Semi-Annual Progress Report No. 6 – Urban Mobility & Equity Center

Submitted to:	U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology
Grant Number	69A43551747123
Project Title:	Urban Mobility & Equity Center
	Morgan State University (Lead Institution) *Virginia Polytechnic Institute and State University* *University of Maryland*
Program Director:	Dr. Mansoureh Jeihani 443-885-1873
Submitting Official:	Same as above
Submission Date:	October 30, 2021
DUNS#: EIN#:	879941318 52-6002033
Recipient Organization:	Morgan State University 1700 E. Cold Spring Lane Baltimore, MD 21251
Recipient Identifying Number or Account Number, if any:	69A43551747123
Grant Period:	11/30/16 to 9/30/23
Reporting Period End Date:	Sept. 30, 2021
Report Term:	Semi-annual. This report covers March 31, 2021, to Sept. 30, 2021.

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 how equity concerns will be addressed amid such changing technologies.

1.2 What was accomplished under these goals?

UMEC Director Dr. Mansoureh Jeihani met with USDOT Secretary Pete Buttigieg to discuss equity and how it impacts mobility for everyone. Also present were Dr. Oscar Barton Jr., the dean of Morgan State University's Clarence M. Mitchell Jr. School of Engineering; Dr. Robert Hampshire, Deputy Assistant Secretary for Research and Technology; and Ms. Dawn Tucker-Thomas, Senior Transportation Specialist and Federal Grants Manager.

Below is a chart listing all 45 UMEC projects. Twenty-seven have been completed and are listed in green type; one project is complete but the results have not been released due to protecting intellectual property. Final reports for these projects are available on our website, www.morgan.edu/umec, and they have been submitted to the appropriate databases.

As we continue to award research grants, all proposals are reviewed by at least three peers who score them on several attributes; those with the highest scores are chosen to receive funding.

We are committed to developing a future workforce with not only the necessary skills but also an understanding of equity and how it relates to transportation.

Project Type/ University	**Project Name**	**PIs**
Core-MSU	Investigating Walking and Biking Activities Among Low-Income Americans	Eazaz Sadeghvaziri, Mansoureh Jeihani
Collaborative-UMD, VT	Analysis of Interrelated Network Improvement Alternatives	Paul Schonfeld Hesham Rakha
Collaborative-UMD, VT	Fare Free Public Transportation: A full-scale real-world experiment in Alexandria, Virginia	Cinzia Cirillo, Hesham Rakha
Collaborative-VT, MSU	Optimum Connected Vehicle Speed Control on Signalized Roadways in Mixed Flow	Hao Chen, Hesham Rakha, Mansoureh Jeihani, Eazaz Sadeghvaziri
Collaborative-MSU, UMD	User Preference Analysis for Mobility-as-a-Service (MaaS) and Its Impact in Maryland	Young-Jae Lee, Hyeon-Shic Shin, Paul Schonfeld
Core-MSU	The Typology of Transportation Accessibility: A Qualitative and Quantitative Meta-Analysis	Hyeon-Shic Shin
Core-MSU	Integrated Optimal Transit Network Design with MaaS Implementation	Young-Jae Lee
Core-VT	Impact of COVID-19 on Ridehailing and Other Modes of Transportation	Jianhe Du, Hesham Rakha
Core-VT	Estimating switching times of Actuated Coordinated Traffic Signals: A deep learning approach	Hesham Rakha, Seifeldeen Eteifa
Core-VT	Developing an Intelligent Connected Vehicle based Traffic State Estimator	Hesham Rakha, Ahmed Abdelrahman, Hossam Abdelghaffar

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	Chenfeng Xiong, Hyeon-Shic Shin

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 (completed but being held to protect intellectual property)	Young-Jae Lee, Amirreza Nickkar
Core – VT	Energy Efficient Transportation Modeling	Hesham Rakha
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	E3: Evaluating Equity in Evacuation:	Cinzia Cirillo, Celeste

– UMD, MSU	A Practical Tool and A Case Study	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 535 people, including researchers, elected officials and journalists. We also email an annual newsletter listing all projects to the same list. Here is the newsletter that was distributed on April 28, 2021.

