Semi-Annual Progress Report No. 4 – Urban Mobility & Equity Center

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	Morgan State University (Lead Institution) *Virginia Polytechnic Institute and State University* *University of Maryland*
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Signature:

1. **ACCOMPLISHMENTS.**

What was done? What was learned?

1.1 What are the major goals and objectives of the program?

The major goal of UMEC is to further urban mobility of people and goods in a safe, environmentally sustainable, and equitable manner and formulate new technologies, policies and practices aimed at mobility. An increasingly important facet of UMEC's research is investigating how automated and connected vehicles will enter the mix, and ensuring planners have the information they need as technology changes.

1.2 What was accomplished under these goals?

Below is a chart listing all 37 UMEC projects; 19 have been completed and are listed in green type. Final reports for these projects are available on our website, www.morgan.edu/umec, and they have been submitted to the appropriate databases. All proposals for projects are reviewed by at least three peers who score them on several attributes; those with the highest scores are chosen to receive funding.

Project Type/ University	**Project Name**	**PIs**
Collaborative – UMD, MSU	EQUITABLE COMPLETE STREETS: Data and Methods for Optimal Design Implementation	Cinzia Cirillo, Mansoureh Jeihani, Paul Schonfeld
Collaborative – VT, MSU	Integrated Optimization of Vehicle Speed Control and Traffic Signal Timing: System Development and Testing	Hao Chen, Hesham Rakha, Mansoureh Jeihani
Collaborative – VT, MSU	Bicyclist Longitudinal Motion Modeling	Hesham Rakha, Karim Fadhioun, Mansoureh Jeihani
Collaborative – MSU, UMD	A Comparative Study of Pedestrian Crossing Behavior and Safety in Baltimore and Washington, D.C., Using Video Surveillance	Celeste Chavis, Kofi Nyarko, Cinzia Cirillo
Core-UMD	Multi-depot and Multi-school bus Scheduling Problem with School Bell Time Optimization	Ali Haghani
Core-UMD	Adoption and Diffusion of Electric Vehicles in Maryland	Cinzia Cirillo
Core-MSU	The Effect of COVID-19 on Mobility and Equity: A Case Study on Transit Users in Baltimore, MD	Mansoureh Jeihani, Celeste Chavis
Core-VT	Estimating Traffic Stream Density Using Connected Vehicle Data	Hesham A. Rakha, Hossam M. Abdelghaffar

Core-VT	A Study of the Impact of Ridesharing on Public Transit Ridership	Hesham Rakha, Jianhe Du
Core-UMD	Optimized Development of Urban Transportation Networks 2.0	Paul Schonfeld
Core-UMD	How Mobility and Accessibility Affect Crime Rates: Insights from Mobile Device Location Data	Lei Zhang
Collaborative –UMD, MSU	Equity in Accessibility to Opportunities: Insights, Measures, and Solutions based on Mobile Device Location Data	Lei Zhang
Collaborative – VT, MSU	Investigating the Effect of Connected Vehicles (CV) Route Guidance on Mobility and Equity	Mansoureh Jeihani, Ali Haghani, Anita Jones
Collaborative – UMD, MSU	E-Bikes Effect on Mode and Route Choice: A Case Study of Richmond, Va., Bikeshare	Celeste Chavis, Vanessa Frias-Martinez
Collaborative – VT, MSU	Developing and Testing an Advanced Hybrid Electric Vehicle Eco-Cooperative Adaptive Cruise Control System at Multiple Signalized Intersections (Short title: EcoCACC for HEVs)	Hao Chen, Hesham Rakha, Mansoureh Jeihani
Core – MSU	Developing Optimal Peer-to-Peer Ridesharing Strategies	Young-Jae Lee, Amirreza Nickkar
Core – VT	Energy Efficient Transportation Modeling	Hesham Rakha
Core – MSU	Demand Responsive Delivery of Food in Baltimore City Food Deserts	Young-Jae Lee, Hyeon-Shic Shin, Richard Pitts
Core – MSU	Optimal Automated Demand Responsive Feeder Transit Operation and Its Impact	Young-Jae Lee, Amirreza Nickkar

