chance to "test drive" these increasingly popular transportation modes.

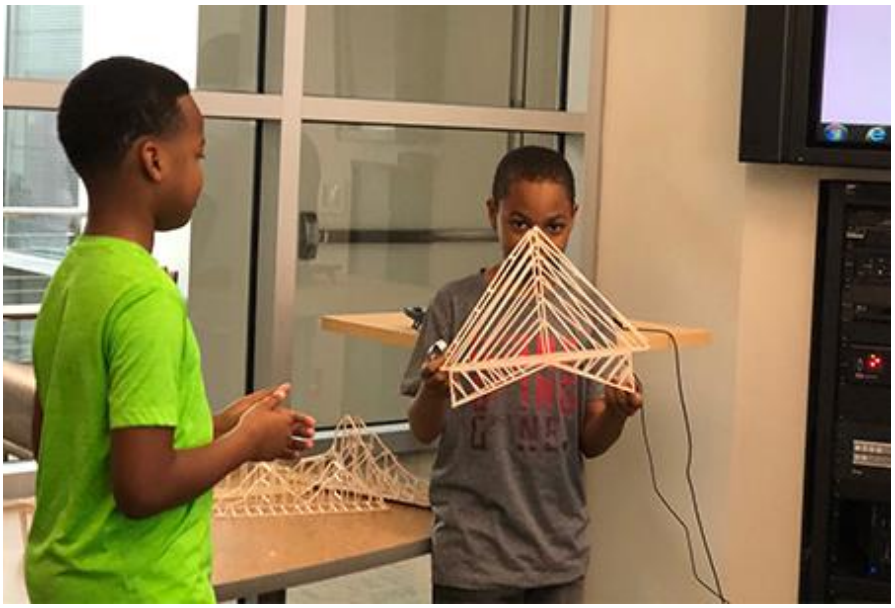
1.3 What opportunities for training and professional development has the program provided?

- Morgan State University offers transportation-related degrees at the bachelor's, master's and doctoral levels, as well as a post-baccalaureate transportation certificate in three schools – the School of Engineering, School of Architecture and Planning, and the School of Graduate Studies. The program is supporting 19 graduate research assistants and four research fellows. Currently Morgan has 79 undergraduates majoring in transportation, with another 414 students majoring in civil engineering. At the master's level, 44 students are enrolled in either the transportation or city and regional planning programs, while two doctoral students are working in transportation. (Note: Some of these students may be counted under the former MATS-UTC grant.)
- All three schools in UMEC also offer civil engineering degrees.
- The University of Maryland has five transportation-related courses – two at the undergraduate level, two at the master's level and one at the doctoral level – taught by faculty or teaching assistants associated with the UTC program.
- Virginia Tech has 19 master's degree students and five doctoral students pursuing transportation-related degrees; two of those doctoral students are supported by scholarship/fellowships and three through research grants. At the undergraduate level, Virginia Tech offers 17 transportation-related courses.
- With an emphasis on safety, especially motorcycle safety, Virginia Tech Transportation Institute and the Virginia Department of Transportation hosted **School Day** on April 19.

School Day at Virginia Tech emphasized motorcycle safety.

- At the *Teacher Transportation Institute*, held this summer, teachers spent two weeks studying roundabouts, visiting local ones and then designing and building a model roundabout, all while learning how to better use STEM concepts in the classroom. They also gained a better understand of the preparation needed for tomorrow's workforce. "I had no idea there were that many careers in transportation," said Robert Henderson, who teaches computer technology at Digital Harbor High School.
- Now in its 22nd year, the *Summer Transportation Institute* brought 20 high school students to campus for a four-week program that included field trips and guest speakers. In addition to exposure to various aspects of the transportation field – this year's program focused on aviation with trips to a flight simulator and local airports – students receive SAT preparation and experience a college campus. The program is free for students. One of the counselors for this year's program, Richard Pitts III, participated in it when he was in high school, which led him to study transportation here at Morgan.
- Because students are making course selections and career decisions at an earlier age, the *Middle School Summer Transportation Initiative* introduces sixth- , seventh- , and eighth-graders to the transportation field. This year's program focused on bridge construction. Students visited area bridges and built models of

different types of bridges from different materials. They also enjoyed field trips, including one to an IMAX presentation about bridges.



