CENTER FOR CONNECTED AND AUTOMATED TRANSPORTATION

Semi-Annual Progress Report for University Transportation Centers

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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 in 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, 2020 through March 31, 2021.

1.A Current Research Status

During this reporting period, projects for the 2021 calendar year were selected. This year's focus is on making an impact. We requested proposals for research that would significantly influence the future of transportation. A high weight was given to the potential for deployment and the strength of their industry and government partners. Responses were received in mid-November. The project proposals were sent to the Technology Advisory Board (TAB) for evaluation. The TAB convened in January of 2021 and the year 5 projects were selected. The TAB consists of member from industry, government, and academia including:

- American Center for Mobility
- Central State University
- Econolite
- Ford
- General Motors
- Illinois Department of Transportation
- Indiana Department of Transportation
- Michigan Department of Transportation
- Purdue
- Toyota
- University of Akron
- University of Illinois at Urbana-Champaign
- University of Michigan
- Washtenaw Community College
- WSP

For 2021, the following projects were selected for funding (alphabetically):

A Data Driven Autonomous Driving System for Overtaking Bicyclists: University of Michigan, Dr. Shan Bao and Dr. Brian Lin. Many bicyclists share the roadway with motor vehicles that drive much faster. Once an accident occurs with bicyclists involved, the death rate of the bicyclist is extremely high. To date there is no mature and reliable technology that helps drivers overtake bicyclists safely and can be as well as accepted by bicyclists. This study follows a systematic method to develop a prototype for an automated overtaking system, specifically for overtaking bicyclists. An experiment of human study will be conducted to evaluate the prototype from both the viewpoints of the driver and the bicyclist that how they want to overtake and be overtaken safely. It is expected that the outcomes can offer the OEMs and suppliers who are keen on developing safe and human-centered automated vehicle systems with useful insights. Furthermore, the insights can be helpful for legislation on the act or guidelines of protecting on-road vulnerable bicyclists. Click here to view the UTC form.

Development of an Integrated Augmented Reality Testing Environment and Implementation at the American Center for Mobility (ACM): University of Michigan, Dr. Henry Liu. This project will develop an integrated solution for autonomous vehicle testing, in which the naturalistic adversarial driving environment (NADE) will be integrated with augmented reality (AR) testing system. The integrated solution will be implemented at American Center for Mobility (ACM). With the AR techniques, the real testing AVs can be tested at a test track and interact with the virtual background vehicles. With the NADE, the maneuvers of the virtual background vehicles will be generated purposely, in that most of the maneuvers are generated from naturalistic driving data, and only at selected moments, selected vehicles execute adversarial moves to challenge the AVs. Click here to view the UTC form.

Development of Situational Awareness Enhancing Systems for AV-Manual Handover and Other Tasks: Purdue, Dr. Samuel Labi and Dr. Sikai Chen. Partially and conditionally automated vehicle systems (AVS) can assist drivers with their driving tasks and have the potential to significantly reduce driving-related burden. Drivers still play a critical role such as monitoring the driving environment when the AVS is engaged and performing certain driving tasks when called upon by the system. However, there is ample evidence in the literature and real-world that drivers cannot maintain necessary situational awareness to safely take over the vehicle when needed. This study aims to design an in-vehicle situational awareness enhancing system (SAES) to facilitate AV-manual take-over in partially and conditionally automated vehicles. Click here to view the UTC form.

Exploring the Prospective Role of Connected Vehicles in Monitoring and Response to Pandemics and Disasters: Purdue, Dr. James Eric Dietz, and Dr. Samuel Labi. The first part of the proposed research will review/upgrade existing models for disease spread monitoring, and to evaluate the efficacy of pandemic-control policies and other interventions. Then the research will assess the two-way risks of infection. The second part of the research will explore how, in the near future, connected vehicles could potentially be used to assist in pandemic monitoring and control, either in a standalone manner or as part of a network of technology entities. Using these two outcomes, a spatiotemporal tool will be developed to assess the risks of pandemic propagation for use in the prospective era of CAVs. Connected vehicle technology can facilitate information exchange between the transport agency and road users during disruptive events. Click here to view the UTC form.

Improving the Efficiency of Trucks via CV2X Connectivity on Highways (Year 2): University of Michigan, Dr. Gabor Orosz. This project aims to deploy a connected smart infrastructure (CSI) on a highway 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 cellular vehicle-to-everything (CV2X) communication. The heavy-duty trucks will utilize the collected data when controlling their longitudinal motion to maximize their fuel economy without compromising their travel time. Click here to view the UTC form.

Large Network Multi-Level Control for CAV and Smart Infrastructure: AI-based Fog-Cloud Collaboration: Purdue, Dr. Sikai Chen, Dr. Samuel Labi, and Dr. Kumares Sinha. The vast expanse of prospective CAV traffic networks is expected to exponentially increase the information availability and complexity of inter-agent interactions. In such an environment, a single system is inadequate to make

decisions for all the agents individually, and therefore, multilevel system decomposition is needed. The research proposes a framework to decompose large transportation networks using a Fog-Cloud collaboration structure. That way, AI and optimization techniques can be scaled up to larger transportation networks with minimal compromises being made in real-time decision making. This research will address regional decision tasks (which require low latency) and network decision tasks (which require high computational capacity). By assigning regional decision tasks to the fog layer and network decision tasks to the cloud layer, we anticipate that systemic efficiency can be improved. Click here to view the UTC form.

Leveraging CAVs for Participatory Traffic Control: University of Michigan, Dr. Yafeng Yin. This project aims to establish the theoretical foundation of proactive, participatory traffic control where connected and automated vehicles (CAVs) are used as mobile actuators to regulate traffic flow across a traffic network. We attempt to integrate traditional, "anonymous" physical controllers (e.g., traffic signals) in the transportation system with personalized, targeted control of CAVs to improve traffic system efficiency. The proposed investigation includes enabling CAVs to function as "traffic stream regulators" to regulate the traffic stream to better manage signalized intersections, and behave as "travel demand distributors" to better distribute the traffic demand across time periods and transportation facilities to reduce traffic congestion. The proposed participatory control framework will be tested in Mcity or a signalized traffic network in the simulation. With the smart traffic corridor in Ann Arbor, it is also possible to test this framework in the real world. Click here to view the UTC form.

