Semi-Annual Progress Report for University Transportation Centers

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Awarded To:
Regents of the University of Michigan
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Ann Arbor, MI 48109

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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 April 1, 2022, through September 30, 2022.

1.A Current Research Status

To date, CCAT has funded 73 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.

**AI-enabled Transportation Network Analysis, Planning and Operations: University of Michigan, Dr. Yafeng Yin.** In this period, a proof-of-concept study on end-to-end learning of user equilibrium of transportation networks with known O-D and link flow observations was completed. The developed 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.

**Deployment of Preemption based Motion Sickness Prevention Technology on a Testbed Vehicle in Mcity: University of Michigan, Dr. Shorya Atwar.** During this period, the previously developed PREACT components were integrated into an operational technology that was deployed in Mcity and validated in realistic driving conditions with human subjects. Specifically, the Active Passenger Stimuli method of preemptive intervention was tested and recorded very promising outcomes in reducing motion sickness.

**Development of A Cooperative Perception System: Purdue University, Dr. Yiheng Feng.** This reporting period, the research team carried out an extensive review of published work related to the project and commenced developing the vehicle perception components utilizing cameras and LiDAR sensors data fusion for object detection and tracking. A cooperative perception system was built in the SUMO/CARLA co-simulation to test the algorithms regarding LiDAR data fusion and 3D object detection.

**Economical Acquisition of Intersection Data to Facilitate CAV Operations: Purdue University, Dr. Samuel Labi.** This reporting period, the research team completed a comprehensive literature review to identify the shortcomings of existing state-of-the-art and state-of-the-practice in intersection data acquisition. The research team also commenced the design of the data diode, a low-cost, high-integrity device to connect to the NTCIP 1202 SPaT data stream from existing traffic signal controllers.

**Impact of Autonomous Freight Delivery on Trucking Operations: University of Illinois at Urbana-Champaign, Dr. Imad Al-Qadi.** This period, A neural network-based framework was developed to
evaluate the local delivery efficiency under traffic equilibrium of drones. A framework that includes mixed traffic conditions was also developed. Field testing was conducted this period as well. The vehicle's lateral position was determined during normal and adverse weather conditions using the electromagnetic (EM) signature in the pavement and an array of sensors that were developed during the lab testing. Field results demonstrated that the vehicle position estimation with more than 2 inches of snow on the lane was statistically similar to the position estimation during normal pavement surface conditions. Lastly, a data-driven model was developed to predict the drag coefficient for trucks in a platoon of size two or three. An optimization strategy was developed to minimize the drag coefficient under various wind conditions. The model was used to calculate the fuel consumption on the highway.

Improving the efficiency of trucks via CV2X connectivity on highways (Year 3): University of Michigan, Dr. Gabor Orosz. The research team has made significant progress with respect to the experimental implementation of the project. In collaboration with MDOT engineers and DES Electric, two CV2X roadside units (RSUs) were installed along the chosen section of highway I-275. At the 5-mile Road location, the RSU was powered using the 110V power supply available from the MDOT cabinet while internet connection was established using an AT&T sim card installed in the RSU. At the Telegraph Road location, power was obtained via a power-over-ethernet, and the internet connection was established using an AT&T sim card. Utilizing a local VPN network that was established at the University of Michigan, the team is now able to communicate with the RSUs through the internet. This allows us to collect data and to deploy codes on the RSUs, which are necessary for the planned experiments. The team has carried out multiple experiments with real vehicles equipped with CV2X on-board units (OBUs). We tested the RSU-to-OBU communication by sending and receiving traditional basic safety messages (BSMs) as well as the new traffic history messages (THMs) and traffic prediction messages (TPMs) developed as part of this project. A new set of RSUs has also been tested experimentally and are planned to be deployed during fall 2023.

Lane management in the era of CAV deployment: Purdue University, Dr. Mohammad Miralinaghi. During the reporting period, the research team started the development of a robust planning framework for CAV-dedicated lane deployment to address the potential CAV market size uncertainty. This framework was designed to minimize some system-wide adversity such as the total emissions relative to the worst-case scenario. It was formulated as a bi-level problem where the upper level captures the decision of the city agency that aims at minimizing some maximum total adversity under different scenarios of potential CAV market size.

Leveraging Control Theory to Facilitate UAV Application for CAV Deployment: Purdue University, Dr. Shaoshuai Mou. During the reporting period, the research team carried out TASK A (review of literature) and TASK B (identification of the features from UAV-captured videos and detection of vehicles based on UAV-generated point cloud). The team also developed a method to identify a pipeline to extract features/information from UAV-captured videos and point cloud data collected through the LiDAR embedded on the UAV can be used to identify surrounding vehicle’s status.

Modeling Naturalistic Driving Environment with High-Resolution Trajectory Data: University of Michigan, Dr. Shuo Feng. During this period, we developed a methodological framework to model a
high-fidelity naturalistic driving environment (NDE) using large-scale real-world trajectory data. Utilizing the proposed method, we can generate complex urban driving environments. The simulated environment is statistically consistent with real-world driving conditions, ranging from normal to safety-critical driving scenarios. This is a significant advancement compared to traditional NDE models that can only match the moments of macroscopic traffic behaviors. The proposed method is implemented in Mcity to extend the SAFE-TEST toolbox to urban areas, which enables the toolbox to be able to evaluate the safety performance of autonomous vehicles in diverse driving conditions. The proposed methodology is summarizing into high-quality research papers.

