Semi-Annual Progress Report No. 5 – 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:	April 30, 2021
DUNS#:	879941318
EIN#:	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 9/30/22
Reporting Period End Date:	March 31, 2021
Report Term:	Semi-annual. This report covers Oct. 1, 2020, to March 31, 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. Safety, technology and commuting, always priorities for UMEC, took on new meaning in the context of COVID-19.

1.2 What was accomplished under these goals?

Below is a chart listing all 40 UMEC projects; 26 have been completed and are listed in green type. Final reports for these projects are available on our website, www.morgan.edu/umec, and they have been submitted to the appropriate databases.

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.

Dr. Eazaz Sadeghvaziri was hired as a postdoctoral research associate at Morgan to supervise research projects, including UMEC research.

Project Type/ University	Project Name	PIs
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	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 – UMD, MSU	E3: Evaluating Equity in Evacuation: A Practical Tool and A Case Study	Cinzia Cirillo, Celeste Chavis
Collaborative – VT, UMD	Developing an Eco-Cooperative Adaptive Cruise Control System for Electric Vehicles	Hao Che Hesham Rakha, Cinzia Cirillo

Collaborative – VT, MSU	Improving Public School Bus Operations: Boston Case Study	Youssef Bichiou, Hesham Rakha Young-Jae Lee, William Eger

1.3 How have the results been disseminated?

When projects are complete, the reports are submitted to various databases and posted online. We also email a one-page fact sheet summarizing research to 535 people, including researchers, elected officials and journalists. We also email an annual newsletter listing all projects to the same list.

We also hosted two days of webinars, which are then available on YouTube. The first day, on Feb. 26, 2021, featured four webinars about research addressing COVID-19, mobility and equity. They are:

- The Effect of COVID-19 on Mobility and Equity: A Case Study on Transit Users in Baltimore, Maryland, presented by Dr. Mansoureh Jeihani and Dr. Celeste Chavis of Morgan State University. The Effect of COVID-19 on Mobility and Equity: A Case Study on Transit Users in Baltimore, MD - YouTube (38 attendees/15 views)
- Willingness-to-pay for Shared Automated Mobility Using an Adaptive Choice-Based Conjoint Analysis during the COVID-19 Period, presented by Dr. Young-Jae Lee, Dr. Hyeon-Shic Shin, and Amirreza Nickkar from Morgan State University. Willingness-to-pay for Shared Automated Mobility Using an Adaptive Choice Based Conjoint Analysis - YouTube (26 attendees/13 views)
- COVID-19 Pandemic Impacts on Traffic System Delay, Fuel Consumption and Emissions, presented by Dr. Jianhe Du of Virginia Tech. COVID-19 Pandemic Impacts on Traffic System Delay, Fuel Consumption and Emissions - YouTube (26 attendees/19 views)
- E3: Evaluating Equity in Evacuation: A Statistical Approach to Small Area Synthetic Population Generation as a Basis for Carless Evacuation Planning Evaluating Equity in Evacuation - YouTube (18 attendees/7 views)
- 7 Minutes to Better Writing 7 minutes to better writing - YouTube (30 attendees/11 views)

The second day, which took place on March 26, focused on Urban Mobility.

- Phased Development of Pre-Designed Rail Transit Line, presented by Fei Wu and Dr. Paul Schonfeld from the University of Maryland (27 attendees/5 views)
- Developing Optimal Peer-to-Peer Ridesharing Strategies, presented by Dr. Young-Jae Lee and Amirreza Nickkar of Morgan State University (26 attendees/5 views)

- Shared Bus-Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts, presented by Dr. Celeste Chavis of Morgan State University (27 attendees/13 views)
- Developing an Optimal Integrated Single Framework Algorithm for the Multi-Level School Bus Network Problem, presented by Dr. Young-Jae Lee and Amirreza Nickkar from Morgan State University (18 attendees/3 views)

Of note is that one of the attendees was a representative from the office of Maryland State Senator Antonio Hayes.

