UTC Semi-Annual Progress Report

Federal Agency and Organization Element to Which Report is Submitted:

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Project Title: Center for Advanced Transportation Mobility

Center Director Name, Title, and Contact Information

Maranda McBride, PhD, Director, Center for Advanced Transportation Mobility

Email: mcbride@ncat.edu; Phone: (336) 285-3359; Fax: (336) 334-7093

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Recipient Organization:

North Carolina Agricultural and Technical State University

1601 E. Market Street, Greensboro, NC 27411

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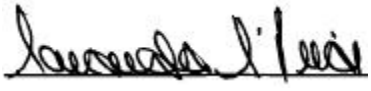

Dr. Maranda McBride, Director, Center for Advanced Transportation Mobility

1. ACCOMPLISHMENTS:

What are the major goals of the program?

The Center for Advanced Transportation Mobility (CATM) will employ multidisciplinary approaches and processes to design, develop, and implement innovative solutions to the transportation needs of vulnerable populations. CATM will utilize the knowledge, skills, and expertise of its affiliates and partners to identify the needs of individuals who are often underrepresented in the design process due to specific physical and/or mental conditions or their socio/economic status. These collaborations will be leveraged to develop and implement comprehensive research, education, workforce development, and technology transfer programs that improve access to transportation for vulnerable users.

CATM endeavors to enhance the transportation industry by achieving the following goals:

1) Develop innovative assistive technologies to enable safe and efficient mobility for individuals with special needs (Research).
2) Develop forward-looking optimization tools to effectively manage transportation system disruptions (Research).
3) Promote equity by increasing access to transportation educational and workforce development opportunities for underserved populations (Education, Outreach, and Workforce Development).
4) Disseminate knowledge about the transportation industry to a broad range of stakeholders using multiple technology transfer methods (Technology Transfer).

The overall goal of the center is to develop and implement research, education, outreach, workforce development, and technology transfer programs to address the need for improved mobility across multiple modes of transportation – primarily highway, rail, and air. In an effort to accomplish this goal, several activities took place during this reporting period. Table 1 provides a list of these activities and their statuses as of September 30, 2020.

Table 1: Progress of period 5 activities

Research	**Status**	**% Complete**
Complete year 1 projects	Behind schedule	90%
Complete year 2 projects	Complete	100%
Initiate year 4 projects	Complete	100%
Complete Year 3 projects	Behind schedule	80%
Complete Year 4 projects	Behind schedule	25%
Conduct annual visit to member institutions to obtain research status reports – Year 4	Cancelled due to COVID-19	50%
Conduct year 5 research proposal solicitation, review, and award process	On schedule	95%
Initiate year 5 projects	On schedule	90%
Conduct annual visit to member institutions to obtain research status reports – Year 5	Forthcoming	0%
Education, Outreach, and Workforce Development Activities		
Recruit and select participants for 2020 Summer High School Transportation Institute (STI)	Complete	100%
Prepare for and hold 2020 Summer High School Transportation Institute (virtual event)	Complete	100%
Select 2020-21 CATM Transportation Scholarship program awardees	Complete	100%
Develop transportation case for case competition	Complete	100%
Prepare students to participate in the SE UTC Spotlight Conference	Forthcoming	50%

Student participation in the 2021 Virtual TRB conference	Forthcoming	0%
Prepare to take students to 2021 Southeastern Region UTC conference	Forthcoming	0%
Develop and conduct Spring 2021 student-to-student K-12 initiative workshops	Forthcoming	0%
Distribute applications for 2021-22 CATM Transportation Scholarship program	Forthcoming	0%
Hold transportation case competition	Forthcoming	0%
Develop and hold 2021 Transportation Awareness Day	Forthcoming	0%
Technology Transfer Activities		
Create and distribute Spring 2020 newsletter	Complete	100%
Assist with the SE Region's Student Spotlight Conference	On schedule	75%
Create and distribute Winter 2020 newsletter	On schedule	75%
Conduct 2020 research webinars	On schedule	75%
Schedule 2021 research webinars	Forthcoming	0%
Assist with the 2021 Southeastern Region UTC Conference planning	Forthcoming	0%
Plan and hold the 4th Annual CATM Symposium	Forthcoming	0%
US DOT Reporting Activities		
Complete and submit PPPR#6	Complete	100%
Complete and submit SF425 for Q12 and Q13	Complete	100%
Complete and submit recipient share report #4	On schedule	90%
Review year 3 final reports for completed research projects	Complete	100%
Upload year 3 final reports to TRID database	Complete	100%
Complete and submit 2020 performance indicator report	On schedule	60%
Update records in RiP database	On schedule	75%
Complete and submit PPPR#7	On schedule	80%
Complete and submit SF425 for Q14 and Q15	Forthcoming	0%
Review year 4 final reports for completed research projects	Forthcoming	0%
Upload year 4 final reports to TRID database	Forthcoming	0%

What was accomplished under these goals?

During the reporting period, a variety of accomplishments were made in the areas of research, education/workforce development, and technology transfer. A summary of the activities and the associated accomplishments are described below.

Research

Table 2 provides a running list of the year 1 through 4 projects that were active at the beginning of the reporting period along with their current statuses, the primary research priority areas that are addressed by each project, and the link to the project abstracts. This is followed by a summary of the key accomplishments associated with each project.

Table 2: Funded projects active during reporting period

Project Title	Status/Award Year	Research Priority Area(s)	Project Link
Automated Last Mile Connectivity for Vulnerable Road Users	Continuing/Y1	IM, RC, PS	https://www.ncat.edu/cobe/transportation-institute/catm/1-last-mile-abstract.pdf
Development, Design, and Calibration of the Vulnerable Road User Mobility Assistance Platform	Continuing/Y1	IM, PS	https://www.ncat.edu/cobe/transportation-institute/catm/catm_documents/3-vrumap-abstract.pdf