**Promoting CAV Deployment by Enhancing the Perception Phase of the Autonomous Driving Using Explainable AI: Purdue University, Dr. Samuel Labi.** During the reporting period, the research team carried out: (a) a thorough review of the literature on explainable AI, computer vision, multi-class classification, visual attention mechanism, and federative learning; (b) evaluated and documented past work on AI deployment in the real-world autonomous vehicles; (c) identified datasets that are densely labeled with both driving environments and the corresponding explanations; and (d) developed multivariate classification algorithm using deep learning models. The team also tested and evaluated multiple different “attention” mechanism to search for the effective model architectures for the prediction task and used a federal learning approach to achieve fast training and privacy preserving).

**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.** For the student classroom component of the project, the following research tasks were completed during this reporting period: 1) the older adult needs assessment, including both the literature review and community engagement portions; 2) planning for the series of presentations to/discussions with the engineering class in which the classroom project is being implemented; 3) administration of the pre-survey of students to measure baseline knowledge of older adult and CAV issues; and 4) implementation of the first classroom presentation (overview of the study given by the PI). For the older driver training component of the project, the following research tasks were completed during this period: 1) development of the pre- and post-training surveys; 2) collaboration with several community activity centers in the Akron-Cleveland area to identify older drivers to serve as participants in the training and surveys; 3) confirmation of a few training dates. In addition, the project team has met monthly to review progress and discuss completed and upcoming project activities.

**xBOT – A Versatile Robot to Assist Testing of Autonomous-Connected Vehicles: University of Michigan, Dr. Sridhar Lakshmanan.** This period, the baseline system was tested, and the design targets were captured. Additionally, the GPS was integrated into the design as well as the interface to the Mcity OS. A utility patent was filed on 07/06/2022.

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. CCAT has surpassed all 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>Technology Transfer Goals</th>
<th>CCAT Annual Target</th>
<th>OCT-MAR</th>
<th>APR-SEP</th>
<th>CCAT TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. OUTPUTS</td>
<td>Research Performance Measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.A. Disseminate research results through publications, conference papers, and policy papers</td>
<td>Technical reports</td>
<td>10</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Papers at conferences, symposia, workshops, and meetings</td>
<td>3</td>
<td>39</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>Peer-reviewed journal articles</td>
<td>6</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>1.B. Develop inventions, new methodologies, or products</td>
<td>Annual number of research deployments</td>
<td>5</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>1.C. Research projects funded by sources other than UTC and matching fund sources</td>
<td>Number of projects</td>
<td>3</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Dollar amount of projects</td>
<td>$900,000</td>
<td>$1,477,130</td>
<td>$16,583,169</td>
</tr>
<tr>
<td>2. OUTCOMES</td>
<td>Research Performance Measures</td>
<td></td>
<td></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>
<td>2</td>
<td>5</td>
<td>80</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>
<td>4</td>
<td>27</td>
<td>23</td>
</tr>
<tr>
<td>3. IMPACTS</td>
<td>Research Performance Measures</td>
<td></td>
<td></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>
<td>2</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Number of conferences organized by the CCAT consortium members</td>
<td>2</td>
<td>23</td>
<td>39</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>
<td>3</td>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>

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

CCAT members hosted or participated in 316 outreach engagements with industry, government, academia, media, and community organizations this reporting period. In total, CCAT research was shared with more than 24,500 people in the last six months. The University of Michigan CCAT outreach log is available upon request.

Two flagship events were hosted by CCAT this period. First, the CCAT Global Symposium on Connected and Automated Vehicles and Infrastructure. The 2022 CCAT Global Symposium on Connected and Automated Vehicles and Infrastructure was held April 12th and 13th at the Michigan Union and served as the first conference that offered hybrid attendance options. The line-up of speakers included Congresswoman Haley Stevens, Congresswoman Debbie Dingell, U.S. DOT Director Shelby Scales, and Michigan Lieutenant Governor Garlin Gilchrist II, to name a few.

The conference received a record number of paid registrations and served as one of the first to return to in-person attendance. Panel sessions focused on Michigan’s role in the transportation system, connected and automated vehicle (CAV) cyber security, the value that historically black colleges and universities (HBCUs) add to transportation research, and transportation equity through the lens of...
shared mobility. Simultaneously, CCAT researchers presented project results through in-depth research reviews, expanding the transportation industry’s body of knowledge. Additionally, we offered a tour of the 32-acre Mcity test facility. On top of the 46 keynotes, moderators, and panelists, over 175 people paid to participate in the 5th annual Symposium and 45 leaders from academia, government, and industry spoke. The breakdown of attendee affiliation is as follows: Academia (65%), Community (1%), Government (9%), and Industry (25%). CCAT received financial support via sponsorship from Michigan Engineering, the University of Michigan Transportation Research Institute (UMTRI), Mcity, and WSP USA.  

