

# C<sup>2</sup>M<sup>2</sup> News

Fall 2019/Spring 2020



## Director's Message

Welcome to the U.S. Department of Transportation Center for Connected Multimodal Mobility (C<sup>2</sup>M<sup>2</sup>) newsletter. We invite you to read about research and news on emerging transportation technologies in this newsletter, and to visit our website at <https://cecas.clemson.edu/C2M2/> for additional information about our center's research, education, outreach, and workforce development efforts.

### C<sup>2</sup>M<sup>2</sup> Future Leaders Program



The landscape of mobility will be transformed dramatically due to rapidly evolving and emerging transportation technologies, such as connectivity and automation. We must create a new generation of transportation leaders to serve as torch-bearers for future mobility systems. These future leaders must respond to mobility challenges with intelligence and social conscience.

Thus, C<sup>2</sup>M<sup>2</sup> is launching a future leaders program in spring of 2020. Alongside our other graduate and undergraduate programs, this new effort seeks to develop the traits required for our students to become leaders in the development and application of emerging mobility systems.

The C<sup>2</sup>M<sup>2</sup> lead institution, Clemson University, is spearheading this effort along with the other C<sup>2</sup>M<sup>2</sup> consortium members (Benedict College, The Citadel, South Carolina State University, and University of South Carolina). Students from all C<sup>2</sup>M<sup>2</sup> partner institutions will participate. The program will feature numerous guest speakers discussing the skills required for future leadership. It will also include demonstration of future mobility technologies, readings and lectures related to emerging mobility systems. In addition, the program will aim to improve the writing and presentation skills of the participants. C<sup>2</sup>M<sup>2</sup> will award a certificate to each participant at the end of this six-week-long program. We are excited about this new program and look forward to seeing its impacts.

Mashrur "Ronnie" Chowdhury, Ph.D., P.E., F.ASCE  
Eugene Douglas Mays Professor of Transportation  
Director, USDOT Center for Connected Multimodal Mobility (C<sup>2</sup>M<sup>2</sup>)  
C<sup>2</sup>M<sup>2</sup> website link: [www.cecas.clemson.edu/C2M2/](http://www.cecas.clemson.edu/C2M2/)

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### Lead Institution



### Partner Institutions

Benedict College



SCState  
UNIVERSITY



THE CITADEL  
THE MILITARY COLLEGE OF SOUTH CAROLINA



UNIVERSITY OF  
SOUTH CAROLINA



## C<sup>2</sup>M<sup>2</sup> 2019 UTC Outstanding Student of the Year

C<sup>2</sup>M<sup>2</sup> is excited to announce that Isa Musa, a South Carolina State University (SCSU) graduate student, has been selected as our 2019 University Transportation Center's Outstanding Student of the Year. Isa was invited to join other UTC Outstanding Student of the Year award recipients in Washington D.C. for a recognition banquet hosted by the Council of University Transportation Centers (CUTC) and the U.S. Department of Transportation. Isa was included in the CUTC 2019 Outstanding Students of the Year booklet and received a \$1000 scholarship. One awardee is selected each year for this honor by each University Transportation Center in the United States.

Isa was nominated by his advisor, Dr. Judith Mwakalonge of SCSU, who stated that "In addition to performing his job at a professional level, Isa demonstrates a good commitment to research as well as service to the university community and the general public." Isa is also known for his curiosity and eagerness to learn, and his good written and oral communication skills.

He is a 2nd-year graduate student in the Master of Science in Transportation program at SCSU. His current research focuses on the dangers faced by pedestrians due to distracted behavior. Before this, Isa received his Bachelor of Science degree in Biology from SCSU in May of 2018. Isa's undergraduate research focused on the toxicity of raw crops from local farmers. This allowed him to make recommendations on how to reduce toxicity levels. Isa was also an instrumental contributor to the initiatives of the Health Professions Society, a professional organization for science majors, where he assisted the executive board with fundraising and recruitment initiatives for the Department of Biological and Physical Sciences at SCSU. In this capacity, he also served as a tutor and mentor for students majoring in STEM (Science, Technology, Engineering, and Mathematics).

