UTC Semi-Annual Progress Report

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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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Signature of Submitting Official:

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, 2019.

Table 1: Progress of period 5 activities

Research	Status	% Complete
Prepare year 4 RFP	Complete	100%
Complete year 1 projects	Behind schedule	90%
Continue making progress on year 2 projects	Behind schedule	90%
Initiate year 3 projects	Complete	100%
Submit proposals for NCDOT Centers of Excellence competition	Complete	100%
Conduct annual visit to member institutions to obtain research status reports – Year 3	Complete	50%
Conduct year 4 research proposal solicitation, review, and award process	On schedule	30%
Conduct annual visit to member institutions to obtain research status reports – Year 4	Forthcoming	0%
Education, Outreach, and Workforce Development Activities		
Develop and hold Transportation Awareness Day	Complete	100%
Hold 27th Summer High School Transportation Institute	Complete	100%
Select 2019-20 CATM Transportation Scholarship program awardees	Complete	100%
Implement NC A&T Transportation Shark Tank Competition	Complete	100%
Prepare to take students to 2020 TRB conference	On schedule	30%
Prepare to take students to 2020 Southeastern Region UTC conference	On schedule	10%

Develop and conduct Spring 2020 student-to-student K-12 initiative workshops	Forthcoming	0%
Distribute applications for 2020-21 CATM Transportation Scholarship program	Forthcoming	0%
Recruit and select participants for 2020 Summer High School Transportation Institute (STI)	Forthcoming	0%
Develop transportation case for case competition	Behind schedule	25%
Develop teacher/counselor transportation workshops	Behind schedule	0%
Technology Transfer Activities		
Coordinate with NCDOT to plan and hold the NCDOT Research & Innovation Summit	Complete	100%
Create and distribute Spring 2019 newsletter	Complete	100%
Create and distribute Fall 2019 newsletter	On schedule	90%
Plan and hold the 3rd Annual CATM Symposium	On schedule	70%
Assist with the 2020 Southeastern Region UTC Conference planning	On schedule	20%
US DOT Reporting Activities		
Complete and submit PPPR#4	Complete	100%
Complete and submit 2019 performance indicator report	Complete	100%
Complete and submit SF425 for Q8 and Q9	Complete	100%
Complete and submit recipient share report #3	Complete	100%
Review year 2 final reports for completed research projects	Complete	100%
Upload year 2 final reports to TRID database	Complete	100%
Update records in RiP database	Behind schedule	50%
Complete and submit PPPR#4	On schedule	80%

What was accomplished under these goals?

During the report 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, 2, and 3 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 of the projects.

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
Multi-scale Models for Transportation Systems under Emergency Conditions	Completed/Y1	IM, RC, TS	https://www.ncat.edu/cobe/transportation-institute/catm/catm_documents/4_2-emergencyabstract.pdf

Analysis of the Non-Driving Mobility Needs of People with Disabilities	Continuing/Y2	IM, PS	https://www.ncat.edu/cobe/transportation-institute/catm/catm_documents/6-mobilityneedsabstract.pdf
Travelers' Rationality in Anticipatory Online Emergency Response	Completed/Y2	IM, RC, PS	https://www.ncat.edu/cobe/transportation-institute/catm/catm_documents/7-travelersrationalityabstract.pdf
Particle Dynamics Model for Hurricane Evacuation and Fuel Shortage: Model Based Policy Analysis	Completed/Y2	IM, RC, PS	https://www.ncat.edu/cobe/transportation-institute/catm/catm_documents/9-particledynamicsabstract.pdf
Multiscale Model for Hurricane Evacuation and Fuel Shortage	New/Y3	IM, RC, TS	https://www.ncat.edu/cobe/transportation-institute/catm/catm_documents/10-multiscalemodelabstract1.pdf
Multi-agent Reinforcement Learning-based Pedestrian Dynamics Models for Emergency Evacuation	New/Y3	IM, RC	https://www.ncat.edu/cobe/transportation-institute/catm/catm_documents/11-multiagentabstract1.pdf
DRONETIM: Dynamic Routing Of uNmanned-aerial and Emergency Team Incident Management	New/Y3	IM, RC, PS	https://www.ncat.edu/cobe/transportation-institute/catm/catm_documents/12-dronetimabstract1.pdf
VRU-Personalized, Optimum, and Dynamic (POD) Routing	New/Y3	IM	https://www.ncat.edu/cobe/transportation-institute/catm/catm_documents/13-vrupersonalizedabstract1.pdf
Real-Time Recommendations for Traffic Control in an Intelligent Transportation System During an Emergency Evacuation	New/Y3	IM, RC	https://www.ncat.edu/cobe/transportation-institute/catm/catm_documents/14-realtimeabstract1.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)