Core – UMD	Dynamic (Time Dependent) Green Vehicle Routing Problem	Ali Haghani, Golnush Masghati Amoli, Moschoula Pternea
Core – UMD	Evaluating Equity Issues for Managed Lanes: Methods for Analysis and Empirical Results	Cinzia Cirillo
Core – MSU	Investigating the Impact of Distracted Driving Among Different Socio-Demographic Groups (formerly Hands on Wheel, Eyes on Road)	Mansoureh Jeihani
Core – VT	Traffic State Prediction: A Traveler Equity and Multi-model Perspective	Hesham Rakha
Core – VT	Development of Multimodal Traffic Signal Control	Hesham Rakha Kyoungho Ahn
Core – MSU	Understanding Access to Grocery Stores in Food Deserts in Baltimore City	Celeste Chavis, Anita Jones
Core – UMD	Optimized Development of Urban Transportation Networks	Paul Schonfeld
Collaborative – UMD, MSU	Optimization of Emergency Traffic Patrols (ETP) Operations	Ali Haghani, Mansoureh Jeihani
Collaborative – VT, MSU	Developing and Testing an ECO-Cooperative Adaptive Cruise Control System for Buses	Hesham Rakha, Hao Chen, Mansoureh Jeihani
Core – MSU	Driver's 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 Parameters Estimation	Mansoureh Jeihani
Core – VT	Developing a Connected Vehicle Transit Signal Priority System	Kyoungho Ahn, Hesham Rakha, Hossam Abdelghaffar

Collaborative – MSU, UMD	Innovative Methods for Delivering Fresh Foods to Underserved Populations	Hyeon-Shic Shin, Young-Jae Lee, Paul Schonfeld
Collaborative – MSU, UMD	Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts	Celeste Chavis, Cinzia Cirillo
Core – MSU	Sustainable Design of Concrete Bus Pads to Improve Mobility in Baltimore City	Mehdi Shokouhian , Kadir Aslan
Core – UMD	Managing the Impacts of Different CV/AV Penetration Rates on Recurrent Freeway Congestion from the Perspective of Traffic Management	Gang-Len Chang
Collaborative – UMD, MSU	E3: Evaluating Equity in Evacuation: A Practical Tool and A Case Study	Cinzia Cirillo, Celeste Chavis
Collaborative – VT, UMD	Developing an Eco-Cooperative Adaptive Cruise Control System for Electric Vehicles	Hao Che Hesham Rakha, Cinzia Cirillo
Collaborative – VT, MSU	Improving Public School Bus Operations: Boston Case Study	Youssef Bichiou, Hesham Rakha Young-Jae Lee, William Eger

1.3 How have the results been disseminated?

When projects are complete, the reports are submitted to various databases and posted online. We also email a one-page fact sheet summarizing research to 510 people, including researchers, elected officials and journalists. We also email an annual newsletter to the same list.

As a result of receiving one such fact sheet, an official from a Maryland state agency contacted Dr. Jeihani about conducting research together.

We also received this response from a fact sheet in May:

> Thank you and your fellow professionals at the Consortium for this important work. As the Delegate represents portions of Anne Arundel County and chairs the Public Health and Minority

Health Disparities Subcommittee of the House Health and Government Operations Committee, she has acute interest in this research. The Delegate looks forward to discussing the findings with her State Delegation colleagues and with the County Executive's key staff.

Respectfully,

Gail Wegner, a proud Anne Arundel County resident

Chief of Staff

Office of Delegate Joseline Peña-Melnyk

A day of webinars on Aug. 6, 2020, attended by 29 people, featured four research projects presented by four UMEC principal investigators; links to these four webinars are under the outputs section.

As detailed later in this report, UMEC research also regularly appears in professional journals and is presented at conferences.

The Baltimore Sun highlighted one of UMEC's workforce development programs, the MDOT/MSU Graduate School Internship Program, in a special education editionn edition on April 24, 2020.

An op-ed written by Dr. Celeste Chavis addressing proposed cuts to public transit is an excellent example of how UMEC researchers are part of the conversation on transportation issues and influence public policy.

https://www.baltimoresun.com/opinion/op-ed/bs-ed-op-0910-baltlimore-mta-cuts-20200910-jgsgdysq6vdt3mdzndgzhpexzm-story.html

Dr. Chavis, identified as being from UMEC, was also part of a radio show addressing the cuts and the need for a regional transportation authority:
https://www.wypr.org/post/baltimores-transit-could-see-more-cuts?fbclid=IwAR1bFEEyJ9YvwfELkA5nDbKbhj9uXRoKey8SoGhBJYnjCxC3v_UBt3yyEzw

It is worth noting that the Maryland Transit Agency has since reversed its position on these cuts.
https://www.baltimoresun.com/politics/bs-md-pol-mta-cuts-opposition-20200930-o7cgncyzybarhdpyfuiptfcipu-story.html?utm_source=onesignal&utm_medium=notification&utm_campaign=2020-09-30-MTA-cancels-bus

Dr. Chavis also was chosen as the recipient for the 2020-2021 Iva G. Jones Medallion. One of the highest honors granted to Morgan faculty, this award recognizes excellence across the areas of teaching, research, service, leadership and character.