Women in Autonomy. A Student Poster Competition was hosted in conjunction with the Global Symposium which was co-sponsored by the Intelligent Transportation Society of Michigan. In total, 11 undergraduate and graduate submissions were received across five universities (University of Illinois at Urbana-Champaign, Purdue University, University of Michigan, Michigan State University, and Penn State). First Place was awarded to Yang Song, and their poster was titled ‘Predicting Asphalt Pavement Roughness with an Ensemble Learning Approach’. Second place was awarded to Sachindra Dahal, and their poster was titled ‘Pavement Assisted Lane Keeping with Passive Material Sensing’. Third place was awarded to Zhen Yang and Jun Ying, and their poster was titled ‘Anomaly Detection Against GPS Spoofing Attacks on Connected and Autonomous Vehicles Using Learning from Demonstration’. All the posters and abstracts received for the 2022 Student Poster Competition can be found on the CCAT website.

Second, the CCAT HBCU Conference. The inaugural CCAT HBCU Conference was held at the University of Michigan Transportation Research Institute (UMTRI) and Mcity. The attendees, a mix of students and faculty, hailed from Benedict College, Bowie State university, Central State University, Morgan State University, and Prairie View A&M University. The conference was kicked off by Dr. Henry Liu, CCAT Director. The morning’s distinguished keynotes included Dr. Alec Gallimore, U-M Dean of the College of Engineering; Paul Ajegba, Michigan D.O.T Director; and the State of Michigan Lieutenant Governor Garlin Gilchrist. The attendees toured Mcity where they experienced:

- Navya Ride – a CCAT funded project that traversed Mcity while the passengers learned about the Mcity test facility and its attributes.
- xBOT Demo - xBOT is a CCAT funded project that is developing a high-tech, low-cost pedestrian for CAV testing. The xBOT can more closely mimic human behavior, unlike most test assets available today.
- SAFE-Test - a CCAT funded project that provides a safe means to test AVs. It addresses the lack of safety-critical scenarios a test vehicle experiences on the roadways. Using augmented reality, background vehicles are inserted that conduct adversarial and rare maneuvers.
- Motion Sickness Demo – a CCAT funded project that equipped a vehicle to test motion sickness prevention techniques, which is a known issue with AVs.

In the afternoon, each HBCU presented current research from faculty and students. The last stop of the day was a tour of the Michigan Robotics Building, which opened in 2021. The primary goal of the conference was to learn about one another’s research and discover potential areas of mutual collaboration for future projects. Additionally, the secondary goal of the conference was to
introduce students to opportunities for graduate studies and to a support network for them. Figure 2 below show some of the highlights of the event. Overall, the CCAT HBCU Conference was a huge success and a new cohort was firmly rooted where students and faculty are able reach out to each other across the organizations to share ideas, collaborate on future projects, and initiate mentorships!

Figure 1: CSU faculty and students getting ready for the Navya automated shuttle ride around Mcity (upper left); Lt. Governor Gilchrist delivering keynote address (upper right); Javon Barrett presenting his research conducted at Morgan State University (lower right).

CCAT also participated in AutoMobili-D and the ITS World Congress. AutoMobili-D is a focused exhibition and conference for mobility technology that was born out of the North American International Auto Show which invites automakers, suppliers, mobility start-ups, venture capitalists, and universities to participate. CCAT shared a booth with the U-M Transportation Research Institute and Mcity to highlight four research projects: U-M Transportation Research Institute’s Smart Intersection Project, Mcity’s Mcity 2.0 and Roundabout Project, and CCAT’s Safe AI Framework for Trustworthy Edge Scenario Tests (SAFE TEST). This booth was created in collaboration with Michigan’s University Research Corridor, an alliance of the state’s three leading institutions including Michigan State University and Wayne State University. The exhibit hall was open to the press and public and saw over 100 visitors.
Washtenaw Community College also was an exhibitor at AutoMobili-D. The WCC exhibit displayed WCC’s Automotive Cybersecurity Programs, featuring its UMLAUT-designed lab workstation, and a Ford Mustang Mach-E Battery Electric Vehicle, with Advanced Connectivity and ADAS systems.

The Intelligent Transportation Society World Congress is an annual, global conference that allows the smart mobility community to come together to explore the deployment of intelligent transportation technologies. This is made possible by exhibitor booths and panel discussions on a variety of topics. This year, over 6,000 industry professionals attended the 5-day event in Los Angeles, CA. CCAT partnered with the U-M Transportation Research Institute and Mcity on an exhibitor booth to highlight the cutting-edge research being conducted by the individual organizations including the SAFE TEST, the Smart Intersections Project, and Mcity 2.0. CCAT Director, Dr. Henry Liu, spoke during two panel sessions titled “Methods for Improving Road Safety: Smart Infrastructure, Crowdsourced Data, and Safety Metrics” and “Live, Virtual, and Constructive Evaluation of Connected and Automated Vehicles”. The combined attendance during the panel sessions reached over 150 people. The exhibit booth was visited by hundreds of people and led to a significant increase in the CCAT distribution list and new relationships were established that may lead to new alliances for future research.