Motion Sickness Alleviation via Anticipatory Control of Active Seats in Autonomous Vehicles: University of Michigan, Dr. Shorya Awtar. The goal of this integrative research project is to develop and demonstrate a passenger motion sickness mitigation solution that employs preemptive or anticipatory control of Active Seats in autonomous vehicles. The resulting proof of concept will enable implementation and deployment of the proposed technology. Based on this apriori knowledge of driving conditions, we will develop algorithms that preemptively control the active seat, for example starting to tilt the seat towards the direction of a turn slightly before the turn happens. Our hypothesis is that such preemptive correction will provide anticipation and reduce body movement, thereby lowering the incidence of passenger motion sickness. Click here to view the UTC form.

Predicting Driver Takeover Performance in Conditional Automation (Level 3) through Physiological Sensing: University of Michigan, Dr. Carol Menassa, Dr. Vineet Kamat, Dr. Da Li, and Dr. Julian Brinkley. Being able to measure and predict the takeover performance (TOP) ahead of time and issue adequate warnings is thus critical to ensure driver comfort, trust, and safety in the system and ultimately acceptance of the technology by different stakeholders. The objective of this project is to perform fundamental research to understand drivers' capabilities of taking over the vehicle safely and promptly at any time in level 3 automation. The main objective of this research will be to investigate the feasibility of using multimodal physiological features collected from drivers in level 3 AVs under different driving and disengagement scenarios (secondary tasks) to develop a personalized and real-time prediction of TOP. Click here to view the UTC form.

Ridesharing with Advanced Air Mobility: Purdue, Dr. Daniel DeLaurentis, and Dr. Dengfeng Sun. In this project, we will design and evaluate ride-sharing schemes that can potentially reduce the time and economical cost on urban commuters, increase the revenue of the transportation service provider, and boost local economics. Activities in the proposed project will include the development of a comprehensive mathematical model for the autonomous aerial ride-sharing service that capture the new characteristics in the futuristic ride-sharing system and the key components of related costs. Based on the new ride-sharing model, a distributed computational framework will be developed to accommodate the large problem size for practical real-time ride-sharing recommendations. Lastly, a resilient variant of the distributed computational algorithm will be proposed and analyzed to mitigate systematic uncertainty and/or cyberattack in the ride-sharing system. Click here to view the UTC form.

Roadside-Based Cybersecurity in CAV Systems: University of Michigan, Dr. Neda Masoud. We aim to develop a holistic framework that integrates physics-based data-driven modeling and dynamic decision making under uncertainty and partial information to improve cybersecurity in CAVs. Major concerns remain as to whether an interconnected network of CAVs and infrastructure is vulnerable to malicious hackers or unintentional faults. In this proposed work, we aim to address open questions on cybersecurity of a network of connected CAVs. Our goal is to develop an integrated real-time, robust, and scalable context-aware framework to ensure safe navigation of CAVs and other road users. The proposed framework contributes to the literature of anomaly detection/identification, data fusion, non-linear control, physics-based learning, and decision making under uncertainty in novel and important ways. Click here to view the UTC form.

The Impact of COVID-19 on User Perceptions of Public Transit, Share Mobility/Micro-Mobility Services, and Emerging Vehicle Types: Purdue, Dr. Konstantina Gkritza. The objective of this project is to investigate the impact of COVID-19 on user perceptions of public transit, shared mobility services, and emerging vehicle types (electric, connected, and autonomous vehicles). As transportation systems remain at the forefront of the COVID-19 pandemic, it is critical to examine the transportation trends and behaviors of shared modes' and emerging vehicle types' users to best plan for transportation policies in the long-run. This project will help transit operators, shared mobility and micro-mobility services operators gain a better understanding of the impacts of the pandemic on user perceptions for public transit, shared mobility, and micro-mobility services. Click here to view the UTC form.

Translation of Driver-pedestrian Behavioral Models at Semi-Controlled Crosswalks into Quantitative Framework for Practical Self-Driving Vehicle Applications: Purdue, Dr. John Fricker. There is a sufficient amount of interaction between pedestrians and vehicles at "semi-controlled" crosswalks to be concerned about the time when "negotiations" between pedestrians and human drivers are replaced by interactions between pedestrians and self-driving vehicles. Although the behavior between pedestrians and drivers at a semi-controlled crosswalk is becoming better understood, much efforts are still needed to translate behavioral models into a quantitative framework for practical self-driving vehicles applications. Click here to view the UTC form.

Using Virtual Reality Techniques for Investigating Interactions between Fully Autonomous Vehicles and Vulnerable Road Users: Purdue, Dr. Samuel Labi, and Dr. Sikai Chen. Communication methods

between vulnerable road users (pedestrians, bicyclists) and FAVs may lead to misunderstanding of intentions and cause more collisions. Road-crossing pedestrians and bicyclists generally rely on informal communication methods, eye contact, facial expression and gestures, to interpret intentions of other road users and make decisions based on the information. With FAVs, these informal communication approaches cannot be realized. Hence, it is necessary to design proper external features of FAV to establish efficient communication method. This project intends to expose participants to simulated testing environments with virtual reality headset and identify potential interface designs for FAV-pedestrian interaction. With pre-experiment collection of participants' socio-demographic data, and behavioral measurements during the experiment, pedestrians' attributes and factors that influence their road-crossing behavior and trust of AVs will be investigated. Click here to view the UTC form.

CSU, UIUC, and Akron will continue working on their multi-year projects that were selected in previous years.

Currently, CCAT researches have 51 active projects and 9 completed projects. 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

For this period, CCAT surpassed all technology transfer goals, most by a significant margin (reference Table 1). 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.