After the March webinar, presenter Dr. Celeste Chavis received the following email from a planner at the Maryland Department of Transportation:

> Hi Celeste,
>
> I really enjoyed your presentation on the shared bike and bus lanes. Patrick McMahon and I worked on the Pratt & Lombard lanes for the Circulator and we always wanted to see analysis like this. Drone use is a great idea. SBBLs came up at length during our discussion Tuesday so you may get a few calls.
>
> Hope all's well,
> Nate
>
> **Nate Evans**
> Active Transportation Planner
> 410-404-1826 (mobile)
> nevans1@mdot.maryland.gov

A third day of webinars is set for April 30, 2020, on connected and autonomous vehicles and energy; we will include the links in the October report.

On April 22, 2021, Dr. Mansoureh Jeihani and Dr. Young-Jae Lee will present research to the Maryland Department of Transportation secretary.

Dr. Mansoureh Jeihani also presented her research into CAVs to the Ford Motor Co. on Feb. 23 and in a T3 webinar series on Feb. 24.

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

We will continue to support UMEC researchers as they complete ongoing projects. We will award the fifth-year funding for collaborative research projects, as well as solicit proposals for the sixth year of funding. We will continue to promote our research to both technical and general audiences.

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

What organizations have been involved as partners?

Maryland Transit Administration
Quality Counts Data Collection Service
City of Richmond
Bewegen

Have other collaborators or contacts been involved?

The BWI Business Partnership offers a series of breakfast webinars, and our interim director, Dr. Mansoureh Jeihani, presented "Transportation: A Key to Human and Economic Development" at 8:30 a.m. on Feb. 24.

https://bwipartner.org/meetinginfo.php?id=165&ts=1611588864

UMEC partnered with BGE, the Baltimore region utility company, to present a two-hour webinar to Morgan and other HBCUs entitled "Getting EVsmart: How Utilities like BGE are driving Equitable Electrified Transportation" that will take place on May 7, 2021.

The newly elected mayor of Baltimore, Brandon Scott, appointed Dr. Celeste Chavis as co-chair of his transition committee on Transportation and Infrastructure in November.

Dr. Mansoureh Jeihani is part of the State of Maryland Connected and Autonomous Vehicle Group, and Morgan State, including UMEC research, was featured in one of their videos (at minute 7:02): https://vimeo.com/489536117/87360f5d2c

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

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

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

Board Member, Central Maryland Transportation Alliance, 2018 – Present (regional)

Member, Complete Streets Equity Workgroup, Baltimore City Department of Transportation, 2017-2019 (regional)
Board Member, Public Advisory Committee (PAC) of the Baltimore Regional Transportation Board (BRTB), 2017 – Present (regional)
Member, Innovative Public Transportation Services and Technologies Committee, Transportation Research Board, 2020 – Present (national)

Dr. Mansoureh Jeihani is:
Chair of Strategy 3 for the Highway Safety Strategic Plan.
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

Morgan State doctoral student Amirreza Nickkar is on the Public Transport Committee of the American Society of Civil Engineers. He also was selected for the 2020 WDCSITE Scholarship Award.

Graduate student researcher Nashid Khadem won a scholarship from the Intelligent Transportation Society of Maryland.

Dr. Kofi Nyarko, associate professor in electrical and computer engineering at Morgan State University, is a partner in UMEC research.

Dr. Javier Bas, a researcher at the University of Maryland, is a partner in UMEC research.

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

A stated goal of our technology transfer plan was developing technologies for signalized intersections.

