Semi-Annual Progress Report for University Transportation Centers

Sponsoring Office: Office of the Assistant Secretary for Research and Technology
Grant Number: 69A3551747105
Project Title: Center for Connected and Automated Transportation (CCAT)

Center Director:
Henry Liu
CCAT Director
University of Michigan Professor
Phone: (734) 647-4796
Mobile: (651) 260-5876
Email: henryliu@umich.edu

Submitted By:
Debby Bezzina
CCAT Managing Director
Phone: (734) 763-2498
Mobile: (734) 751-1778
Email: dbezzina@umich.edu

Submission Date: 4/29/22
DUNS No.: 073133571 TINS No.: 38-6006309

Awarded To:
Regents of the University of Michigan
3003 S. State Street
Ann Arbor, MI 48109

UM Account No.: F045674-00
Period of Performance: 11/30/16 - 9/30/23
Reporting Period: 10/1/21 - 3/31/22
Report Frequency: Semi-Annual
Signature: Debby Bezzina
Semi-Annual Progress Report for University Transportation Centers

1. Accomplishments
The University of Michigan at Ann Arbor (UM), in partnership with Purdue University, University of Illinois at Urbana-Champaign (UIUC), University of Akron (UA), Central State University (CSU), and Washtenaw Community College (WCC), established the USDOT Region 5 University Transportation Center: Center for Connected and Automated Transportation (CCAT). The FAST Act research priority area for CCAT is promoting safety and CCAT focuses its efforts on the field of comprehensive transportation safety and congestion management by taking advantage of connected vehicles, connected infrastructure, and autonomous vehicles. This report documents the progress for the reporting period October 1, 2021 through March 31, 2022.

1.A Current Research Status
During this reporting period, projects for the 2022 calendar year were selected. This year’s focus, in alignment with USDOT goals, was to accelerate novel, not incremental, research projects in the areas of equity, climate change/sustainability, education, and safety, as it relates to connected and automated transportation. At UM, a joint RFP CCAT-Mcity RFP was distributed to UM researchers to reach a wider audience. All project proposals were sent to the Technology Advisory Board (TAB) for evaluation. The TAB convened in March of 2022 and the year 6 projects were selected. In addition to the CCAT partners, representing academia, the TAB consists of members from industry and government including:

- American Center for Mobility
- Econolite
- Ford
- General Motors
- IDOT
- INDOT
- MDOT
- Toyota
- WSP

For 2022, the following projects were selected for funding (alphabetically):

**AI-enabled Transportation Network Analysis, Planning and Operations: University of Michigan, Dr. Yafeng Yi.** This research aims to leverage CAV trajectory data and recent advancements in implicit deep learning to develop an end-to-end modeling framework that would transform the way how metropolitan planning organizations (MPO) analyze, plan, and manage their transportation networks. The proposed framework can directly take empirical, sampled trajectory data as inputs to learn drivers’ route choice behaviors and estimate traffic flow distribution across an urban traffic network. The proposed framework can further prescribe strategies such as lane direction configuration, parking provision, cordon pricing and perimeter control, to better manage the existing supply of urban traffic networks to reduce congestion.

**Deployment of Preemption based Motion Sickness Prevention Technology on a Testbed Vehicle in Mcity: University of Michigan, Dr. Shorya Atwar.** The objective of this project is to deploy a novel motion sickness prevention technology (PREACT) on a custom-designed vehicle testbed in Mcity, and experimentally validate its efficacy under realistic driving conditions with human subjects. The PREACT technology employs prediction algorithms to anticipate impending inertial events associated with driving and makes preemptive interventions (e.g., via tip/tilt seat, tightening seatbelt, and haptic stimuli) before the inertial events happen, thereby averting motion sickness. By mitigating motion sickness and
enhancing comfort and productivity for passengers, the PREACT technology will help overcome a major practical impediment in the adoption of autonomous vehicles by society. This, in turn, will usher in the numerous benefits of AVs – fewer road accidents and fatalities, reduced traffic congestion, lower energy consumption and environmental footprint, reclaimed productivity for passengers, and equitable access to transportation.

**Development of A Cooperative Perception System: Purdue University, Dr. Yiheng Feng.** In this project, we propose to develop a cooperative sensing and perception system with roadside sensors and connected and automated vehicles (CAVs). The Traffic Scanner (TScan) system, which is a Lidar-based roadside perception system mounted on a trailer or a van, will be integrated with a Level 4 autonomous vehicle (AV) to exchange and fuse perception information through wireless communications. The proposed cooperative perception system augments the perception capability of CAV onboard sensors with the information from a roadside system to greatly improve the safety and navigation of CAV under challenging driving scenarios that include (1) roadway temporary blockage by construction equipment, trucks, etc., inside work zones, and (2) frequent occlusions and interactions among vehicles in dense traffic at intersections.

**Economical Acquisition of Intersection Data to Facilitate CAV Operations: Purdue University, Dr. Samuel Labi.** Connected and automated vehicles (CAVs) provide an opportunity for improving safety and reduce pollution, energy consumption, and travel delay. Past and ongoing studies are investigating the operations of CAVs at various subsystems of the transportation system, including freeway weaving sections and urban intersections. In order to make operations decisions however, more cost-effective ways of obtaining and distributing infrastructure data are needed. Unfortunately, existing deployment methods of data collection and delivery are time consuming and costly. This research will investigate alternative cost-effective ways of collecting intersection data to facilitate traffic operations in the prospective era of CAVs. The research will determine the cost to deploy equipment that will make SPaT and MAP data more likely useful to mobile devices.