In this period, CCAT researcher applied for U.S. and International patents for work on "Motion Sickness Alleviation via Anticipatory Control of Active Seats in Autonomous Vehicles." An invention disclosure was filed for work on the project "Reliable V2V Communication Networks: Applications in Fuel-Efficient Platooning." And the invention disclosure Liu, H, Feng, S., Yan, X., and Sun, H. (2021) Simulation of Naturalistic and Adversarial Driving Environment for Autonomous Vehicle Testing, OTT Invention Report #2021-284, University of Michigan, Ann Arbor was filed. This invention disclosure is in discussions to be licensed to the American Center for Mobility.

CCAT researchers regularly meet with their industry and government project champions. This increases the amount of direct interaction with these organizations to enhance technology transfer opportunities. For his period, examples include:

- Extensive meetings, hands-on work sessions, webinars, and demonstrations were held with personnel from McGavic Outdoor Power.
- On-going collaboration with Indiana DOT involves weekly communications and webinars regarding winter operation activities.

- Bi-weekly meetings with NASA Langley Research Center to discuss "Enhanced Methodology for Exploring Autonomy-enabled Multi-Mode Regional Transportation Ride Sharing with Advanced Air Mobility."
- Meetings with PathMaster, Inc. to discuss potential data providers for the project Impact "Analysis of Roadway Surface and Vehicle Conditions on Fleet Formation for Connected and Automated Vehicles."

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

Part II: CCAT UTC Specific Performance Indicators CCAT October 1, 2020 - March 31, 2021			
Technology Transfer Goals			
1. **OUTPUTS**	**Research Performance Measures**	**CCAT Annual Target**	**CCAT YTD OCT-MAR**
1.A. Disseminate research results through publications, conference papers, and policy papers	Technical reports	10	12
	Papers at conferences, symposia, workshops, and meetings	3	58
	Peer-reviewed journal articles	6	33
1.B. Develop inventions, new methodologies, or products	Annual number of research deployments	5	9
1.C. Research projects funded by sources other than UTC and matching fund sources	Number of projects	3	27
	Dollar amount of projects	$300,000	$3,893,019
2. **OUTCOMES**	**Research Performance Measures**		
2.A. Incorporate new technologies, techniques or practices	Number of technology transfer activities that offer implementation or deployment guidance	2	7
2.B. Improve the processes, technologies, techniques in addressing transportation issues	Number of research deliverables disseminated from each research project	4	26
3. **IMPACTS**	**Research Performance Measures**		
3.A. Increase the body of knowledge and safety of the transportation system	Number of instances of technology adoption or commercialization	2	3
	Number of conferences organized by the CCAT consortium members	2	16
3.B. Improve the operation and safety of the transportation system	Number of instances of research changing behavior, practices, decision making, policies (including regulatory policies), or social actions	3	7

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

CCAT members hosted or participated in 112 outreach engagements with industry, government, academia, media, and community organizations this reporting period. Surprisingly, the number of engagements has increased, even with the many restrictions from COVID-19. In total, CCAT research was shared with literally millions of 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 evolves, more and more examples of our leadership come to light. When the FCC issued a Report

and Order that gave away most of the 5.9 GHz safety spectrum and chose CV2X over DSRC, experts at CCAT were called upon to analyze the impacts of the decision. We provided input for a Car and Driver article on the topic. Car and Driver has a circulation of 1.2 million. We also provided input for the ITSA response to the Report and Order. Additionally, we provided content for an Automotive News story, which has a circulation of over 56,000. Lastly, we recorded a podcast for MDOT that was listened to by 362 people.

The CCAT Student Poster Competition for the 20/20 CCAT Global Symposium was delayed until October 28, 2020. In total, we received 19 undergraduate and graduate submissions across 3 universities (University of Illinois at Urbana-Champaign, Purdue University, and University of Michigan). Our panel of judges narrowed these submissions down to four finalists that were able to present their research virtually. Our judges included John Abraham (Macomb County), Barb Land (Square One Education Network), Anthony Magnan (Verizon Wireless), Danil Prokorov (Toyota North America R&D), Liz Pulver (State Farm), and Rini Sherony (Toyota's Collaborative Safety Research Center). Our first finalist was Sachindra Dahal from UIUC whose work was titled "Passive Sensing of Conductive Concrete for Vehicle Lateral Positioning". Our second finalist was Xingmin Wang from U-M whose work was titled "Data Infrastructure for Connected Vehicle Applications". Our third finalist was Xintao Yan from U-M whose work was titled "A Data-driven Simulation of Naturalistic Driving Environment for Autonomous Vehicle Testing". Our fourth finalist was Zhen Yang from U-M whose work was titled "Integrated Traffic Signal and Vehicle Trajectory Control in a Mixed Traffic Condition". After presentations, our judges deliberated and determined our runner-up to be Zhen Yang and our winner to be Xintao Yan, awarding $750 and $1,000 respectively.

This period, CCAT continued the monthly research reviews and re-introduced the Distinguished Lecture Series, albeit in an on-line format. 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 2: Distinguished Lecture Series and Research Reviews for the Reporting Period 10/1/2020 – 3/31/21[1]

Date	Title (Link)	Presenter(s)	Registrants	Attendees	Views
10/21/20	Distinguished Lecture: A Vision for the Future of Michigan Mobility & Electrification.	Trevor Paul, Chief Mobility Officer for the State of Michigan	153	95	207
11/17/20	Research Review: Deploying Cellular Vehicle-to-Everything Infrastructure on Highway I-275	Dr. Gabor Orosz, University of Michigan	230	139	1,385

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

2/25/21	Distinguished Lecture Series: Autonomous and Intelligent Cyber-Physical Systems and the Era of Big Data	Jonathan Sprinkle, University of Arizona	154	102	113
3/31/21	Research Review: Using Artificial Intelligence for Optimal Truck Platooning Under Uncertainties. Funded Research: Operations of Connected and Autonomous Freight Trucks under Congestion and Infrastructure Cost Considerations.	Dr. Hadi Meidani, University of Illinois at Urbana-Champaign	188	120	67

CCAT has leveraged Twitter as an event, research, and PR tool, and since October, has earned over 64,000 impressions and 103 followers (278 total). CCAT utilizes its LinkedIn profile to promote upcoming events including Distinguished Speaker Series, Research Review, and Global Symposium, as well as announce research awards. LinkedIn analytics include receiving 19,300 impressions, over 1,000 profile visits, and 240 new followers (450 total). Finally, CCAT uploads all events to the YouTube channel via live stream and as an edited VOD. CCAT's YouTube analytics since October include 2,150 VOD views, 112 live views, 43 new subscribers (165 total; the most of any UTC YouTube channel), and a watch time of 11,340 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 include a complete overhaul of the website to a new server to improve user experience regardless of device. Over the last six months, the website has received over 1875 unique sessions (total of 2,668), 85% of which were new users. Across those sessions, there were over 6,800 page views. Furthermore, the CCAT newsletter was issued in December of 2020 and March of 2021.