Middle school students studied bridge design.

- *WIN (Women In)* is a program conducted by a local all-girls high school that introduces students to careers by having them shadow with women in various fields during the summer. One student shadowed with one of our civil engineering professors while another shadowed with a transportation professor. The program organizer related that until now the program had not had an engineering component.
- The NTC and UMEC have a relationship with the Maryland Department of Transportation (MDOT) to continue two **internship programs**: undergraduate-level summer internships with the State Highway Administration and full-year, graduate-level internships at the administrative subdivisions of MDOT.

  ♦ At the graduate level, 23 students are working in paid internships at MDOT. They are: Chibuike Nosiri, Danny Brown, Esther Ogunlade, Joseph Bateky, Jami Mensha, Gary Charles, Kelechi Uradu, Michael Awotoye, Michael Cassell, Mohammadreza Jabehdari, Olatunji Dipeolu, Oluwafemi Ebilakun, Snehanshu Banerjee, Obinna Obika, Olutayo Ojo, Oluwatoni Samagbeyi, Sha'Von Terrell, Tolawase Ayanleke, Kehinde Adenuga, Olalekan Asaolu, Tolulope Ajayi, Chinwe Ihuoma, Priscilla Nartey.

  ♦ Four undergraduate students completed paid internships this summer at the SHA: Tamiah Griffin, George Smith, Elizabeth Olusola, and Tamara Beach.

1.4 How have the results been disseminated? If so, in what ways?

Researchers receiving UMEC funding are encouraged to publish their results in journals, present at conferences and create webinars; professional editing services are available to them.

- Dr. Chavis presented at three conferences:
  - Chavis, C. Baltimore Bike Share Infrastructure Planning through the Lens of Equity. 2018 International Conference on Transportation Innovation, Edmonton, Canada. September 6-7, 2018.
  - Chavis, C. Getting to High School in Baltimore. The Carlos Daganzo Transportation Symposium. Berkeley, CA. June 20-22, 2018.
  - Workforce Transportation: Challenges and Opportunities. Baltimore Data Day Opening Session Panelist. Baltimore, MD. July 12, 2018.
- UMEC-funded research at Virginia Tech has resulted in two peer-reviewed publications:
  - Almannaa M., Elhenawy M., and Rakha H.A. (2018), "Predicting Bike Availability in Bike Sharing Systems Using Dynamic Linear Models," 97th Transportation Research Board Annual Meeting, Washington DC, January 7-11. [Paper # 18-01384].
  - Almannaa M., Elhenawy M., Guo F. and Rakha H.A. (2018), "Incremental Learning Models of Bike Counts at Bike Sharing Systems," 21st IEEE International Conference on Intelligent Transportation Systems (IEEE ITSC 2018), Maui, Hawaii, November 4-7.
- Samira Ahangari, a Ph.D. student at Morgan, presented **Developing and Testing an ECO-Cooperative Adaptive Cruise Control System for Buses** (Collaborative Project) at the 2018 ITE Mid-Colonial District Annual Conference in April.
- Graduate student Amirreza Nickkar won second place for a paper submitted for the 23rd National Conference on Rural Public & Intercity Bus Transportation entitled *Effects of Demand Variation on Optimal Automated Demand Responsive Feeder Transit System Operation in Rural Areas*. The award included a trip to the conference this fall in Breckenridge, Colorado.
- Based on UMEC research, the "Impact of Individual Passenger Degree of Circuity on Optimal Transit Network Design" has been accepted for presentation at TRB in 2019.
- UMEC created an Instagram account to share pictures of its summer programs.
- From April 1, 2018, to Sept. 30, 2018, the UMEC website, www.morgan.edu/umec, had 898 visitors.
- UMEC's Facebook page now has 62 followers. In September of 2018, an average of 136 people per day saw some content from the UMEC page. UMEC's Twitter feed, grew from 20 to 32 followers, and in the previous 28 days as of this writing had 902 tweet impressions. UMEC Facebook posts often appear on the National Transportation Center's page, which has 137 followers, and the NTC's Twitter feed, which has 139 followers.
- A second issue of the newsletter, *The UMEC Report*, was distributed in the spring via email to 450 transportation professionals, researchers, community