Multiscale Model for Hurricane Evacuation and Fuel Shortage	Completed/Y3	IM, RC, TS	https://www.ncat.edu/cobe/transportation-institute/catm1/files/10-multiscalemodelabstract1.pdf
Multi-agent Reinforcement Learning-based Pedestrian Dynamics Models for Emergency Evacuation	Continuing/Y3	IM, RC	https://www.ncat.edu/cobe/transportation-institute/catm1/files/11-multiagentabstract1.pdf
DRONETIM: Dynamic Routing Of uNmanned-aerial and Emergency Team Incident Management	Continuing/Y3	IM, RC, PS	https://www.ncat.edu/cobe/transportation-institute/catm1/files/12-dronetimabstract1.pdf
VRU-Personalized, Optimum, and Dynamic (POD) Routing	Continuing /Y3	IM	https://www.ncat.edu/cobe/transportation-institute/catm1/files/13-vrupersonalizedabstract1.pdf
Real-Time Recommendations for Traffic Control in an Intelligent Transportation System During an Emergency Evacuation	Continuing/Y3	IM, RC	https://www.ncat.edu/cobe/transportation-institute/catm1/files/14-realtimeabstract1.pdf
Discrete Dynamics and Epidemiological Multi-Physics Models for Transportation Applications	Continuing/Y4	IM, RC	https://www.ncat.edu/cobe/transportation-institute/_files/23-discretedynamicsabstract-1.pdf
Multi-scale and Collaborative Disaster Evacuation Planning Framework	Continuing /Y4	IM, RC	https://www.ncat.edu/cobe/transportation-institute/_files/22-multiscalecollaborativeabstract-1.pdf
Detecting Early-Stage Dementia Using Naturalistic Driving	Continuing /Y4	IM, PS	https://www.ncat.edu/cobe/transportation-institute/_files/21-dementiaabstract-1.pdf
Evaluation of Web-Based Driving Feedback for Teens and their Parents	Continuing /Y4	IM, PS	https://www.ncat.edu/cobe/transportation-institute/_files/20-drivingfeedbackabstract-4.pdf
Epidemiological Models for Transportation Applications: Secondary Crashes	Continuing /Y4	IM, PS	https://www.ncat.edu/cobe/transportation-institute/_files/17-epidemiologicalmodelsabstract.pdf
Real-Time Recommendations for Traffic Control in an Intelligent Transportation System During an Emergency Evacuation – Part 2	Continuing /Y4	IM, RC	https://www.ncat.edu/cobe/transportation-institute/_files/16-realtime2abstract.pdf
Vulnerable Road Users demand-responsive Transit Optimization with healthcare Privatization (VRUTOP)	Continuing /Y4	IM	https://www.ncat.edu/cobe/transportation-institute/_files/19-vrutopabstract.pdf
Acoustic Situation Awareness and Its Effects on Pedestrian Safety within a Virtual Environment	Continuing /Y4	IM, PS	https://www.ncat.edu/cobe/transportation-institute/_files/18-acousticsituationalawarenessabstract.pdf

IM = Improving mobility of people and goods; RC = Reducing congestion; PS = Promoting safety; ID = Improving durability and extending the life of transportation infrastructure; PE = Preserving the environment; TS = Preserving the existing transportation system

Automated Last Mile Connectivity for Vulnerable Road Users (Last Mile)

During the reporting period, the Last Mile team designed a new protocol for conducting virtual focus groups to safely collect data while eliminating the risk of COVID-19 exposure for participants. They submitted and received IRB approval at Virginia Tech for these procedures and began the process of screening participants. The protocol included new procedures for paying participants that still comply with university policies for paperwork and several iterations with the IRB to ensure participant data is secured.

Development, Design, and Calibration of the Vulnerable Road User Mobility Assistance Platform (VRU-MAP)

Major activities this reporting period include the development of augmented reality of pathing, crowdsourcing of accessibility information, computer vision for sidewalk recognition, and neural networking for accurate object character recognition. These activities all adhere to the major objective of developing a prototype platform.

The team integrated the code into the external-facing server to enable off-site testing. The crowdsourcing module continues to be expanded and better incorporated into the platform's current routing algorithm through interface and utility. Gamification elements are being considered to maintain user interest in assisting with the accessibility of information. Augmented reality development is continuing so that visual elements will be presented along the outlined path for the individual operating the application.

Multiscale Model for Hurricane Evacuation and Fuel Shortage (Multiscale Model)

During this reporting period, the final report was completed for this project and is now available through the CATM website: https://www.ncat.edu/cobe/transportation-institute/catm/catm-documents/catm-multiscale-fuel-shortage-final-report.pdf.

Multi-agent Reinforcement Learning-based Pedestrian Dynamics Models for Emergency Evacuation (Multi-agent)

The Multi-agent team conducted a dynamic recalculation of routes for people with disability, focusing on dynamic change of interrelationship between road width, slope, and unexpected construction during this performance period. In addition, a multi-objective Markov Decision Process based-route optimization focusing on transit schedule change and consideration of waiting time changes on the destination bus-stop change was developed. The project PI has been discussing potential applications with NCDOT engineers who have expressed interest in the project.

DRONETIM: Dynamic Routing Of uNmanned-aerial and Emergency Team Incident Management (DRONETIM)

During the performance period, several papers associated with the DRONETIM project were completed. The topic of these papers was distributed allocation of unmanned aerial and ground emergency resource allocation. The papers included real world scenarios for distributed constraint optimization. The developed code to the problem of unmanned aerial and ground emergency resource allocation was generalized and the state-of-the-art literature review on distributed optimization applied to emergency management was converted to a conference paper. Currently a patent related to this project is pending.

VRU-Personalized, Optimum, and Dynamic Routing (VRU-POD)

The VRU-POD team performed a dynamic recalculation of routes for people with disability, focusing on dynamic changes of interrelationships between road width, slope, and unexpected construction. The team also worked on a multi-objective Markov decision process based-route optimization focusing on transit schedule changes and considering waiting times for bus-stops.

Discrete Dynamics and Epidemiological Multi-Physics Models for Transportation Applications (Multi-Physics Models)

This performance period, the Multi-Physics Models team formulated the epidemic model with COVID-19 data. Preliminary results for pedestrian queues in airports were obtained. Specific objectives for this team include developing computational models for pedestrian interactions in built environments (e.g., airports), modeling the disease spread using the contact network, utilizing the models for effective policy analysis to mitigate disease spread. The significant results obtained thus far include the discovery that pedestrian queue layouts have a significant effect on disease spread and queue layouts with walls and single file queues reduce contacts and infections. The key outcome this performance period was the identification of strategies for pedestrian movement that reduce infectious disease spread.

Multi-scale and Collaborative Disaster Evacuation Planning Framework (Multiscale Collaborate)

The Multiscale Collaborate team started data collection and cleansing; investigated potential factors of airspace capacity and built a prototype of airspace capacity estimation model; and explored the application of reinforcement learning for the multi-agent modeling. Their aim is to integrate the big data of relevant fields such as weather and multi-agent simulation to develop a framework to predict the maximum capacity of the airspace during emergencies. They also constructed the prediction system for airport capacity and experimented with the multi-agent navigation task in dynamic environments based on Deep Q-Network as the prerequisite of flight plan optimization for maximum air transport capacity.

Detecting Early-Stage Dementia Using Naturalistic Driving (Detecting Dementia)

During the reporting period, the research team created the IRB protocol in collaboration with local geriatricians.

Evaluation of Web-Based Driving Feedback for Teens and their Parents (Driving Feedback)

Since April 2020, the Driving Feedback team completed their literature review and began developing the initial experimental design. The literature review was submitted to the GM partner and will be included in the final report.

Epidemiological Models for Transportation Applications: Secondary Crashes (Secondary Crashes)

During the performance period, the Secondary Crashes team obtained and analyzed detailed I4 crash data for FHP and FDOT for 2015 -2017 which will be used as test data. They also formulated the Hawkes point process model for modeling secondary crashes and developed the code for the temporal point process. Their specific objectives are to apply the rich mathematical framework developed in the context of epidemic events to understand and construct predictive models for secondary crashes, establish the dependence between primary and secondary crashes mathematically, and utilize the models for effective policy analysis to mitigate

secondary crashes and the safety of first responders. Significant results seen thus far include obtaining preliminary results for the temporal distribution of secondary crashes for major cities along the I4 highway, obtaining evidence that 8-12% of all crashes in the data set were secondary crashes, and discovering the time lag between primary and secondary crashes varied between 30 and 108 minutes.