Awards

- CCAT sponsored research paper was selected as the Editors' Choice by the ASCE Journal of Infrastructure. Saeed, T.U., Alabi, B.N.T., Labi, S. (2021). Preparing Road Infrastructure to Accommodate Connected and Automated Vehicles: System-Level Perspective. The paper was written based form research on the CCAT project "Design and Management of Highway Infrastructure to Accommodate CAVs."
- Dr. Yan Zhao, 2020 Chinese Overseas Transportation Association (COTA) Best Dissertation Award. The COTA Best Dissertation Award is established to recognize outstanding students with Chinese nationalities for their accomplishments of pursuing doctoral degrees in the transportation field. The award will be presented annually to two selected graduate students for their PhD dissertations, one in transportation policy & planning and the other on transportation science & technology.

- Huang, S., Feng, Y., and Liu, H. (2021) Impact Evaluation of Falsified Data Attacks on Connected Vehicle Based Traffic Signal Control Systems" received the Best Paper Award the Network and Distributed System Security Symposium (NDSS) 2021

Also, this period, we have continued planning for the 4th Annual CCAT Global Symposium on Connected and Automated Vehicles and Infrastructure. The symposium will be held virtually again this year. Although virtual, we reverted to our in-person format with a two-day, two-track event. The first track will have panel discussions with industry experts. The second track, the research track, will focus on disseminating CCAT research results from recently finished or well-established projects. Keynotes for the event include U.S. Representative Bob Latta, Toyota Executive Ryan Eustice, and Dean Alec Gallimore. By the end of March, over 750 people had registered, surpassing the number of attendees from last year. The virtual experience made it easier to attract not only global attendees, but also panelists from Europe and Australia. When planning for the 2022 symposium, we plan on keeping a virtual component in the program for both attendees and speakers.

Since the COVID-19 Pandemic policies of 2020 began, very limited numbers of interpersonal activities have been authorized. This has limited and restricted some CCAT activities and collaborations with organizations, including K-12 school systems. Despite the pandemic, WCC as our educational outreach partner accomplished the following:

Workforce Development Training Accomplishments:

- Cancelled the non-credit training module for automotive cybersecurity in favor of academic modules demanded by industry.
- Completed development of Microsoft EXCEL for Data Analysts using CAV/CAT data as the basis for training the use of the various EXCEL software components. Fourteen modules written to industry standards will be loaded into Blackboard, CANVAS, and the MOODLE Learning Management System and made available to students in Q3 2021.
- Twenty [20] IEEE courses with over 160 modules on CAV/SMART City Technologies were added to Washtenaw's Learning Management System, Blackboard. These IEEE courses are available to academic and workforce instructors for professional development.
- Completed Research and Design of certification training for Microsoft Power BI. Curriculum development expected to be completed by July 2021.
- Completed Research and Design of visualization series based on the Edward Tufte method. Curriculum development expected to be completed by July 2021.
- Completed Research and Design of visualization series that teaches XML code. Activities and animations in development. Curriculum development expected to be completed by July 2021.

Credit Education Certificate and Degree Programs Accomplishments:

- Instructors advanced the development of the Automotive Cybersecurity Lab testing with the procurement of seven Umlaut-designed Cybersecurity Workbenches and other resources in a cross-functional learning environment between the Computer Science & IT Department and the Transportation Technologies [Automotive] Department. The new workbenches allow students to interact with the vehicle infotainment system in an engineering and cybersecurity capacity,

identical to workbenches used by manufacturers, suppliers and development engineering organizations.

- Instructors advanced the Transportation Technologies Curriculum Development on object detection Sensors. 3-D LiDAR Sensors were procured for classroom learning and a demonstration unit was procured for an experimental demonstration vehicle. Also procured were diagnostic software identifying objects from various Cameras/LiDAR sensors to integrate into classroom learning sessions.
- CAV/CAT Equipment procured for WCC educational labs:
    - Received additional Umlaut-designed Automotive Cybersecurity Lab Workbenches for the integration into the Automotive Cybersecurity Certificate curriculum.
    - Received CanBusHack software and hardware simulator to further enhance the Automotive Cybersecurity Lab experiences for students.
    - Received 3-D LiDAR Sensor equipment and software licenses to diagnose and label objects detected in data analyses.

K-12 STEM Technology Awareness & Insight Accomplishments:

- Conducted a Square One Masters of Mobility V2X Connected Vehicle School 2-day training for K-12 students and teachers (Oct/Feb). This was conducted virtually due to COVID-19.
- Due to COVID-19 response policies, cancelled Square One Education Network "Cars that Communicate: V2X Technology" live Youth Camp due to COVID-19 pandemic, and replaced it with a virtual event- K-12 Project. Note- this was a no-charge awareness event for disadvantaged youth in the Ypsilanti/Eastern Washtenaw County area. This virtual camp at the Ypsilanti Parkridge Facility for disadvantaged youth to provide awareness in microprocessor computers. In addition, contracted with Square One Education Network to deliver Micro-Bit Computer virtual awareness education at a second youth camp at the Parkridge community.
- Conducted Computer Awareness Training at Scarlett Middle School in Ann Arbor, to the point of stoppage, due to the COVID-19 pandemic.