UMEC concluded its spring webinar series on April 30, 2021, with three webinars, all of which are available on our YouTube channel:

- The Impact of Eco-Speed Control System on Driver Behavior and Emissions Reduction at Signalized Intersections Using a Driving Simulator, presented by Samira Ahangari and Dr. Mansoureh Jeihani from Morgan State University. (22 attendees/37 views)
- Estimating Traffic Stream Density Using Connected Vehicle Data, presented by Dr. Hossam Abdelghaffar, Mohammad Aljamal and Dr. Hesham Rakha from Virginia Tech. (20 attendees/8 views)
- Multi-Objective Eco-Routing Development for ICEVs, BEVs, and HEVs, presented by Dr. Kyoungho Ahn, Dr. Youssef Bichiou, Mohamed Faraq, and Dr. Hesham Rakha from Virginia Tech. (23 attendees/18 views)
- 7 Minutes to Better Writing was again presented in between webinars by Nancy Jackson of Morgan State University.

The next round of webinars will begin with two scheduled for Nov. 16, 2021.

The Baltimore Sun featured Morgan's driving simulation lab and its new bike simulator in a special education section. 08-01-2021 Education - Flipbook - Page 5 (paperturn-view.com)

https://www.paperturn-view.com/baltimore-sun-media/08-01-2021-education?pid=MTc177203&p=5

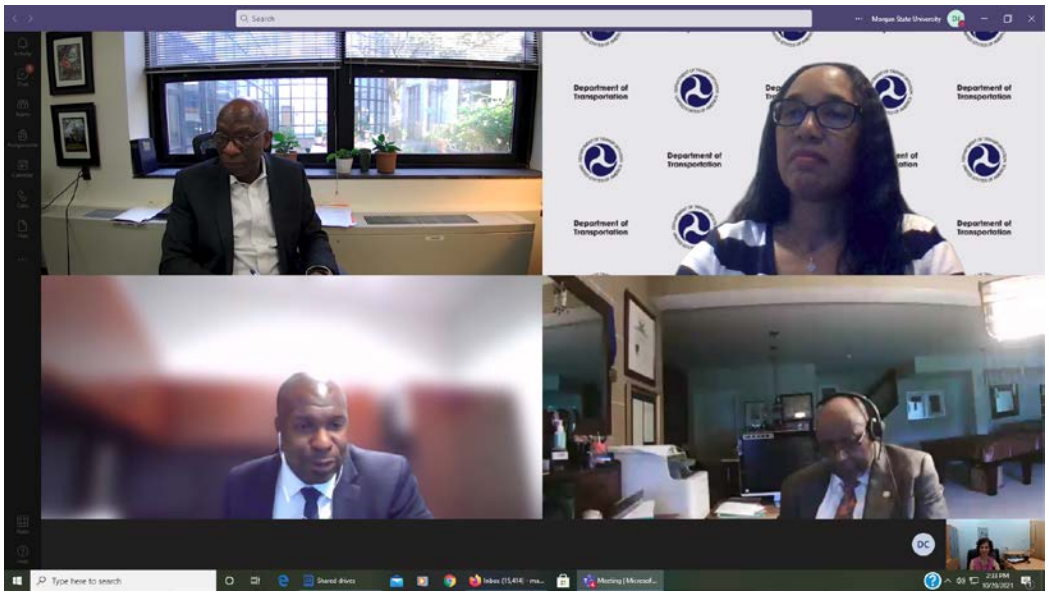
1.4 What do you plan to do the next reporting period to accomplish these goals?

We continue to support UMEC researchers as they complete ongoing projects. Now that the campus has reopened, we can continue research involving human participants, practicing protective measures such as masks, social distancing, and disinfecting work stations and equipment.

We have awarded fifth-year funding for core and collaborative research projects, and we will be soliciting proposals for sixth-year projects. We will continue to promote our research to both technical and general audiences.

