Semi-Annual Progress Report No. 3 – 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?

UMEC now has 28 projects, of which 15 have been completed. They offer new tools, systems and methods to address both long-standing problems such as routing and new technologies such as connected vehicles and infrastructure.

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 current UMEC projects; those in green are complete, and a final report is available on our website, www.morgan.edu/umec.

Achievements of completed projects, detailed later in this report, address issues of modeling and planning.

These projects also afford graduate and undergraduate students the chance to participate in meaningful research.

Project Type University	Project Name	PIs
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 (U. of Md.)
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	Z. Andrew Farkas, 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
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	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 the federal databases and posted online. We also email a one-page fact sheet summarizing the research to

approximately 526 people. As a result of receiving one such sheet, a reporter from the Baltimore Sun interviewed a UMEC researcher for a front-page story.
https://www.baltimoresun.com/ask/bs-ask-traffic-lights-20191015-ietjxqoqkngcvle6xywze65f2e-story.html
We also email an annual newsletter to the same list; the 2020 spring edition is available at
https://www.morgan.edu/school_of_engineering/research_centers/urban_mobility_and_equity_center/publications/newsletter.html.
As detailed later in this report, our research also appears in professional journals and is presented at conferences.

1.4 What do you plan to do the next reporting period to accomplish these goals?
We will continue to support researchers as they complete projects, and we will offer another round of funding for fourth-year core and competitive (collaborative) projects.

2 PARTICIPANTS AND COLLABORATING ORGANIZATIONS. Who has been involved?

2.1 What organizations have been involved as partners?
Maryland Department of Transportation – 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 continues to collaborate on **Improving Public School Bus Operations: Boston Case Study**, and Baltimore County Public Schools is participating as well, with advising and data.

A research scientist from the National Center for Smart Growth has collaborated in **E³: Evaluating Equity in Evacuation: A Practical Tool and Two Case Studies**.

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.

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.

2.2 Have other collaborators or contacts been involved?

Dr. Hyeon-Shic Shin and Dr. Andrew Farkas attended a meeting last fall with the Maryland Transportation Authority and presented research about the role of drones and AVs in moving freight.

Dr. Andrew Farkas attended the National Governors Association's electric vehicle workshop at the Maryland Department of Transportation in November. The meeting focused on developing policies the State of Maryland could pursue, especially ones that ensure utilities are ready to meet the surge in demand as more and more people adopt electric vehicles.

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.

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

Dr. Celeste Chavis serves on the Greater Washington Partnership Transit Oriented Development Task Force.

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 ADB50 (Transportation Planning Application), the Institute of Transportation Engineers (ITE), and 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.

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

In the past six months, we have posted six final reports on our website and submitted them to federal databases. PIs for ongoing projects reported improvements in technology readiness and some completed projects now offer tools that are ready to use.

Outputs from the last six months include:

- **Developing and Testing an ECO-Cooperative Adaptive Cruise Control System for Buse**s resulted in an Eco-CACC system for buses that reduced delays at intersections caused by heavy-duty vehicles.

- **Innovative Methods for Delivering Fresh Foods to Underserved Populations** optimized six methods for last-mile fresh food delivery systems to individuals living in food deserts. This study analyzed the costs and other factors, providing a valuable tool for choosing and designing delivery operations.

- The project **E3: Evaluating Equity in Evacuation: A Practical Tool and A Case Study** generated a synthetic population. In this study, the data from PUMA and census tract levels are combined with IRS data and used to generate the synthetic population, which to the best of authors' knowledge have not been consolidated before for population synthesis purposes.

- The proposed method developed in **Managing the Impacts of Different CV/AV Penetration Rates on Recurrent Freeway Congestion From the Perspective of Traffic Management: A Case Study of MD-100** will allow highway agencies to develop operational guidelines that will enable the traffic operators to properly coordinate with AV flows to make the best use of the roadway capacity and avoid any potential negative impacts of AVs. The collected measures of effectiveness from the experimental results clearly show that at each AV penetration level, there exists a set of optimal behavioral mechanisms for the AV flows to coordinate with non-AV flows to best use roadway capacity and minimize congestion.