Isa is currently working on his master's thesis, which is titled "Trip Generation of Electric Vehicles Charging Stations in Columbia, South Carolina." As the market penetration of electric vehicles continues to expand, so will the need for charging stations. Knowing the number of trips generated per charging station is essential in determining the appropriate number of charging ports, parking ports, and other facilities at charging stations. Currently, knowledge about this is limited and Isa's research will fill this gap. After graduation, Isa would like to continue his work on pedestrian behavior and transportation safety. His preferred career after graduation is in public service.



## Published Project Reports

This season multiple C<sup>2</sup>M<sup>2</sup> sponsored projects were completed and their reports disseminated. These reports can be found in their entirety on our website, at [cecas.clemson.edu/C2M2/project-reports](https://cecas.clemson.edu/C2M2/project-reports). Along with the full reports, readers can also access all supporting data, as well as technology transfer reports that outline the researchers' plans to disseminate their research findings. Summaries of these research projects follow.

### Infrastructure and Policy Needs for Personal Electric Mobility Devices in a Connected Vehicle World

**Lead Principal Investigator** – Judith Mwakalonge, *South Carolina State University*

**Co-Principal Investigators** – Jae-Dong Hong, *South Carolina State University*;  
Mashrur Chowdhury, *Clemson University*

Personal Electric Mobility Devices (PEMDs) are becoming a popular, accessible mode of transportation. However, PEMDs' safety and operational features while running on walkways or roadways are not well-known. This report outlines the outcomes of an investigation on policy and infrastructure needs for PEMDs in a connected vehicle world. The study analyzed safety data from the National Electronic Injury Surveillance System



*Study area (South Carolina Connected Vehicle Testbed, Clemson, South Carolina) of PEMDs in a connected environment operating condition.*

(NEISS) to investigate the characteristics of accidents related to PEMDs. Data was collected from the NEISS Query Builder website for four NEISS product codes (1329-Electric Powered Scooters, 1744-Electric Mobility Carts, 3215-Mopeds, and 5042-Electric Skateboards) from 2006 to 2017. The researchers analyzed PEMD-related injuries by time (year, season, month, and day), the demographics of the victims (gender, age, race), the location of the crashes, and the affected body parts of victims. Following this analysis, an experiment was conducted to examine the effect of a hoverboard on pedestrians' walking speed in traditional operating conditions. Based on the experimental data, a simulated environment was created using the VISSIM micro-simulation software to measure any changes in the behavior of pedestrians with and without the presence of PEMDs on a walkway. Further, the study evaluated the operating characteristics of a hoverboard in a connected environment. Finally, the report provides some recommendations for using PEMDs on walkways shared with pedestrians.



## Published Reports Cont.

### Impact of Transportation on Air Quality at Elementary and Middle Schools in South Carolina

**Lead Principal Investigator** – Gurcan Comert, *Benedict College*

**Co-Principal Investigators** – Samuel Darko, *Benedict College*; Nathan Huynh, *University of South Carolina*; Judith Mwakalonge, *South Carolina State University*



*Air quality eggs and radar set-up at Bridge Creek Elementary School.*

This study investigates the impact of traffic volume on air quality at different geographical locations in the state of South Carolina using multilevel linear mixed models and Grey Systems. Historical traffic volume and air quality data from 2006 to 2016 were obtained from the South Carolina Department of Transportation (SCDOT) and the United States Environmental Protection Agency (EPA) monitoring stations. These data were used to develop prediction models that relate the Air Quality Index (AQI) to traffic volume for selected counties and schools. For the selected counties, two models were developed: one with Ozone ( $O_3$ ) and one with particulate matter ( $PM_{2.5}$ ) as dependent variables. For schools, one model was developed with  $O_3$  as the dependent variable. Statistical methods included linear regression model (LM), linear mixed-effect regression model (LMER), Grey Systems (GM), error-corrected GM (EGM), Grey Verhulst (GV), error-corrected GV (EGV), and LMER combined with EGM. The LM model produced the least accurate estimates while the LMER combined with the EGM model produced the most accurate estimate (average RMSE less than 5%). The models' estimates suggest that air quality in South Carolina will continue to get worse in the coming years due to increasing annual average daily traffic (AADT). An interesting finding is that some counties and schools will have higher levels of  $O_3$  or  $PM_{2.5}$  when AADT decreases, which suggests that there are additional factors other than AADT that influence the air quality in these counties and schools.

