



Semi-Annual Progress Report No. 2 – 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:

A handwritten signature in black ink that reads "J. Andrew Farkas". The signature is written in a cursive style and is placed on a light gray rectangular background.

1. ACCOMPLISHMENTS.

What was done? What was learned?

UMEC now has 26 projects, of which eight have been completed. We have developed a variety of tools, including new methodologies, novel applications of existing methods, smart innovations, algorithms and best practices. The ultimate goal of these efforts is to move people and goods in an equitable and sustainable manner. The achievements to date are in line with UMEC's stated performance measures.

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.

The completed projects have achieved significant results, including patent applications, a new algorithm that will be critical for autonomous transit vehicles, optimized emergency traffic patrols, and best practices for constructing bus pads.

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

Project Type University	Project Name	PIs
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
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:	Hao Chen, Hesham Rakha, Mansoureh Jeihani

Project Type University	Project Name	PIs
	EcoCACC for HEVs)	
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	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

Project Type University	Project Name	PIs
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
Collaborative – VT, UMD	Developing a Connected Vehicle Transit Signal Priority System	Kyoungho Ahn, Hesham Rakha, Young-Jae Lee
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: Equity in Evacuation: A Practical Tool and Two Case Studies	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 540 people; we continue to grow that list. We have received positive

comments, including requests for the full report or contact information for the researchers. Our research has been presented at conferences, including TRB, and published in journals, as detailed later in this report.

For the project **Hands on Wheel, Eyes on Road**, which researched distracted driving, UMEC hosted an event in September that featured the final version of our video, an interactive panel discussion, a display from the nation's premier trauma hospital, and two speakers, including a woman who was involved in a fatal distracted driving crash. Earlier, in July, the research also had been presented to officials from the Federal Motor Carrier Administration.



Participants at the Hands on Wheel, Eyes on Road event.

The [April 30, 2019, edition](#) of the TRB newsletter offered a link to **Sustainable Design of Concrete Bus Pads to Improve Mobility in Baltimore City**.

Dr. Celeste Chavis, the principal investigator for **Understanding Access to Grocery Stores in Food Deserts in Baltimore City**, gave a seminar at UC Davis' Institute of Transportation Studies in California in May; the seminar is available online at <https://ucdcoe.mediasite.com/Mediasite/Play/2ad421908d404063a1455fb6f4e086271d>

Research from **Multimodal Traffic Signal Control** was included in a front-page Baltimore Sun story on traffic signals. <https://www.baltimoresun.com/ask/bs-ask-traffic-lights-20191015-ietjxqoqkngcvle6xywze65f2e-story.html>

1.4 What do you plan to do the next reporting period to accomplish these goals?

We have a solid team of researchers working collaboratively, and we will continue to support them as they complete projects and propose new ones. Each ongoing project has identified goals they intend to accomplish within the next six months. For example, the project **E³: Evaluating Equity in Evacuation: A Practical Tool and Two Case Studies**, which already has identified the population without access to a car by census tracts, will calculate accessibility to safe zones from each census tract in Anne Arundel County, Maryland, taking into account the type of shelter and services offered. They will then share the results of the study with county and regional representatives. In another example, **Energy Efficient Transportation Modeling**, which has developed dynamics-based cycling acceleration/deceleration

models, will develop a rail simulation framework that integrates train dynamics and energy consumption models.

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 **Hands on Wheel, Eyes on Road**.

Boston Public Schools continues to collaborate in improving school bus operations, 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**.

The Electric Vehicle Association of greater Washington DC (EVADC) provided eight vehicles, including an electric police car, for EV Day.

Maryland Department of Transportation – State Highway Administration has been identified as a potential user and collaborator for **Optimized Development of Urban Transportation Networks**.

Maryland Department of Transportation – Maryland Transit Administration has provided in-kind time and data.

The City of Richmond is collaborating and providing in-kind support and data.

Bewegen, 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?

The Mid-Atlantic Aviation Partnership and Virginia Tech Institute for Critical Technology, Virginia Tech, are partnering in research into drone delivery.

Dr. Jehani is chair of Strategy 3 for the Highway Safety Strategic Plan.

Dr. Celeste Chavis is a member of the Greater Washington Partnership Equitable Access Workshop.

Dr. Andrew Farkas serves on the Maryland Zero Emissions Vehicle Infrastructure Council.

Dr. Young-Jae Lee is a voting member of the SAE International Shared and Digital Mobility Committee.