- The project **Developing and Testing an Advanced Hybrid Electric Vehicle Eco-Cooperative Adaptive Cruise Control System at Multiple Signalized Intersections** used a simple HEV energy model to compute the instantaneous energy consumption level for HEVs and a vehicle dynamics model to capture the relationship between speed, acceleration level and tractive/resistance forces on vehicles. The constraints of energy model and vehicle dynamics are used to develop two HEV Eco-CACC-I controllers for single and multiple intersections, respectively. The controllers include two modes: automated and manual, for vehicles with or without an automated control system. The automated mode was implemented into the microscopic traffic simulation software so that connected and automated vehicles (CAVs) can directly follow the energy-optimized speed profile.
- The use of deep learning for traffic signal state prediction, conducted for 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 SPaT data.

- A year-four project **Integrated Optimization of Vehicle Speed Control and Traffic Signal Timing: System Development and Testing** will be the first study to develop 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, respectively.
- Predicting the level of market penetration (LMP) while estimating the total number of vehicles on signalized approaches using only connected vehicle (CV) data is the objective of **Developing an Intelligent Connected Vehicle based Traffic State Estimator**. This project uses a machine learning technique to estimate the LMP.
- The project **Estimating switching times of Actuated Coordinated Traffic Signals: A deep learning approach** uses LSTM Deep Neural Networks for Traffic Signal switching time prediction for the first time.
- **Estimating Traffic Stream Density Using Connected Vehicle Data** uses several approaches, including a machine learning model, to estimate traffic stream density, which is crucial for advanced traffic management systems. The estimates were on signalized links using connected vehicle data, and researchers evaluated a novel variable estimation, a linear Kalman filter, a linear adaptive KF and a nonlinear particle filter to find an accurate method that was easily applicable in the field.
- The project **Developing Optimal Peer-to-Peer Ridesharing Strategie**s has developed an algorithm to solve the P2P multi-driver, multi-rider ride-matching problem; details are being withheld while the research is reviewed for a possible provisional patent application.

Other outputs included:

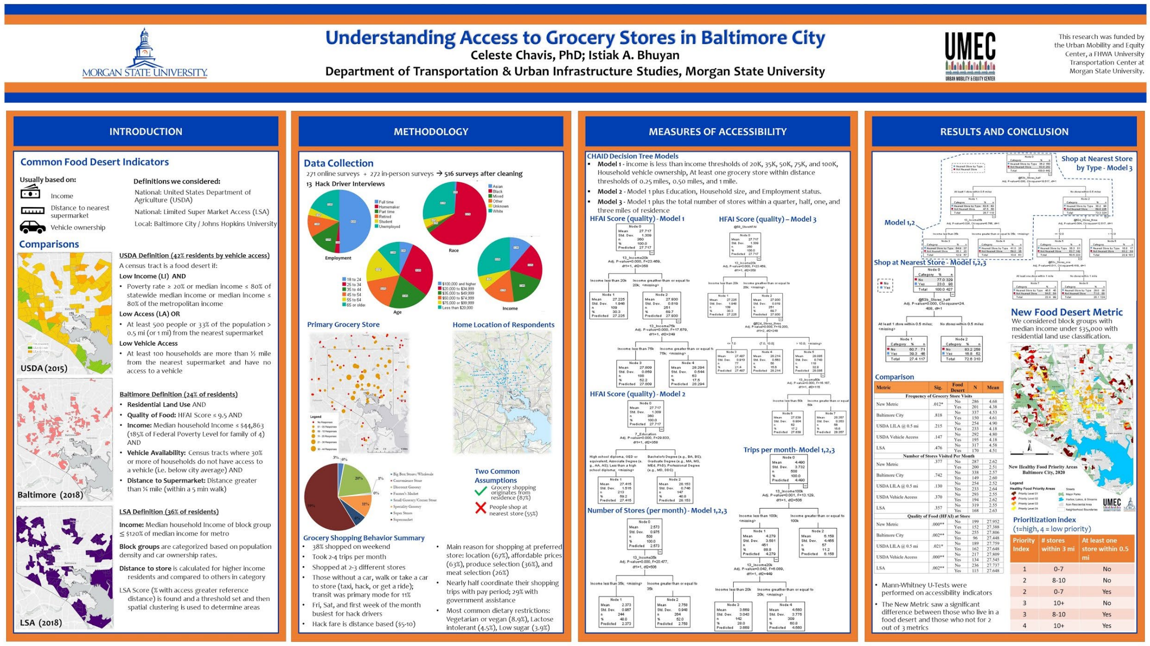
- **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** created an index to identify potentially unsafe bike lanes in a network. The project also developed a database of bike facilities that includes the following data for each roadway segment: facility type, AADT, bus frequency, number of crashes, roadway speed, and video collection via drones. Also, this study used tethered drones to investigate SBBLs. Here is sample footage from a data collection site: https://www.dropbox.com/sh/u0rnh1x0l21c055/AAAR3x_vo2uHct7UN73PIGNqa?dl=0
- COVID-19 provided an unparalleled research opportunity, and **The Effect of COVID-19 on Mobility and Equity: A Case Study on Transit Users in Baltimore, MD** used surveys and analysis of transit data to understand the role of transit in a pandemic.
- As its name suggests, the project **Multi-depot and Multi-school bus Scheduling Problem with School Bell Time Optimization** develops a mixed-integer programming model with the goal of minimizing the total number of buses and the total deadhead duration. It also develops a two-phase heuristic method and solution algorithms. When completed, this research will be immediately implementable.