organizations and government officials. It's available on the UMEC website, https://www.morgan.edu/school_of_engineering/research_centers/urban_mobility_and_equity_center/publications/newsletter.html.

- Press releases will be developed for appropriate media when research and/or results are newsworthy, and fact sheets will be developed to facilitate technology transfer.

1.5 What do you plan to do during the next reporting period to accomplish the goals and objectives?

- All of our research projects will continue toward their stated objectives in a timely fashion.
- UMEC will evaluate the third-year funding round of competitive proposals and choose several for collaborative research.
- UMEC will focus on increasing followers on its social media.
- With an active hurricane season this year, the project **E$^{3:}$ Evaluating Equity in Evacuation: A Practical Tool and Two Case Studies** is timely. The project will map low-income population in the Baltimore metropolitan area, calculate the accessibility to safe zones by private cars and transit in the event of a natural disaster, and evaluate the benefit and costs of different interventions for two jurisdictions, one rural and one urban.
- The project **Developing a Connected Vehicle Transit Signal Priority System** is developing an advanced Transit Signal Priority (TSP) system within a connected vehicle (CV) environment. Specifically, the research effort will develop a CV-enabled TSP system that provides equitable priority for buses (priority with minimum disruption to surrounding traffic) that is effective for near-side, far-side, and mid-block bus stops.
- **Development of Multimodal Traffic Signal Control** is developing an integrated CV simulation platform and an I-SIG algorithm as part of a novel multi-modal traffic signal control system for both connected and automated vehicle application.
- The project **Traffic State Prediction: A Traveler Equity and Multi-modal Perspective** has developed two prediction models to predict bike counts in bike-sharing systems. The next step will be a prediction model for bus/travel demand.
- The project **Developing and Testing an ECO-Cooperative Adaptive Cruise Control System for Buses** will develop energy consumption models for diesel and hybrid electric buses, calibrate bus energy models by real data, and develop a bus ECO-CACC system using the calibrated energy models.
- The project **Drivers' Interactions with Advanced Vehicles in Various Traffic Mixes and Flows (autonomous and connected vehicles (ACVs) electric vehicles (EVs), V2X, trucks, bicycles, and pedestrians) – Phase I: Driver Behavior Study and Parameter Estimation**, has begun implementing some autonomous and connected vehicle features into the driving simulator; this will be completed in the next reporting period.
- Complementing the USDOT's emphasis on safety, **Shared Bus /Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** addresses a

development in infrastructure that has arisen in recent years. Many cities have designated bus lanes, and many jurisdictions allow cyclists in those lanes. This project will study shared bus/bike lanes and analyze cyclist safety, determine whether buses are delayed by cyclists, what type of unsafe maneuvers typically commonly occur and how design and education can improve shared bus/bike facilities.

2. PRODUCTS

2.1 Publications, Conference papers, presentations

- Two papers from the **Development of Multimodal Traffic Signal Control** project**,** one focusing on a kalman filter-based vehicle count estimation approach using probe vehicle data and the other a comparative analysis of centralized or decentralized traffic signal control have been submitted for the 2019 TRB conference.
- Samira Ahangari, a Ph.D. student at Morgan, presented **Developing and Testing an ECO-Cooperative Adaptive Cruise Control System for Buses** (Collaborative Project) at the 2018 ITE Mid-Colonial District Annual Conference in April.
- "Predicting Bike Availability in Bike Sharing Systems Using Dynamic Linear Models," from the project **Traffic State Prediction: A Traveler Equity and Multi-modal Perspective,** was presented at the 97th TRB meeting in Washington last January.
- Another paper from that project, "Incremental Learning Models of Bike Counts at Bike Sharing Systems," will be presented at the 21st IEEE International Conference on Intelligent Transportation Systems November 4-7, 2018 in Maui, Hawaii.
- The paper "Stochastic modeling of bus passenger boarding/alighting time," part of the project **Developing a Connected Vehicle Transit Signal Priority System**, has been submitted for the 2019 TRB meeting.
- The preliminary results of **Evaluating Equity Issues for Managed Lanes: Methods for Analysis and Empirical Results** were presented at the 14th Network on European Communications and Transport Activity Research (NECTAR) conference, which is among the most influential conferences in transportation economics. It took place in Madrid from May 31-June 2, 2017, but this presentation was not included in the last progress report.