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?**

UMEC's performance measures set a goal of six conference presentations and seven technical reports for outputs. In 2019, research was presented 18 times at various conferences, including TRB, and seven technical reports were published.

Outputs from the last six months include:

- 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** uses a driving simulator combined with an eye-tracking system to explore drivers' responses; for example, the combination allowed researchers to create heat maps of where drivers look while the car they are driving is in autonomous mode. The researchers developed a process to combine the outputs of both systems to merge datasets with space and time variables and generate data and graphics; they are in the process of filing a provisional patent application. (And in case you are wondering, while the vehicle was in autonomous mode, the drivers kept looking at the speedometer and the rearview mirror.)
- The above-mentioned project also developed autonomous connected vehicle capabilities for the driving simulator.
- **Traffic State Prediction: A Traveler Equity and Multi-modal Perspective** developed eight toolboxes of models and algorithms to convert current bike share systems into smart systems.
- Using a Nash bargaining game-theoretic framework allowed researchers working on **Development of Multimodal Signal Control** to develop a novel, real-time adaptive, multimodal decentralized traffic signal controller that integrates connected vehicles.
- The project **E³: Evaluating Equity in Evacuation: A Practical Tool and Two Case Studies**, which last spring had developed a robust statistical method based on Copula for synthetic population generation at a small geographical level, used it to generate Copula-based synthetic population for Anne Arundel County, Maryland, using census data. Researchers estimated a car ownership model and

identified the population with no access to a car for all the census tracts in Anne Arundel County.

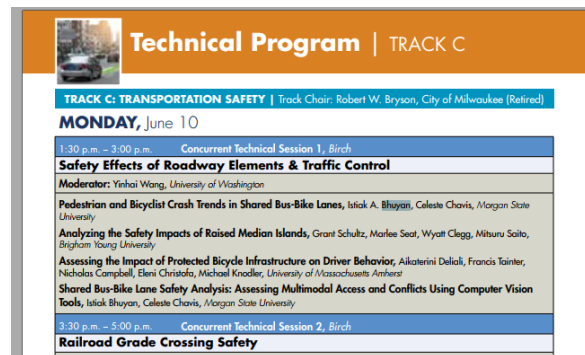
- Although it is in the early stages, the project **Demand Responsive Delivery of Food in the Baltimore City Food Deserts** will create a pilot of a drone delivery network to provide fresh food in disadvantaged neighborhoods.
- The right improvements to a transportation network can redistribute flow to improve congestion and bottlenecks, but others can be counterproductive and wasteful. Recognizing that common ways to prioritize projects do not take into account the interrelations among projects, **Optimized Development of Urban Transportation Networks** created a metaheuristic method based on a genetic algorithm to plan and prioritize projects.
- Previous similar projects focusing on Eco-Cooperative Adaptive Cruise Control only involved on light duty vehicles but **Developing and Testing an ECO-Cooperative Adaptive Cruise Control System for Buses** focuses on heavy-duty vehicles, diesel and hybrid buses.
- Another project that extends the Eco-Cooperative Adaptive Cruise Control System is **Developing and Testing an Advanced Hybrid Electric Vehicle Eco-Cooperative Adaptive Cruise Control System at Multiple Signalized Intersections**. It will allow hybrid electric vehicles to pass signalized intersections with energy-optimized speed profiles. The proposed system will include two modes, automated and manual, for vehicles with or without an automated control system.
- **Shared Bus-Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** created an index to identify potentially unsafe bike lanes in a network. This project also will use drones to collect video data.
- **Energy Efficient Transportation Modeling** has developed dynamics-based cycling acceleration/deceleration models.
- A previous federally funded research project at the University of Maryland passively collected mobile device data that revealed day to day travel patterns of more than 40 percent of the population. Using that data, **Equity in Accessibility to Opportunities: Insights, Measures and Solutions based on Mobile Device Location Data** will analyze how residents in each socio-demographic group and in each neighborhood actually travel to work, purchase food and seek health care

services. The study is the first of its kind to use observed multimodal travel big data from individual mobile devices to systematically study accessibility for underserved population groups.

- A project slated to start next March, **Investigating the Effect of Connected Vehicles Route Guidance on Mobility and Equity** will develop and calibrate a microscopic traffic simulation model to replicate the behavior of connected vehicles in the traffic simulation environment. Different penetration rates of CVs will be developed.
- **The project Innovative Methods for Delivering Fresh Foods to Underserved Populations** designed a prototype system model for evaluating various delivery alternatives and multimodal combinations. Researchers evaluated the model’s sensitivity to various pricing and policy options, as well as external factors, such as the size of the total economic impacts.