## Published Reports Cont.

### Unmanned Aircraft Systems' (UAS) Impact on Operational Efficiency and Connectivity

**Lead Principal Investigator** – Joseph M. Burgett, *Clemson University*

**Co-Principal Investigators** – Dennis C. Bausman, *Clemson University*; Gurcan Comert, *Benedict College*



This report outlines the findings of a study that explores the benefits of unmanned aircraft systems (UAS) technology when deployed by the South Carolina Department of Transportation (SCDOT), specifically focusing on land surveying and bridge inspection. The results of a drone-based land survey experiment found that, given common field conditions, survey points could be within 0.68cm (.022 feet) (XY), 0.09cm (.003 feet) (Z), and 1.46cm (.048 feet) (XYZ) of the true location. As a natural extension of this experiment, it was found that computed stockpile volume estimates ranged between 1.5% and 3.3% of actual.



*Dr. Burgett and flight crew #3 preparing a UAS for a bridge inspection.*

To evaluate how effective UASs can be when supporting bridge inspections, a test bridge was inspected twice by two different bridge inspection engineers (BIEs). Over 90% of the inspection points could be sufficiently observed using a drone. Significant advantages of drone deployment were a reduced need for under-bridge inspection trucks (UBIT), convenient documentation, and keeping the BIEs away from traffic. Limitations of the technology included the lack of tactile contact, deficiencies in observation at difficult angles near obstructions, and flying in GPS-denied environments. The report also elaborates on a proof-of-concept experiment conducted to evaluate the possibility of inspecting a bridge remotely via a 4G cellular live stream broadcast. The remote BIE felt that this was a successful workflow and that this technology could be used to inspect bridges successfully, though inspecting bridges remotely added some additional complications to the process, including insufficient connectivity to stream the video, excessive latency in video and voice commands, and the reliance on leading-edge hardware and software that was not always reliable.



# Outreach Activities



## C<sup>2</sup>M<sup>2</sup> Invited Lectures

C<sup>2</sup>M<sup>2</sup> hosts speakers from across the transportation field to educate and inform participants at member institutions, as well as the general public, about up-to-the-minute developments in the field. Information about recent guest talks follows.



### **The Perfect Storm**

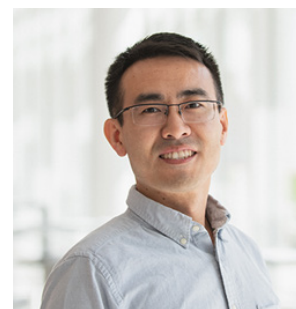
**Mac Devine**

*Vice President and CTO  
for Strategic Customer  
Success, IBM Fellow,  
Watson Cloud Division*

**Presented on:** July 23,  
2019

The definition of a “perfect storm” in weather is a “rare combination of forces leading to an event of unusual magnitude.” We may now be seeing such a storm in transportation. Cloud computing technology is now allowing customers to tap into almost “infinite” data processing capacity. Taking advantage of this, Big Data is transitioning away from “batch orientation” to real-time streaming analytics. Embedded sensors are getting smaller, smarter and cheaper. These dynamics all coming together to allow customers to capitalize on new magnitudes of scale, speed, and cost in data processing. Mr. Devine believes the future is now and we will see significant intensification of this “perfect storm” in transportation data analytics in the near future.

- **Securing**
- **Automotive**
- **Cyber-Physical**
- **Systems**
- **Long Cheng, Ph.D.**
- *Assistant Professor in*
- *the School of Computing,*
- *Clemson University*
- **Presented on:** October 10, 2019



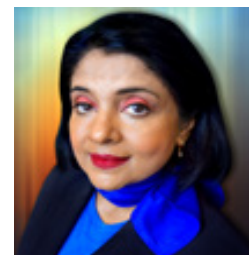
- The increasing level of connectivity and automation in transportation is raising significant security concerns. Recent work has demonstrated the vulnerability of automotive cyber-physical systems (CPSs) to attacks.
- Dr. Cheng gave a brief overview of potential attacks against automotive CPSs, as well as applicable defense mechanisms. He then presented an event-aware anomaly detection framework that can be applied to automotive CPSs. He also described ongoing work on Trigger-Action Integrity Security Enforcement, which can detect CPS anomalies in a preventative manner.