The arrival of a bike simulator, which will be used for UMEC research, was featured in Traffic Technology Today:

https://www.traffictechnologytoday.com/news/safety/morgan-state-university-installs-new-cycling-simulator-to-research-safety.html

1.4 What do you plan to do the next reporting period to accomplish these goals?
UMEC's researchers will continue working on the 18 ongoing projects, and UMEC's director will solicit another round of proposals for fifth-year funding early next year. Researchers will be expected to present and publish their results, and UMEC staff will assist in promoting the research outcomes.

2. PARTICIPANTS AND COLLABORATING ORGANIZATIONS. Who has been involved?

What organizations have been involved as partners?

Maryland Department of Transportation – Maryland Motor Vehicle Administration – Maryland Highway Safety Office provided funding for research into distracted driving for **Investigating the Impact of Distracted Driving Among Different Socio-Demographic Groups**.

MDOT also is a partner in the MDOT/MSU Graduate School Internship Program, which is highlighted under workforce development.

Seoul National University is a partner for the project **Developing Optimal Peer-to-Peer Ridesharing Strategies.**

Boston Public Schools and Baltimore County Public Schools collaborated on **Improving Public School Bus Operations Boston and Baltimore County Public Schools**.

Maryland Department of Transportation – State Highway Administration is an in-kind contributor to **Investigating the Effect of Connected Vehicles (CV) Route Guidance on Mobility and Equity**.

The SHA also has been identified as a potential user of and collaborator for **Optimized Development of Urban Transportation Networks**. Also involved in this project were the Appalachian Regional Council, Pennsylvania State University and North Carolina State University.

Maryland Department of Transportation – Maryland Transit Administration has provided in-kind time and data for **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts**.

The City of Richmond is collaborating and providing in-kind support and data for **E-Bikes Effect on Mode and Route Choice: A Case Study of Richmond, Va., Bikeshare**.

Bewegen, a private company in Quebec, Canada, is collaborating and providing in-kind support and data.

Quality Counts has provided data collection services using drones.

Have other collaborators or contacts been involved?

The Maryland Transportation Authority approved Morgan State University as an approved provider for employees who want to continue their education.

As a result of her research into electric vehicles and Complete Streets, Dr. Cinzia Cirillo has taken part in the discussions following the SAFE rule and has been in conversation with the Attorney State General of California.

Dr. Young-Jae Lee is an Associate Editor for the KSCE Journal of Civil Engineering as well as for Urban Rail Transit. He also serves on the TRB Standing Committee on Automated Transit Systems (AP040) and is a member of the SAE International Shared and Digital Mobility Committee as well as being a member of the Maryland Strategic Highway Safety Plan and the Maryland CAV working group.

Dr. Paul Schonfeld is also an Associate Editor for Urban Rail Transit.

Dr. Celeste Chavis is a:

- Member, Transit Research Analysis Committee (TRAC), Transportation Research Board, 2018 – Present (national)
- Member, Federal Highway Administration (FHWA) Transportation Innovation Education Stakeholders (TIES), 2020 – Present (national)
- Board Member, Central Maryland Transportation Alliance, 2018 – Present (regional)
- Member, Complete Streets Equity Workgroup, Baltimore City Department of Transportation, 2017-2019 (regional)
- Board Member, Public Advisory Committee (PAC) of the Baltimore Regional Transportation Board (BRTB), 2017 – Present (regional)
- Member, Innovative Public Transportation Services and Technologies Committee, Transportation Research Board, 2020 – Present (national)

Dr. Mansoureh Jeihani is chair of Strategy 3 for the Highway Safety Strategic Plan. She is also a member of the Transportation Research Board committee on Artificial Intelligence and Advanced Computing Applications as well as the editorial board of the Journal of Traffic and Logistics Engineering.

Morgan State doctoral student Amirreza Nickkar is on the Public Transport Committee of the American Society of Civil Engineers.

The Intelligent Transportation Society of Maryland awarded a scholarship to graduate student and UMEC researcher Nashid Khadem.