3.1 Publications, conference papers and presentations

- One paper resulting from the project **Hands on Wheel, Eyes on Road** was presented at SIUSAI conference in Canada in August 2019. An oral presentation entitled “A Machine Learning Distracted Driving Prediction Model” also was presented.
- A presentation based on the project **Shared Bus-Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** was presented at the ASCE TD&I Conference in Alexandria Virginia, on June 10, 2019. The presentation focused on using computer vision tools. In addition, two papers were presented:
 - “Pedestrian and Bicyclist Crash Trends in Shared Bus-Bike Lanes,” Istiak A. Bhuyan, Celeste Chavis, Morgan State University
 - “Shared Bus-Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts Using Computer Vision Tools,” Istiak Bhuyan, Celeste Chavis, Morgan State University.
- The principal investigator for **E³: Evaluating Equity in Evacuation: A Practical Tool and Two Case Studies** were invited to give a presentation at the National University of Singapore on statistical data linkage in August 2019. The co-PI will present the results at the 2019 COTA International Symposium on Emerging Trends in Transportation (ISETT) in Rome on Oct. 3-5, 2019.



- The principal investigator for **Optimized Development of Urban Transportation Networks** gave a presentation entitled “Analysis and Scheduling of Interrelated Alternatives for Network Development,” at the 4UniC 2019 Conference, Calgary, Canada, in August 2019. Papers for two other conferences resulted from this project:
 - Shayanfar, E., Schonfeld, P. and Wang, J. “Optimizing the Priority of ADHS Projects by Integrating Simulation and Genetic Algorithm,” 6th International Transportation and Economic Development Conference, Washington, DC, June 2018.
 - Schonfeld, P. “Selection and Scheduling of Interrelated Improvements in Transportation Systems,” COTA International Conference of Transportation Professionals, Beijing, July 5-8, 2018.
- Researchers presented **Developing and Testing an Eco-Cooperative Adaptive Cruise Control System for Buses** at the Road Safety and Simulation Conference, Iowa City, Iowa, Oct. 14-17, 2019.
- The project **Hands on Wheel, Eyes on Road** resulted in the presentation “Distracted Driving Prediction Model Using a Bayesian Network,” at the 91st Annual National Technical Association Conference (NTA), Baltimore, Maryland, Sept. 25-27, 2019.
- Researchers presented “The Gender Role on the Effectiveness of an Eco-Speed Control System in The Vicinity of Signalized Intersections: A Driving Simulator Study, at the 6th International Conference on Women’s Issues in Transportation,” Irvine, California, and Sept. 10-13, 2019.



This Tesla, which seats eight, impressed visitors.

- In July, UMEC helped host EV Day, an event that brought eight electric vehicles to campus to highlight EV technology. Students – including high school students in the Summer Transportation Institute – staff and faculty enjoyed a chance to examine every inch of the cars and chat with the owners. More than 125 people attended.



High school students examined electric vehicles.

- Dr. Jeihani’s driving simulation laboratory was featured in a Baltimore Sun special section on higher education in July.
<http://marketplace.baltimoresun.com/baltimore-md-features/special-section/Education/07-07-2019/Page-1#>
- The “Get Smart” team, which won third place in the International Association of Transportation Regulators 2019 Hack-A-Thon competition, included UMEC researchers – grad students Snehanstu Banerjee, Nashid Khadem, Md. Muhib Kabir and Dr. Mansoureh Jeihani.
- Doctoral student Amirezza Nickkar’s presentation to the Maryland Transportation Innovation Council on June 13, 2019, “Developing an Algorithm for the Optimal Flexible Automated Feeder Transit Network,” detailed UMEC research.

3.2 Journal publications

- Lee, Young-Jae, Mana Meskar, Amirreza Nickkar and Sina Sahebi, “Development of an Algorithm for Optimal Demand Responsive Relocatable Feeder Transit Networks Serving Multiple Trains and Stations”, Vol. 5, Issue 3, pp 186-201, Urban Rail Transit, September 2019
- The project **Optimized Development of Urban Transportation Networks** has resulted in an additional three journal publications:
 - Guo, Q., Chen, S., Schonfeld, P. and Li, Z. “How Time-Inconsistent Preferences Affect Investment Timing for Rail Transit,” *Transp. Research Part B: Methodological*, v118, Dec. 2018, pp 172-192.
 - Shayanfar, E. and Schonfeld, P. “Selecting and Scheduling Interrelated Road Projects with Uncertain Demand,” *Transportmetrica Part A*, 15-2, June 2019, pp 1712-1733.
 - Shayanfar, E., Schonfeld, P. and Wang, J. J. “Prioritizing Highway Development Projects Based on Market Access in Appalachia,” accepted for the *Transportation Research Record*, Feb. 1, 2019.