We have hired a new part-time education coordinator, who plans to grow our workforce development programs. She has created a virtual version of our popular National Summer Transportation Institute, which enabled us to have it this year, and she is working on reviving the Teacher Transportation Institute for next year.

In October, Dr. Mansoureh Jeihani, UMEC director, met with Mr. Morris, an advisor to Secretary Pete Buttigieg, Ms. Dawn Tucker-Thomas, Senior Transportation Specialist and Federal Grants Manager, and Dr. Willie May, Morgan's vice president of research and economic development, and Dr. Oscar Barton, dean of Morgan's Clarence M. Mitchell Jr. School of Engineering. The purpose was to inform Mr. Morris about the capabilities and needs of HBCUs conducting USDOT research.



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

What organizations have been involved as partners?

The Federal Motor Carrier Safety Administration helped fund our National Summer Transportation Institute program, a workforce development initiative aimed at middle and high school students. The money was used to create a special unit on safety and

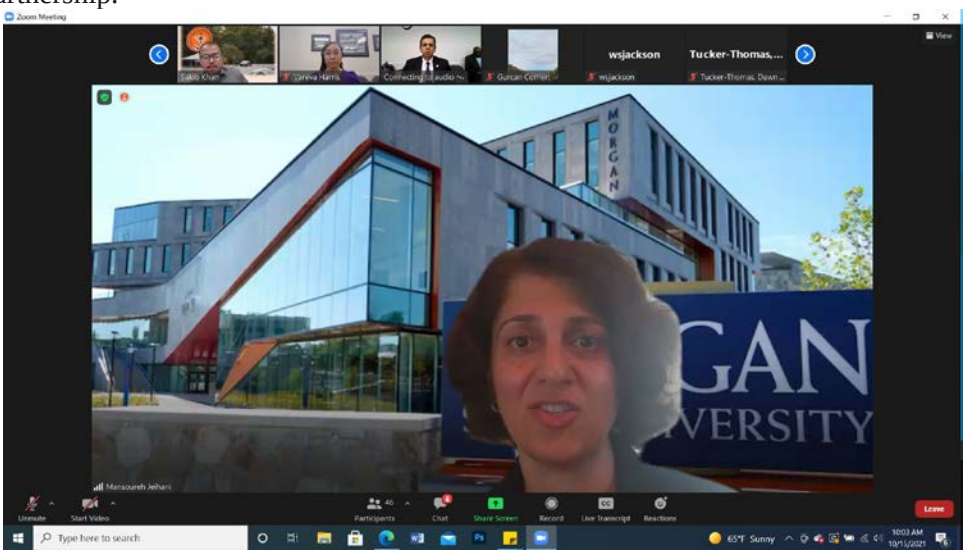
inspections. In addition, BGE, the local utility company, offered a unit on electric vehicles, sponsored a scavenger hunt for EV chargers and gave two laptops as prizes. Giant Food gave a presentation on nutrition, and Free Bikes 4 Kidz supplied two bikes for a concluding raffle.

Cube Root, Inc., a consulting company, supplied video data for **A Comparative Study of Pedestrian Crossing Behavior and Safety in Baltimore and Washington, D.C., Using Video Surveillance**.

Have other collaborators or contacts been involved?

To further workforce development, UMEC partnered with C2M2 at Clemson University to offer a webinar for students entitled Path to Academic Careers for HBCU Students on Aug. 26, 2021.

UMEC Director Dr. Mansoureh Jeihani was a panelist for the C2M2 5th Annual Fall Conference on Oct. 15 where she led a breakout session on HBCU leadership and partnership.