3 OUTPUTS: What new research, technology or process has the program produced?

A new output this year was hosting a day of webinars which featured four of our research projects. The four webinars are now available online:

https://www.youtube.com/watch?v=JfBq30ELEok

https://www.youtube.com/watch?v=HvvLzdqciQE

https://www.youtube.com/watch?v=nguYLA8XKZs

https://www.youtube.com/watch?v=MdHML76qadI

Other outputs from the last six months include:

- The project **Understanding Access to Food Deserts in Baltimore City** developed a novel food desert metric using CHAID decision trees. A new healthy food priority area measure was developed for Baltimore that deemed all residential areas where the median income of the census block group is less than $35,000 as food insecure. A prioritization matrix was developed based on the secondary factors of proximity to the nearest grocery store (at the half-mile threshold) and the number of stores within 3 miles. This measure found a significant difference in the frequency of grocery store visits as well as the quality of food for those who live in a food desert as opposed to those who do not.
- In response to climate change, more sustainable forms of transportation are being promoted, including cycling. This is especially critical for cities; by 2050, the urban population is expected to increase to 66% of the world's population. But tools, measures, and planning techniques need to be developed for cycling and multimodal trips. **Energy Efficient Transportation Modeling** developed a dynamics-based cycling acceleration model that captures cyclist aggressiveness, i.e., how they accelerate, for how long and what is their maximum power. Since riding a bike to a train makes sense, researchers also developed a continuous rail transit simulator (RailSIM) intended for multi-modal energy-efficient routing applications. RailSIM integrates sophisticated train dynamics and energy models to replicate train motion and energy consumption behavior, respectively.

- As part of the project **Developing an Eco-Cooperative Adaptive Cruise Control System for Electric Vehicles**, researchers conducted a stated choice experiment to discover how inclined drivers are to use such a system and calculate its potential market share. A pure cost-benefit analysis – the cost of an Eco-CACC system vs. its associated fuel savings – only favors the gasoline car, not the EV. But in a result that is critical for policy, the researchers discovered that people who buy EVs are likely to pay for Eco-CACC despite its negative cost-benefit outcome because of the improvements in environmental efficiency. This study informs industry stakeholders about the desirability of Eco-CACC from a consumer choice perspective, providing insights into their willingness to adopt it, along with its individual market segment penetration.

- The project **Improving Public School Bus Operations Boston and Baltimore County Public Schools** developed a system, including an advanced routing algorithm, that uses historical and real-time traffic data to predict the traffic state evolution over a short time horizon; the system is used to improve the quality of service in school buses to reduce tardiness caused by transportation.

- **Investigating the Effect of Connected Vehicles (CV) Route Guidance on Mobility and Equity** has developed base traffic simulation models of a real study area in Baltimore, Maryland, for AM and PM peak conditions. These models eventually will help transportation policy makers adopt CV technologies in a manner that achieves a fair transportation system that serves diverse users equally.

- The project **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** created an index to identify potentially unsafe bike lanes in a network. It also developed a database of bike facilities that includes the following data for each bike facility roadway segment: facility type, AADT, bus frequency, number of crashes, roadway speed, Video Data Collection via Drones.

- Researchers are writing the final report for **Developing Optimal Peer-to-Peer Ridesharing Strategies**, which will find the optimal operation of the ridesharing system, providing incentives to ridesharing providers and ridesharing receivers. Eventually, this research can be a foundation for future ridesharing service implementation; at his point on a 1-to-10 technology readiness scale it is a 6.

- **Developing and Testing an Advanced Hybrid Electric Vehicle Eco-Cooperative Adaptive Cruise Control System at Multiple Signalized Intersections** developed the HEV Eco-CACC model using HEV energy consumption and vehicle dynamics models. To develop it, researchers implemented and tested the proposed HEV Eco-CACC controller using the INTEGRATION software and conducted tests using a driving simulator; they conducted data analysis using data collected from simulation software.

- **The Impact of Ridesharing on Public Transit Ridership** will create and employ methodologies that answer the research question in the title, accounting for the spatial and temporal attributes of the data. One output will be a process that can be repeated and innovated upon to further the study of the relationship between public transit and ride-hailing operations; another will be a manual outlining the methodologies used in a step-by-step format for reuse. This project also will compile a dataset containing the transit-equivalent routes for each ride-hailing trip. The transit-equivalent route dataset contains LOS trip characteristics such as walk time, total travel time, estimated fare, and number of transfers.

3.1 Publications, conference papers and presentations

The following projects will be presented at the 2021 TRB Annual Meeting in Washington, D.C.:

- Khadem, Jeihani, Abujana, Kabir, "Drivers' Reaction to Connected and Automated Vehicle Safety Applications in the Vicinity of a Work Zone: A Driving Simulator Study"
- Nickkar, Amirreza and Young-Jae Lee, "Developing an Optimal Integrated Single Framework Algorithm for the Multi-Level School Bus Network Problem"
- Nickkar, Amirreza and Young-Jae Lee, "Optimal Dynamic Demand Responsive Feeder Bus Network Design for a Short Headway Trunk Line"
- Chavis, Celeste, Jones, Anita, "Understanding Access to Grocery Stores: A Data-Driven Food Desert Metric Using CHAID Decision Tree Analysis"
- Chavis, Celeste, Cirillo, Cinzia, "Multi-Modal Traffic Flow in Shared Bus-Bike Lanes: A Scoping Literature Review and Comparison with Baltimore SBBL Infrastructure."
- Bayrak, M., Guler, S. I. and Schonfeld, P. "Implementation Sequence Optimization for Dedicated Bus Lane Projects"
- Wu, F., Schonfeld, P. and Kim, M. "Optimized Restoration Sequence for Disrupted Freight Rail Network."