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 was invited to present at the ITS World Congress on two panels: (1) Methods for Improving Road Safety: Smart Infrastructure, Crowdsourced Data, and Safety Metrics, and (2) Live, Virtual, and Constructive Evaluation of Connected and Automated Vehicles. Our leadership continues in their roles on ITS America’s many subcommittees such as the Smart Infrastructure Committee and the V2X & Connected Vehicles Committee. As industry subject matter experts, our leadership was called upon to speak at U.S. DOT’s V2X Summit regarding what it will take to transition to CV2X and moderate a breakout session on the “Path to V2X Deployment.”

CCAT also supported ITS Michigan this period with the 2022 Traffic Incident Management Operations Partnering Workshop. The Traffic Incident Management Partnering Workshop is a one-day conference and workshop that invites first responders, infrastructure owner operators (IOOS), and more to discuss, learn, and highlight issues surrounding traffic management. CCAT was a sponsor for this workshop by organizing the venue, and providing marketing materials, meals, and technical support. Dr. Henry Liu was the afternoon keynote speaker and discussed the many safety benefits that the U-M
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Transportation Research Institute’s Smart Intersection Project will provide first responders including: faster response times via real-time detection of collisions, traffic signal priority, and emergency vehicle alerts. The event was attended by 109 people.

As part of community outreach, Managing Director Debby Bezzina was interviewed on an Out of the Blank podcast to discuss connected and automated transportation. Other media outlets featuring CCAT included Auto Futures, Munro Live, and Forbes – all featuring Dr. Henry Liu, CCAT Director.

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 2: Distinguished Lecture Series and Research Reviews for the Reporting Period 4/1/22 – 9/20/22¹

<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>5/10/22</td>
<td>Distinguished Lecture Series: Autonomous Vehicle Impacts on Travel-Based Activity and Activity-Based Travel</td>
<td>Dr. Chandra Bhatt, University of Texas at Austin</td>
<td>229</td>
<td>58</td>
<td>156</td>
</tr>
<tr>
<td>6/16/22</td>
<td>Research Review: Autonomous Vehicle Land Change Decision Making</td>
<td>Dr. Brian Lin, University of Michigan</td>
<td>151</td>
<td>63</td>
<td>138</td>
</tr>
<tr>
<td>7/21/22</td>
<td>Distinguished Lecture Series: Certifiable Autonomous Systems through On-line Verification</td>
<td>Dr. Matthius Althoff, Technische Universität München</td>
<td>207</td>
<td>94</td>
<td>141</td>
</tr>
<tr>
<td>8/24/22</td>
<td>Research Review: Traffic Signal Control via Decentralized Decomposition Approaches</td>
<td>Dr. Siqian Chen, University of Michigan</td>
<td>147</td>
<td>52</td>
<td>66</td>
</tr>
<tr>
<td>9/29/22</td>
<td>Distinguished Lecture Series: Using Traffic Signals to Reduce Congestion</td>
<td>Dr. Michael Cassidy, University of California, Berkely</td>
<td>195</td>
<td>83</td>
<td>104</td>
</tr>
</tbody>
</table>

CCAT has leveraged Twitter to promote its events, research, and reports. In the past six months, the Twitter profile has earned over 48,000 impressions and 72 followers for a total of 492. 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 36,506 impressions, over 1,100 profile visits, and 271 new followers for a total of 1,410. This makes CCAT the largest LinkedIn account run by a University Transportation Center. CCAT uploads all its events to the channel via live stream, edited VOD,

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

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and edited clips pulled from full webinars. CCAT’s YouTube analytics since April include over 3,500 upload views (1,200 more than the previous six months), 524 live views (4 times the growth from the past six months), 83 new subscribers (403 total; the most of any UTC YouTube), and a watch time of 48,864 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 improved search functionality, dedicated Global Symposium event page, and dedicated research profile pages. Over the last six months, the website has received over 15,163 unique sessions.

Awards

The University of Michigan won the Technology Transfer Tournament, hosted by the National Operations Center of Excellence and the U.S. DOT ITS JPO PCB program. The award ceremony was held at the 2022 ITE Annual Meeting in New Orleans, LA from July 31st - August 3rd. The competition requires students to work directly with public agencies to solve real-world transportation problems utilizing ITS and TSMO solutions. The students were part of the Michigan Transportation Student Organization (MiTSO) and partnered with the Michigan Department of Transportation.

WCC Workforce Development Training

- Developed Training Module- “Power BI for Data Analysis- Smart Cities”. Objective continues-planning for a sustainable future by reducing the dangerous and costly impacts of integrated streets and roads [Stroads] by visualizing the data. Developed a new relationship with Unmudl to market and sell WCC’s CCAT classes. First enrollment occurred this Fall 2022. Added 12 new Freemium Classes:
  - Freemium 1: Infrastructure Tasks, Jobs and Smartsheet
  - Freemium 2: Fix the @$*% Roads!
  - Freemium 3: Miles of Roads and Thousands of Bridges
  - Freemium 4: Assign the Right Person to the Right Task
  - Freemium 5: Contact Management
  - Freemium 6: Where’s Darth Blader?
  - Freemium 7: Forms Collect Data
  - Freemium 8: Data Needs to Be _
  - Freemium 9: Calculate the Costs
  - Freemium 10: Financial Functions- Time and Money
  - Freemium 11: Where Does the Money Come From?
  - Freemium 12: Where was the Money Spent?