- A new project just getting started **Investigating the Effect of Connected Vehicles (CV) Route Guidance on Mobility and Equity** examines CV route guidance systems. This project will develop and calibrate a microscopic traffic simulation that, unlike most previous studies, has a real-world medium urban road network. Different penetration rates of CVs (0% - 100%) will be developed, and the systemwide effects of CV-equipped vehicles with route guidance features on mobility and equity will be analyzed.

- **Improving Public School Bus Operations: Boston Case Study** developed two innovative contributions for the optimal algorithm. First, in order to consider the nature of the school bus operation, which contains multiple levels of schools in a single trip, multi-level optimization in one frame is proposed. Second, maximum travel circuity for each student is applied to improve the level of service for students. This research delivers a tool to BPS that accurately estimates the travel time on each individual link on the greater Boston area network, allowing BPS to efficiently plan bus trips and increase their on-time performance. This research makes two main contributions. The first is to consider three levels of schools in three separate time windows in a single framework to optimize the entire routing. Second, the algorithm considers the maximum Degree of Circuity (DOC) for all individual students, which makes all student trips within a certain travel circuity. Because lengthy travels for certain students have been one of the major complaints about school bus routing, it is believed that including the maximum DOC as a constraint of the algorithm can improve the level of service for some students.

- **Optimized Development of Urban Transportation Networks** developed methods for evaluating, selecting and scheduling improvement alternatives for urban transportation networks; as this research continues in a second phase it will develop a model for optimizing the development of rail transit lines while considering demand elasticity and financial factors. For the second phase, optimization methods will be developed for determining when rail transit networks and connected bus feeder routes should be introduced and how their operating characteristics such as service frequencies and fares should be designed. The objectives of the optimization methods will be to minimize total costs or maximize net benefits for urban public transportation systems. The first phase of this project garnered international attention.

- **Developing a Connected Vehicle Transit Priority System** developed an advanced decentralized transit signal priority (TSP) system using a cycle-free Nash bargaining (NB) signal control system. The system allows transit vehicles to use additional or alternative green time to clear the intersection by adjusting signal timing. TSP operations allow a transit vehicle to be promptly served, significantly reduce delay to prevent long waits at signalized intersections.

- The project **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** will create an index to identify potentially unsafe bike lanes in a network.

3.1 Publications, conference papers and presentations
  - https://technical.ly/baltimore/2019/11/18/lyft-affordable-rides-grocery-store-south-west-baltimore-neighborhoods/
  - https://www.baltimoresun.com/politics/bs-md-pol-lyft-grocery-access-20191118-6wf65ioac5dh5hwjcq3trxzmsm-story.html.

  - "A Statistical Approach to Synthetic Population Generation as a Basis for Carless Evacuation Planning" (20-0576 8) by Mohammad Nejad, Sevgi Erdogan, and Cinzia Cirillo, presented at the 99th TRB Annual Meeting, Washington, D.C., January 2020.

  - Ahangari, A., Jeihani, M., Rahman, M.R., Dehzangi, A. "Predicting Driving Distraction Patterns in Different Road Classes Using Support Vector Machine," *99th Transportation Research Board Annual Meeting*, Washington, D.C., January 12-16, 2020.

  - Ahangari, A., Jeihani, M., Rahman, M.R., Dehzangi, A. "Enhancing Distraction Prediction Model Performance Using Random Forest Classifier," *99th Transportation Research Board Annual Meeting*, Washington, D.C., January 12-16, 2020.

  - Ahangari, A., Jeihani, M., Nickkar, A., Chavis, C., Jones, M. "Prediction Model of Commercial Motor Vehicle (CMV) Crash Severity in Maryland, Applying Support Vector Machine Classification," *99th Transportation Research Board Annual Meeting*, Washington, D.C., January 12-16, 2020.

- Ahangari, A., Jeihani, M., Salahshour, B., Ndegwa, M. "A Comprehensive Analysis of Distracted Driving using a Driving Simulator," *99th Transportation Research Board Annual Meeting*, Washington, D.C., January 12-16, 2020.

- "A Rail Simulation System for Multi-Modal Eco-routing Applications" was presented at the Transportation Research Board 98th Annual Meeting last year.

- The findings from **Developing a Connected Vehicle Transit Signal Priority System** have been submitted to the 2020 IEEE Intelligent Transportation Systems Conference (ITSC).