Presented at the 2020 TRB meeting but not previously reported was:

- Raleigh, C., Kim, M. and Schonfeld, P. "Optimization of Service Zones and Frequencies for Freight Deliveries."

UMEC researchers presented projects elsewhere:

- Abdelghaffar, Hossam M, Ahn, Kyoungho and Rakha, Hesham A, "Developing an Adaptive Connected Vehicle Transit Signal Priority Control System", in IEEE 23th International Conference on Intelligent Transportation Systems (ITSC), Sep 2020.
- Nickkar, Amirreza, Young-Jae Lee, and Mana Meskar, "Sensitivity Analysis for the Optimal Automated Demand Responsive Feeder Transit System," 17th International Conference on Automated People Movers and Automated Transit Systems (APM-ATS 2020), June 2020
- Nickkar, Amirreza and Young-Jae Lee," Resource-constrained Automated Demand Responsive Feeder Transit System Project Scheduling Using Metaheuristics," ASCE ICTD 2020, Seattle, WA, May 2020
- Dadvar, Seyedehsan, Celeste Chavis, Young-Jae Lee, "Classification and Analysis of Bicycle and Pedestrian Crashes in Washington, DC," ASCE ICTD 2020, Seattle, WA, May 2020
- Dr. Mansoureh Jeihani was a presenter on April 8, 2020, in the Maryland Department of Transportation's Highway Safety Seminar Series. She presented her research into distracted and impaired driving, conducted as part of the UMEC project **Investigating the Impact of Distracted Driving Among Different Socio-Demographic Groups**, and discussed the use of technology in research, prevention and outreach.
- Multi-Modal Traffic Flow in Shared Bus-Bike Lanes: A Scoping Literature Review and Comparison with Baltimore SBBL Infrastructure was to have been

presented at the ITE Mid Atlantic Conference, but it was canceled due to COVID-19.

- Two papers based on two UMEC projects were published at ASCE conference proceedings:
    - Distracted Driving Prediction Model Using a Bayesian Network Approach
    - Developing and Testing an Eco-Cooperative Adaptive Cruise Control System for Buses

3.2 Journal publications

The project is in boldface type before the citation.

- **Driver's 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 Parameters Estimation.** "Influence of red-light violation warning systems on driver behavior – a driving simulator study," Traffic Injury Prevention, Volume 21, 2020, Issue 4. https://www.tandfonline.com/doi/full/10.1080/15389588.2020.1744135
- **Estimating Traffic Stream Density Using Connected Vehicle Data.** Aljamal M.A., Abdelghaffar H.M., Rakha H.A., Estimation of Traffic Stream Density Using Connected Vehicle Data: Linear and Nonlinear Filtering Approaches. Sensors. 2020; 20(15):4066. https://doi.org/10.3390/s20154066
- **Optimal Automated Demand Responsive Feeder Transit Operation and Its Impact.** Lee, Young-Jae, Amirreza Nickkar, Seyedehsan Dadvar and Mana Meskar, "Impact of Automation on Demand Responsive Feeder Transit Network Design," International Journal of Urban Planning and Smart Cities, Volume 2, Issue 1, Article 3, 2021, Accepted
- Choi, Youngmin, Paul M. Schonfeld, Young-Jae Lee and Hyeon-Shic Shin, "**Innovative Methods for Delivering Fresh Food to Underserved Populations,**" ASCE Journal of Transportation Engineering, Accepted
- **Developing an Eco-Cooperative Adaptive Cruise Control System for Electric Vehicles**. Hao Chen and Hesham Rakha (2020). "Battery Electric Vehicle Eco-Cooperative Adaptive Cruise Control in the Vicinity of Signalized Intersections." Energies, 13(10), 2433, May 2020, DOI: 10.3390/en13102433.
- **Energy Efficient Transportation Modeling.** Wang J, Rakha H. Empirical study of effect of dynamic travel time information on driver route choice behavior, June 2020, Sensors 20(11), DOI: 10.3390/s20113257.
- **Traffic State Prediction: A Traveler Equity and Multi-modal Perspective.** Almannaa, M., Elhenawy, M., Masoud, M., and Rakha H. A New Mathematical Approach to Solve Bike Share System Station Imbalances Based On Portable Stations, 2019 IEEE Intelligent Transportation Systems Conference - ITSC, Oct. 2019, DOI: 10.1109/ITSC.2019.8916876.
- **Energy Efficient Transportation Modeling.** Jinghui Wang, Ahmed Ghanem, Hesham, Jianhe Du, "A Rail Transit Simulation System for Multi-modal

Energy-efficient Routing Applications," International Journal of Sustainable Transportation, 1-16, 13 Mar 2020, DOI: 10.1080/15568318.2020.1718809.