- 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
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- Fiber Optics Course [Infrastructure] Student Enrollments: 125
- Free College Week Classes and Enrollments: 567

**WCC Credit Education Certificate and Degree Programs**

- Currently developing a plan to identify lab space to setup an ADAS station with the equipment purchased last reporting period. This will permit WCC to run ASV 256, ASV 254, and applicable ABR classes through practice calibrations later this semester. One full-time faculty will be taking the lead on the setup of the equipment.

**WCC 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 was completed. The workshop was held on June 23, 2022.
- Planning and development was completed for 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 workshop was held July 1, 2022.

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 recruitment and allow set-up of field equipment near their property for data 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>Personl and technical support on algorithm testing, and data sources</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>INDOT²</td>
<td>Indianapolis, IN</td>
<td>Provided resources for demonstration of the study product</td>
</tr>
<tr>
<td>Purdue</td>
<td>McGavic Outdoor Power</td>
<td>McGavic Outdoor Power Open House, Indianapolis, IN</td>
<td>Engineering support and collaboration</td>
</tr>
</tbody>
</table>

² Includes support from Vincennes, La Porte, Greenfield, Crawfordsville, and Fort Wayne, Districts
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<table>
<thead>
<tr>
<th>Institution</th>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purdue NASA</td>
<td>Hampton, VA</td>
<td>Dr. Michael Patterson provided engineering support.</td>
</tr>
<tr>
<td>Purdue Tippacanoe County Area Planning Commission</td>
<td>West Lafayette, IN</td>
<td>Collaborative research</td>
</tr>
<tr>
<td>Purdue City of Owosso</td>
<td>Owosso, MI</td>
<td>Collaborative research and cost share</td>
</tr>
<tr>
<td>Purdue The Transformation Network</td>
<td>Owosso, MI</td>
<td>Collaborative Research</td>
</tr>
<tr>
<td>Purdue Indiana Department of Transportation</td>
<td>Indianapolis, IN</td>
<td>Collaborative research (in-kind) and cost sharing (cash)</td>
</tr>
<tr>
<td>Purdue Georgia Institute of Technology</td>
<td>Atlanta, GA</td>
<td>Collaborative research</td>
</tr>
<tr>
<td>UIUC ISTAR/Université Gustave Eiffel</td>
<td>Nantes, France</td>
<td>Collaborative research</td>
</tr>
<tr>
<td>UM Aisin</td>
<td>Northville, MI</td>
<td>Provided Aisin’s driver monitoring system and technical support</td>
</tr>
<tr>
<td>UM Clemson University</td>
<td>Clemson, SC</td>
<td>Collaborative research - developed the driving simulation, recruited human subjects, performed the data collection experiment, and collaborated in paper writing</td>
</tr>
<tr>
<td>UM Michigan DOT</td>
<td>Lansing, MI</td>
<td>Collaborative research</td>
</tr>
<tr>
<td>UM Navistar, Inc.</td>
<td>Lisle, IL</td>
<td>Collaborative research, provided a commercial truck</td>
</tr>
<tr>
<td>UM Ford Motor Company</td>
<td>Dearborn, MI</td>
<td>Collaborative research - Provided inputs on using CAVs as probe vehicles for traffic state estimation</td>
</tr>
<tr>
<td>UM Commsignia Ltd</td>
<td>Santa Clara, CA</td>
<td>Collaborative research</td>
</tr>
<tr>
<td>UM M-Vision</td>
<td>Ann Arbor, MI</td>
<td>Commercialization of xBOT</td>
</tr>
<tr>
<td>UM University of Florida</td>
<td>Gainesville, FL</td>
<td>Research collaboration</td>
</tr>
</tbody>
</table>

3. Outputs

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

**University of Michigan**

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- Extend SAFE-TEST demo to Mcity urban areas.
- Utility Patent: A DISTRIBUTED REAL-TIME MACHINE LEARNING ROBOT (07/06/2022)
- Liu, Zhichen and Yin, Yafeng and Bai, Fan and Grimm, Donald K., End-to-End Learning of User Equilibrium with Implicit Neural Networks. Available at SSRN: https://ssrn.com/abstract=4198835 or http://dx.doi.org/10.2139/ssrn.4198835

Central State University


Purdue University

- In the project “Ridesharing with Advanced Air Mobility” a comprehensive mathematical model was developed for the autonomous aerial ridesharing service, and a batch-optimization based algorithm to improve the computational efficiency of the model.

Two databases were created for the project “Behavioral Intention to Ride AVs and Impacts on Mode Choice Decisions, Energy Use and Emissions.” Access is available upon request due to IRB restrictions.


The project “Development of AI-based and Control-based Systems for Safe and Efficient Operations of Connected and Autonomous Vehicles” produced the following outputs: (1) a set of analytical models that describe AI-based and control-based systems for safe and efficient operations of connected and autonomous vehicles; (2) material for the Purdue Graduate course “CE 597 – Artificial Intelligence and Machine Learning for Autonomous Vehicle Operations;” (3) research material and datasets to support future research related to the subjects of multilevel control for safe and efficient operations of connected and autonomous vehicles.