- **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** was to have been presented at the ITE Mid-Atlantic Conference but the event was canceled due to COVID-19.

- The six graduate students pictured below were each awarded $1,000 to attend the 38th Annual Lifesavers National Conference on Highway Safety Priorities. They are all studying transportation and involved in UMEC research, except Dr. Snehanshu Banerjee (second from left) who just graduated in December with his Ph.D. in transportation. Unfortunately, due to the COVID-19 virus, the conference was canceled. You can read about them here: https://news.morgan.edu/2020-lifesavers/

3.2 Journal publications
The following publications resulted from the project **Traffic State Prediction: A Traveler Equity and Multi-modal Perspective**:
- Almannaa M., Elhenawy M., and Rakha H. (2019) "Dynamic Linear Models to Predict Bike Availability in a Bike Sharing System," International Journal of Sustainable Transportation, Volume 14, 2020 - Issue 3.
- Ashqar, H., Elhenawy M., and Rakha, H. (2019). "Modeling Bike Counts in a Bike-Sharing System Considering the Effect of Weather Conditions," Case Studies on Transport Policy (DOI: 10.1016/j.cstp.2019.02.011).

The project **Development of Multimodal Traffic Signal Control** produced the following publications:

- Abdelghaffar H. and Rakha H. (2019), "A Novel Decentralized Game-Theoretic Adaptive Traffic Signal Controller: Large-Scale Testing," Sensors (DOI: 10.3390/s19102282).
- Abdelghaffar H. and Rakha H. (2019), "Development and Testing of a Novel Game
- Theoretic De-Centralized Traffic Signal Controller," IEEE Transactions on Intelligent Transportation Systems (DOI: 10.1109/TITS.2019.2955918).
- AlHadidi T. and Rakha H. (2019), "Modeling bus passenger boarding/alighting times: A stochastic approach," Transportation Research Interdisciplinary Perspectives (DOI: 10.1016/j.trip.2019.100027).
- Calle-Laguna A., Du J., and Rakha H. (2019), "Computing optimum traffic signal cycle length considering vehicle delay and fuel consumption," Transportation Research Interdisciplinary Perspectives (DOI: 10.1016/j.trip.2019.100021).

The following publications are a result of the project **Energy Efficient Transportation Modeling**:

- Fadhloun K. and Rakha H. (2019), "A Novel Vehicle Dynamics and Human Behavior Car-Following Model: Model Development and Preliminary Testing," International Journal of Transportation Science and Technology (DOI: 10.1016/j.ijtst.2019.05.004)
- Loulizi A., Bichiou Y., and Rakha H. (2019), "Use of Life Cycle Cost Analysis and Multiple Criteria Decision Aid Tools for Designing Road Vertical Profiles," Sustainability (DOI: 10.3390/su11247127).
- Wang J., Ghanem A., Rakha H.A., and Du J. (2020), "A Rail Transit Simulation System for Multi-modal Energy-efficient Routing Applications," International Journal of Sustainable Transportation. https://doi.org/10.1080/15568318.2020.1718809.

The project **Optimized Development of Urban Transportation Networks**, which had three previous journal articles noted in the last semi-annual progress report, resulted in the following publication:

- Peng, Y., Li, Z. and Schonfeld P. "Optimal Development of Rail Transit Networks over Multiple Periods," accepted for *Transp. Research Part A: Policy and Practice,* July 2018; re-submitted Nov. 2018, accepted Jan. 15, 2019.

The project **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** resulted in the following journal article:

- Snehanshu Banerjee, Mansoureh Jeihani, Nashid K. Khadem & Md. Muhib Kabir (2020) Influence of red-light violation warning systems on driver behavior – a driving simulator study, Traffic Injury Prevention, DOI: 10.1080/15389588.2020.1744135

3.3 Books or other non-periodical one-time publications
The project **Dynamic (Time Dependent) Green Vehicle Routing Problem** will be a chapter in a forthcoming book.