Real-Time Recommendations for Traffic Control in an Intelligent Transportation System During an Emergency Evacuation – Parts 1 and 2 (Real-Time and Real-Time2)

During the performance period, the Real-Time team identified significant factors or cues for residents or drivers in deciding dynamic evacuation routes under uncertain environment and incomplete information, identified the dependence of evacuation traffic in eastern NC, and proposed and tested a graph theoretical approach to analyze airport network disruption and identify feasible airports to reroute from hurricane affected airports.

Vulnerable Road Users demand-responsive Transit Optimization with healthcare Privatization (VRUTOP)

A TRB 2021 paper was submitted during the performance period. The paper described the study including the interactions between the key contributing trip characteristics influencing the uncertainty of time windows. The PI has been discussing potential applications with some Greensboro DOT engineers who are interested in the project. Discussions were also initiated with the NCDOT public transportation division manager for a research idea submission in which VRUTOP will be applied to the North Carolina public transit system.

Acoustic Situation Awareness and Its Effects on Pedestrian Safety within a Virtual Environment (Situation Awareness)

The Situation Awareness team completed pilot studies aimed at identifying ideal locations on-campus to perform observation studies of both pedestrians and drivers and administered surveys. Specific objectives of the pilot studies were to identify key actions performed by both parties that would be indicators of safe and unsafe behavior. In combination with extensive literature reviews, this information is being used to create the observation checklist, survey and focus group questions, and initial system requirements for the development of the virtual environment. Significant takeaways thus far are, but are not limited to, the need for a programmer on the research team to begin modeling the environments.

Research Assistants

There was a total of 28 students working as research assistants on projects within CATM during the reporting period. Table 3 provides a breakdown of these students by classification and gender.

Table 3: Demographics of student research assistants

Classification	Male	Female	Total
Undergraduate	4	4	8
Master's	3	2	5
Doctoral	11	4	15
Total	**18**	**10**	**28**

Along with the research projects currently being funded through the UTC grant, Table 4 lists additional transportation research grants connected to the center that were active during the reporting period and the agencies that are funding them.

Table 4: Transportation research grants awarded

Project Title	Lead Institution	Funding Agency
NC Transportation Center of Excellence in Advanced Technology Safety and Policy	University of North Carolina – Chapel Hill	NC Department of Transportation
University Transportation Center of Excellence – Mobility and Congestion	North Carolina State University	NC Department of Transportation

Education

CATM Transportation Scholarships were awarded to 12 NC A&T supply chain majors. The CATM Incentive Awards were awarded to two STI alumni who are new Freshmen enrolled at NC A&T and majoring in supply chain management. These students will participate in activities related to their major through virtual lectures and presentations during the Fall 2020 semester.

New student research assistants received training specific to the projects to which they are assigned. For instance, two undergraduate students working on the Situation Awareness project are registered for course credit under an industrial and systems undergraduate research course at the 2xxx level; while one doctoral student is registered for one thesis credit. As a part of the onboarding process, a specific objective was for all students to obtain a Social and Behavioral Research (Basic Course) Certificate through the Collaborative Institutional Training Initiative (CITI) to gain a basic understanding of research ethics and integrity. Learning objectives of the research are to (1) learn about vehicle-pedestrian communication, (2) write virtual reality scenarios for a vehicle approaching an on-campus crossing, (3) collect human subject data, (4) analyze the data, and (5) document and present overall procedure and results of the research. To accomplish this in a timely manner, the team meets weekly to discuss literature reviews performed by the students and discuss pilot findings in preparation for protocol submission for IRB approval. Similar processes are being followed for students assisting with the other CATM research projects.

CATM staff were also involved in recruitment and selection for the CATM Scholars Program, TRB Fellowship Program, and Dwight D. Eisenhower Fellowship Program during this reporting period. These activities resulted in 13 CATM Scholars, 1 TRB fellow, and 3 Eisenhower Fellows.

Workforce Development and Outreach

The Summer High School Transportation Institute was held virtually using the Zoom platform (Figure 1) from July 13th to July 31st. Thirteen rising high school juniors and seniors were selected to participate. The first portion of their day included lectures and presentations from supply chain/transportation faculty, professionals, and researchers. The latter part of the day included presentations in SAT math and English preparation, resume writing, the college application process, and other development activities. There were three hands-on activities: solar powered car assembly, bridge building, and a transportation "shark tank" activity. Figure 2 illustrates one of the interactive presentations and the solar car activity. Based on a survey completed on the last day of the program, 50% of the students said they would seek educational study in a supply chain/transportation major and 30% of the students said they would seek a career in the supply chain/transportation industry.