UMEC partnered with BGE, the Baltimore region utility company, to present a two-hour webinar "Getting EVsmart: How Utilities like BGE are driving Equitable Electrified Transportation" on May 7, 2021. (39 participants)

Graduate student and UMEC researcher Istiak Bhuyan volunteered on a collaborative project with the Johns Hopkins University, Baltimore Transit Equity Coalition and Baltimore community members that produced the report Transit Equity & Environmental Health in Baltimore. Transit Equity & Environmental Health in Baltimore | Bloomberg American Health Initiative (jhu.edu)

Dr. Young-Jae Lee is an Associate Editor for the KSCE Journal of Civil Engineering as well as for Urban Rail Transit. He was a guest editor for a special issue in July of the Journal of Advanced Transportation; the issue is Advanced Data Intelligence Theory and Practice in Transport. 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. 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)

A member of three Transportation Research Board committees, (Bicycle, Equity in Transportation, Innovative Public Transportation Services & Technologies) (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)

Dr. Mansoureh Jeihani is:

Chair of Strategy 3 for the Highway Safety Strategic Plan.

Member, Maryland Connected and Autonomous Vehicle Working Group

Member, Maryland Zero Emission Electric Vehicle Council

Member of the Transportation Research Board committee on Artificial Intelligence and Advanced Computing Applications

Member, editorial board of the Journal of Traffic and Logistics Engineering.

Member, National Cooperative Highway Research Program (NCHRP) Panel - Transportation Research Board, 2019-Present

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

Our research is timely, addressing some of the most pressing issues of today as well as those of a future in which transportation will shift from traditional vehicles to electric, autonomous, and connected ones. For example, one project that began this month is a real-world experiment with fare-free public transportation; the researchers already have received additional grant money for further study from the National Science Foundation.

- As national policy increasingly looks to electric vehicles as a method of combating climate change, predicting just who those EV adopters will be and marketing EVs to them is critical. The project **Adoption and Diffusion of Electric Vehicles in Maryland** first explored the factors that most influence EV adoption and then carried out a predictive analysis based on machine learning methods. Research compared several different machine learning methods and found that a Support Vector Machine with polynomial kernel slightly outperformed the others, although all of them exhibited comparable predictability, implying robust findings.
- With bus driver shortages plaguing school systems, the project **Multi-depot and**

Multi-school Bus Scheduling Problem with School Bell Time Optimization is quite timely. The researchers studied the multi-depot and multi-school bus scheduling problem with school bell time optimization (MDBSPBO) with the goal of minimizing the total number of buses and the total deadhead duration. Spreading bell times, which change the bell times within a reasonable time window, makes more trips become compatible and could reduce the total number of buses. The researchers developed a heuristic method to solve the large-scale MDSBSPTWs directly. This methodology is a Tabu-search-based Ant Colony Optimization method. This method works without dividing the problem into different phases and is very efficient. This heuristic method, namely the Tabu search-based Ant Colony Optimization method, is proposed to solve the MDSBSPTWs. The Tabu Search method is used to find the best combination of the school dismissal time plan. Under each fixed school dismissal time plan, the Ant Colony Optimization algorithm is used to find the best bus schedule. Several school systems have tested this.

- **The Effect of COVID-19 on Mobility and Equity: A Case Study on Transit Users in Baltimore, MD** explores how individual transit riders, who may have had no other option for transportation, fared during the pandemic and how transit agencies balanced reduced revenue with the need to provide service for essential workers and others. One output of this research is a dashboard that allows planners and transit agency officials to compare how 10 comparable cities handled the pandemic for both rail and bus.
- Another pandemic-related project **Impact of COVID-19 on Ridehailing and Other Modes of Transportation** is exploring the changes in ridesharing travel during COVID-19 in terms of travel frequency, travel distances, and travel times. It also is investigating the associated changes in other modes of transportation to understand the interaction of ridesharing with other non-automobile travel modes in an integrated traffic system. It has created a bikeshare trips geodatabase with origins, destinations, trip length and user information.
- Now in its final stages, **EQUITABLE COMPLETE STREETS: Data and Methods for Optimal Design Implementation** studied the interaction between a bicyclist, bus driver and car driver using simulation. The research team has developed models for evaluating urban streets with various allocations of their available space among mixed traffic, bus and bicycle lanes. Various widths have been analyzed for those lane types. Equilibrium mode choice has been explored with logit models. This topic is particularly timely given initiatives in Maryland to improve infrastructure for walkers and cyclists.
- The project **Integrated Optimization of Vehicle Speed Control and Traffic Signal Timing: System Development and Testing** is developing an optimal control system to improve the transportation system efficiency and fuel economy on arterial roads by simultaneously optimizing vehicle speeds and traffic signal timings. It's the first study to develop such an integrated optimization of vehicle speed control and signal timing and test it in microscopic simulation software and a driving simulator for CAVs and CVs.
- **Developing an Intelligent Connected Vehicle based Traffic State Estimator**, which predicts the level of market penetration while estimating the total number