General Outreach:

- WCC continued active leadership roles on key Mobility [CAV/CAT/Infrastructure] organizations, including ITS Michigan, American Center for Mobility, MICHauto, USDOT ITS PCB, IEEE, MI CAV Working Group, MI Alliance for Greater Mobility Advancement [MAGMA], NOCoE & TSMO, SAE and others.
- The Cybersecurity activity held a "Cyber Learn-a thon" in cooperation with Cisco Networking Academy, open to all ages 14 and up, that logged over 100 participants.
- 2021 Motor Bella Automobili-D Exhibit event being planned in lieu of the 2021 NAIAS, September 21-22, 2021. Comprehensive Outreach planning activities are underway.
- 2020-21 ITS PCB Community College Workgroup #2 Meetings: "Fostering ITS Employer/Community College Connections and Partnerships"; WCC collaboration and presentations on education/training programs and partners continues.
- The ATC Director presented three repeating Mobility Occupation presentations during the WCC STEAM Week, March 4, 2021. The audience in part consisted of high school and college students seeking occupational pathway options.

- Several WCC news articles were written about personnel involvement and development in the technologies of CAV/CAT. Also reported were the activities and personnel surrounding WCC's new Automotive Cybersecurity Certificate programs

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.

CCAT Org.	Org.	Location	Contribution
Akron	ODOT District 4	Akron, OH	Data sources and project support.
Akron	PathMaster, Inc.	Twinsburg, OH	Personnel and technical support on algorithm testing, data sources.
Akron	City of Akron	Akron, OH	Personnel and technical support.
Purdue	McGavic Outdoor Power	Noblesville, IN	Development of electric vehicle de-icing prototype, which included integration of automated application equipment and Raven controller into GEM electric vehicle.
Purdue	Area Planning Commission of Tippecanoe County	Lafayette, Indiana	Mutual assistance in counting vehicles, pedestrians, and other users of selected locations on city streets.
Purdue	Indiana Department of Transportation	Indianapolis, IN	Collaborative research (in-kind) and cost sharing (cash).
Purdue	NEXTRANS Center	West Lafayette, IN	Use of driving simulator equipment and other facilities
Purdue	Purdue University	West Lafayette, IN	Provided COVID protective gear for driving simulation experiments
Purdue	NYU Shanghai	Shanghai, China	Collaborative Research
Purdue	Georgia Institute of Technology	Atlanta, GA	Collaborative research
UM	Ford Motor Company	Dearborn, MI	Financial support ($221,125), in-kind support for facilities and technical collaboration.
UM	Mcity	Ann Arbor, MI	Financial Support
UM	Intent Design	Farmington Hills, MI	Guidance and inputs on the design of the Active Seat system, on various testing and safety standards associated with seating and in-cabin automotive technologies, and on commercial adoption in the automotive industry.

3. Outputs

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

University of Michigan

- "On the Deployment of V2X Roadside Units for Traffic Prediction" by Lejun Jiang, Tamas Molnar and Gabor Orosz submitted to Transportation Research Part C.
- Website launched for the International Symposium on Transportation Data and Modeling (ISTDM) Symposium.
- Implemented weaving models on Mcity's augmented reality platform.
- Tafreshian, A., Masoud, N., & Yin, Y. (2020a). Ride-Matching for Peer-to-Peer Ridesharing: A Review and Future Directions. Service Science, 12(2-3), 44-66.
- Tafreshian Amirmahdi, and Neda Masoud. Using Subsidies to Stabilize Peer-to-Peer Ridesharing Markets with Role Assignment. Transportation Research Part C: Emerging Technologies. 120, 2020.
- Zhang Zhenhao, Amirmahdi Tafreshian, and Neda Masoud. Modular Transit: Using Autonomy and Modularity to Improve Performance in Public Transportation. Transportation Research Part E: Logistics and Review. 141, 2020.
- Jalgaonkar, N., Sousa Schulman, D., Ojha, S., and Awtar, S., "A Visual-Vestibular Model to Predict Motion Sickness Response in Passengers of Autonomous Vehicles," SAE Technical Paper 2021-01-0104, 2021, https://doi.org/10.4271/2021-01-0104.
- U.S. Pat. App. No. 17/072,802: Passenger State Modulation System for Passenger Vehicles Based on Prediction and Preemptive Control (Shorya AWTAR, Nishant JALGAONKAR, and Daniel SCHULMAN).
- PCT/US2020/056198: Passenger State Modulation System for Passenger Vehicles Based on Prediction and Preemptive Control (Shorya AWTAR, Nishant JALGAONKAR, and Daniel SCHULMAN).
- Mi, T., and Yin. Y. Multiagent Reinforcement Learning for Arterial Traffic Signal Control.
- Wang, X., Yin, Y., Feng, Y., and H. Liu, Learning the max pressure control for urban traffic networks considering the phase switching loss, Transportation Research Part C, major revision, 2021.
- Conference Paper: T. Kleinow et al., (2020) "A Validated Model for Non-Line-of-Sight V2X Communications" 2020 Antenna Measurement Techniques Association Symposium (AMTA), Newport, RI, USA, pp. 1-6.
- Media Story: Why your first driverless car is decades, not years away. February 1, 2019. https://umdearborn.edu/news/articles/why-your-first-driverless-car-decades-not-years-away.
- Media Story: How autonomous technology could transform long-haul trucking. April 7, 2019. https://umdearborn.edu/news/all-news/articles/how-autonomous-technology-could-transform-long-haul-trucking.
- Yang, Z., Feng, Y., and Liu, H.X. (2021). Vehicle Trajectory Planning with Hierarchical Imitation Learning in Highway Merging Scenarios, to be Presented at TRB 100th Annual Meeting, 2021.
- Liu, L., Feng, S., Feng, Y., Zhu, X., and Liu, H. X. (2021). A Learning-based Stochastic Driving Model for Autonomous Vehicle Testing, to be Presented at TRB 100th Annual Meeting, 2021.
- Sun, H., Feng, S., Yan, X., and Liu, H. X. (2021). Corner Case Generation and Analysis for Safety Assessment of Autonomous Vehicles, to be Presented at TRB 100th Annual Meeting, 2021.
- Wang, X., Feng, Y., Yin, Y., and Liu, H. X. (2021). Max-Weight Control for Urban Traffic Networks Considering Phase Switching Loss, to be Presented at TRB 100th Annual Meeting, 2021.