The Last Mile team worked closely with EasyMile during the reporting period to map multiple autonomous vehicle routes on VTTI's facilities and train a team of VTTI employees to be certified operators of the vehicle. The team began testing the shuttle in regular daily service on a route between VTTI's buildings and a bus stop that services the buildings. The team discovered several problems that can cause the vehicle to stop and require a 15-minute reset and they are working with EasyMile to perform a major upgrade of the vehicle's software and diagnose the issue. The team also developed a focus group protocol for VRUs to explore how autonomous vehicle technology could assist their mobility. In addition, the team developed a survey for local paratransit riders to document their transit needs and began measuring traffic densities and speeds on the road where the Last Mile project will test operations with participants. This survey has been administered to elderly users of Blacksburg Transit's dedicated service to the Warm Hearth retirement community.

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

During the reporting period, the VRU-MAP team implemented a back-end server to enable use of the app outside Virginia Tech. The iOS development has now taken lead, enabling the use of

larger-screened iPads. The crowdsourcing module continued to be expanded during this period so that it is better incorporated into the platform's current routing algorithm. Augmented reality implementation is underway providing users with an easy-to-understand view of their path. A parallel implementation using Google Maps API is being developed by the NC A&T team to integrate with public transportation. Improvements were made to the overall functionality and interface of the app.

<u>Multi-scale Models for Transportation Systems under Emergency Conditions (Emergency)</u>

The Emergency team completed their project during the reporting period. Accomplishments included the completion of the simulation model on group travel using Anylogic and another simulation for pedestrian modeling. During the course of their research, they found that group size has a significant effect on the overall evacuation time. Furthermore, group size interacts with evacuation instructions significantly. Two final reports were submitted for this project (one for each project thrust) and posted on the CATM website.

<u>Analysis of the Non-Driving Mobility Needs of People with Disabilities (Disability Survey)</u>

During the reporting period, the Disability Survey team completed the survey, interviews, and data analysis. They are now in the process of writing the final report.

<u>Travelers' Rationality in Anticipatory Online Emergency Response (Travelers' Rationality)</u>

The Travelers' Rationality team made significant strides towards the development of a model that allocates emergency vehicles more effectively during the reporting period. They compared the real-time travel time-based allocation policy simulated in Transmodeler against current operations. The developed model suggested a policy that would significantly reduce incident-induced delay and improve mobility. To accomplish this predictive emergency vehicle dispatching, there were three different components of the project: 1) Prediction modeling of crashes, secondary crashes, and incident duration; 2) Choice modeling of travelers; and 3) Online anticipatory dispatching of emergency vehicles.

<u>Particle Dynamics Model for Hurricane Evacuation and Fuel Shortage: Model Based Policy Analysis (Hurricane Evacuation)</u>

The Hurricane Evacuation project was completed during the reporting period and the final report written. The team succeeded in developing a time optimal refueling strategy for empty fuel stations that helps reduce fuel shortages. In addition, they developed an agent-based model simulation to study the refueling capabilities of fuel stations at exits along busy interstates during hurricane events. The final report for this study can be found on the CATM website.

<u>Multiscale Model for Hurricane Evacuation and Fuel Shortage (Multiscale Model)</u>

Accomplishments made by the Multiscale Model team during the reporting period include1) Developed a model to represent fuel shortages during hurricanes as an epidemic, 2) Parametrized the model with data from Hurricane Florence and Hurricane Irma, 3) Developed a correlation between hurricane evacuation traffic data and fuel shortage data, 4) Developed a predictive model for the hurricane fuel shortage based on the above correlation, 5) Developed optimal control methodology for resource allocation to reduce fuel shortages, and 5) Developed codes for on-the-fly analysis and tested it for the beginning stages of fuel shortage during the recent Hurricane Dorian.