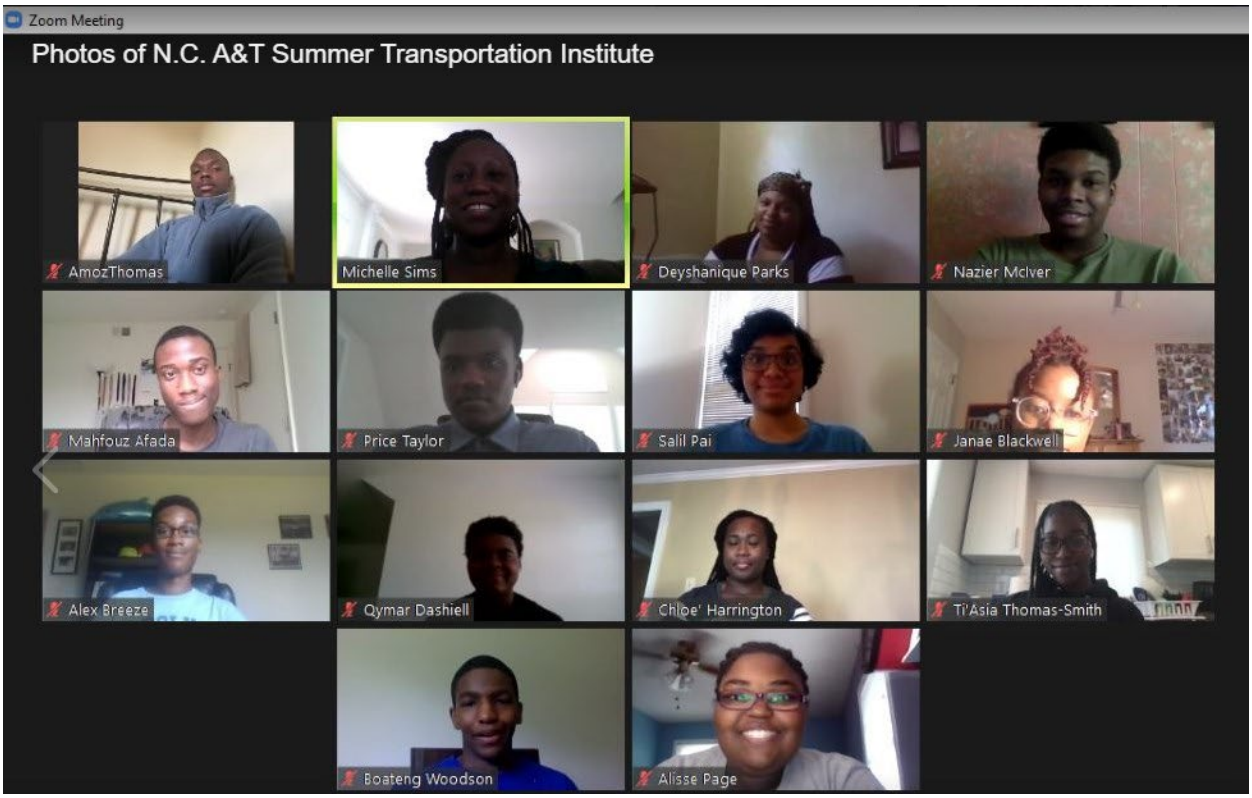

Figure 1: Snapshot of NCA&T's virtual STI 2020 students and their facilitator

Figure 2: Snapshots of STI road design workshop (left) and solar car test (right)

On July 17th, CATM's director participated in an STI panel where she and other transportation professionals described how they came to work in the transportation field and answered students' questions about their experiences in transportation. Thirteen students and three CATM staff members attended the session. Several students posed really good questions and expressed their interest in transportation as a career.

Researchers at ERAU conducted a CATM seminar for the high school students on July 28th titled "AI-Enabled Drone Detection and Negation." Seventeen students attended the seminar and it was well received by the students.

Technology Transfer

On April 30th, VTTI researchers conducted a webinar for state and local stakeholders and others as an educational opportunity for learning about Low Speed Autonomous Vehicle (LSAV) (Figure 3). They talked about their experience with the implementation of an LSAV at a public test site in Blacksburg, VA. The LSAV shuttle was deployed to support CATM's Automated Last Mile project.

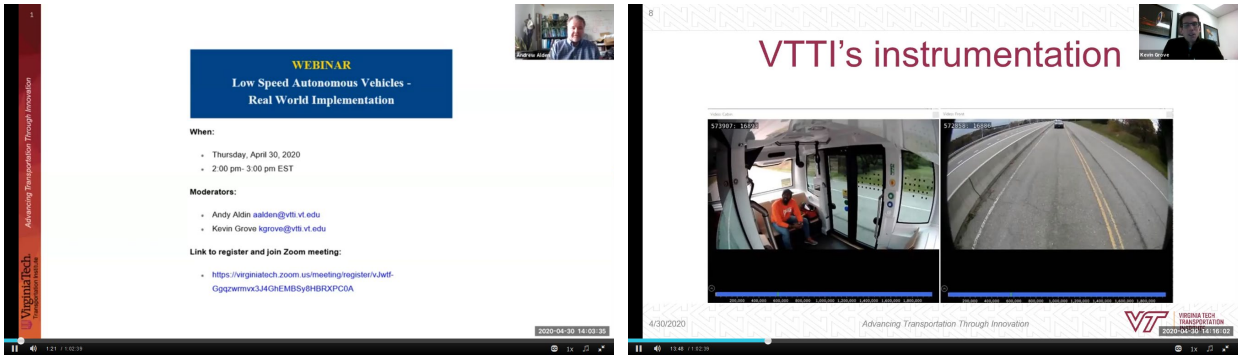

Figure 3: Snapshots from Last Mile project webinar

On May 1st, NCA&T researchers working on the VRU-MAP project moderated a discussion in which humans were given top consideration over technology in an effort to "fit the machine to the human" rather than the other way around (Figure 3). Virtually all research on autonomous vehicles to date focuses on the technical or mechanical requirements successfully constructing driverless vehicles. Very few studies have looked at the role of humans and VRUs interacting with autonomous vehicles naturally in society. This presentation was designed to bring light to these often overlook aspects of design.

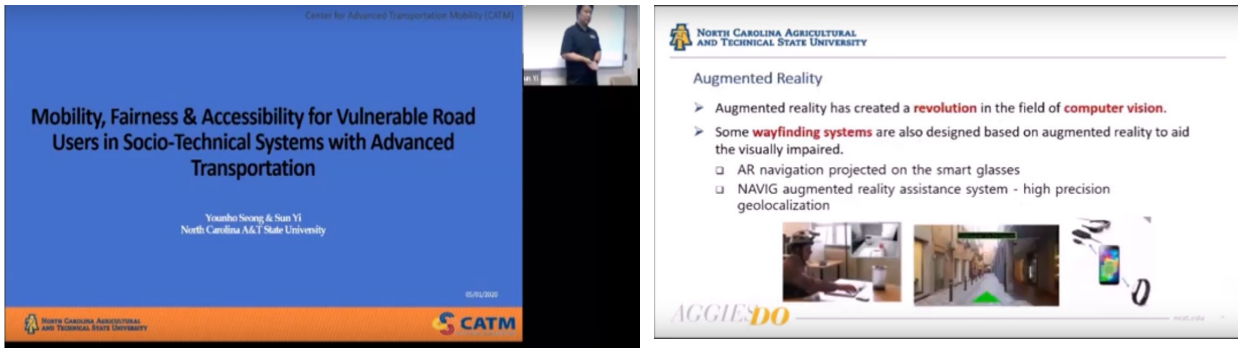

Figure 4: Snapshots from VRU-MAP project webinar

On August 27th, ERAU researchers working on the Secondary Crash project presented findings from their project in a virtual webinar (Figure 4). Topics covered in this webinar included an overview of an epidemic model for fuel shortages during hurricane evacuation, point process model for secondary crashes, and pedestrian movement and infection spread through air travel.

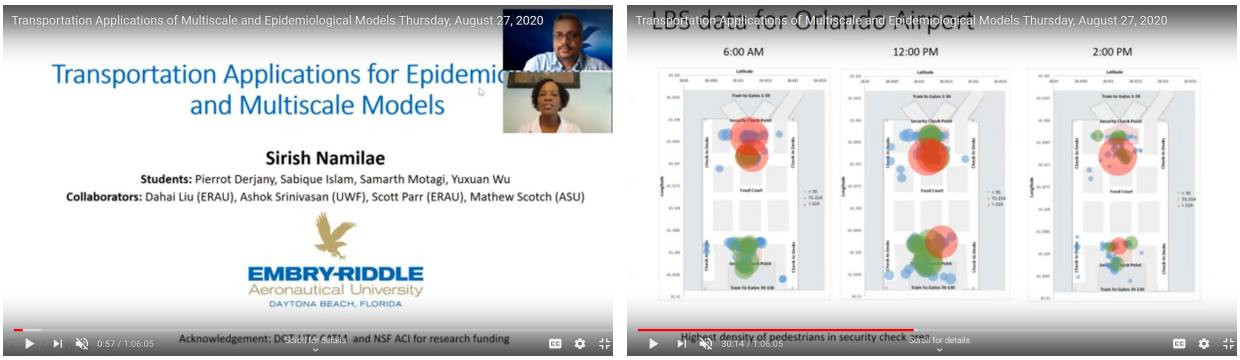

Figure 5: Snapshots from Secondary Crash project webinar

During this performance period, the VRU-POD team has been discussing the implementation of VRU-POD to NC public transit system with the NCDOT.

