Semi-Annual Progress Report for University Transportation Centers

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Project Title: Center for Connected and Automated Transportation (CCAT)

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Date: April 30, 2019
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 will focus 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, 2018 through March 31, 2019.

The mission of the center is to significantly impact the evolution of the U.S. next-generation transportation systems with emerging technologies related to safety, mobility, and sustainability and to provide national and regional leadership for connected and automated transportation research, science, education, training, and deployment. To that end, CCAT’s two main goals are (1) sponsor research to (2) conduct outreach related to connected and automated transportation. These goals aim to produce significant technology transfer in accordance with our technology transfer plan.

In this reporting period, CCAT finalized its technology transfer plan and began executing key elements of the plan. Three major elements define the technology transfer plan:

1. Establishing a Technology Advisory Board;
2. Enhancing the Project Selection Process; and
3. Conducting research reviews.

1.1 Technology Advisory Board

This period, the CCAT Technology Advisory Board (TAB) was established. The CCAT TAB consists of experts from industry, government, and academia. The member organizations are Central State University, Econolite, Ford Motor Company, General Motors, Illinois Department of Transportation, Indiana Department of Transportation, Michigan Department of Transportation, Purdue University, Toyota, University of Akron, University of Illinois at Urbana-Champaign, University of Michigan Transportation Research Institute, Verizon Wireless, Washtenaw Community College, and WSP. The TAB met in February 2019 for the annual project selection and continues to virtually meet to finalize the 2019 research project portfolio. They will meet again in the next reporting period to review the existing CCAT research thrusts and develop research themes within each thrust. The outcome will be used for year 4 (2020) research project selection.

1.2 Enhancing the Project Selection Process

Each project proposal for year 3 funding was submitted to the Technology Advisory Board (TAB) for review. Each TAB member reviewed and rated the papers using the established criteria before the summit held on February 22, 2019. At the summit, all projects were discussed. From the proposals submitted, the TAB established the year 3 (2019) project portfolio. Comments from the TAB members were incorporated into the final project scope. Overall, the TAB experts’ input enhanced the value of the
individual projects by making them more relevant to all CCAT stakeholders, creating a very valuable research portfolio to the CAV Transportation space at large. Furthermore, each project was evaluated on the strength of its potential for technology transfer resulting in real-world deployments. The following projects were approved for 2019 funding:

**Real-time Distribution Optimization of Traffic Signal Timing (UM).** Leveraging recent advancements in distributed optimization, and the growing connectivity and computational capability of vehicles and infrastructure, this research will revolutionize real-time adaptive signal control via distributed optimization. The proposed research consists of three thrusts. Thrust 1 focuses on advancing distributed optimization and parallel computing techniques for solving network-level signal optimization models with discrete variables, nonconvex/nonlinear objective function and/or constraints. Thrust 2 further distributes the computation task to individual vehicles, by further decomposing distributed intersection-level sub-problems to smaller problems that can be solved at the vehicle level, or treating them as fully independent economic agents that negotiate the right-of-way through intersections. Thrust 3 uses simulation to validate results and deploy the system developed in Thrust 1 in the City of Ann Arbor.

**How Vehicle Connectivity Based Eco-Routing Choices Will Impact Driver Decision Making (UM).** The development of advanced technologies has provided options of energy-saving route alternatives, eco-routing choices. Eco-routing is the identification of the most energy-efficient route for a vehicle to travel between two points and is offered as a way in which drivers can reduce fuel consumption and consequently reduce the carbon footprint of their journeys. This work proposes methods of assessing and modeling how vehicle connectivity based eco-routing choices impact drivers’ decision making when provided with different sources of information.

**Accelerated Training for Connected and Automated Vehicles Based on Adaptive Evaluation Method (UM).** This project focuses on resolving the inefficiency problem caused by the long-tail phenomena in the development of connected and automated vehicles (CAVs) to accelerate the training process. The training of CAV model can be divided into two stages. In the first stage, the model is trained with naturalistic driving data. In the second stage, when the training efficiency is greatly compromised by the long-tail phenomena, a reinforcement learning based mechanism with critical scenarios is proposed. The critical scenarios, which contain vulnerabilities of the CAV model, can be generated by the adaptive evaluation method. An incremental learning mechanism is designed and a discount factor will be introduced according to the probability of the critical scenarios. Importance sampling technologies will be applied to guarantee the accuracy of the discount factor. Meanwhile, a training and testing platform will be designed and built to validate the proposed accelerated training framework.

**Reliable V2V Communication Networks: Applications in Fuel-Efficient Platooning (UM).** The application is multi-truck platooning—lead truck is manually driven; following ones are autonomous. Key is maintaining closer than normal gap distance for drafting purposes, resulting in increased fuel efficiency. Vehicle-to-vehicle (V2V) communications between the vehicles enables autonomy—V2V failure impacts autonomy. Based on data collected from recent weeklong tests at the American Center for Mobility (ACM), PIs have identified specific use cases where V2V fails when using DSRC. This proposal addresses two follow-on research problems: (i) the cause of DSRC failure, and (ii) the ability of CV2X to overcome
such failures. Further ACM testing is proposed, along with a modeling and simulation effort to understand the failure modes. Proposed research leverages already funded research from DOD and DOE that is focused on the demonstration of realizable fuel efficiency in long-haul trucks. This project is partially funded through Mcity utilizing Ford tailored funds. Ford is very active on the project, developing test scenarios, making the technology transfer very strong.