2.2 Websites or other internet sites

www.morgan.edu/umec
www.facebook.com/urbanmobilityandequitycenter
www.twitter.com/UMECresearch
ntcumec (Instagram)

As part of its mission to be a community resource, UMEC posts guests blogs on its website. The bloggers represent a variety of voices interested in transportation, and they

explore topics ranging from complete streets to bike advocacy to autonomous vehicles. The blogs can be found under the News & Events section.

2.3 Technologies or techniques

UMEC's research projects reflect the priorities of the U.S. Department of Transportation Strategic Plan for FY 2018-2022 with their emphasis on innovation and accountability. Our research particularly focuses on the rapidly arriving innovations surrounding the development of autonomous and connected vehicles and connected infrastructure.

- An algorithm was developed for the project **Optimal Automated Demand Responsive Feeder Transit Operation and Its Impact**. This allows for optimal flexible feeder bus routing and considers the relocation of buses for multi-stations and multi-trains. The algorithm successfully handled relocating the buses when the optimal routing was not feasible with the available buses. The algorithm limited the maximum Degree of Circuity for each passenger while minimizing total cost.
- **$E^{3:}$ Evaluating Equity in Evacuation: A Practical Tool and Two Case Studies** will impact the management of evacuation, especially for disadvantaged populations. The methods based on small area estimation and population synthesis will be applied and transferred to transportation.
- The project **Developing and Testing an ECO-Cooperative Adaptive Cruise Control System for Buses** develops energy consumption models for diesel and hybrid-electric buses, calibrates bus energy models by real data and develops an adaptive cruise control system for heavy-duty vehicles. This project and the following one are examples of the innovation targeted in the strategic plan.
- A similar project, **Developing an Eco-Cooperative Adaptive Cruise Control System for Electric Vehicles,** develops and tests a system that will consider queue impacts and multi-intersections. The system with be tested in mixed traffic, with conventional, battery-operated and hybrid vehicles using microscopic simulation software. A prediction model will be developed to forecast connected automated EV ownership and predict the adoption of Eco-CACC system for EVs and other types of vehicles; this will be used to estimate the nationwide benefits of the proposed ECO-CACC system.
- The project **Traffic State Prediction: A Traveler Equity and Multimodal Perspective** has created a prediction model that can help bike-sharing companies improve their services. It also can be used in commercial software for transit agencies to manage bus schedules. By enhancing the multi-modal transportation system, it reduces congestion.
- **Development of Multimodal Traffic Signal Control** will develop an integrated CV simulation platform and an I-SIG algorithm which will be implemented on a CV simulation platform.

- **Sustainable Design of Concrete Bus Pads to Improve Mobility in Baltimore City** will formulate a newly proposed design for sustainable concrete bus pads that can withstand various loading scenarios to minimize cracking, an important advancement in infrastructure.

2.4 Inventions, patent applications or licenses

Dr. Mansoureh Jeihani and graduate student Zohreh Rashidi Moghaddam have filed an intellectual property disclosure form with the Office of Technology Transfer for a software-oriented interface they developed that ties a set of algorithms for optimizing traffic light operation with software embedded in a driving simulator. The interface was created as part of their research into driver behavior in the Safety and Behavioral Analysis Center.