**Impact of Autonomous Freight Delivery on Trucking Operations: University of Illinois at Urbana-Champaign, Dr. Imad Al-Qadi.** Currently, the number of trucks on the road is mainly controlled by the number of truck drivers. There is a deficit of nearly 61,000 truck drivers in the US as of 2019 (Costello et al, 2019). However, with the advent of autonomous and connected vehicles, this shortage is expected to shrink and ultimately vanish, meaning that the number of trucks on the road network will increase significantly. Autonomous and connected trucks are expected to hit the market in 2022 with increasing levels of autonomy each year. Autonomous truck operations also bring exciting opportunities on energy savings by forming platoons. While truck platooning is beneficial on corridor analyses, real-life implementation of platooning will depend on many factors such as roads’ suitability for platoons, additional investment needed for connected infrastructure, addressing first- and last-mile delivery issues, adverse weather and traffic conditions, and pavement durability capable of sustaining increased truck traffic. To quantify the impact of these uncertainties, a virtual case analysis is crucial. The need for human-free delivery of goods and services during the COVID-19 crisis further spurred the interest of using drones as a complementary means of delivery. The possibility of using drones, together with truck
platoons, as a civilian/industrial freight delivery solution will be explored in this project. The main objective of this study is to develop a case study and compare the operation costs and benefits of truck platoons to traditional trucking. As a result of the case study, recommendations will be outlined for efficient platoon operation.

**Improving the efficiency of trucks via CV2X connectivity on highways (Year 3): University of Michigan, Dr. Gabor Orosz.** We will deploy a connected smart infrastructure (CSI) on a highway in order to collect and aggregate traffic information that can be used by heavy duty trucks traveling the corridor to improve their efficiency. The system will consist of a set of roadside units which collect traffic data via cameras and cellular vehicle-to-everything (CV2X) communication. The heavy-duty trucks of different levels of automation will utilize the collected data when selecting their lane and controlling their longitudinal motion in order to maximize their fuel economy and minimize their travel time. The impact of these trucks on the rest of the traffic flow will also be evaluated.

**Lane management in the era of CAV deployment: Purdue University, Dr. Mohammad Miralinaghi.** Smaller headways between vehicles provide an opportunity to address traffic congestion and its attendant adverse impacts. CAV-dedicated lanes can help reduce headway. However, building new lanes for CAV use, is very costly. Such high cost can be avoided by redistributing/reallocating existing roadway widths to HDV and CAV lanes. In doing this however, the road agency must contend with not only planning-level questions about the influence of CAV market demand on the feasibility of CAV dedicated lane deployment and sustainability impacts, but also operations-level issues regarding the impacts of the value of time, early/late arrival penalties on departure time choices of CAV and HDV commuters and the associated congestion consequences. The first part of the research (the planning context) will incorporate CAV market size uncertainties and width differentials between CAV and HDV lanes. The mathematical problem posed by these considerations is complex and to solve the problem in reasonable time, we will develop a solution algorithm and test it on real-life road networks. The second part of this project addresses a specific but common context of highway operations – a road section that has limited capacity and multiple lanes, commuters using either CAV or HDV during the morning peak period, with identical desired arrival times, early/late arrival penalty but different values of time.

**Leveraging control theory to facilitate UAV application for CAV deployment: Purdue University, Dr. Shaoshuai Mou.** Unmanned Aerial Vehicles (UAVs) that are equipped with Vehicle-to-Everything (V2X) communication offer another dimension of communication in the CAV environment. Recent research has shown that UAVs can acquire and transit aerial data to ground vehicles and other end users quickly and cost-effectively, and provide greater efficiency compared to surveillance cameras in terms of camera angles, scale, and view. Also, recent studies have used microscopic traffic simulation to investigate the potential benefits a CAV-UAV connected network. In the proposed study, we intend to use real life (albeit, smaller scale) simulation of both UAV and CAVs. The proposed study will assess the performance of CAV with connected UAVs in terms of congestion mitigation, safety, fuel economy and emissions vis-à-vis the baseline case of CAV only. The study will identify the conditions at which UAV application can be most beneficial to CAV deployment. It will be shown how the UAV could use control theory to prescribe safe and efficient movement of CAVs. The practical benefits of the proposed product
can be numerous: a reliable UAV-CAV data domain can help the road agency enhance traffic safety risk assessment and vehicle trajectory monitoring.

**Modeling Naturalistic Driving Environment with High-Resolution Trajectory Data: University of Michigan, Dr. Shuo Feng.** In this project, a methodological framework for modeling the high-fidelity naturalistic driving environment (NDE) with high-resolution trajectory data will be developed. Different from traditional NDE models that mainly match the moments of macroscopic traffic behaviors, the high-fidelity NDE models will match the distributions of microscopic driving behaviors, which are critical for safety-critical applications such as autonomous vehicle testing and training. The large-scale high-resolution data that is being collected by roadside sensors will be leveraged. The developed NDE models will be implemented in the SAFE-TEST toolbox for the safety assessment of autonomous vehicles at the American Center for Mobility, which will significantly expand the toolbox into the complex urban driving environment. Both the high-resolution data collection system and SAFE-TEST toolbox were developed by the PI research team with previous CCAT and Mcity sponsored projects.

**Promoting CAV deployment by enhancing the perception phase of the autonomous driving using explainable AI: Purdue University, Dr. Samuel Labi.** The perception phase, the weak link in the driving task, has been identified as the key cause of most autonomous vehicle (AV) accidents. This has been attributed to the relative infancy of computer vision (CV), the key technology in perception. Deep learning (DL) approaches have been used widely in computer vision applications, from object detection to semantic understanding, but are generally considered as black boxes due to their lack of interpretability which exacerbates user distrust and hinders their deployment in autonomous driving. It has been argued that explainable AI (XAI), an emerging concept in contemporary computer science literature where model outputs can be understood by humans, offers an opportunity to address this issue. Thus, the proposed research project will develop an explainable end-to-end autonomous driving system as an improvement to existing autonomous driving systems. To do this, we will use a state-of-the-art self-attention-based model that generates driving actions with corresponding explanations using visual features from images from onboard cameras. The model will imitate human peripheral vision by performing soft attention over the images’ global features.