**Development of machine-learning models for autonomous vehicle decisions on weaving sections of freeway ramps (UM).** Automated freeway driving is being developed by all major automotive OEMs. Previous studies show that merging onto the freeway via entrance ramps and getting off the freeway via exit ramps are the sites of more crashes than any other segment. Furthermore, the weaving sections where both entrance and exit ramps meet have the most crashes within that aforementioned segment. To date no system can recommend when and how lane changes should be made in weaving sections with limited length to ensure that traffic stays safely and smoothly separated. It is expected that the outcomes of this project will offer user-centered design principles to automotive OEMs and tier-1 suppliers for the development of automated vehicle systems that safely perform lane changes specifically in the freeway weaving sections.

**Investigation of AV Operational Issues using Driving Simulator Equipment (Purdue).** The proposed research addresses five aspects associated with human take over from AV: (1) characterizing the level of risk in the driving environment, as a function of the traffic conditions, roadway design features, road environment conditions, and AV passenger attributes, (2) establishment of take-over warrants, that is, the given combinations of risk factors that will require take over, (3) take-over alerts, specifically, evaluating the efficacy of various alert alternatives: visual, auditory, tactile, and any combination of these, (4) assessing the propensity of an AV operator to take over the vehicle control, as a function of the nature of perceived risk and the prevailing levels of the risk factors (attributes of the driver, vehicle, the road design, and the road environment), (5) measuring and modeling the effective response time, in other words, the time taken for the operator to take over the vehicle (from the time of receipt of the AV’s alert to take over or the operator’s self-recognition of driving hazard without receiving alert) to the time the operator is in full control. The outcome of the research is the development of recommendations regarding AV take over.

**Enhanced Methodology for Exploring Autonomy-enabled Multi-mode Regional Transportation (Purdue).** Increasing the level of autonomy in both small aircraft and autos has the potential to generate greater efficiency and utility in multimodal regional transportation systems. In previous research, the PI and collaborators developed a computational analysis framework to assess the impact of aircraft technology advancement in electric propulsion and autonomy on the future of on-demand, regional air transportation system. A sensitivity analysis revealed increasing level of autonomy and an improved ride-sharing model (on the ground and in the air) could lead to significant increase in the total number of individuals who could afford this new mode of transportation. Activities in the proposed project would enhance our current computational framework with models for autonomous automobile option and thereby take a holistic approach to evaluate the impact of autonomy at a multi-modal level of operation. Outcome models, analysis, and metrics will increase the research community's ability to
characterize the impacts of differing levels of autonomy as well as the synergistic benefit of a ride-sharing economy in both air and ground modes.

**Smart Interaction – Pedestrians and vehicles in a CAV environment (Purdue).** “Semi-controlled” crosswalks exist because of the desire for pedestrians to cross there and the use of stop signs or signals is not warranted. However, there is a sufficient amount of interaction between pedestrians and vehicles at “semi-controlled” crosswalks to be concerned about the time at which “negotiations” between pedestrians and human drivers are replaced by interactions between pedestrians and self-driving vehicles. If the appropriate sensor and control technology can lead to an alternative to “CAVs always yield to pedestrians”, we will have achieved a form of “smart interaction”, which can be a useful element of smart mobility.

**Ridesharing, Active Travel Behavior, and Personal Health: Implications for Shared Autonomous Vehicles (Purdue).** Autonomous vehicles (AVs) have been argued to have both positive and negative impacts on public health. Most important benefits relate to a reduction of injuries and fatalities from traffic crashes, and decrease in pollutant emissions. On the other hand, AVs can limit opportunities for daily activity and associated health benefits. Additionally, if the adoption of this technology is not properly planned, it could likely lead to increases in vehicle-miles traveled (VMT) as AVs may provide mobility for those too young to drive, the elderly and the disabled. This would result in both reduced physical activity and increased air pollution, leading to non-communicable diseases, which are responsible for two-third of all deaths globally. Although there has been much research on the safety impacts of AVs, the potential implications of AVs on active travel behavior and personal health outcomes such as physical activity and obesity rates are not well understood to date. This project will assess the relationship between ridesharing (as a proxy for shared travel behavior), and active travel behavior (often measured as the number of trips made by walking or biking), and identify personal health-related outcomes expected due to the adoption of shared AVs (SAVs). Strategies to better capitalize the benefits and mitigate the adverse impacts that this technology could bring will be also offered.