- **Adoption and Diffusion of Electric Vehicles in Maryland** uses a machine learning approach to classify adopters and non-adopters of EVs.
- The project **Bicyclist Longitudinal Motion Modeling** is developing a dynamics-based model in both constrained and unconstrained cycling conditions while accounting for bicyclist behavior variability.
- **EQUITABLE COMPLETE STREETS: Data and Methods for Optimal Design Implementation** has formulated a method for evaluating alternative allocations of road space.
- **A Comparative Study of Pedestrian Crossing Behavior and Safety in Baltimore and Washington, DC, Using Video Surveillance** develops a computer vision pipeline approach to identify and track pedestrians and conflicting vehicles. It developed object detection models and object tracking; using a deep neural network for object tracking improved the accuracy, and adopting two different CV algorithms improved object detection and tracking. Here is a video illustrating the development of the detection algorithm: detection_DC_video_short.mp4 - Google Drive
- **A Study of the Impact of Ride-hailing on Public Transit Ridership** uses real-time geospatial analyses to estimate the extent to which ride-hailing services have contributed to declines in public transit ridership.
- **Equity in Accessibility to Opportunities: Insights, Measure and Solutions based on Mobile Device Location Data** uses big data from individual mobile devices to systematically study accessibility. Having a clear understanding of equity issues is critical to developing policies to address them.
- **E-Bikes' Effect on Mode and Route Choice: A Case Study of Richmond, Va Bike Share** addressed a lack of research into how e-bikes, which remove some of the physical barriers to biking, are used and by whom.