**Using an Experiential Learning Framework to Promote Student Awareness of and Sensitivity to Issues of Inclusion Among Older Adults with Regard to Automated Vehicles: University of Akron, Dr. Ping Yi and University of Michigan, Dr. Lisa Molnar.** The development of connected and automated vehicles (CAVs) is poised to be one of the most transformative transportation advances in recent history and holds promise for reducing traffic crashes and maintaining mobility among older adults. At the current time however, challenges remain in ensuring that CAVs are accessible, acceptable, affordable, and otherwise inclusive for older adults. There is a tremendous opportunity to build sensitivity among students studying engineering and other automotive-related fields to the issues of older adults and CAVs, as an explicit part of their education. There is also an opportunity to train older adults themselves to improve their knowledge about CAVs, potentially leading to greater acceptance of these technologies. This project has two objectives. The first is to increase students’ awareness of and sensitivity to issues of older adult accessibility, acceptability, affordability, and other aspects of inclusion...
related to CAVs, using a framework of experiential learning. The second objective is to increase older drivers’ awareness and understanding of CAV technologies so that they are better prepared to take advantage of the safety features of these technologies.

In all, CCAT has funded 72 research projects. Currently, 36 are active; 11 are completed – final reports and all outputs, outcomes and impacts have been submitted; and 25 are in the final report writing stages. During this reporting period, work was performed on active projects but due to page limitations could not be included in this report. Semi-annual status reports are available upon request. Additionally, for full project descriptions and final reports, visit the CCAT website.

1.B Tech Transfer Metrics for this Period
CCAT continues to put technology transfer on the forefront of all activities and is directly attributable to the success of the center. CCAT maintains a strong Technology Advisory Board (TAB) to ensure that our research can be directly transferred to industry and government for implementation and deployment. At the midpoint of the year, CCAT has surpassed all but one our annual goals as shown in Table 1 below.

Table 1: CCAT Technology Transfer Goal Targets and Actual Performance for this Period

<table>
<thead>
<tr>
<th>Part II: UTC Specific Performance Indicators</th>
<th>CCAT October 1, 2021 - March 31, 2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Transfer Goals</td>
<td></td>
</tr>
<tr>
<td>1. OUTPUTS</td>
<td></td>
</tr>
<tr>
<td>1.A. Disseminate research results through publications, conference papers, and policy papers</td>
<td>Technical reports</td>
</tr>
<tr>
<td></td>
<td>Papers at conferences, symposia, workshops, and meetings</td>
</tr>
<tr>
<td></td>
<td>Peer-reviewed journal articles</td>
</tr>
<tr>
<td>1.B. Develop inventions, new methodologies, or products</td>
<td>Annual number of research deployments</td>
</tr>
<tr>
<td>1.C. Research projects funded by sources other than UTC and matching fund sources</td>
<td>Number of projects</td>
</tr>
<tr>
<td></td>
<td>Dollar amount of projects</td>
</tr>
<tr>
<td>2. OUTCOMES</td>
<td></td>
</tr>
<tr>
<td>2.A. Incorporate new technologies, techniques or practices</td>
<td>Number of technology transfer activities that offer implementation or deployment guidance</td>
</tr>
<tr>
<td>2.B. Improve the processes, technologies, techniques in addressing transportation issues</td>
<td>Number of research deliverables disseminated from each research project</td>
</tr>
<tr>
<td>3. IMPACTS</td>
<td></td>
</tr>
<tr>
<td>3.A. Increase the body of knowledge and safety of the transportation system</td>
<td>Number of instances of technology adoption or commercialization</td>
</tr>
<tr>
<td></td>
<td>Number of conferences organized by the CCAT consortium members</td>
</tr>
<tr>
<td>3.B. Improve the operation and safety of the transportation system</td>
<td>Number of instances of research changing behavior, practices, decision making, policies (including regulatory policies), or social actions</td>
</tr>
</tbody>
</table>
Semi-Annual Progress Report for University Transportation Centers

The real testament to successful technology transfer is the creation of intellectual property and the deployment of it in the real world. In this period the following technology transfer successes were realized:

- Optimizing Signals as a Service, based on “Traffic Signal Control Using Vehicle Trajectory Data”, US Patent No. 10,497,259 B2, invented by Liu, H. and Zheng, J. Optimization results were implemented in March 2022 by the Road Commission of Oakland County (RCOC) for the City of Birmingham for 32 traffic signals.

1.C Dissemination of Research and Other Outreach, Education, Leadership and Workforce Development

CCAT members hosted or participated in 160 outreach engagements with industry, government, academia, media, and community organizations this reporting period. In total, CCAT research was shared with more than 23,500 people in the last six months. The University of Michigan CCAT outreach log is available upon request.

A key CCAT goal is to be a national thought leader for connected and automated transportation. As the center continues to evolve, so does our leadership. This period, CCAT leadership input was sought on the current and potential effects related to connected vehicles and spectrum by the U.S. Government Accountability Office as part of a bipartisan request from the House of Representatives Transportation and Infrastructure Committee. Additionally, Debby Bezzina, CCAT Managing Director, participated in two high-level events, further demonstrating our thought leadership. First, on January 19, 2022, the NTSB Episode 1: V2X Overview, Effectiveness Research, and Wi-Fi Interference aired on YouTube. This is the first in a series of NTSB’s 2021-2022 most wanted list of transportation safety improvements. This 1-hour episode already has nearly 1900 views and is growing daily. Second, Ms. Bezzina taught a two-hour class for NHTSA’s Office of Defects on connected vehicle technology. The class provided novices with an overview of connected vehicle and infrastructure technology and applications and how it will pave the way for a national automated vehicle deployment. Furthermore, Dr. Kandiah and Dr. Nedunuri, both from CSU, serve on the Transportation Energy Committee of the Transportation Research Board (TRB-AMS10) Research Cluster – Environmental Justice and Future Mobility Group.