of vehicles on signalized approaches using only CV data, continues to test three estimation approaches, each of which are applied to an intersection in downtown Blacksburg, Virginia.

- Using deep learning for traffic signal state prediction, the centerpiece of the project **Estimating switching times of Actuated Coordinated Traffic Signals: A deep learning approach**, has not been carried out by previous researchers and could be adopted in a large scale to modify Signal Phase and Timing (SPaT) data. On a scale of 1 to 10 for technology readiness, with 10 being ready for immediate implementation, this project is a 9.

3.1 Publications, conference papers and presentations

- Fadhloun, K., Rakha, H., and Mittal, A. **"Bicycle Longitudinal Motion Modeling**." Paper submitted for publication to Transportation Research part B.
- Dr. Samira Ahangari will present her article "DRIVING SIMULATOR STUDY OF THE EFFECTIVENESS OF AN ECO-SPEED-CONTROL (ESC) SYSTEM VIA DIFFERENT TYPES OF ECO-SPEED-GUIDANCE (ESG) IN THE VICINITY OF MULTIPLE SIGNALIZED INTERSECTIONS" at the 2022 Transportation Research Board. The article, co-authored by Dr. Mansoureh Jeihani, grew out of Dr. Ahangari's thesis which involved work on several UMEC projects.
- Nashid K Khadem, and Drs. Hyeon-Shic Shin, Young-Jae Lee, Young Choi and Paul M. Schonfeld will present their paper "OPTIMAL OPTIONS FOR THE FRESH FOOD DELIVERIES IN BALTIMORE FOOD DESERTS" at the 2022 Transportation Research Board.
- Dr. Celeste Chavis, a UMEC researcher, and Don Halligan, who serves on UMEC's advisory board, were both featured in a radio interview about data and transit dollars on July 28, 2021.
  https://www.wypr.org/show/on-the-record/2021-07-28/transit-dollars-and-data

- Dr. Cinzia Cirillo presented the results of the project **EQUITABLE COMPLETE STREETS: Data and Methods for Optimal Design Implementation** to the MSTM team at the Maryland Department of Transportation State Highway Administration. A paper relating to that project also was presented at the 2021 Transportation Research Board.

- The project **Estimating switching times of Actuated Coordinated Traffic Signals: A deep learning approach**
  - Submitted a paper to IEEE ITSC titled "Assessing the Robustness of LSTM Neural Networks for the Prediction of Actuated-Coordinated Traffic Signal Change Times"
  - Revised and submitted a paper to TRB titled " Evaluating the Impact of Look Back Period on LSTM Predictions for Actuated Traffic Signal Switching Times"
  - Revised and submitted a paper to TRB titled "Assessing the Robustness of LSTM Neural Networks for the Prediction of Actuated-Coordinated Traffic Signal Change Times."

- Changes in Bikeshare Travel Behavior during the COVID-19 Pandemic: The Chicago Case Study was accepted for presentation at TRB 2022.

3.2 Journal publications

Enhancing the Performance of a Model to Predict Driving Distraction with the Random Forest Classifier - Samira Ahangari, Mansoureh Jeihani, Anam Ardeshiri, Md Mahmudur Rahman, Abdollah Dehzangi, 2021 (sagepub.com) in *Transportation Research Record*

Eteifa, S., Rakha, H. A., & Eldardiry, H. (2021). Predicting Coordinated Actuated Traffic Signal Change Times using Long Short-Term Memory Neural Networks. *Transportation Research Record*, https://doi.org/10.1177/03611981211000748.