**A Virtual Reality Framework to Measure Psychological and Physiological Responses of the Self-Driving Car Passengers (Purdue).** Understanding human behavior when interacting with self-driving cars is important, since these cars will greatly affect our daily lives in the near future. Therefore, because passengers may be anxious and skeptical about such cars, the aim of this proposal is to develop a virtual reality framework and incorporate virtual reality technology to examine and understand the physiological responses of self-driving car passengers when exposed to various conditions. After developing the proposed virtual reality framework, volunteers will be asked to participate in studies examining their anxiety levels and other psychological and physiological responses. Participants will act as car passengers in a virtual self-driving car and be immersed in a virtual reality trip. Participants will be asked to wear a head-mounted display (HMD) and enjoy the trip in the self-driving car. During the experiment, the participants’ anxiety will be captured by recording the electro dermal responses using galvanic skin response (GSR) sensors. Studies in which the somatic anxiety of car passengers can be measured by sensors are critical to understanding the impact of self-driving cars on drivers’ behavior.
Using Driving Simulator Environment to Determine Interactions between User Behavior and Infrastructure Design under Autonomous Vehicles (Purdue). This study will use immersive driving simulator environments in conjunction with stated preference surveys to analyze the interactions between user behavior and infrastructure design changes under AVs while factoring emerging trends of shared-mobility services, electrification, and the promotion of sustainable transportation modes (such as mass transit, biking and walking). A road network corridor in Atlanta, GA will provide the immersive driving simulator environment, with the current road infrastructure design and human-driven vehicles (HDVs) representing the base case. Thereafter, modifications to the infrastructure design to reflect AVs, shared-mobility services, electrification and sustainable transportation modes will be used to analyze users’ door-to-door travel choices under route navigation. The study will factor benefits in terms of safety, mobility, and emissions reduction with costs of electrification and autonomy from users’ perspective to understand how users would respond to different infrastructure designs, and how infrastructure designs can be used to influence user behavior under AVs. The study insights will be used to develop guidelines that can aid state and local transportation agencies to develop near- and medium-term infrastructure design modifications to enable efficient, smooth transition to an AV future that additionally factors other emerging transportation-related trends.

Multi-front Approach for Improving Navigation of Autonomous and Connected Trucks (UIUC). Connected and autonomous vehicles (CAV) and autonomous and connected trucks (ACT) reduce congestion, increase efficiency, and improve safety, but they also increase pavement damage. This project will optimize the benefits and drawbacks of ACT at two levels. At the network level, ACT’s shipment routing and scheduling strategy for freight transportation that minimizes total cost will be developed. At the corridor level, real-time optimization will be performed; hence, ACT and platoons can adjust their configuration as they roll and external conditions change (e.g., wind speed, pavement condition). Accurate pavement damage prediction and ACT positioning affect successful deployment of the optimization in both levels. Accuracy of pavement damage prediction will be increased by including resting periods, so the effect of truck separation in a platoon can be quantified. ACT positioning control will be enhanced by modifying material characteristics to allow better communications with the pavement.

Development of a Prototype Safety Advisory System to Aid Senior Citizens in Gap Selection (University of Akron). This project proposes to conduct a concept design and feasibility test of a prototype safety advisory system for older drivers to enter the roadway from a senior care facility. With the increasing number of older drivers as the population continues to age, traffic safety for this group of people has become a more important issue than ever before. Compared with drivers of other age groups, many older drivers (65 or older) are suffering from gradual degradation of their perception and reaction ability, and decline in motors kills and coordination as they operate vehicles. The proposed system utilizes the data acquisition and communication capabilities in the connected vehicles technology to help older drivers avoid unsafe traffic conditions. This feasibility study will include control logic development and field-testing of the system.
Two proposals from Purdue are still being evaluated. Only one will be approved. Additionally, Central State University is currently finalizing their year 3 research project. These two projects will round out the final year 3 research project portfolio. In the next reporting period, all of the above projects will be entered into RiP and the associated UTC forms will be posted to the CCAT website (ccat.umtri.umich.edu).

1.3 Research Reviews
For this reporting period, the research reviews detailed in the technology transfer plan were executed at the 2019 CCAT Annual Global Symposium for Connected and Automated Vehicles and Infrastructure. See section 1.5 below.

1.4 Current Research Status
CCAT currently has 27 ongoing research projects. In this reporting period, four projects have been completed and their final reports are in progress or in the final review stages.

- Operations of Connected and Autonomous Freight Trucks under Congestion and Infrastructure Cost Considerations. I. Al-Qadi, J. Roesler, Y. Ouyang, H. Meidani:
  - CAV instrumentation and potential infrastructure modifications to enhance road-vehicle communication.
  - Quantification of drag forces in platoon using computational fluid dynamics.
  - Optimization of lateral position of a platoon to minimize pavement damage.
  - Pavement design framework that considers cost and opportunities when platoons are applied.

For the next reporting period, those final reports will be submitted to U.S. DOT and posted to the CCAT website (ccat.umtri.umich.edu/reports/). A synopsis of their findings will be included in the semi-annual progress report #5.

The other 23 projects are described on the CCAT website (ccat.umich.edu/research/). We are in the process of developing a portal to access current project status rather than just the UTC form. This will be rolled out in the next reporting period.