Have the results been disseminated?

Various forms of dissemination took place during the reporting period. For instance, the Last Mile team submitted an abstract to SAE International's Business of Automated Mobility Forum for presentation and subsequent publication. The paper discusses VTTI's lessons learned and suggests best practices for future testing and deployment of low-speed automated shuttles. In addition, the VRU-MAP research team presented at two professional functions on the status of the project and the developments of the platform. The DRONETIM team has submitted a journal article revision, conference paper, and patent application related to their project. Members of the Multi-Physics Models team participated in an interview with journalists that led to a news story in Business Insider. The Multiscale Collaborate team presented a paper at the INFORMS 2020 annual meeting while the Driving Feedback team sent copies of their literature review to their GM collaborators for review and feedback. The VRUTOP team had a paper accepted to TRB 2021 and the Spring 2020 CATM newsletter was distributed during this reporting period. CATM activities, events, and reports were posted on the CATM website.

What do you plan to do during the next reporting period to accomplish these goals?

Below is a list of the primary tasks for the next reporting period. Some of these activities are contingent upon the operating status of the consortium members due to the COVID-19 pandemic.

- Distribute the Winter 2020 newsletter
- Continue research project specific activities
- Select Year 5 competitive research grant awards
- Hold at least two research webinars
- Review and post final reports for completed projects
- Recruit for NC A&T's 29th Summer High School Transportation Institute
- Recruit applicants for the 2021-22 DDETFP and 2021-22 CATM Scholars
- Hold the Second Annual Transportation Awareness Day that was postponed until 2021
- Organize the 4th Annual CATM Symposium that was postponed until 2021
- Help plan and participate in the 2020 UTC Conference for the Southeastern Region that was postponed until 2021

2. PARTICIPANTS & COLLABORATING ORGANIZATIONS:

Organizations that have been involved as partners

Table 5 provides a list of the individuals who were involved in center activities as partners during the reporting period and their associated organizations. This list does not include the center staff at NC A&T nor the various students involved in CATM activities.

Table 5: List of partners

Organization Name	Organization Location	Partner's Contribution to the Project	Name (First and Last)	Partner University
Dept. of Industrial and Systems Engineering	Greensboro, NC	Collaborative Research	Xiuli Qu, Ph.D.; Lauren Davis, Ph.D.; & Younho Seong, Ph.D.	NC A&T
Dept. of Computational Science and Engineering	Greensboro, NC	Collaborative Research	Hyoshin (John) Park, Ph.D.	NC A&T
Dept. of Electrical and Computer Engineering	Greensboro, NC	Collaborative Research	Ali Karimoddini, Ph.D. & Abdollah Homaifar, Ph.D.	NC A&T
Dept. of Mechanical Engineering	Greensboro, NC	Collaborative Research	Sun Yi, Ph.D.	NC A&T
Virginia Tech Transportation Institute	Blacksburg, VA	Facilities	Jon Antin, Ph.D.	Virginia Tech
Virginia Tech Transportation Institute	Blacksburg, VA	Collaborative Research	Andrew Alden, Ph.D.; Kevin Grove, Ph.D.; Justin Owens; & Andrew Miller	Virginia Tech
Virginia Tech	Blacksburg, VA	Collaborative Research	Charlie Klauer, Ph.D.	Virginia Tech
Institute for Transportation Research and Education	Raleigh, NC	Collaborative Research	Kai Monast	NC State University
Dept. of Graduate Studies, College of Aviation	Daytona Beach, FL	Collaborative Research	Dahai Liu, Ph.D.; Jennifer Thropp, Ph.D.; & Scott Winter, Ph.D	ERAU
Aerospace Engineering	Daytona Beach, FL	Collaborative Research	Namilae Sirish, Ph.D.	ERAU
North Carolina DOT	Raleigh, NC	Financial Support	Neil Mastin, Curtis Bradley, Ph.D.	
General Motors	Detroit, MI	In-Kind Support	Maureen Short	
Salem VA Medical Center	Salem, VA	In-Kind Support	Mamta Sapra	
Florida DOT	Tallahassee, FL	In-Kind Support	Joey Gordon	
Carilion Clinic Center for Healthy Aging	Roanoke, VA	In-Kind Support	Kye Kim	

Other collaborators or contacts involved

During the reporting period, Drs. Maranda McBride and Hyoshin Park continued working with researchers at UNC-Chapel Hill, Appalachian State University, UNC-Charlotte, NC State University, Duke University, and Fayetteville State University on two separate NCDOT Transportation Centers of Excellence grants which were awarded in Fall 2019. They also established a new collaborative with Dr. Venktesh Pandey, a new faculty member at NC A&T, and initiated work on the development of an NSF grant proposal.

Dr. Xiuli Qu collaborated with Dr. Xiaohong Yuan in the Department of Computer Science at NC A&T on identifying disaster-related tweets and potential public panic events using different learning-based methods. Dr. McBride collaborated on a transportation safety research paper with researchers from the University of North Texas and the University of Alabama. She also worked on building collaborations with colleagues at the Collaborative Sciences Center for Roadside Safety at UNC-Chapel Hill.

Drs. Joseph Huscroft and Lauren Davis continued mentoring the 2019 NC A&T Eisenhower Fellows as they completed their research papers during the reporting period and Dr. Ahren Johnston initiated his service as a mentor to the 2020 NC A&T TRB fellow. In addition, three faculty members volunteered as mentors to the six 2020 NC A&T Dwight D. Eisenhower Fellowship Program applicants and provided assistance as they completed their applications.

3. OUTPUTS:

The subsections below outline some of the outputs that have resulted from the research projects listed in Table 2 as well as the education, workforce development, and technology transfer activities.

Publications, conference papers, and presentations

Journals

- Folsom, L., Ono, M., Otsu, K., and Park, H. Scalable information-theoretic path planning for a rover-helicopter team in uncertain environments. International Journal of Advanced Robotic Systems, revise and resubmit. Acknowledgement of federal support: yes.
- Pugh, N., Park, H., Namilae, S., and Liu., D. Safe and efficient airport evacuation considering pedestrian dynamics. IEEE Transactions of ITS, under review. Acknowledgement of federal support: yes.
- Pugh, N., and Park, H. High-order Markov model for prediction of secondary crash likelihood considering incident duration. IEEE Access, under review. Acknowledgement of federal support: yes.
- Shirzad, K., Darko, J., Folsom, L., Pugh, N., Park, H., Owens, J., and Miller, A. Adaptive Personalized routing for vulnerable road users, IEEE Transactions on Intelligent Transportation Systems, under review. Acknowledgement of federal support: yes.