- Yan, X., Feng, S., Sun, H., and Liu, H. X. (2021). A Data-driven Simulation of Naturalistic Driving Environment for Autonomous Vehicle Testing, to be Presented at TRB 100th Annual Meeting, 2021.
- Huang, S., Feng, Y., and Liu, H. X. (2021). A Data Driven Method for Falsified Vehicle Trajectories Identification by Anomaly Detection, to be Presented at TRB 100th Annual Meeting, 2021.
- Feng, Y., Huang, S., Wong, W., Chen, Q.A., Mao, M.Z., and Liu, H. X. (2021). On the Cybersecurity of Traffic Signal Control System with Connected Vehicles, to be Presented at TRB 100th Annual Meeting, 2021.
- Zheng, F., Chen, J., Wang, H., Liu, H.X., and Liu, X.B. (2020) Developing a dynamic utilization scheme for exclusive bus lanes on urban expressways: an enhanced CTM-based approach versus a microsimulation-based approach, IET Intelligent Transport Systems, 14(12), 1657-1664. DOI: 10.1049/iet-its.2019.0546
- Feng, S., Yan, X., Sun, H., Feng, Y., and Liu, H.X. (2021) Intelligent driving intelligence test for autonomous vehicles with naturalistic and adversarial environment. Nature Communications 12, 748. doi: 10.1038/s41467-021-21007-8
- Yang, Z., Feng, Y., and Liu, H. (2021) A cooperative driving framework for urban arterials in mixed traffic conditions, Transportation Research Part C: Emerging Technologies, 124, doi: 10.1016/j.trc.2020.102918.
- Zhao, Y., Guo, X., and Liu H.X. (2021). The Impact of Autonomous Vehicles on Commute Ridesharing with Uncertain Work End Time. Transportation Research Part B: Methodological 143, 221-248. https://doi.org/10.1016/j.trb.2020.11.002
- Wong W., Wong S.C., and Liu H.X. (2021) Network Topological Effects on the Macroscopic Fundamental Diagram. Transportmetrica B: Transport Dynamics, Vol. 9, 376-398. https://doi.org/10.1080/21680566.2020.1865850

Purdue University

- Winter Operations Resources from related INDOT Projects related to the “Intelligent Sidewalk De-icing and Pre-treatment with Connected Campus Maintenance Vehicles” are posted at this website: https://tinyurl.com/INDOT-Calibration
- Performed testing and found solution for instances when limited satellite visibility had a negative impact on automated brine application.
- The following training videos were developed/refined during this reporting period:
  - How to Create Application Shapefiles (https://youtu.be/J5M3BuZcgtI)
  - Brine Application Demonstration (https://youtu.be/JDwVfUKQpfk)
  - Smart Mobility Brine Demo (https://youtu.be/4WbN9IlN2wc)
  - How to Operate Raven CR7 Controller (https://youtu.be/AY3JnTUyKEM)
- Paper at conference. "Incorporating Conflict Risks in Pedestrian-Motorist Interactions: A Game Theoretical Approach", Yunchang Zhang and Jon D. Fricker, Purdue University, Paper 21-01638, Session 1099, Mon. 1/25/2021.
- Peer-reviewed journal article. Yunchang Zhang and Jon Fricker. "Investigating Temporal Variations in Pedestrian Crossing Behavior at Semi-Controlled Crosswalks: a Bayesian Multilevel Modeling Approach”, accepted 11/1/2020 for publication in Transportation Research Part F.

- Peer-reviewed journal article. Yunchang Zhang and Jon Fricker. "Quantifying the Impact of COVID-19 on Non-Motorized Transportation: A Bayesian Structural Time Series Model", accepted 1/9/2021 for publication in Transport Policy.
- A game-theoretic model has been developed to quantify probabilities of conflict and confusion under alternative scenarios.
- Reinforcement learning techniques have been integrated into the traffic simulation software (SUMO) to investigate the optimal control strategies at crosswalks.
- The draft final report for the project "Behavioral Intention to Ride in AVs and Impacts on Mode Choice Decisions, Energy Use and Emissions" was completed and will be submitted next period.
- Gkartzonikas, C., L.L, Losada Rojas, S. Christ, V.D. Pyrialakou, and K. Gkritza, "Behavioral Intention to Ride in Autonomous Vehicles: Theoretical Constructs and Empirical Results from Three U.S. Cities", Transportation (under review, submitted October 24, 2020).
- New theoretical model to assess behavioral intention; methodology to assess value of travel time savings based on a choice experiment.
- Gkartzonikas, C., Y. Ke, and K. Gkritza, "A Tale of Two Modes: Who Will Use Single User and Shared Autonomous Vehicles," Case Studies in Transport Policy (under review, submitted January 11, 2021). (Tier 1).
- Methodology to identify market segments and assess transportation disadvantaged areas.
- Survey data for Indianapolis and Chicago
- Losada Rojas and K. Gkritza, "Individual and Location-based Characteristics Associated with AV Adoption in the Chicago Metropolitan Area: Implications for Public Health," Journal of Transport & Health (under review, submitted December 17, 2020).
- Database for transportation health related factors in both Chicago and Indianapolis.
- Ha, P., Chen, S., Du, R., Dong, J., Li, Y., Labi, S. (2020). Vehicle connectivity and automation: A sibling relationship, Front. Built Environ., doi.org/10.3389/fbuil.2020.590036.
- Saeed, T.U., Burris, M., Labi, S., Sinha, K.C. (2020). An empirical discourse on forecasting the use of autonomous vehicles using consumers' preferences, Technological Forecasting & Social Change 158,120130.
- Labi, S., Alabi, B.N.T., Saeed, T. (2020). Preparing road infrastructure to accommodate connected and automated vehicles – A system-level perspective, Journal of Infrastructure Systems.
- Seilabi, S., Tabesh, M., Davatgari, A., Miralinaghi, M., Labi, S. (2020). Promoting autonomous vehicles using travel demand and lane management strategies, Front. Built Environ., doi.org/10.3389/fbuil.2020.560116.
- Miralinaghi, M., Tabesh, M., T., Correia, G. H. de A., Seilabi, S. E., Davatgari, A., and Labi, S. (2020). Parking facility location and user pricing in the era of autonomous vehicle operations, Next-generation Transport Systems Conference, W. Lafayette, IN.
- Guo, Y., Peeta, S., Labi, S. (2021). Impacts of Attitudinal Factors and Prospective Roadway Designs on Autonomous Vehicle Adoption and Vehicle Fuel Choice. Transportation Research Board 100th Annual Meeting, Washington, DC.