In this period, planning continued for the 2022 CCAT Global Symposium on Connected and Automated Vehicles and Infrastructure, to be held on April 12th and 13th, 2022. This was by far the most labor-intensive Symposium that the Center has ever hosted due, in part, to the fact that it is a hybrid event, offering both in-person and virtual attendance options – a first for CCAT, and for most organizations. The in-person aspect requires development of a COVID strategy including communicating vaccination, masking, and contract tracing requirements to attendees, and food preparation that minimizes exposure. Offering a live stream for the virtual attendees also adds complexity (and cost). It requires working with a media team that can film the conference in its entirety and leverage our YouTube
platform while simultaneously providing closed captioning due to ADA requirements. Furthermore, many speakers were not ready to travel to conferences and wanted to participate virtually which meant ordering large projectors and screens so that in-person attendees would be able to view the speaker that was calling in via Zoom. To maximize value for attendees, we leveraged our relationship with Mcity to offer a tour of the 32-acre facility which required adding this option to registration, working with a shuttle bus company, and reserving parking spaces with the city to pick up attendees outside the venue. The line-up of speakers includes Congresswoman Haley Stevens, Congresswoman Debbie Dingell, Director Shelby Scales, and Lieutenant Governor Garlin Gilchrist II. We project that the CCAT 2022 Global Symposium will have a record number of paid participants. Additionally, as a precursor to the symposium, an Autonomy in Transportation in Education (ATE) workshop is also being planned. The Autonomy in Transportation Education (ATE) workshop will bring together a select number of experts in Connected and Automated Vehicles (CAVs) from academia and industry to participate in round-table discussions on the existing gaps in transportation education as it relates to CAVs, and how to fill them.

CCAT also supported ITS Michigan this period with planning its 2022 Traffic Incident management Operations Partnering Workshop. This workshop brings together first responders to promote safe, quick clearance of traffic incidents. Getting incidents off the road quickly improves traffic flow and makes the road safer for both the travelers and the responders. This year’s event will be held at the University of Michigan in May and Dr. Henry Liu, CCAT Director, will present how connected vehicle and infrastructure technology can keep first responders safe.

CCAT continued the bi-monthly research reviews and the Distinguished Lecture this reporting period. All are available on CCAT’s YouTube channel (links below). The distinguished lecture series is intended to share important information to our stakeholders that is within the expertise of the CCAT consortium but is not necessarily from a specific research project from prominent experts in the field.

<table>
<thead>
<tr>
<th>Date</th>
<th>Title (Link)</th>
<th>Presenter(s)</th>
<th>Registrants</th>
<th>Attendees</th>
<th>Views</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/27/21</td>
<td>Research Review: Cycling Safety: From Crash Data Analysis to a naturalistic Cycling Study</td>
<td>Dr. Fred Feng, UM Dr. Shan Bao, UM</td>
<td>145</td>
<td>83</td>
<td>108</td>
</tr>
<tr>
<td>11/30/21</td>
<td>Distinguished Lecture Series: Autonomous and Connected Vehicle Safety</td>
<td>Dr. Azim, Eskandarian, Virginia Tech</td>
<td>277</td>
<td>129</td>
<td>248</td>
</tr>
<tr>
<td>2/24/22</td>
<td>Distinguished Lecture Series: Trustworthy Artificial Intelligence</td>
<td>Dr. Jeannette M. Wing, Columbia</td>
<td>292</td>
<td>117</td>
<td>156</td>
</tr>
</tbody>
</table>

Table 2: Distinguished Lecture Series and Research Reviews for the Reporting Period 10/1/21 – 3/31/22

1 Presentations and videos are not listed in the output section to save space and omit redundant reporting.

Date: April 29, 2022
CCAT has leveraged Twitter to promote its outreach activities, final reports, publications, and more. In the past six months, the Twitter profile has earned over 38,184 impressions and 69 followers for a total of 420. The LinkedIn profile is used to similarly promote upcoming events, research updates, and promote awards that researchers have received. This provides CCAT with the opportunity to have those researchers share the posts and grow the audience. LinkedIn analytics include receiving 70,732 impressions (more than double from the six months prior), over 1,663 profile visits, and 417 new followers for a total of 1,080. CCAT is also the most subscribed University Transportation Center (UTC) YouTube and LinkedIn channels. CCAT uploads all its events to the channel via live stream, edited VOD, and edited clips pulled from full webinars. CCAT’s YouTube analytics since October include over 2,700 upload views, 448 live views, 56 new subscribers (318 total), and a watch time of 22,824 minutes.

The CCAT website provides a wide array of information for those that work within and outside the CCAT umbrella. All research projects and their UTC and Final Report forms are available along with Semi-Annual Progress Reports. Updates since the last SAPR includes a revamped event and news page. Over the last six months, the website has received over 17,884 hits.