1.5 Dissemination of Research and Other Outreach, Education, Leadership and Workforce Development
This period, CCAT organized and hosted the second annual Global Symposium for Connected and Automated Vehicle and Infrastructure on February 26-27, 2019. This two-day, two-track event included panel discussions as well as deep dives on current CCAT research initiatives. The 2019 Global Symposium
for Connected and Automated Vehicles and Infrastructure focused on overarching research issues related to CAV research, technology, testing and deployments, policy, as well as education, training and workforce development. The CCAT Global Symposium greatly enhances the body of knowledge and technologies. Keynotes and special speakers included:

- Marcy Klevorn, Executive Vice President and President of Mobility, Ford Motor Company
- Eugene W. Grant, Mayor, Seat Pleasant, Maryland
- Shailen Bhatt, CEO ITS America
- Dr. Lawrence Burns, former University of Michigan professor and author of "Age of Automobility"

The first track of the symposium consisted of seven panels, moderated by industry, government, and academia experts:

- International Panel on Connected and Automated Vehicles – This panel explored connected and automated vehicle testing and deployments in the U.S. and abroad. The panel discussed both DSRC and CV2X; development and deployment of automated vehicles, level 3 and above; and AV testing.
- Smart Cities Prepare for the Future of Mobility – This panel explored how cities are preparing for a truly smart, livable, economically vibrant future by discussing three key themes: (1) performance and resilience; (2) vision and leadership; and (3) service and inclusion.
- Leadership, Education, and Professional Development – Education and professional development are critical to the successful deployment of connected and automated vehicle technologies in industry. The need exists for both engineers as well as skilled technicians in the product development process. This panel focused on how Washtenaw Community College is providing career pathway solutions for talent that meet industry demanded skills and competencies.
- Keynote and Panel Discussion: Shaping the Future of Mobility with Connected and Automated Vehicles.
- Policy and Social Justice – Connected, automated and shared mobility solutions have the greatest potential to positively impact the lives of those living in historically underserved communities, senior citizens and the economically challenged. The absence of public transportation or personal vehicle ownership leave thousands without access to healthcare, education, and social interactions reducing their quality of life and often exacerbating economic hardships. U-M is on the forefront of transportation as an issue of social justice. How, and who, are benefiting from a shared economy – and how do we create balance?
- Federal Research on Automated Vehicles – Cooperative automation allows automated vehicles to communicate with other vehicles and the infrastructure to coordinate movements and increase efficiency and safety. The U.S. Department of Transportation is conducting research to measure the benefits of augmenting automated vehicle capabilities with connected vehicle technologies to enable cooperative automation.
- Your Turn to Drive – Human Factors Issues During Transition from Automatic to Manual Vehicle Control – This panel presented a scenario where an automated vehicle system encounters a situation it can’t handle and makes a request for the human operator to take control. Panelists
examined issues concerning system design, driver-vehicle interface design, regulatory and testing issues, and forensic investigation topics.

Figure 1: International Panel on Connected and Automated Vehicles. From left to right: Vince Park, Senior Director of Engineering, Qualcomm; Andreas Mai, CEO and Founder, ecomo.world LLC; Dr. Jim Sayer, Director, UMTRI; Sue Bai, Principal Engineer, Honda R&D Americas; and moderator Scott Belcher, President and CEO, SFB Consulting.

The second track consisted of research reviews of several current CCAT research projects. Each session lasted one hour and provided attendees an opportunity to learn about CCAT research and ask questions about our work. The following research projects were highlighted:

- **CAV Testing Scenario Design and Implementation using Naturalistic Driving Data and Augmented Reality** – Testing and evaluation is a critical step in the development and deployment of connected and automated vehicles (CAVs), and yet there is no systematic way to design representative scenarios for validating CAV systems. This presentation detailed how to generate testing scenario libraries for CAV evaluation systematically by mining and examining crash and naturalistic driving databases. Additionally, CAV testing in closed test facilities with an augmented reality environment was also discussed.

- **Purdue Driving Simulator** – Having conducted a wide range of CCAT research using the Purdue driving simulator, this topic explored drivers’ response to different types of real-time traffic information; rationale and methods used in investigating the effect of different AV driver introductory materials on trust, acceptance, and takeover performance for Level 3 automation; and plans to investigate the effects of different road designs on user acceptance of AVs and their willingness to purchase L4 AVs.

- **Efficient and Fast Algorithms for Real-Time Management of Connected Vehicles** – Future transportation management systems can exploit advances in approximation theory and scientific computing to produce analytics and inform control actions in a real time fashion. Towards this goal, two challenges were addresses: (1) data flood and (2) expensive simulation models.

- **Autonomous Freight Transportation: Some Opportunities and Challenges** – This talk discusses some opportunities and challenges associated with the emerging freight delivery systems based on autonomous trucks and drones. Topics included spatial formation and temporal scheduling of truck platoons for line-haul shipments, as well as optimal layout of transshipments for last mile deliveries. Autonomous truck platooning with properly planned lateral displacements can increase shipment capacity and fuel efficiency without significantly accelerating the damage accumulation within
pavement structures was discussed, as well as how to minimize the last-mile delivery cost by drones, with or without considering mid-air congestion and continuous traffic equilibrium.