- Miralinaghi, M., de Almeida Correia, G. H., Seilabi, S. E., and Labi, S. (2020). Designing a Network of Electric Charging Stations to Mitigate Vehicle Emissions. Institute of Electrical and Electronics Engineers (IEEE) 2020 Forum on Integrated and Sustainable Transportation Systems (FISTS), Delft, South Holland Province, Netherlands, 2020.
- Miralinaghi, M., Tabesh, M., T., Correia, G. H. de A., Seilabi, S. E., Davatgari, A., and Labi, S. (2020). Robust design of electric charging locations under travel demand uncertainty and driving range heterogeneity, Next-generation Transport Systems Conference, W. Lafayette, IN.
- Miralinaghi, M., Davatgari, A., Tabesh, M., T., Correia, G. H. de A., Seilabi, S. E., and Labi, S. (2020). Minimizing urban vehicular emissions through the efficient design of electric charging station network, Next-generation Transport Systems Conference, W. Lafayette, IN.
- Miralinaghi, M., Correia, G. H. de A., Seilabi, S. E., and Labi, S. (2021). Managing Urban Vehicular Emissions Through the Efficient Design of Electric Charging Station Infrastructure. Transportation Research Board 100th Annual Meeting, Washington, DC., 21–03592.
- Miralinaghi, M., T. Tabesh, M., Correia, G. H. de A., Seilabi, S. E., Davatgari, A., and Labi, S. (2021). Robust Design of Electric Charging Locations under Travel Demand Uncertainty and Driving Range Heterogeneity. Transportation Research Board 100th Annual Meeting, Washington, DC., 21–03594.
- Mwamba, I., and Labi, S. (2020). Economic and financial implications of EV infrastructure and operations, Next-generation Transport Systems Conference, W. Lafayette, IN.
- An innovative infrastructure-based solution to address the connectivity gap of CAVs and a new modeling framework to evaluate its impacts and a new modeling framework to optimize the incentive policies for CAVs
- Bi, J., Wang, Y., Peeta, S., "Optimal Mixed-traffic Operations with Lanes Dedicated to Autonomous Vehicles", INFORMS 2020, Virtual, Nov. 2020.
- The final report for “Cooperative control mechanism for platoon formation of connected and autonomous vehicles” has been written and will be submitted next reporting period.
- The final report for "Development of a dynamic network traffic simulator for mixed traffic flow under connected and autonomous vehicles technologies - Phase 2" has been written and will be submitted next reporting period.
- The final report for "Development of in-vehicle information dissemination mechanisms to reduce cognitive burden in the information-rich driving environment - Phase 2" was written and will be submitted next reporting period.
- The final report for “Impacts of in-vehicle alert systems on situational awareness and driving performance in SAE level 3 vehicle automation” was written and will be submitted next reporting period.
- Liu, Y., Zhou, A., Wang, Y., Peeta, S. (2021). Proactive Longitudinal Control to Manage Disruptive Lane Changes of Human-Driven Vehicles in Mixed-Flow Traffic. IFAC 2021 Proceedings. Accepted.

University of Akron

- Added to dataset at minor intersection entrance when vehicles select proper gaps to enter the roadway.
- Data collected to set up the "before" baseline for simulation of "what if" options.

University of Illinois at Urbana Champaign

- Al-Qadi, I. L., Okte, E., Ramakrishnan, A., Zhou, Q., & Sayeh, W. (2021). Truck-Platoonable Pavement Sections in Illinois' Network. Illinois Center for Transportation/Illinois Department of Transportation.
- Okte, E., Al-Qadi, I. L., (forthcoming). "Determining Road Networks' Platoonability". In: Journal of Transportation Engineering, Part A: Systems. doi: https://doi.org/10.1061/JTEPBS.0000556
- Zhou, Q., Okte, E., Al-Qadi, I. L., (forthcoming). "Predicting Pavement Roughness Using Deep Learning Algorithms". In: Transportation Research Record.
- She, R., & Ouyang, Y. (2021). Efficiency of UAV-based last-mile delivery under congestion in low-altitude air. Transportation Research Part C: Emerging Technologies, 122, 102878.
- A YouTube video was developed for ASU's pavement lab that also features the ongoing UTC project. https://www.youtube.com/watch?v=cLQQar8vzAo&t=27s.
- A technique was developed for high performance computing (HPC) purposes. The job scheduler of computing cluster was integrated with ansys journal file to automate running random realization of the model.
- Dynamic programming-based framework to minimize life-cycle cost (including energy and pavement) by optimizing platoon configuration and pavement rehabilitation schedule simultaneously.
- Obtaining master curve from experimental data was developed during this period. Permanent deformation curves were obtained for three rest periods. The curves were shifted to obtain a Master curve using a shift function.
- Tested sensor with new EM material combination that can be used for safer navigation of AVs during adverse weather condition and much easier to magnetize and de-magnetize.

Central State University

- MOVES 3.0 Emission rates.
- Ground level emissions concentrations collected.
- Developed requirements for a web application on iOS and Android platforms to calculate and display estimated emissions levels to drivers from their vehicles on predefined roads and intersections in Ohio.
- Developed requirements to procure instruments that can measure aerosol properties such as diameter required for environmental monitoring and actual inhalation studies.