Books and Non-Periodical, One-Time Publications

- Nothing to report

Other Publications, Conferences, and Presentations

- Alden, A., and Grove, K. Low Speed Autonomous Vehicles - Real World Implementation. CATM Webinar. Acknowledgement of federal support: yes.

- Alabi, M., Seong, Y., and Yi, S. Decision-making model for emergency evacuation based on the Lens Model using machine learning and Monte-Carlo simulation for incomplete information environment. 2020 HFES Annual Conference, accepted. Acknowledgement of federal support: yes.
- Darko, J., and Park, H. Modeling and assessing the impact of a traveler's preference on transit route-choice behavior. 2021 TRB Annual Meeting, submitted. Acknowledgement of federal support: yes.
- Meda, H., Davis, L.B., and Vogiatzis, C. A graph theoretical approach integrating geospatial information to analyze airport network disruptions. 2020 INFORMS Virtual Annual Meeting, accepted. Acknowledgement of federal support: yes.
- Mhatre, S., and Qu, X. Optimization based decision making for the restoration of road transportation system after a hurricane. 2020 INFORMS Virtual Annual Meeting, accepted. Acknowledgement of federal support: yes.
- Mhatre, S., and Qu. X. Traffic pattern discovery during recent hurricane evacuations in North Carolina: A case study. 2020 INFORMS Virtual Annual Meeting, accepted. Acknowledgement of federal support: yes.
- Richmond, D,. and Qu, X. Transportation network resilience in Charlotte, North Carolina for day-to-day disruptions. 2020 Virtual Institute of Industrial and Systems Engineers Annul Research Conference, accepted. Acknowledgement of federal support: yes.
- McBride, M. Center for Advanced Transportation Mobility update. NCDOT UTC Virtual Roundtable Discussion, presented. Acknowledgement of federal support: yes.
- McBride, M. DOT Research programs and University Transportation Centers (UTC) program panel. U.S. DOT Historically Black Colleges & Universities (HBCUs) and Minority Serving Institutions (MSIs) Capacity Building Virtual Event, presented. Acknowledgement of federal support: yes.
- McBride, M. Transportation programs in Aggie Land. Rowan County Virtual Summer Transportation Institute, presented. Acknowledgement of federal support: yes.
- McBride, M. Transportation professionals panel. NCA&T Virtual Summer High School Transportation Institute, presented.
- Namilae, S. Transportation Applications of Multiscale and Epidemiological Models. CATM Webinar, presented. Acknowledgement of federal support: yes.
- Namilae, S. Panel Discussion on Data-Driven Computing-Intensive Modeling, presented.
- Pugh, N., Park, H., Namalie, S., and Liu., D. Safe and efficient airport evacuation considering pedestrian dynamics. INFORMS2020 Annual Meeting, presented. Acknowledgement of federal support: yes.
- Shirzad, K., Darko, J., Folsom, L., Pugh, N., Park, H., Owens, J., and Miller, A. A personalized trip planner for vulnerable road users. 2021 TRB Annual Meeting, submitted. Acknowledgement of federal support: yes.
- Kwakye, K., Seong, Y., and Yi, S. An Android-based mobile paratransit application for vulnerable road users. Proceedings of 24th International Database Engineering & Applications Symposium, Article No. 28, presented. Acknowledgement of federal support: yes.
- Seong, Y., and Yi, S. Mobility, Fairness and Accessibility for Vulnerable Road Users in Socio-Technical Systems with Advanced Transportation. CATM Webinar, presented. Acknowledgement of federal support: yes.
- Yang, Y., Zhang, Kai., Liu, D., and Song, H. Autonomous UAV navigation in dynamic environments with double deep Q-networks. Proceedings of the Digital Avionics Systems Conference, accepted. Acknowledgement of federal support: yes.
- Zhang, K., Jiang, Y., Liu, D., Song, H. (2020), Spatio-temporal data mining for aviation delay prediction, Proceedings of the International Performance Computing and Communications Conference, accepted. Acknowledgement of federal support: yes.

- Zhang, K., Liu, Y., Wang, J., Song, H., and Liu, D., Tree-based airspace capacity estimation. 2020 Integrated Communications Navigation and Surveillance Conference, published. Acknowledgement of federal support: yes.

Websites or other internet material

- Low Speed Autonomous Vehicles - Real World Implementation Webinar Replay: https://video.vt.edu/media/CATM+-+Real+World+Autonomous+Shuttles/1_95vudqxa
- Mobility, Fairness & Accessibility for Vulnerable Road Users in Socio-Technical Systems with Advanced Transportation Webinar Replay: https://youtu.be/sbRFnriTFTc
- Transportation Applications of Multiscale and Epidemiological Models Webinar Replay: https://www.youtube.com/watch?v=Cg3eVso2Ehc&feature=youtu.be&fbclid=IwAR3ScH15zoR0kdBJmk-GrKWiiaEwHwq83LGjSI_vXsIw4DiY47LP9KRtEbs
- CATM Website: https://www.ncat.edu/cobe/transportation-institute/catm/index.php
- CATM Spring 2020 Newsletter: https://www.ncat.edu/cobe/transportation-institute/_files/pdfs/newsletterspring2020ada.pdf
- CATM Facebook Page: https://www.facebook.com/NCATCATM/
- STI Facebook Page: https://www.facebook.com/groups/627756624232070/
- Webpages where STI program information is provided: https://www.ncat.edu/cobe/transportation-institute/summer-high-school-transportation-institute.php

Technologies or techniques

- The Multi-Physics Model Team developed a new model combining pedestrian dynamics and infectious disease spread and parameter sweep algorithms to address the vast parameter space in their problem.

Inventions, patent applications, and/or licenses

- Park, H., Folsom, L., Darko, J., Ono, M., Otsu, K. System and methods for efficient robotics navigation through global mapping, USPTO, provisional application, USSN 63/074889, submitted. Acknowledgement of federal support: yes.

Other products

Publications

- Nothing to report

Data

- Nothing to report

4. OUTCOMES:

The results of the activities during this reporting period are increasing understanding and awareness of transportation issues in the following ways:

- Last Mile project: The extensive procedures developed for conducting virtual focus groups with vulnerable populations has made it possible for the team to gather data about transportation issues during a very difficult and dangerous time. These procedures can be applied in the future to continue gathering data about transportation issues in other communities, including Greensboro.
- VRU-MAP project: This project is designed to assist individuals with disabilities while they are moving throughout the built environment. Current efforts by the research team strive to elucidate

the issues for not only those with physical disabilities, but also cognitive, developmental, or perceptual limitations, as these individuals are often not considered despite sometimes requiring more specialized or intensive accommodations. While the development of the app is underway, ongoing efforts highlight the needs that all individuals have when maneuvering through the world.
- VRU-POD project: The results of this project will help VRUs identify and avoid inaccessible places in the current pavement network as a short-term solution until urban transportation and sidewalk networks can be redesigned to eliminate inaccessible areas.
- Multi-Physics Model project: This project highlights the importance of pedestrian movement and infectious disease spread at airports.
- Multiscale Collaborate project: Accurate estimation of airspace capacity is essential to a safe, efficient and predictable air transportation system. Conventional approaches focus on controller workload using airspace complexity measurements that only consider operational conditions of controllers. However, such model-driven methods do not completely demonstrate airspace capacity in the real world because of lack of consideration for other critical factors such as weather. To address this challenge, a new airspace capacity estimation model is proposed based on regression tree ensembles. The model combines multi-source data to quantify the maximum transportation capacity of sector under different circumstances.
- Secondary Crashes project: The models resulting from this project will provide effective means of identifying secondary crashes from historical crash data. The analysis can be used for effective policy analysis to mitigate secondary crashes and improve safety of first responders.
- VRUTOP project: This research focuses on improving the transit service of vulnerable road users while addressing recent trends in Medicaid transformation.