### **SecAI: Integrating Cyber Security and Artificial Intelligence (AI) with Applications in Internet of Transportation and Infrastructures**

**Bhavani Thuraisingham, Ph.D.,** *Louis A. Beecherl, Jr. Distinguished Professor of Computer Science, Executive Director of the Cyber Security Research and Education Institute, University of Texas at Dallas*

**Presented on:** October 18, 2019

Dr. Thuraisingham focused on three aspects of the developing integration of artificial intelligence (AI) and security over the past decade, and applied them to the Internet of Transportation. First, she presented the developments in applying AI techniques for detecting cybersecurity problems, such as insider threat detection, as well as the advances in adversarial machine learning. Second, she discussed developments in securing the Internet of Transportation and its supporting infrastructures, including their privacy implications. Finally, she described ways in which SecAI could be incorporated into the Internet of Transportation.



## Outreach Activities

### 3rd Annual C<sup>2</sup>M<sup>2</sup> Fall Conference

C<sup>2</sup>M<sup>2</sup> hosted our 3rd Annual Fall Conference at the Madren Conference Center in Clemson, South Carolina on October 18, 2019. This year's conference featured Dr. Bhavani Thuraisingham of University of Texas at Dallas (UTD) as the keynote speaker, updates from our Associate Directors, a student poster competition, and afternoon demonstrations of the ongoing research sponsored by C<sup>2</sup>M<sup>2</sup>. Attendees came from throughout South Carolina and included students, researchers, and transportation industry members. This year's conference also featured demonstration of drones and connected and automated (CAV) vehicles. Dr. Thuraisingham's and Dr. Chowdhury's presentations can be found on our [Youtube](#) channel and our website.





# Connected and Automated Vehicles (CAVs) Workshop at South Carolina State University (SCSU)

On Friday, March 2nd, Dr. Mizanur Rahman, C<sup>2</sup>M<sup>2</sup>'s Assistant Director, and two Clemson C<sup>2</sup>M<sup>2</sup> Ph.D. students traveled to South Carolina State University (SCSU) in Orangeburg to lead a CAV training workshop for SCSU students and faculty. It was entitled "Connected and Automated Vehicles (CAVs) in the Transportation Cyber-Physical



*C<sup>2</sup>M<sup>2</sup> CAV Workshop at SCSU*

Systems." The workshop provided fundamental knowledge about CAV software and hardware to the attendees. Attendees also learned about CAV system basics and received hands-on training in CAV simulation software. A total of eight students and one faculty member, from varied academic backgrounds, attended.



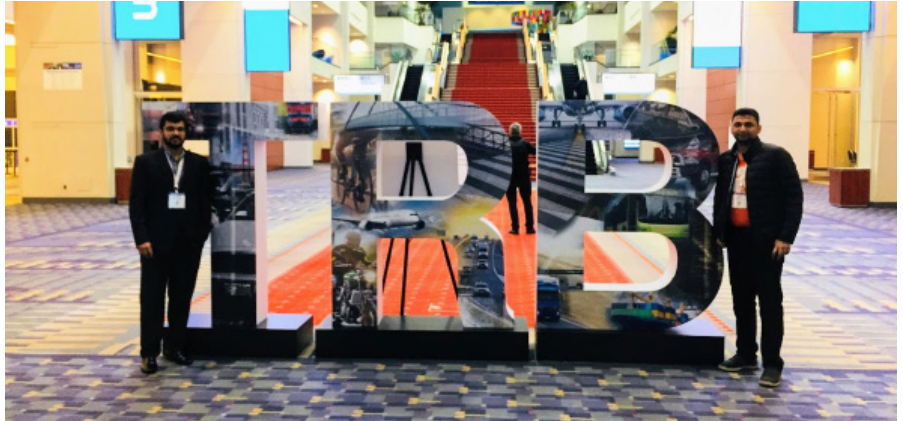
*C<sup>2</sup>M<sup>2</sup> CAV Workshop at SCSU*