3.4 Websites or other Internet sites

www.morgan.edu/umec In the first quarter of 2020, some 678 unique visitors and 82 returning visitors viewed 2,048 pages. The home page continues to be the most popular page, but now the completed research page is the second most popular. All final reports are archived there.

www.facebook.com/urbanmobilityandequitycenter We now have 94 followers of our Facebook page. In March 2020 alone we reached 111 people, 46 of whom engaged with our posts. These included readers as far away as Bangalore, India; Bucharest, Istanbul; Johor Bahru, Malaysia; and Langeoog, Germany. A Facebook post on 12/18/19 congratulating students selected for the Lifesavers Conference reached 1,076 people and had 412 engagements. A video of one of our projects was featured on another Facebook page:
https://www.facebook.com/TransportationMSU/videos/559083554682384

Twitter [@UMEC research](https://twitter.com)). Impressions are the number of times users saw the tweet. For November 2019 we had 2,516 impression, and the top tweet was about using a portable driving simulator at the Montgomery County Police Department, which had 243 impressions. In December 2019 we had 1,618 impressions; the top tweet announced the UMEC student of the year with 69 impressions. Although 2020 began with 1,909 impressions in January, the numbers dropped in February (724) and March (802) because we tweeted very little due to coping with the workplace changes resulting from the COVID-19 virus.

Instagram: ntcumec (https://www.instagram.com/ntcumec/). UMEC now has 50 followers on Instagram. This highly visual platform doesn't always easily lend itself to the information we want to convey, and a goal for the upcoming year is to take more pictures of our research.

You Tube: We have a You Tube Channel.
https://www.youtube.com/channel/UCQ4GSAlNdKTKz6qhWqH1hQA

3.5 Technologies or techniques

- In **Managing the Impacts of Different CV/AV Penetration Rates on Recurrent Freeway Congestion From the Perspective of Traffic Management: A Case Study of MD-100,** a methodology has been presented to analyze the impacts of different AV flows on a highway network using microsimulation. The methodology was applied to a two-lane congested highway in Maryland, and the results of different AVs settings show that improper AV behavioral mechanisms can severely impede traffic operations at all AV penetration levels. The experimental results, tested in the study, highlight the existence of an optimal set of behavioral mechanisms for AV flows that must be executed over different segments of the commuting freeway under the given traffic volume to maintain and improve traffic flow. A responsible highway agency can follow this proposed method to develop operational guidelines that will enable the traffic operators to properly coordinate with AV flows to make the best use of the roadway capacity and avoid any potential negative impacts of AVs.

- **E3: Evaluating Equity in Evacuation: A Practical Tool and a Case Study** created a new tool that planners can use to identify populations that lack access to cars in the event of an evacuation. Researchers used Anne Arundel County, Maryland, as a case study and they were able to create a statewide map.

- **Developing Optimal Peer-to-Peer Ridesharing Strategies** will find the optimal operation of a ridesharing system including ride matching and vehicle routing as well as finding the optimal financial structure for the ridesharing system, which can provide incentives to ridesharing providers and ridesharing receivers. Eventually, this research can be a foundation for future ridesharing service implementation. This has important equity considerations, since ridesharing makes transportation more affordable.

- **Developing and Testing an ECO-Cooperative Adaptive Cruise Control System for Buse**s successfully developed a system to reduce delays at intersections caused by heavy duty vehicles.

- The project **Developing and Testing an Advanced Hybrid Electric Vehicle Eco-Cooperative Adaptive Cruise Control System at Multiple Signalized Intersections** has developed an HEV Eco-CACC model using HEV energy consumption and vehicle dynamics models. The proposed HEV Eco-CACC system will be the first eco-driving system that uses HEV energy consumption and vehicle dynamics models. The next step will be to test it using microsimulation software and a driving simulator.

- **Developing a Connected Vehicle Transit Signal Priority System** developed an advanced TSP system using a cycle-free NB signal control system.

- The project **Investigating the Impact of Distracted Driving Among Different Socio-Demographic Groups** developed a Machine Learning prediction model, for which a provisional patent has been filed.

- The project **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** implemented connected an automated vehicle features in a driving simulator. This advances the existing simulator technology to provide capability to study drivers' interactions with sophisticated systems.