3.3 Books or other non-periodical one-time publications

Nothing to report.

3.4 Websites or other Internet sites

www.morgan.edu/umec The website had 2,735 visitors in the first three quarters of 2020 and a total of 7,039 page views. After the home page, the research pages continue to be the most popular.

www.facebook.com/urbanmobilityandequitycenter We have 104 followers; our most popular post in the last six months was viewed 233 times. Here is an example of a post promoting our research that featured drone video/ https://www.facebook.com/TransportationMSU/videos/559083554682384

Twitter @UMEC research). We have 56 followers and our tweets average 985 impressions per month; impressions are the number of times users saw the tweet. Seven tweets were retweeted.

Instagram: ntcumec (https://www.instagram.com/ntcumec/). UMEC now has 50 followers on Instagram. However, since this is a platform for pictures and we have been working remotely with no events to take pictures of, we have not used Instagram much these past few months.

You Tube: We have a YouTube Channel.
https://www.youtube.com/channel/UCQ4GSAlNdKTKz6qhWqH1hQA
Our most recent additions were the four webinars, noted under Outputs.

3.5 Technologies or techniques

Morgan State University was able to add a bicycle simulator to its Safety and Behavioral Analysis Center; the bicycle simulator can be integrated with the two existing driving simulators to study interactions between cars and bicycles. When research resumes on campus, it will be ready.

Other technologies and techniques include:

- Two algorithms, one for a single signalized intersection and one for multiple intersections, were developed as part of **Developing**

an Eco-Cooperative Adaptive Cruise Control System for Electric Vehicles.

- An advanced routing algorithm, part of **Improving Public School Bus Operations Boston and Baltimore County Public Schools**, serves three different levels of schools – elementary, middle and high schools – in a single framework, making it a more realistic routing algorithm.

- The proposed HEV Eco-CACC system in **Developing and Testing an Advanced Hybrid Electric Vehicle Eco-Cooperative Adaptive Cruise Control System at Multiple Signalized Intersections** will be the first eco-driving system that uses HEV energy consumption and vehicle dynamics models; on a technology readiness scale of 1 to 10, it is an 8.

- **The Impact of Ridesharing on Public Transit** developed a two-part (ArcGIS/Matlab) methodology to spatially analyze the extent to which a ridesharing trip is replaced by transit. The project also developed new methodologies to analyze the research question through source data, rather than employing empirical studies (stated- and revealed-preference surveys). These methods combine GTFS data with source data in ArcGIS to determine the real-time equivalent transit trip.

- The project **Estimating Traffic Stream Density Using Connected Vehicle Data**, which developed a Kalman filter (KF) approach to estimate the total number of vehicles on an Isolated Intersection using CV data, also developed an adaptive KF (AKF) to dynamically estimate the error values in the state and measurement estimates as well as an AKF with a neural-network (AKFNN) approach. This project also will develop a nonlinear machine learning technique to estimate the LMP of CVS.

- Although it is in the early stages, **Adoption and Diffusion of Electric Vehicles in Maryland** is trying to integrate economic concepts into transportation modeling; that technique will also be used for **EQUITABLE COMPLETE STREETS: Data and Methods for Optimal Design Implementation**.

- **A Comparative Study of Pedestrian Crossing Behavior and Safety in Baltimore and Washington, DC, Using Video Surveillance** implemented pretrained YOLOv3 (You Only Look Once) Deep Neural Network using ImageAI (a python library which supports state-of-the-art machine learning algorithms) on video footage of pedestrians and achieved a higher level of accuracy and implemented another state-of-the-art pretrained model called RetinaNet.

3.6 Inventions, patent applications and/or licenses

To date, UMEC research has resulted in five provisional patent applications, one of which has just filed the final paperwork to become a utility patent (U.S. Patent Application No. 17/017,084). A sixth provisional patent is in the works.

4 OUTCOMES. What outcomes has the program produced? How are the research outputs described in section 3 above being used to create outcomes?