The activities that took place during the reporting period are expected to affect the passage of new policies, regulation, rulemaking, or legislation in the following ways:

- Last Mile project: The research is expected to identify gaps in current ADA guidance, which did not consider driverless automated vehicles when issued. The research is also expected to identify new policies which could facilitate testing and deployment of automated shuttle technologies in the future. In particular, the research will help identify best practices that will prevent deployments from damaging public trust in automated transportation.
- VRU-POD project: The optimal policies based on VRUPOD a will lead to the discovery of the most accessible route in an adaptive fashion. The technique is considered personalized wayfinding since users with disabilities choose the importance of parameters affecting the sidewalk by the AHP method. A case study was carried out on a mid-size network to show the performance of different methods and recommend the optimal path to individuals with disabilities.
- Multiscale Collaborate project: An interpretable data-driven model that estimates the capacities of the National Airspace System and highlights factor importance for airspace capacities was presented. The airspace capacity estimated by the proposed model is dynamically adjusted based on the real-time environment that has the potential to be a guideline for temporary flight path changes or air traffic selections for emergency landings.

The research activities during the reporting period have led (or will lead) to increases in the body of knowledge in the following ways:

- Last Mile project: The research will document how outreach and experience with automated technology can impact user attitudes and acceptance. The research will also document how vulnerable road users prefer to utilize an autonomous shuttle.
- DRONETIM project: The model for collaborative assignment of UAVs and ERVs can improve how incidents are managed on roadways. The solution using the Max-sum algorithm produced an increase in overall system utility, converging faster than DSA algorithm. Although the model was applied to randomly generated scenarios, for real-world applications this model can be easily modified and implemented for incident management on roadways, fully integrating and utilizing the benefits of UAVs. This model provides a roadmap for effective ERV assignment through the

use of UAVs and the information provided from their task assignments. UAVs can be successfully integrated into a collaborative multi-agent approach which can greatly mitigate the effects of incidents on the roadways. The proposed method is unique since it addresses communication between heterogeneous vehicles for improved efficiency.

- Multi-Physics Models project: Scientific contributions of this project include a new model combining pedestrian dynamics and infectious disease spread and parameter sweep algorithms to address the vast parameter space in this problem.
- Multiscale Collaborate project: This project is interdisciplinary research including machine learning, modeling and optimization. In this work, the underlying theories were learned and the skills of preprocessing and analysis for large-scale and complex data sets were obtained. This work deepens our understanding about the air transportation regulations.
- Secondary Crashes project: This project models secondary crashes using the theory of Hawkes point process models for the first time. This will lead to the application of the rich mathematical framework developed in the context of epidemic events to understand and construct predictive models for secondary crashes.
- Real-Time project: A full Lens model framework to characterize the evacuation decision using Machine Learning, a Monte Carlo Simulation, and Latin hyper cube sampling were developed. A graph theoretical approach to analyzing airport network disruption and identifying feasible airports to reroute from airports affected by a hurricane was proposed and tested.

The following projects are expected to result in improved processes, technologies, techniques and skills in addressing transportation issues:

- Last Mile project: The research will identify how communication, outreach, and training practices can improve adoption in the real world. Specifically, the research will study the effectiveness of outreach in shaping rider opinion and adoption.
- DRONETIM project: Dispatching policies for emergency teams have been studied and implemented to minimize the time needed to respond to a sequence of incident requests. An important opportunity for policy improvement is the integration of UAVs with emergency response teams. The role of the UAV in a heterogeneous vehicle-team is to explore uncertain traffic conditions, detect unexpected non-recurring events, and augment information gained from loop detectors, automatic vehicle identification technology, probe vehicles, and other sensors. Integration of UAVs into an emergency response team can be achieved through a constraint satisfaction problem framework.
- VRU-POD project: Prior work has focused on wayfinding for people with disabilities using static parameters related to the sidewalk; however, this might be impractical in real world situations. Routing with static parameters is only applicable when the same fixed route is used and conditions of the route are valid every day. This project provides a VRUPOD model incorporating dynamic parameters for VRU wayfinding.
- Multi-Physics Models project: This project highlights the importance of pedestrian movement as it relates to infectious disease spread at airports.
- Multiscale Collaborate project: Air-related data sets are usually messy for data analysis. In this project, a pipeline was designed to parse these data sets and fuse the data from different sources which helps practitioners interested in addressing air transportation issues apply machine learning.
- Secondary Crashes project: The models developed for this project will provide effective means of identifying secondary crashes from historical crash data. The resulting analysis can be used for effective policy analysis to mitigate secondary crashes and increase the safety of first responders.
- Real-Time project: The predictive models of evacuation traffic volumes in eastern NC during a hurricane evacuation can assist government agencies in making better traffic control policies during such an event.
- VRUTOP project: This project is expected to improve access to health care in underserved areas using public transportation and Mobility as a Service, while considering Medicaid shifts towards privatization.

The following activities are expected to result in the enlargement of the pool of trained transportation professionals:

- Last Mile project: Multiple VTTI staff have been trained for the operation, maintenance and route mapping functions of the EasyMile shuttle vehicle.
- Research projects: Students from diverse backgrounds continue to receive specialized training during the course of their research that can be transferred to future jobs in transportation.
- Education and Workforce Development activities: Several students are exposed to the various careers in transportation for the first time through the CATM program activities. These exposures will result in some deciding to further consider additional training and careers in transportation.

The following research projects have led or will lead to the adoption of new technologies, techniques or practices:

- Last Mile project: The team's research may lead to best practices in training and outreach on automated vehicles. This training and outreach may in turn lead to new deployment initiatives and outreach, if successful.
- Multiscale Collaborate project: Different from the conventional methods such as operations research in air traffic management, machine-learning-centric approaches were adopted which capture the hidden patterns in the real data to support automated decision-making.
- Secondar Crashes project: This project for the models secondary crashes using the theory of Hawkes point process models first time.

Table 6 contains the center-specific performance measures for outcomes, the target per year, and the current status of each goal.