2.5 Other products such as databases, physical collections, audio or video products, software or NetWare, model education aids, curricula, instructions, equipment

A video, designed for high school and college classes, that uses a game show format to emphasize the dangers of distracted driving has been produced and is awaiting a formal release.

3. PARTICIPANTS & COLLABORATING ORGANIZATIONS

3.1 What organizations have been involved as partners?

Morgan State University (lead)

- Financial Support
- In-Kind support
- Facilities
- Collaborative Research
- Personnel exchanges

Virginia Tech, Blacksburg, Virginia

- Financial Support
- In-Kind support
- Facilities
- Collaborative Research
- Personnel exchanges

University of Maryland

- Financial Support
- In-Kind support
- Facilities
- Collaborative Research
- Personnel exchanges

3.2 Have other collaborators or contacts been involved?

Maryland Department of Transportation State Highway Administration, Virginia Department of Transportation, Appalachian Regional Council, North Carolina State University, Baltimore Metropolitan Council, Maryland Transit Administration

4. IMPACT

4.1 What is the impact on the development of the principle disciplines of the program?

UMEC's research already has contributed to the body of knowledge and offered such tools as predictive methods and algorithms, and that will continue in the second year.

- The project **Traffic State Prediction: A Traveler Equity and Multimodal Perspective** develops prediction models for the transit passenger demand problem.
- The algorithm developed in **Optimal Automated Demand Responsive Feeder Transit Operation and Its Impact** provides a mechanism for future evaluations of how efficient automated feeder services are and how they will compare with the fast-approaching automated ridesharing and carsharing services. Eventually, these studies will help predict users' travel behaviors and modal choices between the automated ridesharing/carsharing operation and the automated feeder service for mass transit.
- The project **Evaluating Equity Issues for Managed Lanes: Methods for Analysis and Empirical Results** developed methodology that impacts the evaluation of transportation projects. The incorporation of income effect and taste heterogeneity may lead to a new paradigm in the appraisal of projects that involve a change in the income of individuals.

4.2 What is the impact on other disciplines?

UMEC's research projects incorporate a multidisciplinary approach that may include computer science, operational research, urban planning, economic impacts and environmental engineering. The results may influence equally diverse fields.

- The project **Improving Public School Bus Operations: Boston Case Study** aims to develop a system that gives route selection in order to ensure children arrive at school on time. This will impact the performance of the public education system.
  - The project **Optimal Automated Demand Responsive Feeder Transit Operation and Its Impact** shows that when unit operating costs decline, total operating cost and total costs obviously decline. Furthermore, when unit operating costs decline, the average passenger travel distance and total passenger travel costs decline while the ratio of total operating costs per unit operating costs increases. That means if unit operating costs decrease, the portion of passenger travel costs in total costs increases, and the optimization process tends to reduce passenger costs more while reducing total costs. Travel times and costs in hypothetical networks can be compared.
  - Compensating Variation is an economic concept. Therefore, transportation studies with an economic component may be favored by the results of **Evaluating Equity Issues for Managed Lanes: Methods for Analysis and**

Empirical Results. Studies on inequality will benefit from the proposed methods since Compensating Variation is directly related to income.

4.3 What is the impact on the development of transportation workforce development?

- The project **Development of Multimodal Traffic Signal Control** engages students by providing opportunities for research in transportation engineering and assistantships.
- The results of **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** could be used by transit agencies to improve driver training.
- The project **Developing a Connected Vehicle Transit Signal Priority System** provides assistantships and opportunities for students to conduct research.
- A PhD student has been working on the development of the project **Evaluating Equity Issues for Managed Lanes: Methods for Analysis and Empirical Results**; and a junior graduate student has helped with programming tasks.
- A senior Ph.D. student has been working full time on **$E^{3:}$ Evaluating Equity in Evacuation: A Practical Tool and Two Case Studies**, while a younger student is trained to take over the tools when the other graduates. These students have developed skills on data analytics (especially data integration), statistics, and transportation modeling.
- UMEC continues to support the **two internship programs,** involving a total of 27 students this year, detailed in Section 1.3 of this report. A participant in the 2017-2018 Maryland Department of Transportation-Morgan State University Graduate School Internship Program, Zohreh Rashidi Moghaddam sums up her experience. "I got hired," she said. She had just received her master's in Transportation Studies in May, and had worked for the past year as an intern in the MDOT-Maryland Transit Administration Office of Performance Management. "I was responsible for the data analysis of public transit performance," she said. She is the 14th intern to be hired, proving once again that the program is a successful workforce development initiative.