3.1 Publications, conference papers and presentations

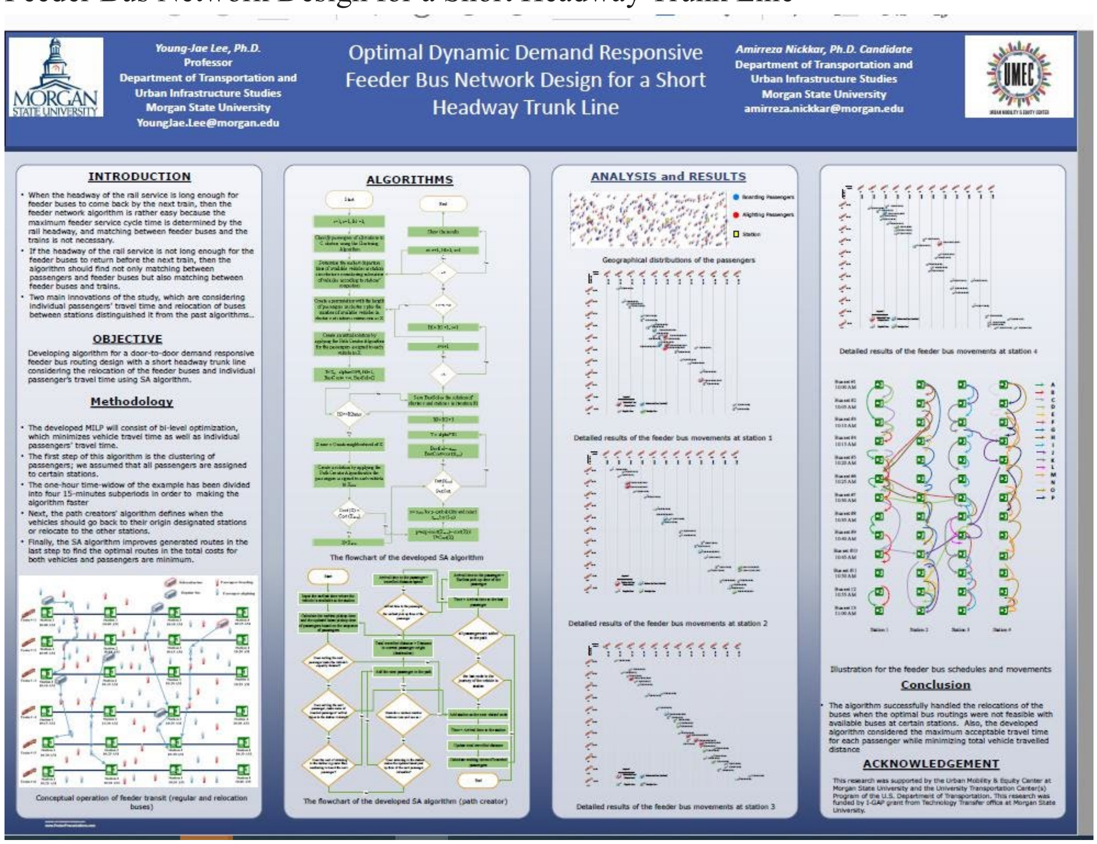
The following projects were presented at the 2021 TRB Annual Meeting in Washington, D.C.:

- Amirreza Nickkar and Dr. Young-Jae Lee, "Developing an Optimal Integrated Single Framework Algorithm for the Multi-Level School Bus Network Problem"
- Khadem, N., Jeihani, M., Kabir, M., Abujana, J., "Drivers' Reaction to Connected and Automated Vehicle Safety Applications in the Vicinity of a Work Zone: A Driving Simulator Study"
- Dr. Celeste Chavis, Istiak Bhuyan, "Understanding Access to Grocery Stores: A Data-Driven Food Desert Metric Using CHAID Decision Tree Analysis"

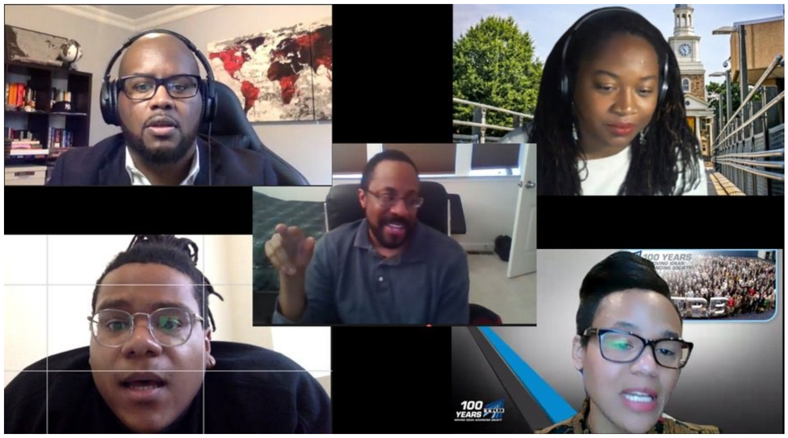


- Dr. Celeste Chavis, "Multi-Modal Traffic Flow in Shared Bus-Bike Lanes: A Scoping Literature Review and Comparison with Baltimore SBBL Infrastructure"