3.3 Books or other non-periodical one-time publications

The book *Transportation Network Modeling and Calibration*, written by UMEC researcher Dr. Mansoureh Jeihani, will be used as a textbook at both Louisiana State University and Virginia Tech.

3.4 Websites or other Internet sites

www.morgan.edu/umec

UMEC’s website had 5,325 page views last year. After the home page, the ongoing and completed research pages are the most popular.

www.facebook.com/urbanmobilityandequitycenter

During the last six months, this page averaged 50 impressions a day; impressions are the number of times our content appears on someone else's screen. We have 90 followers.

Twitter ([@UMEC_research](https://twitter.com/UMEC_research)). In the last six months, UMEC tweets averaged 2,140 impressions per month; impressions are the number of times users saw the tweet.

Instagram: ntcumec (<https://www.instagram.com/ntcumec/>). This is a fairly new platform for UMEC, one we have just begun to use in the past year. It's popular with a younger demographic; 64% of 18- to 29-year-olds use it. UMEC's Instagram has 41 followers.

You Tube. We have had a total of 581 views. This is also an underused social media platform, and we hope to add more videos in the future. (You Tube prevents a direct link to a video in a .pdf; to find our video, go to youtube.com and enter Final Cut Hands on Wheel, Eyes on Road in the search box.)

3.5 Technologies or techniques

- 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** adopts autonomous and connected vehicle technology for driving simulator tests. This allows for testing the capabilities, effectiveness and public acceptance of ACV technology.
- The project **Shared Bus-Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** uses drones to collect video data.
- **Optimized Development of Urban Transportation Networks** gives planners a new way to prioritize projects in an inter-related network.
- **Innovative Methods for Delivering Fresh Foods to Underserved Populations** designed a conceptual delivery network model and a micro-level analysis.

3.6 Inventions, patent applications and/or licenses

- As mentioned above, researchers figured out how to combine the outputs of a driving simulator and eye-tracking system to generate data; as of this writing they are in the process of filing for a provisional patent.
- Filing an intellectual property disclosure form led to a provisional patent for research into **Optimal Automated Demand Responsive Feeder Transit and its Impact**, which also received an I-Gap Award grant.

- Researchers are in the process of filing a provisional patent for a machine learning distraction prediction model developed as part of **Hands on Wheel, Eyes on Road**.
- A provisional patent application has been filed for an interface between a traffic light optimization algorithm and driving simulator software, part of the project **Developing and Testing an ECO-Cooperative Adaptive Cruise Control System for Buses**.

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

Performance measures for 2019 outcomes include two technology transfer activities that offer implementation or deployment guidance. Two such completed projects, **Sustainable Design of Concrete Bus Pads to Improve Mobility in Baltimore City** and **Optimization of Emergency Traffic Patrols Operations** offer best practices for construction and a model to design a network for optimum response, respectively.

Testimony was another stated outcome, and the event **Hands on the Wheel, Eyes on the Road** offered a compelling, heartbreaking story of distracted driving.

Outcomes for the last six months include:

- The project **Development of Multimodal Traffic Signal Control** tested the proposed controller on a road network in downtown Los Angeles, California, including the most congested downtown area, with 457 signalized intersections. The results were compared to the performance of a decentralized phase split and cycle length controller. The results showed significant average travel time reductions on the intersection links of 35.1%, a reduction in the average queue length of 54.7%, a reduction in the average number of stops of 44%, a reduction in CO2 emissions of 10%, and a reduction in the fuel consumption of 10%.
- The method, for which a provisional patent application has been filed, used in **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** contributes to understanding the acceptance and effectiveness of ACV technology. It also will increase awareness of these technologies. Both are critical as ACV technology becomes more widespread.
- The project **Hands on Wheel, Eyes on Road** increased the awareness of distracted driving and its consequences. One important discovery from this research is that hands-free calls while driving cause drivers to reduce their speed almost as much as hands-free calls do.
- When completed, the project **E-Bikes' Effect on Mode and Route Choice: A Case Study of Richmond, Va., Bikeshare** will provide recommendations for infrastructure improvement and route choice guidance.