Jianhe Du, Hesham Rakha, Fethi Filali, and Hoda Eldardiry, "COVID-19 Pandemic Impacts on Traffic System Delay, Fuel Consumption and Emissions," *International Journal of Transportation Science and Technology*, 2021. 10 (2): p. 184-196.

Dr. Young-Jae Lee and Dr. Amirreza Nickkar had a paper accepted both for presentation at the Transportation Research Board and publication in the *Transportation Research Record*: "Developing an Optimal Peer-to-Peer Ride-Matching Problem Algorithm with Ride Transfers."

Dr. Amirreza Nickkar, who as a doctoral student worked on several UMEC projects, has had a paper resulting from his thesis accepted for publication in the *Transportation Research Record*, "Willingness-to-Pay for the Automated Safety Features in Vehicles; An Adaptive Choice-Based Conjoint Analysis Approach."

Bayrak, M., Guler, S. I. and Schonfeld, P. "Implementation Sequence Optimization for Dedicated Bus Lane Projects," accepted for *Transportation Research Record*, March 18, 2021.

3.4 Websites or other Internet sites

www.morgan.edu/umec

The website has 3,802 visitors so far this year and 8,455 page views.

LinkedIn

We added LinkedIn this year and we have 81 followers.

www.facebook.com/urbanmobilityandequitycenter

We have 146 followers, but we cross post on the NTC Facebook page, which has 285 followers. We are in the process of establishing one page for both so that our reach is not diluted.

Twitter @UMEC research).

We have 68 followers, but the NTC page, which retweets our tweets, has 149 followers. Again, we plan to create one Twitter page for both research groups, which should increase our reach. Our tweets average 1,282 impressions per month.

Instagram: ntcumec (https://www.instagram.com/ntcumec/).
We have 58 followers on Instagram.

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

3.5 Technologies or techniques

- **Estimating switching times of Actuated Coordinated Traffic Signals: A deep learning approach** utilized LSTM Deep Neural Networks for Traffic Signal switching time prediction for the first time. The predictions are proposed to modify Signal Phase and Timing (SPaT) messages to enable Eco Driving.
- **A Comparative Study of Pedestrian Crossing Behavior and Safety in Baltimore and Washington, D.C., Using Video Surveillance** used multivariate clustering for intersection selection to analyze pedestrian behavior. The project also created a GIS database that contains socio demographic and land use data for Washington, D.C., and Baltimore, Maryland. Here is a video of the detection algorithm: https://urldefense.proofpoint.com/v2/url?u=https-3A__drive.google.com_file_d_1S4FDmetRtvI166QxfwAmPwBrvusqjlBe_view-3Fusp-3Dsharing&d=DwMFaQ&c=0CCt47_3RbNABITTvFzZbA&r=tkSzIt60NpJxRGk4AL7jZsc4Go-Bt7IqLGgL4Pyx3Bc&m=82qaji46Z7iaOhNMVIZQgpzCO8JROVI7bdz9SNgkQwU&s=pUT44-Dgo7Z0zJN3vUgK5OAAf6FPxLj87Wm_01aGqqw&e=
- The project **Integrated Optimal Transit Network Design with MaaS Implementation** is building an algorithm that will help transit agencies design and modify their networks as they consider MaaS implementation. Mobility as a Service (MaaS), an emerging trend, is a shift from individually owned transportation to mobility provided as a service -- transit, bike sharing, e-scooter sharing, shared mobility and ride hailing -- through a unified gateway that creates and manages the trip, for which users can pay with a single account.
- Since most vehicles on the road do not have automated control, the proposed CV control system in **Integrated Optimization of Vehicle Speed Control and Traffic Signal Timing: System Development and Testing** ensures that non-CVs can also be optimized to drive on arterial roads with the consideration of human errors and perception reaction delay.