4. Outcomes

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

University of Michigan

- Developed models for determining the probability of packet reception using CV2X and DSRC communication based on the simulated received power. This model allows for a direct conversion between simulated field power and packet reception rate prior to physical testing.

Purdue University

- Indiana LTAP funded project: Winter Operations Best Practices and Training for Local Agencies contract ($100,222)
- Automated Brine Vehicle was used for winter operations on the Purdue University campus during winter events on December 15, 2020 and following dates in 2021: January 23, January 25, January 28, February 10, and February 12. A total of 14.1 linear miles of sidewalk was successfully treated with the automated brine system during these winter events.
- Trained academia, state DOT and local agencies on automated brine vehicle benefits and usage.
- Increased understanding of behavior of pedestrians and motorists in a variety of situations at the same site. This can form the basis of an analysis of the performance of similar crossing facilities when new technologies are employed for vehicles and pedestrians. Additionally, Pedestrian and vehicle trajectory data is available for subsequent safety and efficiency analysis.
- Identification of infrastructure changes needed in the CAV era.
- Increased awareness of current deficiency of road infrastructure to accommodate CAVs.

University of Illinois at Urbana Champaign

- The analyses were performed using cluster computing and a prediction accuracy of 90% was demonstrated for 1000 realization of the randomized system.
- Based on pavement FE model which considers complex conditions showed that rest period does not affect fatigue cracking and rutting. Experimental data showed opposite trend for rutting.
- Tested electromagnetic materials successfully in normal and adverse conditions that were embedded into concrete material. Designed and developed sensor array so that the laboratory idea can be expanded to lane keeping.
- Tested electromagnetic materials successfully in normal and adverse conditions that were embedded into concrete material. Designed and developed sensor array so that the laboratory idea can be expanded to lane keeping.

Central State University

- Trained four (4) students on suing MOVES to calculate emissions.

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

- Increased the body of knowledge for the transportation industry by sharing test results and lessons learned including:
  - Effects of occluding obstacles on wireless communication for both CV2X and DSRC radio networks.
  - Lessons learned about proper testing procedures including the importance of selecting a range of testing transmit powers to ensure a good mix of received and lost packets.
- Demonstrated concrete difference in packet reception probability for similar power levels and SNR for CV2X and DSRC and determined that all else being equal, CV2X offers improved performance in

the NLOS tests we performed and can be recommended. The difference of about 10 dB in reception cutoff power is reflected in other testing such as the 5GAA's V2X functional and performance test report.

Purdue University

- Knowledge gained in the research and initial deployment of the automated brine application system has developed capabilities in the connected and automated space for small campus vehicles and will provide information needed to scale precision application of de-icing chemicals to highways and airports.
- Improvements to the operation and safety of semi-controlled crosswalks by developing a database and identifying factors that affect pedestrian and motorist behavior. This information will be used to test the impact of new technologies on crosswalk safety and performance.
- Increased body of knowledge regarding (a) need for infrastructure retrofit for CAVs (b) specific changes needed.

University of Illinois at Urbana Champaign

- CFD is computationally expensive and successful training of a surrogate model is promising to address platooning problems which depend on the calculation of drag force using CFD.
- Different from regular traffic, truck platoons bring unique pros and cons that require proper strategy to yield best economical gain. The proposed link cost function is characterized for platooned truck traffic and is at the optimality of operational level control (i.e., platoon configuration, rehabilitation schedule). This provides useful data and insights for highway administrative and shipment carriers and could aid in operational decisions.
- Master curve obtained using shifting can be used to obtain the permanent deformation for any new rest period without conducting the experiment.
- Materials and sensors that work both in normal and adverse conditions tested successfully. AVs can use this robust system as a complement to existing camera and GPS sensors, especially in adverse weather conditions, for lane keeping.

6. Changes/Problems:

In this period, CCAT continued to struggle with the impacts of COVID-19. Although campuses were reopened, many restrictions remained, such as a delay in bringing student researchers back on campus until the fall semester and banning human subject interactions until proven methodologies for ensuring the safety of the participants and researches could be established. Another impact that cannot be overlooked is the general decrease in traffic. Many of our studies involve collecting data in a live environment. However, the environment looks much different today than it did a year ago. For example, on Plymouth Road in Ann Arbor, in September of 2020, vehicle traffic has decrease 63% and pedestrian traffic has decreased by 92%, as compared to September of 2019.

Below is a summary of changes and problems for each of our consortium members, including issues stemming from COVID-19.

Akron

- Progress on data collection has been largely delayed due to at-home work operations by employees of tire companies and state DOTs, affecting the project "Impact Analysis of Roadway Surface and Vehicle Conditions on Fleet Formation for Connected and Automated Vehicles."
- Low traffic volume due to prolonged pandemic affected the ability to collect field data for the project
- Work was slowed down due to campus wide restrictions on lab work and face-to-face meetings, delaying research on the project "Development of a Prototype Safety Advisory System to Older Drivers in Gap Selection," including interactions with the older drivers as research subjects.

WCC

- Instead of supporting students to attend conferences, WCC has redirected their efforts to buy supplies for students, deliver then to their houses, for the students to participate remotely.

Purdue University

- COVID-related restrictions on campus impacted the throughput of driving simulator experiments for the project "Development of AI-based and control-based systems for safe and efficient operations of connected and autonomous vehicles."
- Experimental work on human subject related driving simulation slowed considerably during the reporting period due to the COVID pandemic, affecting the timing of the project "Investigation of AV Operational Issues using Driving Simulator Equipment.

7. Special Reporting Requirements: Final Reports

This period, the final report below was completed, edited to meet 508 compliance, and posted to the CCAT website. Additionally, all outputs, outcomes, and impacts from the project were documented and submitted.

Lakshmanan, Sridhar, & Richardson, Paul & Watta, Paul, (2021), "Reliable V2V Communication Networks: Applications in Fuel-Efficient Platooning". Report No. CCAT Project Number 16, Center for Connected and Automated Transportation, University of Michigan.
URL: http://hdl.handle.net/2027.42/166585 or http://dx.doi.org/10.7302/381