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  Five of the 11 graduate students who participated in the MDOT-MSU internships attended a luncheon concluding the 2017-2018 program.

4.4 What is the impact on physical, institutional and information resources at the university and/or other partner institutions?
Nothing to report.

4.5 What is the impact on technology transfer?

- Our technology transfer plan has been approved and is available on our website.
- An intellectual property disclosure form was filed for an interface developed at Morgan State University. Because the market may be limited for this software interface, which ties a set of algorithms for optimizing traffic light operation with software embedded in a driving simulator, it might not justify the costs of a full patent application. However, it indicates that the process of protecting intellectual property and considering monetizing it is working.
- Project proposals are reviewed with the possibility of technology transfer in mind, with an emphasis on outputs.
- The results of the project **Understanding Access to Grocery Stores in Food Deserts in Baltimore City** will be used to develop a partnership between Baltimore City's Department of Planning and an on-demand ride-sharing company to provide grocery store access to residents of West Baltimore. This study will aid in the pricing and structuring of this partnership.
- The results of the study **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** study will directly impact the implementation and design of SBBLs in Baltimore City.
- The results of Evaluating **Equity Issues for Managed Lanes: Methods for Analysis and Empirical Results** will be shared with Transurban, which is managing the express lanes in the Virginia side of the Beltway. Methods will be also available to other interested parties.

- The project **Developing and Testing an ECO-Cooperative Adaptive Cruise Control System for Buses** develops a cruise control system for buses; automotive companies may consider implementing the system into different types of vehicles.
- **Traffic State Prediction: A Traveler Equity and Multi-modal Perspective** will develop a prediction model that can be used in commercial software for transit agencies to manage bus schedules.

4.6 What is the impact on society beyond science and technology?

The completed research should result in outcomes that make life a little easier, such as the adoption of a method that streamlines transportation, reducing congestion, and data that influences the development and adoption of sound policy. Our faculty is actively engaged in initiatives that allow them to share their research in both formal presentations and informal conversations. Below is a sampling of projects with a broader reach.

- The projects **Developing a Connected Vehicle Transit Signal Priority System, Developing and Testing an ECO-Corporative Adaptive Cruise Control System for Buses** and **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** will help relieve congestion by maximizing buses' ability to move swiftly through urban areas. The emphasis on safety in the latter project has the potential to decrease bike accidents, substantially reducing health costs and human suffering. Those who depend on transit for access to jobs and activities will enjoy shorter bus rides.
- . **$E^{3:}$ Evaluating Equity in Evacuation: A Practical Tool and Two Case Studies** has the potential to save thousands of lives. It also develops methods that ensure that low-income residents won't literally be left behind in the event of a natural disaster.
- The project **Understanding Access to Grocery Stores in Food Deserts in Baltimore City** contributes to improved health by providing an accurate metric to measure access to fresh, healthy food. The results of the study will be used to develop a partnership with a transportation company to provide grocery store access, and governments can use it to entice grocers.

5. CHANGES/PROBLEMS

5.1. Changes in approach and reason for change?

Nothing to report.

5.2 Actual or anticipated problems or delays and actions or plans to resolve them

Nothing to report.

5.3 Changes that have a significant impact on expenditures

Nothing to report.

5.4 Significant changes in use or care of animals, human subjects and/or biohazards

Nothing to report.

5.5 Change of primary performance site location form that originally proposed

Nothing to report.

5.6 Additional information regarding products or impacts

Nothing to report.

6. SPECIAL REPORTING REQUIREMENTS

There are no special reporting requirements at this time.