3.6 Inventions, patent applications and/or licenses

- Provisional Patent Application for Safety Applications for Work Zones, 63/159,901, 3/11/2021. A work zone safety application will help commercial vehicle operators to navigate their way through or around work zones. There are two different user interfaces – one will be for a worker at the work zone or their contractor, and one will be for commercial vehicle road users.

- Provisional Patent Application for Integrated Automated Wheelchair and Adapted Automated Vehicle System, 63/231,379, 8/10/2021. UMEC researchers invented an Automated Wheelchair (AW) that will enable people with multiple types of disabilities to move independently within an airport terminal, from curb drop-off to gate access. The AW is aimed to be programmable to navigate its destination through the best route with a minimum of manual intervention and could be scaled to broader operating design domains beyond this project. We are in the process of building an AW**.**

- Non-Provisional Patent Application for Distracted Driving Recognition Model Using Machine Learning, 17/389,741, 7/30/2021. UMEC researchers developed a model using machine learning to predict distraction patterns with respect to the different roads and driving environments. The model recognizes if drivers are distracted based on their driving performance and the type of distraction, i.e. texting, handheld phone call, hands free phone call, voice command, clothing, eating/drinking.

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

- The project **Adoption and Diffusion of Electric Vehicles in Maryland** identified factors that indicate a person's propensity to adopt an electric vehicle. It's no surprise that tax incentives and vehicle prices were critical, but other attributes were crucial as well, such as range, the time of charging, and the existence of charging infrastructure in the household. This is valuable information for the automotive and power industry.
- The models and new algorithms developed for **Multi-depot and Multi-school Bus Scheduling Problem with School Bell Time Optimization** could be used to develop school bus routes from multiple depots for any school system, solving a complicated problem all school systems face.
- The project **Bicyclist Longitudinal Motion Modeling** provides a comprehensive investigation of the traffic flow dynamics of bicycles. It develops a dynamics-based model for the description of the longitudinal motion of bicycles in both constrained and unconstrained cycling conditions while accounting for bicyclist behavior variability. Multi-modal modeling tools also are being developed that will integrate cycling behavior modeling with vehicle modeling.
- Although the project is not yet complete, it is anticipated that the systems proposed in **Integrated Optimization of Vehicle Speed Control and Traffic Signal Timing: System Development and Testing** will improve the mobility of arterial traffic, reducing delays and emissions, which particularly benefits low-income areas.
- As discovered in the project **Impact of COVID-19 on Ridehailing and Other Modes of Transportation**, bikeshare was used more than ever during the pandemic due to the natural distancing between travelers and the open air nature of it. As the analysis results show, users may use bikeshare more on daily commutes, and this verifies the feasibility of using bikeshare for regular commuting use. The spatial correlation of highly used bike dock stations with public transit stops reminds us to better coordinate bike and public

transit modes in the future if we want to better utilize bikeshare as a routine commuting mode.

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?

- The project **Adoption and Diffusion of Electric Vehicles in Maryland** used machine learning to identify who might be a potential adopter of an EV. Researchers also addressed the issue of misclassification -- people identified as potential adopters when, in fact, they are not -- which can severely impact expensive marketing campaigns that use socioeconomic information to profile would-be buyers. Along the same line, successfully identifying EV adopters makes policies promoting EVs more efficient.
- The tools developed by the project **Bicyclist Longitudinal Motion Modeling** will help planners with cycling operations and management.
- The tests developed in **Integrated Optimization of Vehicle Speed Control and Traffic Signal Timing: System Development and Testing** will help government stakeholders and industry companies estimate the benefits of implementing the proposed system.
- **Investigating the Effect of Connected Vehicles (CV) Route Guidance on Mobility and Equity** is exploring the system-wide effect of both car and bus connected vehicles on equity. Data from various scenarios has been analyzed, and the impact of different traffic conditions and CV penetration rates investigated. These findings give insight into the impacts of gradual deployment of CVs on mobility and equity and help planners develop policies on advanced vehicles.
- The project **Impact of COVID-19 on Ridehailing and Other Modes of Transportation** illustrates the need for policies that improve dock station distribution and better coordination of bikesharing with public transit.