- Improving the Operational Efficiency of a Major-Minor Intersection in Mixed Traffic Flow with Connected Vehicles – This project explores a potential application of the connected vehicle technology to improve the efficiency at an intersection of major-minor streets. When connected vehicles are mixed with conventional vehicles, speed adjustment by connected vehicles may be able to create adequate gaps in the traffic stream to allow minor street vehicles to enter the intersection without the need for a dedicated timing phase to improve signal operation. In the 1st part of the project, gap characteristics were analyzed and simulation models built for simple cases. In this presentation additional modeling analyses for more complex cases, successful trail test of the control logic with integrated system hardware and software, and site survey and preparation for the field test was discussed.

- Time Resolved Roadway Resistance Study for Connected Vehicles – Despite the advancement in CAV technologies in recent years, there is still a significant need for studying the active safety features of vehicles and their interactions with the pavement. Factors affecting emergency braking and rolling resistance, such as tire-surface friction, braking system and environmental conditions, vary from one situation to another; therefore, the conventional estimation method based on predefined parameters cannot sufficiently support the data need of the advanced safety features. The presentation discussed a time-resolved braking distance estimation concept to explore the impact of pavement surface, roadway slope, tire condition, and vehicle braking system as the conditions change. It was found that calculating braking distance based on generated driving power and active driving-resistance forces may help increase the data accuracy while reducing the data needs to improve vehicle safety.

- Incorporating Air Pollution Information into CAV systems – Preliminary efforts on incorporating air pollution data obtained from traffic-congested areas along the freeways was presented. Our plans to develop a system to obtain this data from the traffic counts based on the passage of trucks and cars using pollutants that would fall under NAAQS and greenhouse gases was discussed. Ideas on how this data may be used in CAV systems to alert vehicles approaching congested areas and to seek alternative routes was presented and feedback solicited from the consortium.

In addition to the panels and research tracks above, a student competition was also held. Instead of the usual poster session, this competition called for papers from students, either individually or groups. The student competition was “DREAM BIG! What would you do if one day someone came to you and said - here’s $15M. Go save the world - or maybe not the world, but our city. Develop an app? Smart chips in infrastructure? Parking solutions? Social justice?” Papers from the top three were presented at the symposium. The winners were awarded scholarships sponsored by ITS Michigan.
This period, the CCAT Distinguished Lecture Series efforts continued. This series promotes and disseminates scholarly knowledge in the area of connected and automated transportation by drilling down into a particular topic area reaching students, industry, and government. Our next event, scheduled for May 16, 2019, features Paul Ajegba. Paul is the new director of the Michigan Department of Education. He will share his perspectives on connected and automated transportation and infrastructure: “From Research to the Roadways of Michigan and the Region.”

CCAT publishes a bi-annual electronic newsletter, distrusted to nearly 2,000 professionals in the connected and automated space. The newsletter features a review of current and ongoing research as well as articles highlighting real-world implementation utilizing intelligent transportation solutions. The latest newsletter can be found on the CCAT website (ccat.umtri.umich.edu/news/).

CCAT, in conjunction with Mcity and UMTRI, hosted a networking event at the 98th TRB annual meeting. CCAT research was highlighted and it offered our research faculty and staff an opportunity to network with industry, government, and academia. Additionally, CCAT sponsored several University of Michigan students from the Michigan Transportation Student Organization (MiTSO) to attend the TRB annual meeting.
In addition to the above, CCAT research has been disseminated frequently and featured in many high-profile channels. Below is a summary for each consortium member:

**University of Michigan**

- University of Michigan, Twitter: [https://twitter.com/umsi/status/1117804521206571009](https://twitter.com/umsi/status/1117804521206571009).
- University of Michigan, News: [https://news.umich.edu/air-traffic-control-for-driverless-cars-could-speed-up-deployment/](https://news.umich.edu/air-traffic-control-for-driverless-cars-could-speed-up-deployment/).
- A Mcity white paper entitled "Combining real and virtual worlds improves driverless vehicle testing" has been published. [https://mcity.umich.edu/combining-real-and-virtual-worlds-improves-driverless-vehicle-testing/](https://mcity.umich.edu/combining-real-and-virtual-worlds-improves-driverless-vehicle-testing/).
- In this period, the University of Michigan also completed 18 various outreach engagements focusing on connected and automated transportation. Audiences included industry, government, academia, and community. The University of Michigan CCAT outreach log is available upon request.