Table 6: CATM Outcome Performance Measures

Outcome #	Goals	Research Performance Measures	Target per year	Current Status
Outcome #1 (technology focused)	Adoption of new technologies to help vulnerable road users identify suitable transportation services	Number of technology transfer activities that offer implementation or deployment guidance	2	0
Outcome #2 (technology focused)	Enhanced decision-making techniques that improve the efficiency and effectiveness of emergency evacuation processes	Number of decision-making technology training courses or webinars developed and delivered	2	4
Outcome #3	Automated vehicle design guidelines based on an increased understanding and awareness of human perceptions of and interactions with automated vehicles	Number of human factors guideline documents published	2	0

Outcome #4	Dissemination of research results through presentations, publications, conference papers, and technical reports	Number of presentations and workshops given	6	52
		Number of peer-reviewed journal papers published	2	10
		Number of newsletter articles, conference papers, and technical reports published	10	26

5. IMPACTS:

What is the impact on the effectiveness of the transportation system?

- Multiscale Collaborate project: The machine learning model of enroute airspace estimation using regression tree and the ensemble methods based on it has achieved the highest R^2 of 0.8751, lowest MSE of 0.0587 for the given features (i.e., weather, ATC facilities, human factors). It concludes that the model can be used to predict the control workload for an airspace with relatively accurate results. The sub-model, which predicts the flight delay, obtained an error of 5 minutes, approximately. The path planning model based on deep reinforcement learning is trained to adapt the complex and dynamic environments. Multi-agent navigation tasks in different unknown environments with moving obstacles were tested and the success rate was 100%.

What is the impact on the adoption of new practices, or instances where research outcomes have led to the initiation of a start-up company?

- VRU-MAP project: The research being developed, in the form of the app and the implementation of the app, may lead to commercialization of said app to individuals with disabilities. These individuals who choose to adopt this application platform for their navigational needs are expected to have better mobility while traveling outside of the car, including transit, rail, or other options.
- Multi-Physics Models project: This project is expected to result in the design of pedestrian movement strategies to reduce infectious disease spread.
- Multiscale Collaborate project: The flight delay model resulting from this project can reduce the average wait time of passengers and reduce the cost of airlines and airports. The recommendation system can improve the efficiency of air transportation under emergency.
- Secondary Crashes project: The models developed will provide effective means of identifying secondary crashes from historical crash data. The analysis can be used for effective policy analysis to mitigate secondary crashes and increase the safety of first responders.
- Real-Time project: The developed Lens model that characterizes the evacuation decision using Machine Learning, Monte Carlo Simulation, and Latin hyper cube sampling can be used to predict individuals' evacuation decisions. The proposed graph theoretical approach can be used by the airline companies to analyze the disruptions of severe weather to airport networks and reschedule the routes disrupted by a severe weather.

What is the impact on the body of scientific knowledge?

- Multi-Physics Models project: New modeling techniques combining pedestrian movement and infectious disease spread will result in the development of strategies to mitigate infectious disease spread.

- Multiscale Collaborate project: The proposed modeling framework has the potential to optimize the efficiency of evacuation for airports under emergency. The proposed modeling framework will provide: 1) pre-alerts of natural disasters to both transportation authorities and the public, and 2) evaluations of air traffic controllers' performance and estimations of the maximum capacity of the local airport to transportation authorities to make optimal evacuation plans.
- Secondary Crashes project: This project for the models the secondary crashes using the theory of Hawkes point process models for the first time. This will lead to the application of the rich mathematical framework developed in the context of epidemic events to understand and construct predictive models for secondary crashes. The resulting analysis can be used for effective policy analysis to mitigate secondary crashes and increase safety of first responders.
- Real-Time project: The models developed in the project will help governments organize effective emergency evacuations and can reduce the impact of hurricane disruptions on airline transportation.

What is the impact on transportation workforce development?

- Multiscale Collaborate project: This research is multidisciplinary in nature. Students get cross training in the field of computer science, engineering, and aviation/transportation. They will be well prepared for their future career in aviation and other areas of transportation.
- Secondary Crashes project: So far three students were directly trained in transportation-related concepts through the project.
- Real-Time project: Four graduate students and two undergraduate students have been involved in the project. Working on this project prepares them with a better understanding of Intelligent Transportation Systems and the impact of hurricanes on transportation systems.
- Education and Workforce Development activities: The STI program helped make high school student aware of career options in transportation. Several of the students indicated their intent to consider degrees and/or careers in transportation in the near future.

Table 7 contains the center-specific performance measures for impacts, the target per year, and the status of each goal.

Table 7: CATM Impact Performance Measures

Impact #	Goals	Research Performance Measures	Target per year	Current Status
Impact #1 (technology focused)	Increase in the number of vulnerable road users able to acquire transportation services that fit their special needs	Number of instances of vulnerable road user technology adoption or commercialization	2	1 created/ 0 adopted
Impact #2 (technology focused)	More effective and efficient emergency transportation management processes	Number of instances optimization models or technologies are utilized or commercialized	3	10 created/ 0 adopted
Impact #3	Increase the body of knowledge for human factors in automated vehicles	Number of instances of research changing behavior, practices, decision making, policies (including regulatory policies), or social actions	2	0

6. CHANGES/PROBLEMS:

The COVID-19 pandemic required the Last Mile team to completely revise their data collection methods. Virginia Tech's IRB suspended all participant research involving human contact due to COVID-19; therefore, the Last Mile team designed new virtual focus group protocols for data collection during COVID-19, which required significant coordination with both IRB and fiscal groups at the university. The team's initial deployment of the EasyMile found that it is not appropriate to place vulnerable populations in the vehicle during operation, even with an operator present. This led the team to change the focus group protocols to accommodate viewing but not riding. In addition, instead of the Detecting Dementia team targeting participants diagnosed with MCI, they are now targeting those who may be considered as being pre-MCI.

The project completion dates for several projects (e.g., Last Mile, VRU MAP, DRONETIM, VRU-POD, Real-Time) have been extended due to delays caused by the pandemic. Some new projects also experienced delays in their ability to recruit and onboard student researchers during the summer so more projects may need to request extensions in the future.

Additionally, travel restrictions and teleworking are being enforced on each of the campuses due to COVID-19. This unexpected pandemic continues to disrupt travel plans to present results at regional and national conferences. As a result, the CATM staff has decided to postpone the 4th Annual CATM Symposium that was to be held during the Fall 2020 semester. Due to the lack of results that several projects have been able to obtain because of the pandemic disruptions and restrictions and the vast number of conferences, symposia, and other meetings being held virtually in Fall 2020 and Spring 2021, the staff has opted to wait until Fall 2021 to hold its 4th symposium in hopes of being able to have an in-person event. A 5th symposium is expected to take place in Fall 2022 during which the final results of all of the CATM funded projects during the lifetime of this UTC grant award are expected to be presented.

Due to the COVID-19 pandemic, NC A&T had to pivot but successfully facilitated a virtual STI program via the Zoom platform. Problems that had to be addressed during the virtual program included making sure participants had secure internet connectivity and a device that would allow them to log in to the Zoom platform daily.

7. SPECIAL REPORTING REQUIREMENTS

Nothing to report for this period.