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 project **A Comparative Study of Pedestrian Crossing Behavior and Safety in Baltimore and Washington, D.C., Using Video Surveillance** adopted two different CV algorithms for better accuracy for object detection and tracking and used Region of Interest (ROI) to determine the pedestrian crossing for jaywalking implementation.
- **Investigating the Effect of Connected Vehicles (CV) Route Guidance on Mobility and Equity** provides recommendations regarding after-market packages to be used for low-income, non-CV owners as well as information on accommodating mobility-challenged travelers in CVs. This research also helps transportation agencies take advantage of their capabilities in incident detection and congestion relief. The research findings also provide insights into the benefits and impacts of CV buses versus non-CV buses, as a result of CV car penetration rates, and explore feasible ITS strategies to benefit transit users who can’t afford CVs.

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

- The detailed framework for application of LSTM to traffic signal switching time prediction, developed in **Estimating switching times of Actuated Coordinated Traffic Signals: A deep learning approach**, provides a benchmark for researchers utilizing deep learning to tackle the same problem. The new efforts show it is robust to different traffic conditions during the COVID-19 pandemic.
- The models and algorithms developed in **Multi-depot and Multi-school Bus Scheduling Problem with School Bell Time Optimization** are state-of-the-art and will be significant additions to the body of knowledge in this field.
- Although not yet complete, the project **Integrated Optimal Transit Network Design with MaaS Implementation** will show how the emerging transportation modes can work together with existing modes to maximize efficiency. Improving and modernizing transit services is an important equity consideration.

5.3 What is the impact on transportation workforce development?

- **EQUITABLE COMPLETE STREETS: Data and Methods for Optimal Design Implementation** is providing partial funding for three Ph.D. students, two at the University of Maryland and one at Morgan State University.
- The project **A Comparative Study of Pedestrian Crossing Behavior and Safety in Baltimore and Washington, D.C., Using Video Surveillance** was included in the 2021 Smart City Research Experience for Undergraduates and Teachers training program at Morgan State University.
- **Developing an Intelligent Connected Vehicle based Traffic State Estimator** provides graduate students with opportunities for research in transportation engineering as well as developing and disseminating educational materials. The developed approach can be used as teaching material in transportation engineering courses.
- The project **Estimating switching times of Actuated Coordinated Traffic Signals: A deep learning approach** has given students a chance to become familiar with data analytics and new methodologies involving deep learning.
-

6 CHANGES/PROBLEMS.

6.1 Changes in approach and reasons for change.

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

All projects that involved using human subjects in the driving simulator at Morgan State University have experienced delays since the campus was closed due to COVID-19; the campus reopened in August.

- The project **Bicyclist Longitudinal Motion Modeling** was delayed because the newly purchased bike simulator wasn't working properly and the company had to send a replacement, which wasn't available until late August.
- The PI for **A Comparative Study of Pedestrian Crossing Behavior and Safety in Baltimore and Washington, D.C., Using Video Surveillance** is taking a three-month maternity leave this fall, and both of the graduate researchers on that project are also expecting in late fall/winter.
- The project **Developing an Intelligent Connected Vehicle based Traffic State Estimator** was granted a six-month extension to increase the estimation accuracy of the adaptive multivariate Kalman Filter approach, which is proposed to estimate the CV level of market penetration along with the total number of vehicles.
- The project **The typology of transportation accessibility: A qualitative and quantitative meta-analysis** was delayed because the graduate student hired to work on it had a conflict with another job and couldn't continue to work on the project. Another student will need to be hired and the project will need to request a no-cost extension.

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.

Nothing to report

6.5 Change of primary performance site location from that originally proposed

The project **A Comparative Study of Pedestrian Crossing Behavior and Safety in Baltimore and Washington, D.C., Using Video Surveillance** may be able to survey more locations than originally proposed.

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.