**Awards**

- Neda Masoud, CCAT PI and Assistant Professor for the Civil and Environmental Engineering Department at the University of Michigan, has received the CUTC – Cambridge Systematics New Faculty Award. This is given annually to a tenure-track faculty member in transportation education and recognizes outstanding teaching and research contributions to the transportation field.
- Imad Al-Qadi, University of Illinois Urbana-Champaign Bliss Professor of Engineering and Illinois Center for Transportation director, has been selected as the 2021 recipient of the American Society of Civil Engineers’ Robert Horonjeff Award. The prestigious award recognizes a person or organization for outstanding achievements in and contributions to the field of air transportation engineering.
- Henry Liu, CCAT Director, receives ITS Outstanding Paper Award from INFORMS for “Intelligent Driving Intelligence Test for Autonomous Vehicles with Naturalistic and Adversarial Environment.”
- CCAT PI Mohammad Miralinaghi received recognition at 2022 TRB Meeting for his role as a paper review team member of the Air Quality and Greenhouse Gas Mitigation Committee.
- CCAT student Abdullah Nafakh Receives Eldon J. Yoder Memorial Award.
- CCAT student Isaiah Mwamba Receives 2021 Student Engagement Award.
- CCAT student Bortiorkor Naa Alabi Receives 2022 International Road Federation (IRF) Executive Fellowship Award.
COVID-19 policies remained in effect during this period that limited or restricted some CCAT activities and collaborations with stakeholder organizations, particularly K-12 school systems. Despite these restrictions, WCC as our educational outreach partner accomplished the following:

**Workforce Development Training**

- Training Module “Power BI for Data Analysis- Smart Cities.” Research, design, and training development continued with focus on planning for a sustainable future by reducing the dangerous and costly impacts of integrated streets and roads by visualizing the data.
- Training Module “Power BI for Data Analysis- Smart Money.” Research, design, and training development continued with focus on creating relationships between data sets.
- Training Module “Power BI for Data Analysts – Smart Apps.” Research, design, and training development continued with focus on using app data to improve mobility.
- Training Module “Smartsheet for Data Analysts – Smart Insights.” Research, design, and training development continued with focus on effective use of data hierarchies for groups and organizing tasks.
- WFD Class Modules Developed and Offered [ITS, Data/Project Management, Fiber Optics]:
  - a) XML & EXCEL; b) Visualize the Code- XML; c) Smartsheet Essentials; d) Visualize the Data; e) Power BI; f) Power BI- Smart Money
  - Total training enrollments from both WorldEd and WCC Lumens Registrations: 42.
  - Fiber Optics Course [Infrastructure] Student Enrollments: 105.

**Credit Education Certificate and Degree Programs**

- Procured ADAS Calibration and Verification System equipment to integrate into transportation technologies programs. In addition, procured automotive cybersecurity equipment to analyze automotive network communications and OTA signal identification. Two lab technicians are learning how to set-up and utilize the newest ADAS mobile units.

**K-12 STEM Technology Awareness and Insight**

- Planning and development for the Square One Masters of Mobility V2X Connected Vehicle Lab School Training for K-12 Students and Teachers workshop series. The next planned workshop is targeted for June 2022.
- Planning and development of the Square One V2X Youth Summer Camps, which are offered free of charge to low income and otherwise disadvantaged youth from the school districts of Ypsilanti, Willow Run and Eastern Washtenaw County. The planned offering of the workshop is July 2022.

**General Outreach**

- WCC CCAT Project Team Members and other staff participated in the Ann Arbor SPARK a2TECH360 events, including Mobility Row, October 8, 2021. The exhibit displayed WCC’s Automotive Cybersecurity Programs, featuring its UMLAUT-designed lab workstation. Also exhibited were the
Transportation Technologies programs, featuring the 2021 Ford Mustang Mach-E, battery electric vehicle. The exhibit was located on Liberty Street in Ann Arbor and covered by news media. The audience consisted of the public, businesses, and educators from all around the region.

- **WCC STEM/STEAM WEEK Programs, March 1-3, 2022**: WCC cross-functional activities designed, developed, and delivered three days of awareness presentations over the internet to secondary education students, teachers, counselors, and the Washtenaw County School officials. Relevant presentations, virtual tours of labs, and panel discussions centered on the mobility of the future; transportation and manufacturing; automotive cybersecurity; and engineering and manufacturing.

### 2. Participants and Other Collaborating Organizations

One of the CCAT goals is to collaborate with other organizations within the CCAT consortium, within Region 5, and nationally. The following table summarize the collaborations that occurred during this reporting period.

<table>
<thead>
<tr>
<th>CCAT Member</th>
<th>Collaborating Organization</th>
<th>Location</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akron</td>
<td>Concordian at Sumner</td>
<td>Copley, OH</td>
<td>Provide contact information for the seniors living in their complex for</td>
</tr>
<tr>
<td></td>
<td>Independent Living</td>
<td></td>
<td>recruitment and allow set-up of field equipment near their property for data</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>collection.</td>
</tr>
<tr>
<td>Akron</td>
<td>The Landing of Stow</td>
<td>Stow, OH</td>
<td>Personnel and technical support on algorithm testing, and data sources.</td>
</tr>
<tr>
<td>Akron</td>
<td>PathMaster, Inc.</td>
<td>Twinsburg, OH</td>
<td></td>
</tr>
<tr>
<td>Akron</td>
<td>City of Akron</td>
<td>Akron, OH</td>
<td>Traffic Engineering Dept. personnel and technical support.</td>
</tr>
<tr>
<td>Purdue</td>
<td>McGavic Outdoor Power</td>
<td>Noblesville, IN</td>
<td>Development of electric vehicle de-icing prototype.</td>
</tr>
<tr>
<td>Purdue</td>
<td>Carnegie Melon University</td>
<td>Pittsburgh, PA</td>
<td>Helped design AI and control-based systems and hosted CCAT researcher, Dr.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sikai Chen, as visiting scholar as part of project collaboration.</td>
</tr>
<tr>
<td>Purdue</td>
<td>Nanyang Technological</td>
<td>Singapore</td>
<td>Cost share and collaborative research.</td>
</tr>
<tr>
<td></td>
<td>University</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purdue</td>
<td>Indiana Department of</td>
<td>Indianapolis, IN</td>
<td>Collaborative research (in-kind) and cost sharing (cash).</td>
</tr>
<tr>
<td></td>
<td>Transportation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purdue</td>
<td>Georgia Institute of</td>
<td>Atlanta, GA</td>
<td>Collaborative research.</td>
</tr>
<tr>
<td></td>
<td>Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UIUC</td>
<td>IDOT</td>
<td>Indianapolis, IN</td>
<td>Collaborative research.</td>
</tr>
<tr>
<td>UM</td>
<td>Ford Motor Company</td>
<td>Dearborn, MI</td>
<td>Provided inputs on using CAVs as probe vehicles for traffic state estimation.</td>
</tr>
<tr>
<td>UM</td>
<td>Clemson University</td>
<td>Clemson, SC</td>
<td>Collaborative research.</td>
</tr>
</tbody>
</table>