  ### 3.6 Inventions, patent applications and/or licenses
  - An intellectual property disclosure entitled "Safety Applications for Work Zones" was submitted to the Office of Technology Transfer. Mansoureh Jeihani was the PI for this invention.
  - A provisional patent application (PPA) entitled " Driving Distraction Recognition Model Using Machine Learning" was filed with the U.S. Patent Office. Inventors include Samari Ahangari, Mansoureh Jeihani,, Abdollah Dehzangi, and Arsalan Hassan Pour
  - A provisional patent application (PPA) entitled "A Multipurpose Adaptive Eco-Speed Control Method Applicable to Driving Simulators" was filed with the U.S.

Patent Office. Inventors include Mansoureh Jeihani, Samari Ahangari, and Zohreh Rashidi Moghaddam.
- A provisional patent was filed by Mansoureh Jeihani, and Snehanshu Banerjee for a Method to Merge Datasets with Space Time Variables. This resulted from the project **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**

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

One of the stated goals of UMEC's technology transfer plan is to develop, modify or incorporate new technologies, techniques or practices, and the following items meet that goal.

Outcomes for the last six months include:

- While distracted driving is a well-known and investigated problem, the impact of the distraction depending on what type of road the driver is on had not been studied. **Investigating the Impact of Distracted Driving Among Different Socio-Demographic Groups** examined six common types of distraction, including texting, on four different classes of road: rural collector, freeway, urban arterial, and local road in a school zone. The findings are of use to those involved in crafting policy and education about distracted driving.

- The project **E3: Evaluating Equity in Evacuation** estimated a binomial car-ownership model for the State of Maryland and created a census tract-level map. The proposed population synthesizing method can provide reliable and granular-level input for activity-based models developed to understand the travel and behavioral pattern for individuals in cities and small towns. These studies would help planners and policy makers better examine alternative scenarios to address the needs of underserved communities and measure the accessibility of different population segments for effective and equitable evacuation planning.

- New cars come equipped with all kinds of assistance and warning technologies. But how do drivers respond to them, and are they effective? These questions were answered by the project **Driver's Interactions with Advanced Vehicles in Various Traffic Mixes and Flows (connected and autonomous vehicles (CAVs) electric vehicles (EVs), V2X, trucks, bicycles and pedestrians) - Phase I: Driver Behavior Study and Parameters Estimation**. Researchers found that Pedestrian Collision Warning and Red-Light Violation Warning significantly impacted participant braking behavior; participants resorted to initial aggressive braking in the presence of these applications. Forward Collision Warning had a positive influence on change in speed while Curve Speed Warning had no impact on speed and wasn't effective. The steering wheel and throttle Take Over Reaction time (TORt) in the post autonomous mode being 2.47 seconds and 2.98 seconds, respectively, is greatly influenced by the annual miles driven, age, and familiarity with this technology. Based on the findings, certain driver-related parameters

were identified; TORt, Deceleration Rate and Change in Speed, which could be integrated into a traffic simulator to simulate realistic human driving behavior in a traffic mix of human-driven and autonomous vehicles.

- The project **Developing and Testing an ECO-Cooperative Adaptive Cruise Control System for Buse**s successfully adapted technology researchers had developed for light-duty vehicles to heavy-duty ones such as buses. Anyone who has been stuck behind a bus at an intersection knows how slowly they accelerate. By providing the driver with information needed to traverse the intersection without stopping, this technology reduces those delays and subsequently improves the flow of traffic, which in turn reduces emissions and fuel consumption.

- Considering that most current vehicles on the road do not have automated control, the proposed manual HEV Eco-CACC system in **Developing and Testing an Advanced Hybrid Electric Vehicle Eco-Cooperative Adaptive Cruise Control System at Multiple Signalized Intersections** ensures that non-automated-control vehicles can proceed through signalized intersections, producing savings on travel time, energy and emissions. At the same time, the automated HEV Eco-CACC system can help automated vehicles achieve even more savings since they can follow the algorithm recommendations more precisely than human drivers. This will be the first eco-driving system that uses HEV energy consumption and vehicle dynamics models.

- The project **Developing an Eco-Cooperative Adaptive Cruise Control System for Electric Vehicles** developed an Eco-CACC system for battery electric vehicles.

- The outcome of **Improving Public School Bus Operations: Boston Case Study** will help the local education department better design the routes of its school buses, thanks to a better vision of average travel speeds on the links in the area.