**Washtenaw Community College**

WCC completed the following workforce development, education, K-12 STEM, and outreach activities:

- Presented WCC's Advanced Transportation Center (ATC) Programs and collaborating partners, such as UMTRI and CCAT, and collaborated with other colleges and universities in developing knowledge, skills and abilities for Intelligent Transportation Systems occupations at the joint Volpe-ITS America PCB Academic Workshop in Tampa, FL.
- Facilitated/supported ATC Program exhibits & equipment demonstrations at the 2019 NAIAS Automobili-D and other business collaborations as part of the Detroit North American Auto Show.
- Facilitated and hosted ATC program ITS / CAV education and training for ITS Michigan Webinar: "WCC: Shaping the Future of Advanced Transportation."
- Hosted the Michigan Connected and Automated Vehicle Working Group where business, industry, government and education experts convene for a quarterly session to discuss important topics in connected and automated transportation.
- The Detroit Regional Chamber and MICHauto: Promoted WCC ATC programs to businesses and industry, invited WCC to participate in its 2019 Annual MICHauto Summit with businesses.
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- Conducted student computer programming training at Scarlett Middle School in Ann Arbor, MI.
- Sponsored and hosted conference at WCC entitled “Impact 2018- Our Mobility Future”. The Ann Arbor Greater Regional Chamber of Commerce organizes this annual event. This year’s program included activities, speakers, and a panel discussion. The program gave attendees the starting point to learn what mobility technology is, what it will become, and how its impact will change both the business community and society. This is a community event and geared towards expanding the knowledge base of the community, rather than industry, academia, or government.
- Michigan Gov. Whitmer visit to WCC campus and tour of ATC facilities and equipment. Coordinated with Ann Arbor-Ypsilanti Chamber of Commerce.
- Contributed to AUTO-ISAC’s monthly cybersecurity webinar presentations and weekly newsletters on the latest automotive and infrastructure cyber risks.
- Initiated planning for “Cybersecurity Hackathon” with academic instructors and collaborating companies.
- Conducted several key outreach demonstration sessions using combinations of the GRIMM ACE Cyber Security workbench and the Polaris Slingshot vehicle with CAV Sensors. Examples of the venues and audiences for these demonstration sessions included:
  - WCC Board of Trustees
  - Michigan Governor Whitmer, Lt. Governor Gilchrist
  - MI 8th District Representative- Slotkin
  - WCC President’s Leadership Luncheon
  - MI CAV Workgroup Meeting [CAR]
  - ”Hire Michigan Vet” Recruiting Event at WCC
  - 2019 NAIAS Automobili-D Industry/Press Previews
- Supported the preparation and delivery of Square One’s "Masters of Mobility Innovative Vehicle Design" for K-12 students and teachers at WCC, February 2019, offering CEU’s to the K-12 teachers.
- Preparations for supporting the Square One "Innovative Vehicle Design Challenge" with a vehicle repair trailer, to be held at Kettering University, May ’19, including judging high school vehicle projects.
- Development and preparations to deliver Square One "Cars that Communicate: V2X Technology" Youth Camp in August 2019 for low income/disadvantaged youth in Ypsilanti and Eastern Washtenaw County [Parkridge] Communities.
- Hosted "Hire a Michigan Veteran" job recruiting event, by UMTRI for the CAV/Mobility Industry.
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.

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<tr>
<th>CCAT Org.</th>
<th>Org.</th>
<th>Location</th>
<th>Contribution</th>
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<tbody>
<tr>
<td>WCC</td>
<td>GRIMM</td>
<td>Grand Rapids, MI</td>
<td>Developed the Automotive Cybersecurity Educator Workbench for use at WCC and</td>
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<td></td>
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<td>trained 5 faculty instructors for 400 hours in GRIMM’s Defensive Automotive</td>
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<td>Engineering Training.</td>
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<td>UM</td>
<td>Mcity</td>
<td>Ann Arbor, MI</td>
<td>Funding for additional projects including a pedestrian detection deployment</td>
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<td>and the transportation control room.</td>
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<tr>
<td>UM</td>
<td>University of New South Wales</td>
<td>Sydney, Australia</td>
<td>Collaborative research.</td>
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<tr>
<td>UM</td>
<td>Nissan North America, Inc.</td>
<td>Sunnyvale, CA</td>
<td>Input for use cases to ground research in real-world applications.</td>
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<tr>
<td>Purdue</td>
<td>Indiana Department of Transportation</td>
<td>Indianapolis, IN</td>
<td>• $70,000 for pedestrian research.</td>
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<td>• $65,000 for research on how AV impacts energy demand and GHS emissions.</td>
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<td>• $70,000 for infrastructure design for CAVs research.</td>
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<tr>
<td>Purdue</td>
<td>Chongqing University of Posts and Telecommunications</td>
<td>Chongqing, China</td>
<td>• $200,000 for research.</td>
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<td>• Driving simulator equipment, laboratory space and facilities, student</td>
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3. Outputs

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

**University of Michigan**

Semi-Annual Progress Report for University Transportation Centers

- Yin, Y., Equilibrium analysis on integrated morning-evening commuting and parking patterns under the fully autonomous vehicle environment, Transportation Research Part B (under revision).
- Brewer, R., Understanding Trust, Transportation, and Accessibility through Ridesharing at CHI 2019.