### 3. Outputs

In this reporting period, the CCAT consortium produced the following products and other outputs:

**University of Michigan**

- The project “Roadside-based Cybersecurity in Connected and Automated Vehicle Systems” has developed solutions that demonstrate the degree to which platoons of vehicles are vulnerable to
cyberattacks, compared to a solo vehicle; what attack types are more likely to create instability; and potential solutions on how to detect attacks.


Central State University
Poster: Jalen Smith, Assessment of Near-Road Emissions of Air Pollutants and Greenhouse Gases from Vehicles Across Congested Ohio Highways, 2022 Research and Scholarly Activities Day, April 21, 2022, Central State University, Wilberforce, OH 45384

Purdue University
PI Samuel Labi wrote an editorial in Computer-Aided Civil and Infrastructure Engineering journal, Volume 36, Issue 10, page 1227-1228, titled “An influential journal elevating the civil engineering profession and raising its image in the engineering league.”


University of Akron

Semi-Annual Progress Report for University Transportation Centers

University of Illinois at Urbana Champaign

- She, R., Ouyang, Y., (Accepted for publication). Generalized Link Cost Function and Network Design for Dedicated Truck Platoon Lanes to Improve Energy, Pavement Sustainability and Traffic Efficiency. To: Transportation Research Part C.
- Other outputs from the project “Impact of Autonomous Freight Delivery on Trucking Operations” include (1) improvements to the 3D truck aerodynamic model; (2) a machine learning based method used to solve the optimal conditions for truck platooning; (3) a framework to transfer the experimental data to the rutting calculation of AASHTOWare PMED framework without changing transfer functions that considers mixed traffic; and (4) methodology to determine the vehicle’s position within the lane using vehicle and infrastructure interaction enabled by EM signature of pavement.

4. Outcomes

The application of outputs has produced the following outcomes during this reporting period:

University of Michigan

The project “Leveraging Connected and Automated Vehicles for Participatory Traffic Control” has increased understanding of the implications of CAVs on traffic operations.

Central State University

The breadth of CCAT is expanding at Central State University as more departments are getting involved. This period, the Computer Science Department was brought on board to develop an app for the project “CAV Deployed Vehicles as Real Time Sensors for Assessing Greenhouse Gases.” In addition to faculty member Dr. Cao, several computer science students will be involved with the app development.

Purdue University

- PI Samuel Labi accepted an invitation to serve as guest editor on (a) Sustainability Journal Special Issue on “Smart Cities—The Role of Transportation, Artificial Intelligence and Big Data,” with co-editors: Sikai Chen, Ali Karimoddini, Hua Liang Teng, in November 2021; (b) Computer-aided Civil and Infrastructure Engineering (CACAIE) Special Issue on “Adaptations of emerging transport technologies towards smart infrastructure,” with Co-editors: Kaan Ozbay, Xiaobo Qu, Toshiyuki Yamamoto, in October 2021.
- PI Samuel Labi accepted an invitation by Tsinghua University to serve as an Editorial Board member for their Journal of Intelligent and Connected Vehicles (Tsinghua University, IEEE).
- The implementation of the intelligent sidewalk de-icing and pre-treatment system was showcased through field demonstrations with local Indiana agencies and presentations at various conferences, including the TRB annual conference and the Indiana Department of Transportation Open House. These demonstrations and presentations helped to increase the understanding and awareness of
Semi-Annual Progress Report for University Transportation Centers

the efficacy of a smart deicing system for sidewalks (and prospectively, roads and runways in future applications). Winter maintenance is an important transportation issue at a national level, as it severely impairs transportation efficiency, safety, and quality of life. Therefore, the research product not only increased the body of knowledge regarding winter maintenance, but also showed how the process of ice control could be facilitated cost-effectively using new technologies. The involvement of students in all aspects of this project helps increase the pool of transportation professionals trained to address problems of winter maintenance. The adoption of this new technology can benefit residents and businesses located at areas subject to freeze conditions during the winter season.

- The literature review for the project “The Impact of COVID-19 on User Perceptions of Public Transit, Shared Mobility/Micro-mobility Services, and Emerging Vehicle Types” helped increase the team’s understanding and awareness of COVID-19’s impact on transportation.

- The project “Development of AI-based and Control-based Systems for Safe and Efficient Operations of Connected and Autonomous Vehicles” provides strong justification to both CAV companies and DOTs for investment in installing connectivity facilities, and that investments in connectivity facilities can greatly benefit the entire transportation system by enhancing mobility and safety.

- The project “Design and Management of Highway Infrastructure to Accommodate CAVs” increased the understanding in (a) the use of more advanced techniques for descriptive and prescriptive modeling of asset performance, cost, and evaluation; (b) identification of potential new asset types to render the built infrastructure better prepared to accommodate autonomous vehicles; (c) identification and measurement of the need for modifying the dimensions of existing asset types; (d) appraisal of the performance (cost and benefits) of the infrastructure changes as described above, relative to a base case scenario (where no changes are made to the infrastructure that the CAVs use); and (e) assessment of the sensitivity of the infrastructure preparation needs to different levels of CAV market penetration and level of autonomy.