- **Developing a Connected Vehicle Transit Priority System** found that the new system significantly improved various margins of error at a four-legged isolated signalized intersection. In particular, the new system reduced average vehicle delay up 67.5%, 73.2%, 71.1%, and 3.4% compared to FP, PS, PSC, and DNB controllers, respectively. Further, the study found that transit vehicles reduced their average travel time up to 15.6%, average passenger travel time up to 15.2%, average total delay up to 23.3%, average stopped delay up to 68.3%, and fuel consumption up to 6.17% with the developed system.

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 research serves as a source of knowledge for policy makers and government officials, as illustrated in this excerpt from an article: "The mayor pointed to research from **Morgan State University** indicating that people across income levels in Baltimore prefer to shop at multiple grocery stores, and most don't go to the store that is geographically closest to their home." (Full

story: https://technical.ly/baltimore/2019/11/18/lyft-affordable-rides-grocery-store-south-west-baltimore-neighborhoods/

Impacts for the last six months include:

- The project **Investigating the Impact of Distracted Driving Among Different Socio-Demographic Groups** reinforced the well-known dangers of texting and driving but also discovered some valuable insights into lesser-known distractions. Drivers who were putting on or taking off clothing reduced their speed significantly and veered from the center of the lane, yet this common and avoidable behavior isn't a target of public education campaigns. Eating and drinking also caused drivers to veer from the center lane; while regulating it would be difficult, this research suggests it is worthy of educating drivers about the risk. A key impact of this project is the finding that drivers talking on a hands-free device reduced their speed by up to 33 percent; that is inconsistent with the cell phone usage policies of most states, which allow hands-free devices.

- As a result of **Improving Public School Bus Operations: Boston Case Study**, bus routes will be designed according to a realistic and accurate mapping of the travel speeds in the area, improving on-time performance and eliminating extremely lengthy rides for some students.

- As cities allocate limited right away to multimodal transportation, more cities are implementing shared bus-bike lanes (SBBLs); however, there is a lack of research on the safety of such facilities. The interaction of buses, bicyclists and scooters, mostly during passing maneuvers, is a growing concern as there is a common observation that motorist often do not share the roads efficiently. Crashes in shared bus-bike lanes are mostly due to narrow lanes, overtaking, and oncoming traffic. **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** will investigate the causes of these accidents and will provide guidelines and selection criteria for the implementation of SBBLs.

- When it is completed, **E-Bikes' Effect on Mode and Route Choice: A Case Study of Richmond, VA, Bikeshare** will inform local jurisdictions about the potential benefits of including e-bikes in bikesharing fleets. This has equity considerations since this study will determine if e-bikes eliminate some physical limitations to bike riding. The study also will provide recommendations for infrastructure improvement and route choice guidance.

  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?
  The system in **Developing an Eco-Cooperative Adaptive Cruise Control System for Electric Vehicles** could be included in future vehicles to reduce energy consumption at intersections.
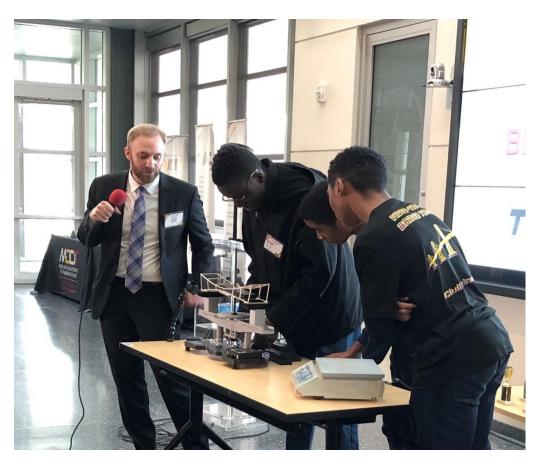
The Maryland Transit Administration may use the results of **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** to improve bus operator training and design recommendations.

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

- **Improving Public School Bus Operations: Boston Case Study** makes significant contributions to the body of knowledge about school bus routing.

- **Innovative Methods for Delivering Fresh Foods to Underserved Populations** offers a comprehensive comparison of delivery methods.

- For the project **E3: Evaluating Equity in Evacuation**, the data from PUMA and census tract levels are combined with IRS data and used to generate the synthetic population, which to the best of authors' knowledge have not been consolidated before for population synthesis purposes.