- Amirreza Nickkar, Dr. Young-Jae Lee, "Optimal Dynamic Demand Responsive Feeder Bus Network Design for a Short Headway Trunk Line"



- Because of our emphasis on equity, Dr. Celeste Chavis (pictured below in top right corner) was a panelist for a TRB panel called "Arrested Mobility: Exploring the Impacts of Over-policing BIPOC Mobility." It received a lot of publicity and was attended by more than 250 people.



Dr. Chavis was quoted in this article:
https://www.bizjournals.com/baltimore/news/2021/03/15/highway-to-nowhere-federal-momentum-tear-it-down.html

Dr. Young-Jae Lee and graduate student Amirreza Nickkar presented Developing an Optimal Integrated Single Framework Algorithm for the Multi-Level School Bus Network Problem at the WDCSITE Project of the Year Awards Virtual Meeting on Feb. 25, 2021. WDCSITE represents transportation professionals in Northern Virginia, Maryland and the District of Columbia and is part of the Institute of Transportation Engineers.

3.2 Journal publications

"Machine Learning Methods for the classification of potential electric vehicle purchasers," by Javier Bas, Zhenpeng Zou, Cinzia Cirillo, was published in print in Technology Forecast and Social Change.

An article by Samira Ahangari, Dr. Mansoureh Jeihani, Dr. Anam Ardeshiri, Dr. Md Mahmudur Rahman and Dr. Abdollah Dehzangi, entitled "Enhancing Driving Distraction Prediction Model Performance Using Random Forest Classifier" has been accepted for publication in the Transportation Research Record.

3.3 Books or other non-periodical one-time publications

Nothing to report.

3.4 Websites or other Internet sites

www.morgan.edu/umec In the last 30 days the website had 437 visits, 351 unique visitors and 903 page views.

www.facebook.com/urbanmobilityandequitycenter We have134 followers. On average, our posts reach 45 people and 17 engage with them.

Twitter @UMEC research). We have 62 followers and our tweets average 2,724 impressions per month; impressions are the number of times users saw the tweet. In February, a tweet for Black History Month saluting Morgan's former Dean of Engineering Dr. Eugene M. DeLoatch earned 4,085 impressions.

Instagram: ntcumec (https://www.instagram.com/ntcumec/). UMEC has 49 followers on Instagram.

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

3.5 Technologies or techniques

As previously stated, **Estimating switching times of Actuated Coordinated Traffic Signals: A deep learning approach** takes a novel approach and details the modeling framework for applying machine learning to transportation problems. This project is an 8 out of 10 for technology readiness. The project **Estimating Traffic Stream Density Using Connected Vehicle Data** recommended using the linear Kalman filter approach to estimate traffic density, since it is simple, applicable to the field and accurately estimates vehicle counts. The project **Equity in Accessibility to Opportunities: Insights, Measures and Solutions based on Mobile Device Location Data** is the first study that uses mobile device big data to systematically study accessibility with a data-driven approach. As a new data source, mobile device location data offers a novel paradigm for measuring and analyzing accessibility.

3.6 Inventions, patent applications and/or licenses

A utility patent was granted to Dr. Young-Jae Lee for the algorithm developed as part of **Optimal Automated Demand Responsive Feeder Transit Operation and Its Impact**, a first-year project. Four provisional patents are on file and a fifth provisional patent application has just been filed. An intellectual property disclosure form has been created for a sixth project.

In January, the National Transportation Center and UMEC received an award from the Council of University Transportation Centers for technology transfer. A link to the acceptance video is provided below under workforce development.