- The project “Facilitating Electric Propulsion of Autonomous Vehicles through Efficient Design of a Charging-station Network” increased the understanding and awareness of transportation issues related to the fuel type to be used for propulsion in the CAV era. Furthermore, three graduate students were involved in this research, enriching the pool of trained transportation professionals in electric infrastructure planning to support AV operations.

- The project “Large Network Multi-Level Control for CAV and Smart Infrastructure: AI-based Fog-Cloud Collaboration” demonstrated the feasibility of decomposing a large (typically, urban) traffic networks using a Fog-Cloud (F-C) collaboration structure.

- The project “Changes in Highway Agency Expenditures and Revenue in an Era of CAVs” fosters an understanding and awareness of highway finance in a changing world of transportation technology, an issue that has persisted over time. The research also increased the body of knowledge regarding the net effect of CAV operations on the amount of travel; the expenditure changes of highway agencies due to CAV operations, the changes in highway revenue in the era of CAV operations recognizing that CAVs will most likely be EVs, and how highway equity will change in the era of CAV operations.

- The research “A Virtual Reality Framework to Measure Psychological and Physiological Responses of the Self-Driving Car Passengers” increases the body of knowledge on how virtual reality could be used to understand human-autonomous vehicle interactions.
University of Akron

- The data analysis from the project “Development of a Prototype Safety Advisory System to Aid Senior Citizens in Gap Selection” indicates that most older drivers are “afraid of” the emerging CAV technologies that are gradually promoted at different levels of sophistication by newer vehicle models. This presents a social equity issue as well as a marketing issue.
- The project “Access Control at Major-Minor Intersection through CAV in Mixed Traffic” has increased understanding and awareness of transportation issues for 20 graduating senior students, helping to shape the next-generation of transportation engineers.

University of Illinois at Urbana Champaign

Several outcomes resulted from the project “Impact of Autonomous Freight Delivery on Trucking Operations” including (1) developed a data-driven model to predict the drag coefficient of a two to three truck platoon that can predict the drag coefficient of each truck; (2) determined that penetration level affects the rutting significantly as the rest period influences permanent deformation of the pavement; and (3) successfully demonstrated lane keeping can be achieved by using EM signature of the pavement created using passive materials.

5. Impacts

In addition to the impacts that CCAT outreach has on the body of knowledge and technology, these additional impacts were derived from CCAT research this reporting period.

University of Michigan

- The project “Leveraging Connected and Automated Vehicles for Participatory Traffic Control” trained two PhD students to conduct original research to address transportation issues.
- Reduced travel delay in Oakland County, MI by 10-20% in the pilot area of the traffic signal optimization system – Optimizing Signals as a Service (OSaaS), which was derived from findings from the project “Trajectory Based Traffic Control with Low Penetration of Connected Vehicles.”

Central State University

On October 15, 2021, Dr. Kumar Nedunuri participated in the C2M2 5th Annual Fall Conference. At this conference the role of HBCUs in the UTC program was discussed. One very stark fact was brought to light. Most HBCUs were brought on board to a UTC team as an outreach partner, not to conduct research. CSU discussed the scholarly research that it conducts through its partnership with the University of Michigan and encouraged other HBCUs to seek out the same using the successful model. This small action may have lasting impacts on HBCUs and the UTC program. It will play a part in expanding CSUs’ roll on the Michigan team for the next UTC competition.

Purdue University

- Funding of the de-icing project has made possible the adoption of new technology for the winter maintenance industry. Through the project it was found that that brining operations on I-465, the interstate around Indianapolis, had over 600 locations where brine was required. By automating the brining process, this technology removes distractions from the driving task. That way, the driver can focus on traffic and driving the vehicle safely, knowing that the correct amount of brine...
is applied at appropriate locations. This technology currently is used for liquid material but could be expanded to solid materials making winter operation maintenance safer for all road users.

- The research on the project “Development of Situational Awareness Enhancing Systems for AV-Manual Handover and Other Tasks” has helped increase the body of knowledge and expand the understanding and awareness of the need for vigilance of AV drivers and passengers in the era of CAVs.

- The project “Design and Management of Highway Infrastructure to Accommodate CAVs” demonstrated the need for a separate management system for CAV related infrastructure. At the current time, most agencies have in place a management system for each class of physical assets: bridge management system, pavement management system, and drainage infrastructure management system. A few agencies also have a traffic hardware management system, tunnel management system, and safety infrastructure management system. With the advent of new asset classes because of CAVs, there will arise a need to establish a management system for this new class of assets.

- The project “Investigation of AV Operational Issues using Driving Simulator Equipment” has increased the body of knowledge and expanded the understanding and awareness of the need for consideration to be given to human interaction with the machine (AV). This research product is expected to influence new legislation and new vehicle designs to foster smooth human-machine interaction.

- The project “Facilitating Electric Propulsion of Autonomous Vehicles through Efficient Design of a Charging-station Network” impacts the transportation industry in two ways: (1) preparedness of electric supply through efficient design of the locations of charging stations, and (2) emissions reduction.

- The project “Large Network Multi-Level Control for CAV and Smart Infrastructure: AI-based Fog-Cloud Collaboration” strongly justifies CAV manufacturers, technology companies, and the road agencies to invest in connectivity infrastructure (on the road) and connectivity equipment (in vehicles). The results of the published papers are evidential of benefit that connectivity-equipped AVs and connectivity investments in HDVs can yield to the entire traffic stream in terms of operational efficiency and mobility. The research also provides justification for prospective wide adoption of 5G/LTE for reduced latency that results in enhanced mobility and safety, particularly in the context of large-scale traffic networks such as those typical of large urban areas.