The outputs of the project “Design and Management of Highway Infrastructure to Accommodate CAVs” include: (a) 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) an 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) an assessment of the sensitivity of the infrastructure performance to different levels of CAV supply (maturity) and demand (AV penetration rates). Finally, the research examined the need for a separate management system for CAV related infrastructure.


University of Akron


University of Illinois at Urbana Champaign

A clustered-generalized vehicle routing problem was proposed to describe the routing decision of a multiple cooperative trucks over a roadway network to service a continuous demand region. A mixed-integer formulation was developed and was solved exactly (using Gurobi) for small instances. Heuristics and metaheuristics are being developed to solve large cases with improved efficiency and practicality.

A framework to transfer the experimental data to rutting calculation using AASHTOWare framework, without modifying the transfer functions that consider mixed traffic. A holistic framework was
developed to compute pavement distresses due to truck platoons by considering both lateral position (truck offset) and rest period (truck spacing).

- Patent: METHOD OF MAINTAINING LATERAL POSITION OF A VEHICLE ON A ROADWAY, METHOD OF CONFIGURING A ROADWAY FOR LATERAL POSITION SENSING, AND PAVING MATERIAL PRODUCT.
- A robust model that can compute the drag coefficients under various wind conditions. This model overcomes the existing issues of computational complexity.

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

**University of Michigan**
- The project “Improving the Efficiency of Trucks via CV2X Connectivity on Highways,” significantly increased understanding of infrastructure-assisted automated driving. In particular, the project demonstrates how to deploy infrastructure on highways as well as how much energy can be saved using infrastructure support. The project also evaluated C-V2X range and reliability and showed how they depend on geography and the layout of the physical infrastructure.
- The analysis of the data during this reporting period for the project “Predicting Driver Takeover Performance in Conditional Automation (Level 3) through Physiological Sensing” revealed that the harder the secondary tasks prior to the takeover leads to lower engagement of the drivers during the takeover periods which could distract people from preparing for the takeover activities.
- For the project “Deployment of Preemption-based Motion Sickness Prevention Technology on a Testbed Vehicle in Mcity” the efficacy of preemptive Active Passenger Stimuli (APS) in mitigating motion sickness was demonstrated.
- Through the project “Modeling Naturalistic Driving Environment with High-Resolution Trajectory Data” advanced AI and machine learning technologies were adopted. It is the first time that a simulation model can reproduce the real-world driving environment with statistical realism, particularly for safety-critical situations. It can be used to enable remote access of the simulation environment to test and train autonomous vehicles.
- A new modeling paradigm that can potentially transform how metropolitan planning organizations analyze, plan, and manage their transportation networks was developed from the project “AI-enabled Transportation Network Analysis, Planning and Operations.”

**Purdue University**
- INDOT is equipping six (6) tractor-trailers with de-icing equipment based on the successful project “Intelligent Sidewalk De-icing and Pre-treatment with Connected Campus Maintenance Vehicles.”
- The project “Enhanced Methodology for Exploring Autonomy-enabled Multi-mode Regional Transportation” has shaped the models being deployed in Purdue’s NASA sponsored computational model for advanced aerial mobility.
- The project “Ridesharing with Advanced Air Mobility” increased understanding and awareness of ridesharing with AAM. Also, the optimization model and solving method are useful for general ridesharing systems.
The project “Pedestrian-Vehicle Interaction in a CAV Environment – Explanatory Metrics” demonstrated that pedestrians and motorists engage in non-verbal “negotiation” to decide priority and predicted values of pedestrian wait times under different scenarios.

The project “Smart Interaction – Pedestrians and Vehicles in a CAV Environment” exceeded expectations, in that the results went far beyond a basic "inventory" and categorization of interactions between pedestrians and motorists. Appropriate statistical analysis has revealed factors and relationships that are described in three papers listed in the Outputs section.

The project “Translation of Driver-Pedestrian Behavioral Models at Semi-controlled Crosswalks into a Quantitative Framework for Practical Self-driving Vehicle Applications” (1) developed a method for converting video recordings into a large-scale spatial-temporal trajectory dataset including 800 pedestrians and cyclists interacting with more than 500 vehicles; and (2) developed a framework that uses pedestrian and vehicle trajectory data and a spatial-temporal graph convolutional network technique, to forecast anticipated heterogeneous trajectories and behaviors of road users in real time.

The framework and method above make it possible for an agency to intelligently track movements at crosswalks. Other outcomes include a supporting database and an identification of the factors that affect pedestrian and motorist behaviour.

The project “Behavioral Intention to Ride AVs and Impacts on Mode Choice Decisions, Energy Use and Emissions” has several outcomes: (1) reviewed stated preference/choice studies related to autonomous vehicles; (2) summarized the benefits, barriers, and opportunities associated with AV deployment; (3) provided lessons learned and research gaps associated with AV adoption/deployment; and (4) examined the factors affecting public acceptance of AVs and SAVs and their potential implications on energy use and greenhouse gas emissions based on different levels and timing of market penetration.