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

- Simulation tests conducted as part of **Developing and Testing an Advanced Hybrid Electric Vehicle Eco-Cooperative Adaptive Cruise Control System at Multiple Signalized Intersections** using the INTEGRATION software validated the performances of the proposed controllers under the impact of signal timing, speed limit, and road grade. The simulation tests also demonstrated the benefits of using the proposed HEV Eco-CACC-I controllers in a traffic network with multiple intersections.
- The project **Optimized Development of Urban Transportation Networks 2.0** brings together eight papers; five of them focus on methods for evaluating, sequencing and scheduling interrelated improvements in a transportation network while two others present methods for designing flexible route services and one addresses improving the reliability of rail transit networks. The papers demonstrate the applicability of the developed methods to transportation networks.
- The project **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** found that such lanes are safe for cyclists, good news for cities that lack space to add bike lanes. Nor do bikes delay buses. But enforcement is needed to ensure the lanes are free from stopped cars and delivery vehicles, which cause buses and bikes alike to have to maneuver around them into traffic.
- **Investigating the Effect of Connected Vehicles (CV) Route Guidance on Mobility and Equity** provides recommendations regarding after-market packages for low-income, non-connected vehicle owners as well as information about accommodating mobility-challenged travelers in CVs.
- As a result of **The Effect of COVID-19 on Mobility and Equity: A Case Study on Transit Users in Baltimore, MD**, transit agencies will improve scheduling and safety considerations and be better prepared for the steep reduction in fare revenue.
- **Adoption and Diffusion of Electric Vehicles in Maryland** has a direct application for public administrations interested in fostering the acquisition of EVs, as well as for private companies in the energy and automotive industry that are looking for a reliable procedure to classify potential clients for whom they have only limited information.
- When completed, the project **Bicyclist Longitudinal Motion Modeling** will allow the development of multi-modal modeling tools that would integrate cycling behavior modeling with vehicle modeling.
- **A Comparative Study of Pedestrian Crossing Behavior and Safety in Baltimore and Washington, DC, Using Video Surveillance** furthers understanding of the microscopic behavior of pedestrians and critical factors affecting pedestrian behavior.
- The estimated outcomes from **Developing an Intelligent Connected Vehicle based Traffic State Estimator** can be provided to traffic signal controllers to optimally determine the allocation of green time for each traffic signal phase, leading to better intersection performance measures.
- The methods produced in **A Study of the Impact of Ride-hailing on Public Transit Ridership** can be used by transit agencies internally to evaluate opportunities and redundancies in service.

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?

- Researchers implemented a manual model of the controller proposed in **Developing and Testing an Advanced Hybrid Electric Vehicle Eco-Cooperative Adaptive Cruise Control System at Multiple Signalized Intersections** in a driving simulator and found that drivers could follow the recommended speed advisories and the controller helped them drive smoothly and save fuel at intersections. An already highly fuel efficient vehicle can be made even more efficient.
- **Optimized Development of Urban Transportation Networks 2.0** offers eight interrelated papers in one place, and the methods developed in them are already usable for evaluating, selecting and scheduling interrelated network improvement projects.
- The project **How Mobility and Accessibility Affect Crime Rates: Insights from Mobile Device Location Data** investigated possible correlations between mobility, accessibility and the crime rate, specifically burglaries. This is a controversial topic in the region, where attempts have been made to limit transit to suburban areas because of a perceived link between transit and crime. The study found that an increase in crime was linked to non-motorized travel, such as non-residents walking or biking through the neighborhood, not transit.
- Researchers for **Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts** met with representatives from the Maryland Transit Administration for evaluating bus performance using the dataset.
- **Investigating the Effect of Connected Vehicles (CV) Route Guidance on Mobility and Equity** will help planners develop policies for advanced vehicles and equip roads with units to best take advantage of this technology.
- Determining common causes of unsafe maneuvers and near misses for pedestrians, a result of the project **A Comparative Study of Pedestrian Crossing Behavior and Safety in Baltimore and Washington, DC, Using Video Surveillance**, will improve pedestrian safety.
- The developed real-time estimation model resulting from **Developing an Intelligent Connected Vehicle based Traffic State Estimator** will improve the design and operation of transportation systems, helping planners develop an efficient, adaptive traffic signal controller.
- The project **A Study of the Impact of Ride-hailing on Public Transit Ridership** provides a thorough approach and a fine-tuned series of real-time spatial analyses that investigate the replace-ability of ride-hailing trips with public transit. The results encourage public transit agencies to investigate opportunities to collaborate with ride-hailing companies.
- **E-Bikes' Effect on Mode and Route Choice: A Case Study of Richmond, VA Bike Share** revealed that this relatively new mode of transportation is associated with longer trips, shorter trip times, higher speeds and lower elevations. However, the case study area is rather flat, so further research is needed in a hillier terrain. They were also associated with higher average numbers of trips on major roads than traditional bikes.