- The project “Changes in Highway Agency Expenditures and Revenue in an Era of CAVs” has determined that state DOTs will be incentivized to seek additional funding in the CAV era to (1) meet higher highway expenditures, and (2) offset the reduction of highway revenues. Agencies will be motivated to take action to increase or decrease the license fees of each vehicle class to correct the inequity that will result from the shifts on highway expenditures and revenues.

- Understanding of passenger anxiety can help determine ways to increase passenger comfort in their interactions with self-driving cars. The findings will help to expand knowledge on human-autonomous vehicle interaction (human factors) in VR, in preparation for the inevitable era of self-driving cars.

**University of Akron**

- The project “Development of a Prototype Safety Advisory System to Aid Senior Citizens in Gap Selection” will impact older drivers in a profound way. The project will guide OEMs to an effective design for gap selection systems that will make driving safer for older drivers.
The project “Impact Analysis of Roadway Surface and Vehicle Conditions on Fleet Formation for Connected and Automated Vehicles” explores in-depth understanding of the limitations with the design and application of a CAV fleet, which identifies possible unsafe cases for the CAV fleet to determine safe car-following spacing in real conditions.

The project “Access Control at Major-Minor Intersection through CAV in Mixed Traffic” provides solutions that have the potential to reduce signal disruptions due to vehicles entering intersections from a minor street. As a result, the improved operation can help reduce delay on the mainline road as well as on the minor street.

University of Illinois at Urbana Champaign

Several impacts resulted from the project “Impact of Autonomous Freight Delivery on Trucking Operations”:

- Optimized truck position for autonomous truck platooning that improves fuel consumption and minimizes road deterioration.
- Demonstration properties developed for the project can be used as an educational tool to clearly teach the effects of truck platooning.
- A truck-drone cooperative delivery system has the potential to fill the gap in the continuous modeling of such systems with congestion concerns. The solution consists of the optimal travel speed, as well as the density and speed distribution near the moving truck under equilibrium. The solution provides insights, or even theoretical optimal bounds, on practical deployment of such cooperative delivery systems, where aerial traffic safety must be considered while pursuing operational efficiency.
- The framework developed can act as a guide to check the adequacy of the existing pavements and for designing new pavements.

6. Changes/Problems:

In this period, CCAT continued to struggle with the lingering impacts of COVID-19. Below is a summary of changes and problems for each of our consortium members, including issues stemming from COVID-19.

University of Michigan

The project “Leveraging Connected and Automated Vehicles for Participatory Traffic Control” was extended through December 31, 2022, due to supply chain issues in 2020/21 that affected the deployment timeline and subsequently the data collection and analysis.

Purdue University

- The timeline for the project “The Impact of COVID-19 on User Perceptions of Public Transit, Shared Mobility/Micro-mobility Services, and Emerging Vehicle Types” has been delayed due to impacts of COVID-19 on human subjects’ research as well as student recruiting.
- Due to COVID-19 and related university protocols in classrooms, research spaces, etc., there were significant delays in recruiting participants for human factor research experiments for the projects “Development of Situational Awareness Enhancing Systems for AV-Manual Handover and Other Tasks,” “Investigation of AV Operational Issues using Driving Simulator Equipment,” and “Using
Virtual Reality Techniques to Investigating Interactions between Fully Autonomous Vehicles and Vulnerable Road Users.”

- Due to the COVID pandemic, some challenges were faced in recruiting students to complete the research for the projects “Design and Management of Highway Infrastructure to Accommodate CAVs,” “Large Network Multi-Level Control for CAV and Smart Infrastructure: AI-based Fog-Cloud Collaboration,” “Facilitating Electric Propulsion of Autonomous Vehicles Through Efficient Design of a Charging-station Network,” and “Adapting Land Use and Infrastructure for Automated Driving.”

- Due to the COVID pandemic, some challenges were faced in recruiting human subjects for the projects “Design of Urban Landscape and Road Networks to Accommodate CAVs, Part II” and “Using Driving Simulator Environment to Determine Interactions Between User Behavior and Infrastructure Design Under Autonomous Vehicles.”

**University of Akron**

- Originally, the pandemic prevented the research team from close contact with older drivers needed to conduct the research experiment for the project “Development of a Prototype Safety Advisory System to Aid Senior Citizens in Gap Selection,” which induced a delay to the program timeline. All data has now been collected and the project has been scheduled to be completed by June 30, 2022.

- Data collection was delayed due to work-at-home arrangement by companies and government agencies, affecting the project “Impact Analysis of Roadway Surface and Vehicle Conditions on Fleet Formation for Connected and Automated Vehicles.” Beginning in the fall of 2021, normal progress resumed.

**WCC**

- Efforts were made to develop and conduct youth awareness training at Ann Arbor Scarlett Middle School for computer programming and related topics. However, this project had to be cancelled because WCC was unable to obtain approvals to proceed from Scarlett Middle School faculty and administrators.

- The training module “Visualize the Data – Power BI Expansion to Industries” was put on hold, pending SME resource scheduling.

7. **Special Reporting Requirements: Final Reports**

This period, the final reports below was completed, edited to meet 508 compliance, and posted to the [CCAT website](http://www.ccatwebsite.com). Additionally, all outputs, outcomes, and impacts from the project were documented and submitted.


*Yin, Yafeng & Mi, Tian, (2021), "2021 International Symposium on Transportation Data and Modelling". CCAT Project No. 21, Center for Connected and Automated Transportation, University of Michigan. URL: [https://dx.doi.org/10.7302/1709](https://dx.doi.org/10.7302/1709)*

Date: April 29, 2022


Additionally, there are currently 16 CCAT final reports in the final stages of editing that will be submitted next period.