The project “Public Acceptance and Socio-Economic Analysis of Shared Autonomous Vehicles: Implications for Policy and Planning” increased understanding and awareness of autonomous vehicles’ public acceptance, especially by those highly transportation disadvantaged. Also, the spatial autocorrelation analysis showed that both Indianapolis and Chicago transportation need areas were not randomly distributed in the space.

The project “Ridesharing, Active Travel Behavior, and Personal Health: Implications for Shared Autonomous Vehicles” developed possible scenarios for AV deployment and their impact on health, which should be considered by policy makers. It also enhanced understanding of characteristics that influence AV adoption and health outcomes.

The project “Development of AI-based and Control-based Systems for Safe and Efficient Operations of Connected and Autonomous Vehicles” (1) increased understanding and awareness of the need for widespread vehicle connectivity among CAVs and HDVs; and (2) gave strong justification to both CAV company and DOT’s investment in installing connectivity facilities; and for CAV manufacturers, technology companies, and the road agencies to invest in connectivity equipment and facilities.

The study “Adapting Land Use and Infrastructure for Automated Driving” developed a novel roundabout control strategy in the era of CAV operations. It is expected that when CAVs reach a certain level of market penetration, prospective changes will need to be made to roundabout...
design and operations, to protect the safety of the road users and fostering travel mobility and security. This will require changes in traffic laws through regulation, legislation, and/or policy.

University of Akron
- Increased understanding and awareness of transportation issues for 20 graduating senior students.
- The results of the project “Development of a Prototype Safety Advisory System to Aid Senior Citizens in Gap Selection” have provided a further understanding of the problems the older drivers are facing. This helps inform the project “Promoting Inclusive Design and Deployment of Connected and Automated Vehicles for Older Adults through Education and Training of Engineering Students and Older Drivers,” which is a collaboration between UMTRI and the University of Akron.

University of Illinois at Urbana Champaign
The CCAT supported Ph.D. student graduated in May 2022 and is now working for EPRI (Electric Power Research Institute). The task leader and his student have completed a regional I-CORPS on commercialization of the technology. Recently, national I-CORPS proposal to participate in for further commercialization of the technology was submitted.

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 “A Data-Driven Autonomous Driving System for Overtaking Bicyclists” has influenced the sponsor’s research path to include VRUs with an emphasis on bicyclists.
- The project “Development of Machine-learning Models for Autonomous Vehicle Decisions on Weaving Sections of Freeway Ramps” research findings were presented at the CCAT Research Review, to Mcity Leadership companies, and to the industry demonstrated the capability of implementing computational models in a real automated vehicle.
- The project “Improving the Efficiency of Trucks via CV2X Connectivity on Highways” demonstrated increased energy efficiency of road transportation systems and the corresponding environmental impact. This will lead to very significant societal benefits.
- This work from the project “Roadside-based Cybersecurity in Connected and Automated Vehicle Systems” will contribute to transportation safety and efficiency. Cyberattacks can have fatal consequences. By detecting cyberattacks and excluding the anomalous information from the decision-making process, this work will render transportation systems safer. Create disruption and delay may be another objective of an attacker. Furthermore, string instability will lead to increased fuel consumption. As a result, this work will contribute to making CAV systems more energy efficient.
- The project “Modeling Naturalistic Driving Environment with High-Resolution Trajectory Data” provides a high-fidelity traffic simulator that can be used for both the training and testing of autonomous vehicles, which help improves the safety performance of autonomous vehicles to reduce fatalities and improve travel efficiency. It also contributes to improving the transportation...
Semi-Annual Progress Report for University Transportation Centers

system’s safety, reliability, etc. Furthermore, the research findings have been presented in UM courses to further education about autonomous vehicles and transportation.

- The xBOT project will decrease, by a factor of 10, the investment required for launching commercial ADAS, AVs and CVs.

Purdue University

- Funding for the project “Intelligent Sidewalk De-icing and Pre-treatment with Connected Campus Maintenance Vehicles” 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 and know that the correct amount of brine is applied at appropriate locations. This technology currently is used for liquid material but then could be expanded to solid materials making winter operation maintenance safer for all road users.

- The project “Ride-sharing with Advanced Air Mobility” improves air ridesharing’s safety and reliability, as well as its feasibility.

- The project “Pedestrian-Vehicle Interaction in a CAV Environment – Explanatory Metrics” improves the operation and safety of semi-controlled crosswalks by developing a database and identifying factors that affect pedestrian and motorist behavior.
  - This information can be used to test the impact of new technologies on crosswalk safety and performance.
  - We maintain an ongoing relationship with the Area Plan Commission of Tippecanoe County, whose staff is engaged in data collection of pedestrian, bicycle, and scooter activity at busy locations downtown and near campus. We shared data and analysis of “hotspots”.
  - A coupling project with INDOT is a perfect complement to this study, in that it offers opportunities to apply a variety of designs and control methods to other types of crossing locations.

- The project “Smart Interaction – Pedestrians and Vehicles in a CAV Environment” provides information that could help improve safety and mobility of pedestrian and vehicle movements at semi-controlled crosswalks. This information can be used to test the impact of new technologies on crosswalk safety and performance. A coupling project with INDOT is a perfect complement to this study, in that it offers opportunities to apply a variety of designs and control methods to other types of crossing locations.