UMEC has consistently met the goals it set for developing new technologies and techniques and promoting their availability and use.
Outcomes for the last six months include:

- The test results in the project **Developing an Eco-Cooperative Adaptive Cruise Control System for Electric Vehicles** indicate that the energy-optimum solution for BEVs differs from that for internal combustion engine vehicles (ICEVs), demonstrating the need for vehicle-tailored optimum trajectories. The simulation tests demonstrate that using the BEV Eco-CACC MS algorithm, developed as part of this research, to pass multiple intersections produces up to 11% energy savings.

- Though the existence of food deserts are well known among researchers, there is a lack of consensus on how food deserts are defined and identified. The project **Understanding Access to Food Deserts in Baltimore City** surveyed 573 Baltimore City residents, providing an in-depth analysis of individual grocery store choice and travel decisions. The study found that most people grocery shopped 2-4 times in a given month and at 2-3 different grocery stores; the choice of the store depends on the items purchased. In evaluating food desert metrics, two common assumptions are made: (1) trips originate from home and (2) people shop at the nearest store. This study found that the second assumption does not hold as an overwhelming percentage of those surveyed (77%) do not shop at their nearest grocery store. This is key information when addressing the problem of food deserts, resulting in the City of Baltimore initiating a partnership with the ride-hailing service Lyft to address the issue.

- The cyclists dynamics and RailSIM models developed as part of the project **Energy Efficient Transportation Modeling** give planners new tools that can be implemented when developing multimodal routes.

- The project **Improving Public School Bus Operations Boston and Baltimore County Public Schools** considers the maximum Degree of Circuity for all individual students, requiring them to be within a certain travel circuity to improve service. Lengthy travel time on the bus, even when students live fairly close to the school, is a major complaint among parents.

- **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** will provide understanding of the differences between vehicle-cyclist and vehicle-scooter interactions on shared facilities.

- When completed, **E-Bikes' Effect on Mode and Route choice: A Case Study of Richmond, VA, Bikeshare** will determine if e-bikes provide additional mobility by eliminating some physical limitation to riding a bike, creating a more comfortable and safer experience for riders, and these results will inform local

jurisdictions about the potential benefits of including e-bikes in bike-sharing fleets.

- Although it is not yet complete, the project **A Comparative Study of Pedestrian Crossing Behavior and Safety in Baltimore and Washington, DC, Using Video Surveillance** will understand the microscopic behavior of pedestrians and critical factors affecting pedestrian behavior, examine the compliance to traffic laws of pedestrians and drivers, and determine common causes of unsafe maneuvers and near-misses involving pedestrians.

5. IMPACTS. What is the impact of the programs/ How has it contributed to improve the transportation system: safety, reliability, durability, etc.; transportation education; and the workforce?

UMEC continues to impact the areas reflected in its core mission, improving mobility and fuel consumption, and examining the equity of transportation systems. Impacts for the last six months include:

- The project **Energy Efficient Transportation Modeling** provides information needed to develop systems that reduce dependency on single-occupant cars, a step that is critical for reducing climate change.

- **ECO-CACC for EVs** is the latest in a series of projects to develop tools that allow the Eco-CACC concept to be expanded to all vehicles. This research discovered that Eco-CACC systems can improve the fuel efficiency of even already-efficient vehicles. This project also had some important insights for marketers; for example, it discovered through a stated choice experiment that even though such a system is not cost-effective on an EV, EV owners still were willing to embrace it for that improvement in fuel efficiency.

- The project **Improving Public School Bus Operations Boston and Baltimore County Public Schools** gives school system officials a much more realistic way to generate school bus routings, taking into account that buses need to serve three levels of schools, contend with traffic, and not keep students on board for unduly long periods of time.

- The data-driven yet simplistic methodology presented in **Understanding Access to Food Deserts in Baltimore City** can be replicated to other municipalities; developing an accurate method of prioritizing areas for investments to reduce food disparities is vital to address the prevailing systemic divestiture of resources on communities.

- Scooters and cyclists are vulnerable roadway users. Limited roadway space has resulted in cities creating shared bus-bike facilities to accommodate cyclist and mass transportation. By separating buses and bikes from general traffic, sustainable modes of transportation are promoted. However, it is not clear if this

accommodation puts cyclists in harm's way. **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** will examine that and provide design recommendations.

- **The Impact of Ridesharing on Public Transit Ridership** will provide transit agencies and ride-hailing services with insight into overlap and discontinuities between the two services. Only the City of Chicago has implemented legislation requiring that ride-hailing services report trip data; other cities may find that in doing so deeper internal exploration can be executed to better their public transit operations and initiate collaboration with ride-hailing services.