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

Nothing to report.

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

- The models and algorithms developed for **Multi-depot and Multi-school bus Scheduling Problem with School Bell Time Optimization** will be a significant addition to the body of knowledge in this field.
- For **Estimating switching times of Actuated Coordinated Traffic Signals: A deep learning approach,** the detailed framework for application of LSTM to traffic signal switching time prediction provides a benchmark for researchers using deep learning to tackle the same problem.
- **Equity in Accessibility to Opportunities: Insights, Measure and Solutions based on Mobile Device Location Data** offers a new paradigm for using the massive amounts of data generated by individual mobile devices.

5.3 What is the impact on transportation workforce development?

The National Transportation Center and UMEC were honored with an award from the Council of University Transportation Centers for workforce development. View the acceptance video at Created for the 2021 CUTC Annual Awards Banquet - YouTube

On Dec. 8, 2020, Dr. Jeihani was a panelist for the Maryland STEM Career Fair for Girls, which had more than 350 high school girls attend.

The National Summer Transportation Institute will be offered virtually to high school and middle school students this July. The program introduces them to the transportation field and the STEM concepts needed for such work.

A Ph.D. student at Morgan will use the project **EQUITABLE COMPLETE STREETS: Data and Methods for Optimal Design Implementation** as part of his dissertation; two other Ph.D. students at the University of Maryland also have worked on this project.
The project **A Comparative Study of Pedestrian Crossing Behavior and Safety in Baltimore and Washington, DC, Using Video Surveillance** is being adapted for inclusion in the 2021 Smart City Research Experience for Undergraduates and Teachers training program at Morgan State University.

All of our projects afford graduate students the opportunity to participate in research, helping to improve their performance and skills.

6 CHANGES/PROBLEMS.

6.1 Changes in approach and reasons for change.

The project **Demand Responsive Delivery of Food in Baltimore City Food Deserts**, which had been funded with $40,000 from the USDOT and a $20,000 match, was canceled and all monies returned to the center's budget. The original PI retired a few months after the project began. The PI who took it over had not started the project, which required significant lab time as well as hiring a graduate research assistant, before the pandemic closed the campus. UMEC had already completed two successful projects addressing food deserts, and given the lack of progress on this one coupled with the uncertainties of when the campus would reopen, we decided to cancel it.

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

The project **Estimating switching times of Actuated Coordinated Traffic Signals: A deep learning approach** had issues with the memory management and data size for training the LSTM models which were tackled by developing more efficient data manipulation and preparation algorithms to feed the network

The project **EQUITABLE COMPLETE STREETS: Data and Methods for Optimal Design Implementation** needs substantial time in the simulation lab to study interactions of pedestrians, cyclists and drivers, but the Morgan campus is still closed due to COVID-19. Morgan is planning to reopen in stages this summer.

6.3 Changes that have a significant impact on expenditures.

Nothing to report.

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

Nothing to report

6.5 Change of primary performance site location from that originally proposed

Researchers continue to work remotely to varying degrees due to the pandemic.

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.