- **Managing the Impacts of Different CV/AV Penetration Rates on Recurrent Freeway Congestion From the Perspective of Traffic Management: A Case Study of MD-100** presents a systematic procedure for understanding how AV flows impact traffic under different AV behavioral mechanisms (i.e., car-following and lane-changing), penetration rates, and volume levels.

- An increased understanding of drivers' interactions with connected and automated vehicles is a contribution of the project **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**.

- **Investigating the Impact of Distracted Driving Among Different Socio-Demographic Groups** contributes significantly to evaluating the effects of specific distractions and road types on driver behavior.

5.3 What is the impact on transportation workforce development?

- The Maryland Department of Transportation/Morgan State University Graduate School Internship Program provided 16 interns with a year-long experience in the various agencies within MDOT. The students worked full time during the summer and breaks and part time during the semester. In the past few years, several students have been hired by MDOT. "An internship program, such as this, is an excellent strategy for investing in MDOT's future successes, often leading to discovering of future colleagues and leaders," said Sheryl Johnson, a Talent and Development Learning Specialist with MDOT. "This program has helped our organization to bridge the gap when it comes to finding the next generation of talented problem solvers, innovators, and future leaders." The program is scheduled to be featured in the Baltimore Sun's April 26 Education section.

- UMEC helped host the inaugural Maryland Bridge Challenge on Jan. 31, 2020, co-sponsored with the Maryland Department of Transportation and Civil Engineering (TRAC). Eighteen teams of middle and high school students built and tested bridges.

- Congratulations to (below from left) Md Muhib Kabir, Samira Ahangari, Nashid Khadem, Nkiruka Jane Nwachukwu and Arsalan Hasan Pour. All grad students in the Department of Transportation & Urban Infrastructure Studies, they attended the Emerging Researchers National Conference 2020; UMEC Director Dr. Mansoureh Jeihani mentored them. They were slated to showcase their solution for a green transportation mode, which addresses the United Nations Sustainable Development Goals, at the 2020 HBCU Making and Innovation Showcase.

- Students at all levels are involved in meaningful transportation research activities at the three UMEC universities. Because UMEC research is accepted for posters and presentations at conferences, students have a chance to travel, present and network. One specific example is the project **Optimized Development of Urban Transportation Networks;** a graduate research assistant prepared his master's thesis on it (which was scheduled to be defended on April 13) and wrote a journal paper based on his thesis.

- Morgan State University hosted the Summer Transportation Institute, a four-week program that exposed 15 high school students to careers in transportation and the academic skills needed to access those careers.

6 CHANGES/PROBLEMS.

6.1 Changes in approach and reasons for change.
The outbreak of the coronavirus COVID-19 forced universities to close their campuses and teach remotely. Obviously, this affected data collection, particularly in laboratory settings such as the driving simulator. Researchers were able to continue some aspects of their research – such as mathematical formulations, developing algorithms and modeling – remotely. Research teams communicated via video platforms and conference calls.

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

Because of the virus, we are expecting some delays in research. As of this writing, it's hard to gauge the effects since we don't know how long the pandemic and resulting mitigation measures will last. For example, the next step for the project **Developing and Testing an Advanced Hybrid Electric Vehicle Eco-Cooperative Adaptive Cruise Control System at Multiple Signalized Intersections** is to bring participants in to test it in a driving simulator, which we cannot do at this time.

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.

We also may not be able to hold our National Summer Transportation Institute, an on-campus summer program for high school students that exposes them to transportation concepts and careers, if the campus is not reopened. Its format of field trips, group activities and hands-on projects would not lend itself well to distance learning.

For the project **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts,** Quality Counts sent the processed data about two months late; this is a novel study and they underestimated the time to completion.

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 researchers and subjects from exposure to the COVID-19 virus, the university campuses of all three schools in our consortium were closed.

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

In the end of December 2020, Dr. Z. Andrew Farkas, who had directed UMEC since its inception, retired. In the beginning of January, Dr. Mansoureh Jeihani, a professor at Morgan and a UMEC researcher, was appointed interim director. The transition went smoothly, and administrative activities and research are proceeding as normally as possible given the situation with COVID-19.