- The developed real-time estimation model for estimating the number of vehicles on signalized approaches using CV data, developed for **Estimating Traffic Stream Density Using Connected Vehicle Data**, will be applicable in improving the design and operations of transportation systems, which helps planners to develop an efficient adaptive traffic signal controller. The estimate outcomes can be provided to traffic signal controllers to optimally determine the allocation of green time for each traffic signal phase, leading to better intersection performance measures.

- Although it is in the early stages, **The Effect of COVID-19 on Mobility and Equity: A Case Study on Transit Users in Baltimore, MD** will provide information on the role and ridership of public transit during the pandemic; this is an important equity issue for those who depend on public transportation to access jobs and services.

- As Complete Streets are increasingly adopted nationwide, the project **EQUITABLE COMPLETE STREETS: Data and Methods for Optimal Design Implementation**, which began last month, will optimize the allocation of space on Complete Streets.

5.1 What is the impact on the adoption of new practices, or instances where research outcomes have led to the initiation of a start-up company?

Nothing to report.

5.2 What is the impact on the scientific body of knowledge?

- Considering three levels of schools in three separate time windows in a single framework to optimize routing is a contribution of **Improving Public School Bus Operations Boston and Baltimore County**.

- **The Impact of Ridesharing on Public Transit Ridership** is, to the best of the researchers' knowledge, the only research that approaches the research question through real-time spatial analyses.

5.3 What is the impact on transportation workforce development?

All of these projects give students an opportunity for meaningful involvement in the research. A few notable examples:

- The project **Investigating the Effect of Connected Vehicles (CV) Route Guidance on Mobility and Equity** provided the opportunity to learn one of the most sophisticated microsimulation tools, Aimsun, to perform traffic micro modelling to replicate the impact of connected vehicles in a shared environment.

- A graduate student working on **The Impact of Ridesharing on Public Transit Ridership** has expanded her knowledge of ArcGIS and learned new programs and problem-solving skills.

- The developed approach in **Estimating Traffic Stream Density Using Connected Vehicle Data** can be used as a teaching material in transportation engineering courses.

6 CHANGES/PROBLEMS.

6.1 Changes in approach and reasons for change.

The project **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** expanded its scope to include how scooters use the shared bus/bike lanes since they recently have become a popular form of transportation and riders use the shared lanes.

Outreach activities associated with projects are not feasible in a pandemic; at this point recruiting in-person participation – i.e., to drive the simulator – is on hold.

6.2 Actual or anticipated problems or delays and actions or plans to resolve them.

The Morgan State University campus remained closed this fall as students attended virtually. Because of COVID-19, researchers were unable to guarantee the safety of research subjects in the simulation lab or the graduate students collecting the data. All such participatory research has been suspended until the campus re-opens, which will not be until at least early 2021.

Due to the financial fallout from the coronavirus, the State of Maryland instituted a hiring and spending freeze. This necessitated canceling the 2020-2021 MDOT/MSU Graduate School Internship Program since these are paid internships. The 2019-2020 MDOT/MSU interns were able to finish the year-long program with the last few months done remotely. MDOT initiated a pilot online program for 2020-2021, and one Morgan student is participating, although the internship is unpaid.

We were not able to hold our National Summer Transportation Institute – a summer program for high school students that exposes them to transportation concepts through field trips, hands-on projects and speakers – due to the virus. Plans are underway to design a virtual version of the program, in case the campus is not open next summer.

6.3 Changes that have a significant impact on expenditures.
Nothing to report.

6.4 Significant changes in use or care of human subjects, vertebrate animals, and/or biohazards.
To protect students, faculty and staff – as well as researchers and subjects – from exposure to the COVID-19 virus, the university campuses of all three schools in our consortium were closed through summer 2020. Morgan has remained closed for the fall. The University of Maryland is currently in Phase 2 of research activities, allowing 50 percent of researchers in its labs; a return to full research, Phase 3, will not happen until January 2021. Virginia Tech reopened its campus but only 7 percent of classes are in-person.

6.5 Change of primary performance site location from that originally proposed
Researchers worked from home via laptops, shared files and video conferencing tools.

7. SPECIAL REPORTING REQUIREMENTS

All of our completed research projects – indicated in green in the table at the beginning of this report – have been submitted to the following databases: research.hub@dot.gov, NTLDigitalSubmissions@dot.gov, TRIS-TRB@nas.edu, and the Transportation Library at Northwestern University, The Volpe National Transportation Systems Center, the Federal Highway Administration Research Library and the National Technical Information Service.

Research projects conducted in Maryland are also submitted to MD-SOAR, a statewide repository.