- More cities are implementing shared bus-bike lanes (SBBLs), but there is a lack of research on the safety of such lanes. **Shared Bus-Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** will investigate the causes of crashes and provide guidelines and selection criteria for implementing SBBLs. The research will also see how newly popular scooters use these facilities and examine the difference between vehicle-cyclist and vehicle-scooter interactions.
- **Improving Public School Bus Operations: Boston Case Study** will help local education departments better design their school bus routes.

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?

Two stated impacts were workforce development and improvements to the transportation system measured in the form of three intellectual property disclosures.

The Maryland Department of Transportation/Morgan State University Graduate School Internship Program placed 16 interns in year-long positions in state transportation agencies for 2019-2020. For more than three decades this program has served as a pipeline of talent for MDOT and other transportation organizations. Of note is that many of the interns are people of color and women.



The 2018-2019 MDOT/MSU Graduate School Interns

Five IPs were filed and applications have been made for two provisional patents.

Impacts for the last six months include:

- 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** impacts the testing of ACV technology in a driving simulator with an improved method.
- The developed model in **Hands on Wheel, Eyes on Road** can be improved upon and developed as an aftermarket tool to be used in vehicles to warn drivers of being distracted, which can increase safety.
- **E³: Evaluating Equity in Evacuation: A Practical Tool and Two Case Studies** will help local, state and federal agencies efficiently plan for evacuation in case of emergency, especially for a vulnerable segment of the population.

5.1 What is the impact on the effectiveness of the transportation system?

- The project **Developing and Testing an ECO-Cooperative Adaptive Cruise Control System for Buses** will improve transit operations by reducing delays and achieving major/fuel energy savings while reducing emissions.
- The better school bus routing plans developed as a result of **Improving Public School Bus Operations: Boston Case Study** will decrease the amount of time students spend on the bus.

5.2 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?

- Thanks to the project **Improving Public School Bus Operations: Boston Case Study**, estimated link travel times will be updated in the local bus routes planning software. A better bus routing system will be developed.
- The proposed system developed in **Developing an Eco-Cooperative Adaptive Cruise Control System for Electric Vehicles** can be implemented into electric vehicles to reduce energy consumption at signalized intersections.

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

- The methodology used in **E³: Evaluating Equity in Evacuation: A Practical Tool and Two Case Studies** contributes to the literature on synthetic population, which is one of the pillars in activity-based modeling and agent-based simulation. The methods developed and applied in this project also contribute to the area of small area transportation statistics.

5.4 What is the impact on transportation workforce development?

- 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.
- 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.
- The developed algorithm and software from the project **Developing a Connected Vehicle Transit Signal Priority System** can be used as teaching material in transportation engineering courses.

6 CHANGES/PROBLEMS.

6.1 Changes in approach and reasons for change.

Initially, researchers planned to collect the video data for **Shared Bus-Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** by using fixed cameras installed in parking lots or on poles. But the results were not satisfactory, and

they switched to using drones to maintain high quality over a large stretch of road. The project also added e-scooters to the analysis; when the proposal was written, Baltimore City did not have e-scooters, but recently they have proliferated in the city.

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

Two ongoing projects requested and received extensions of a few months. One of them, **Improving Public School Bus Operations: Boston Case Study**, encountered difficulty using real data to show the developed optimal school bus routing algorithm, so they need to develop synthetic data with reasonably real situations.

The research is complete and the final report for the project **Understanding Access to Grocery Stores in Food Deserts in Baltimore City** is partially written. However, Morgan's School of Engineering is undergoing an ABET re-accreditation evaluation, and the PI was tasked with preparing materials for the ABET evaluation in October. The deadline for the final report has been extended.

The micro-level analysis for **Innovative Methods for Delivering Fresh Foods to Underserved Populations** took longer than initially planned; the team is finishing the final report as of this writing.

6.3 Changes that have a significant impact on expenditures.

Researchers involved in the project **Shared Bus-Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** eliminated weekend data collection because they had to use a drone for data collection, which was more costly.

6.4 Significant changes in use or care of human subjects, vertebrate animals, and/or biohazards.

Nothing to report

6.5 Change of primary performance site location from that originally proposed

Nothing to report

7. SPECIAL REPORTING REQUIREMENTS

Nothing to report