- The study “Translation of Driver-Pedestrian Behavioral Models at Semi-controlled Crosswalks into a Quantitative Framework for Practical Self-driving Vehicle Applications” has potential to enhance safety, mobility, and reliability of operations at semi-controlled crosswalks. The study products can be used to test the impact of new technologies on crosswalk safety and performance. A related project (sponsored by INDOT) complements this study by making it possible to investigate the efficacy of different intersection designs and control methods.

- The findings of the project “Behavioral Intention to Ride AVs and Impacts on Mode Choice Decisions, Energy Use and Emissions” reinforce the need for broader testing of AV technology in urban areas coupled with public education campaigns to harvest public awareness and acceptance.

- The project “Public Acceptance and Socio-Economic Analysis of Shared Autonomous Vehicles: Implications for Policy and Planning” provided insights into perceptions of and attitudes toward Shared Autonomous Vehicles (SAVs) that can help the transportation and urban planners, original
equipment manufacturers, and ridesharing service companies prepare for the deployment of SAVs. It also identified strategies to supplement traditional transit services with SAVs (e.g., as feeder modes for first/last-mile trips) and providing premium on-demand services with a lower capacity than conventional buses but with greater flexibility and comfort can enhance the attractiveness of public transit service.

- The project “Ridesharing, Active Travel Behavior, and Personal Health: Implications for Shared Autonomous Vehicles” offered a starting point for researchers interested in the influence of transportation innovation and the general well-being of the population. The research findings can also awaken the interest of policymakers to integrate the effects of those relationships into transportation planning. The results provided some possible effects of AV on transportation equity and health issues.

**University of Akron**

- Once implemented, the benefits of the project “Access Control at Major-Minor Intersection through CAV in Mixed Traffic” include potential reduction in signal disruptions due to vehicles entering intersections from minor street. As a result, the improved operation can help reduce delay on the mainline road as well as on the minor street.
- 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. This study helps identify possible unsafe cases for the CAV fleet to determine safe car-following spacing in real conditions.
- The benefits of the project “Development of a Prototype Safety Advisory System to Aid Senior Citizens in Gap Selection” include assistance offered to older drivers for safer gap selection at roadway entrances. The pros and cons of different means of communication provided to older drivers on the type of gaps are assessed and drivers’ willingness to receive and preference of the type of information from the system can help the OEM to address those issues accordingly.

**University of Illinois at Urbana Champaign**

- A holistic framework was developed to make operational-level decisions for both trucks and drones in a hybrid delivery system, including routing trajectories, travel speed, and fleet sizes. 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.
- A framework to analyze the effect of rest period and lateral position under mixed traffic conditions was developed. The framework could act as a guide to check the structural adequacy of existing pavement and for designing new pavements. In addition, the proposed framework could be used to predict distresses.
- The method was developed to enable lane keeping in adverse weather conditions. The proposed method has promising results to assist vehicles with ADAS system or AVs to stay within the lane accurately even when current optical sensors fail to perceive the environment. The proposed method if adopted by infrastructure owners and operators, could bring a paradigm shift in pavement design by having future roads not just meet physical properties standard, but also electromagnetic properties standard to enable vehicle to pavement interaction.
• The quantity of fuel consumption is proportional to drag coefficient. The proposed model could save fuel consumption by identifying optimal position of trucks within a platoon to minimize drag coefficients. The reduction of fuel consumption is also beneficial for the environment.

6. Changes/Problems:
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 “Promoting Inclusive Design and Deployment of Connected and Automated Vehicles for Older Adults through Education and Training of Engineering Students and Older Drivers” had changes to the team. One of our original Co-Investigators (Neda Masoud) took an unexpected leave of absence for fall and winter terms. Because the team had planned to implement the classroom project in her fall class, the team replace her with Dr. Feng Zhou and are implementing the classroom project in his Dearborn campus class. Given the change in the class and the nature of what is being taught (i.e., a focus on human centered design rather than data mining which was the focus of Dr. Masoud’s class), Carol Flannagan, another Co-Investigator on the original proposal who was planning to collaborate on the data mining classroom project, is no longer involved in the project. None of these changes have impacted our schedule or ability to carry out the project tasks.

University of Akron

In preparation of the final report for the project “Access Control at Major-Minor Intersection through CAV in Mixed Traffic,” a computer hard drive problem caused a loss of some data and video. The students who worked on the project have left the university, so it took quite some time to reconnect with them to recover the data.

WCC

• Minor adjustments to the year 6 budget were submitted and approved.
• Training Module- “Visualize the Data- Power BI Expansion to Industries” is currently on-hold, pending SME resource scheduling.
• An insufficient number of students were available this fall to run CSS 285 – Essentials of Automotive Penetration Testing, but a sufficient cohort of students should be available this Winter 2023 semester to run this course.

UIUC

Due to the limitation of computational power, truck platoon is reduced to three truck cases only.

7. Special Reporting Requirements: Final Reports
There were no final reports submitted this period.