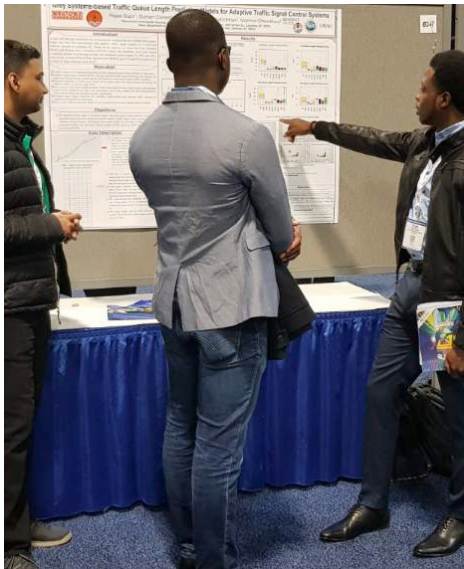


## ..... C<sup>2</sup>M<sup>2</sup> at TRB 2020

We are proud of the work of our C<sup>2</sup>M<sup>2</sup> affiliated researchers and students presented at the Transportation Research Board (TRB) 99th Annual Meeting in Washington D.C. on January 12 - 16, 2020. Our center representatives presented posters, presided over committees, and delivered lectern talks showcasing the breadth of their research.



*Clemson Students at TRB*



*Benedict College students demonstrating their poster at TRB*

conversation" reception on January 13th at the Walter E. Washington Convention Center. It was open to all TRB attendees. The event provided time and space for our affiliated researchers and students to network with other transportation professionals to encourage collaborative projects and further the goals of our center.

We are excited to announce that this year the C<sup>2</sup>M<sup>2</sup>-authored paper "Evaluation of Project Development Process at State Transportation Agencies" was awarded 3rd place in the 99th TRB Poster Session: Research Topics in Construction Management. This paper was authored by Weimin Jin, a Clemson University transportation engineering Ph.D. student, who worked in collaboration with Ph.D. candidate Tanin A. Haidary (Construction Science Management), Dr. Dennis C. Bausman (Construction Science Management), and Dr. Mashrur "Ronnie" Chowdhury (Civil Engineering).

In addition to these activities, C<sup>2</sup>M<sup>2</sup> was excited to host our very first "Breakfast and Con-



*Clemson student Weimin Jin presenting his winning poster*

# C<sup>2</sup>M<sup>2</sup> News

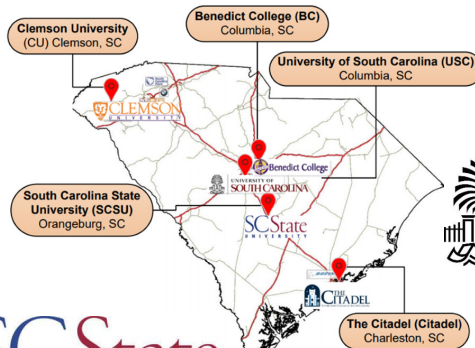
That's it for now! Look for our next newsletter for more exciting developments.



Benedict College



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## The Center for Connected Multimodal Mobility (C<sup>2</sup>M<sup>2</sup>) FUTURE LEADERS PROGRAM

- Weekly program launching - **February 28 - April 24, 2020**  
2:00 - 3:00 PM on Fridays (online participation available)
- Field trips, readings and lectures will aim to improve participants' writing and presentation skills
- Program will feature numerous guest speakers discussing emerging mobility, transportation technologies and leadership qualities
- Certificate awarded upon completion



For more information please contact:  
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[mac@clemson.edu](mailto:mac@clemson.edu)

<https://cecas.clemson.edu/c2m2>  
Or sign up online: <https://forms.gle/NfsTCvLn6F2SXyqDA>

Thank you! Keep up to date with all our  
activities at [cecas.clemson.edu/c2m2](https://cecas.clemson.edu/c2m2)