**Washtenaw Community College**

- Delivery of ITS Field Technician Online Training module with more participant feedback data.
- Created and delivered a communications and education plan to students and academic counselors and advisors to facilitate moving interested students into ITS career pathways, including pre-engineering technologies.
- Integrated ITS technologies/courses into Automotive Service curricula in the areas of IT Networks, Communications and Cybersecurity. Delivered integrated courses to IT and Automotive students in the Fall '18/Winter '19.
- Incorporated a new Cybersecurity Curriculum Laboratory experience with the GRIMM Automotive Cybersecurity Educator workbench.
- Prepared a demonstration vehicle with sensors, cameras, LiDAR, DSRC Transceiver for promotion of ITS & V2X technologies at various events.
- Developed and offered a DSRC V2X Connected Vehicle course in the Fall '18/Winter '19.
- Developed a new IT Networks/Communications course focused upon the automotive application.

**Purdue**

- The research project Development of a dynamic network traffic simulator for mixed traffic flow under connected and autonomous vehicle technologies, Phases I & II produced:
  - A database of results of the experiments.
  - A new graduate-level course on human factors and driving simulation has been approved to be taught at Purdue University, and will start in Fall 2019. Drs. Sam Labi and Dustin Souders, both CCAT staff, will teach it.
Semi-Annual Progress Report for University Transportation Centers

- For the project Non-connected vehicle detection using connected vehicles - Phases I and II, developed:
  - CV car-following model in mixed CV and HDV flow.
  - Probabilistic inference model for the unequipped vehicle location estimation.
- For the project Pedestrian-Vehicle Interaction in a CAV Environment –Explanatory Metrics a video archive was created to detect and document the variety of behaviors exhibited by pedestrians and motorists at semi-controlled sites. Here, “semi-controlled” means sites marked with “State Law Yield to Pedestrian within Crosswalk” signs.
- MAI Toulouki, EG Mantouka, EI Vlahogianni, K Gkritza, K Kepaptsoglou, Perceived Impacts of c-ITS on the Economy, Quality of Life and Transportation System Performance: The Case of Greece, Transportation Research Board 98th Annual Meeting, Transportation Research Board.
- KC Sinha, Preparing Highway Infrastructure for Autonomous Vehicles, Invited Lecture, 2019 Global Symposium on Connected and Automated Transportation and Infrastructure, U.S DOT Center for Connected and Automated Transportation (CCAT), The University of Michigan, Ann Arbor, MI.
- S Labi. Ongoing CCAT Research and Elements of Highway Design and Management the CAV Era, invited presentation, Hong Kong Society for Transportation Studies (HKSTS), presented at Hong Kong Polytechnic University, October 2018.
- S. Labi. Quantifying the Relationship Between Funding Levels and Performance Using Interstate Highway Bridge Data, Presentation at the 98th Annual Meeting of the Transportation Research Board, Washington, DC.
Semi-Annual Progress Report for University Transportation Centers

- S. Ghahari, B. Alabi, S. Labi. The Bridge Investment Performance Nexus at an Aggregate Level: Accounting for Situational and Measurement Biases, Presented at the 98th Annual Meeting of the Transportation Research Board, Washington, DC.
- Y. Ha, M. Miralinaghi, S. Labi. Equity and Emissions Considerations in Autonomous Vehicle Dedicated Lane Deployment Scheme, Presentation at the 98th Annual Meeting of the Transportation Research Board, Washington, DC.
- S. Labi. CCAT Research and Highway Design & Management in an Era of Autonomous Vehicles, Presentation at the INDOT/JTRP Peer Exchange The Indiana Traffic Management Center (TMC), Indianapolis, November 16 2018.
- S. Labi. CAV Impacts on Highway Design, and Operational Revenues and Expenditures, Invited Presentation, Chang’An University, Xian, China, October 2018.
- TU Saeed, S Labi, KC Sinha. Autonomous Vehicle Use in Small- and Medium-Sized Metropolitan Areas During the Transition Phase, Presentation to the Institute of Transportation Engineers, W. Lafayette, IN.

University of Illinois at Urbana-Champaign

Development of pavement damage models considering platooning.
Development of a data-driven framework for traffic speed prediction using spatially-limited data collected by autonomous vehicles.
Finite element method simulation of air resistance on truck body under the effect of platooning using Ansys Fluent.
Dynamic programming scheme to optimize the steady-state platoon configuration.

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

**University of Michigan**
- Created a new platform for Connected and Automated Vehicle (CAV) safe and cost-effective CAV testing and evaluation.
- The work completed so far on the project *Machine Learning, Human Factors and Security Analysis for the Remote Command of Driving*, contributes to the body of scientific knowledge by uncovering new challenges when using look ahead approaches in crowdsourcing in a more complex and realistic autonomous vehicle context. We find that false positives and premature prediction of danger are not uncommon and need to be accounted for in instantaneous crowdsourcing workflows. We also find that dealing with a large number of potential futures with many variable objects is another challenge for instantaneous crowdsourcing prediction workflows.
- Findings from the project *Supporting People with Vision Impairments in Automated Vehicles: Challenge and Opportunities*:
  - Showed the ways in which transportation for people with vision impairments is challenging in ridesharing contexts (Brewer and Kameswaran, May 2019). Findings also showed the nuances of transportation based on a spectrum of vision loss with perceptions of using an autonomous vehicle differing based on previous experience with driving. People who had prior experience preferred semi-autonomous vehicles and people who had never driven before preferred fully autonomous vehicles (Brewer and Kameswaran, October 2018).
  - Increased the body of knowledge and safety of the transportation system: using ridesharing as a proxy for understanding autonomous vehicles for blind and low vision people and describe safety challenges in personal vehicles. Our findings show that there is an emphasis on driver, and we describe what makes the driver of ridesharing vehicles a crucial stakeholder in the transportation process.

**Washtenaw Community College**
- Developed industry occupational skill requirements for Traffic Professionals for the City of Ann Arbor.
- Increased development and evaluation of DSRC training and emerging C-V2X Cellular [5G] capabilities.
Purdue

- One (1) PhD student, who contributed to the *Adapting Land Use and Infrastructure for Automated Driving* project, graduated in this reporting period.
- Launched SPR-4301: Assessment of an Offset Pedestrian Crossing for Multilane Arterials, sponsored by the Indiana DOT.
- Launched Feasibility Study and Design of On-Road Electric Vehicle Charging Technologies, Sponsored by the Indiana Department of Transportation.
- Launched SPR-4319: Cost/Benefit Analysis of Installing Fiber Optics on INDOT Projects, Sponsored by Indiana DOT.

University of Illinois at Urbana-Champaign

- Research under the project *Operations of Connected and Autonomous Freight Trucks under Congestion and Infrastructure Cost Considerations*:
  - Investigated two optimization algorithms, particle swarm optimization (PSO) and pattern search algorithm (PSA), aimed to improve the reported agentic algorithms (GAs). The results showed that PSO yielded the optimum solution as compared to GAs and PSA. As for convergence rate, PSA was found to be the superior with 10 times faster convergence rate.
  - Designed a test to evaluate the feasibility of modifying magnetic properties of rigid pavements.
- Identified approaches to test in laboratory to enhance CAV and pavement interactions.
- Limitations of CAV instrumentation is mainly caused by adverse environmental conditions such as fog and snow. Infrastructure modification is an alternative to address the issues.
- Air resistance dominates truck fuel consumption cost and the portion that can be reduced through platooning. Freight carriers have great motivation to adopt connected and automated vehicle technology to reduce the operational cost on a daily basis. The result from this model provides insights for highway administrations to identify the extra pavement rehabilitation cost induced by channelized traffic, and the necessity of imposing dynamic control on highway segments to alleviate the additional cost. With historical knowledge of the O-D and the demand of freight flow over a highway network, restrictive actions can be taken to diverge the traffic flow to prevent the vicious cycle between pavement deterioration and congestion.

5. Impacts

In addition to the impacts that the CCAT Global Symposium and Distinguished Lecture Series, and other CCAT outreach activities, have on the body of knowledge and technology, these additional impacts were derived from CCAT research this reporting period:

University of Michigan

- Patent application submitted for the Connected and Automated Vehicle (CAV) safe and cost-effective CAV testing and evaluation platform.
The analysis framework developed through *Adapting Land Use and Infrastructure for Automated Driving* project, helped improve and enhance our understanding of the commuting problem with AVs, and sheds insights on future parking supply planning and management, congestion pricing and traffic management. This work was presented at two conferences.

**Washtenaw Community College**

- JOB CREATION: WCC, working in conjunction with UMTRI, established an internship program for its students. Seven students went through the program. The students were part of the team that installed dedicated short-range communication devices on vehicles as part of the Ann Arbor Connected Vehicle Test Environment project (DTFH6115H00005). Two of the students graduated from WCC and were able to secure positions in the industry working on connected and automated vehicles. The experience gained through the internship at UMTRI was key to their new employment and their pay is significantly higher because of the relevant work experience.

**University of Illinois at Urbana-Champaign**

- Enhanced vehicle-pavement interaction can improve safety of autonomous vehicle navigating in adverse weather conditions. Field testing of robustness of the system would help in safe deployment of AV in large scale at places with adverse weather conditions.
- Proposed framework can result in accurate traffic speed prediction, which is essential for individuals and business sectors in helping them make optimal travel decisions. This framework can contribute to reliable and timely traffic speed predictions, which is vital for advanced traffic management in intelligent transportation systems (ITS). Ultimately, the proposed framework can contribute to mitigate traffic congestion, improve the level of service, and consequently provide reliable, safe, and green transportation.
- Optimization results demonstrate great potential of savings for both highway administrations and freight carriers. This model may serve as a decision-support tool for freight carriers on daily route-planning, and for highway administrations to design regulations and/or engineering guidelines on rehabilitation of infrastructure, predicting location and intensity of congestion due to platooned traffic, pricing for heavy duty vehicle permits, and proactive decisions to diverge traffic in the highway network.

6. **CHANGES/PROBLEMS:**

None to report at this time.