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

During the reporting period, Multi-agent team members at NC A&T worked on path planning of evacuation routes at the airport while team members at ERAU provided pedestrian dynamics as an input to path planning.

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

The DRONETIM team successfully demonstrated that unmanned aerial vehicle (UAV) and emergency response vehicle (ERV) coordination works better than the traditional myopic method of coordination (nearest algorithm). The developed model works in an automated framework for UAVs that can be coordinated with ERVs to maximize efficiency of the distribution of limited resources for the management of traffic incidents. The information that is acquired by the UAVs through its assignment was utilized by the ERVs to support the execution of their arrivals at incident locations. UAV assigned tasks include checking the status of the road shoulder, confirming shockwave, and updating the severity of the crash resulting from the incident. If the task is assigned to a UAV, the respective information is used by the ERV to manage its speed and minimize its response time to its destination or to effectively manage the task at the incident location. In a benchmark with numerous scenarios, the developed model performed better than previous models by maximizing the total utility of the system in a simulated environment.

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

During the reporting period, NC A&T worked on path planning of evacuation routes at the airport and ERAU provided pedestrian dynamics as an input to path planning.

Real-Time Recommendations for Traffic Control in an Intelligent Transportation System During an Emergency Evacuation (Real-Time)

Throughout the course of the reporting period, the Real-Time team conducted a visualization analysis of flight connections of different airlines between airports before, during and after Hurricane Matthew, and submitted the results as a conference paper. They also started identifying the factors affecting airline rescheduling. Potential actions that are supported by the smart components in the current NC road transportation system and can be used for traffic control during a hurricane evacuation were also identified. They also contacted the persons at the NC Department of Transportation (NCDOT) to find available data of NC traffic flows during Hurricanes Florence (2018) and Dorian (2019). A traffic analyst at NCDOT has agreed to retrieve the traffic data requested for the project. One of the graduate students on the team identified critical roads to daily disruptions in the Charlotte, NC area. He retrieved the public available data and built a network model for the study. Another graduate student worked on the development of a machine learning model to identify the factors affecting drivers' choice of evacuation routes. They collected the historical data of Hurricane Matthew for training the machine learning model. An undergraduate student on the team is analyzing traffic flows during the Hurricane Irma evacuation. Information on traffic volumes during the evacuation utilized for this analysis was requested and received from the Florida Department of Transportation (FDOT).

There was a total of 47 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	7	11
Master's	10	5	15
Doctoral	13	8	21
Total	**27**	**20**	**47**

In addition to the research projects currently being funded through the UTC grant, Table 4 lists another transportation research project that was active during the reporting period and the agency that fund it. The final report for this project was submitted during the reporting period and is posted on the STC website.

Table 4: Additional transportation research project

Project Title	Funding Agency
Can You Hear It Now? A Study of Personal Listening Devices and Pedestrian Safety	Southeastern Transportation Center

Education

CATM supported eight Transportation Scholars and one Transportation Incentive Award recipient during the reporting period. The Transportation Scholars Program is open to NC A&T students majoring in Supply Chain Management. These students receive scholarships each semester in an amount according to their GPA. They are also required to participate in various transportation-related activities such as conferences, workshops, presentations, and industry visits throughout the academic year. The Transportation Incentive award is a scholarship offered to incoming Supply Chain Management freshman students at NC A&T who are also alumni of NC A&T's STI program.

On September 21, 2019, CATM scholars attended the Street Safe Lifesaving Driving Experience. Street Safe is a 501c3 dedicated to decreasing the number of teen deaths due to distracting driving in NC. This 4-hour event included a discussion of distracted driving, graphic visuals of distracted driving accidents, and hands-on activities to experience how easy it is to become distracted while driving.

Over the last two years, CATM has been supporting two graduate and two undergraduate members of the Aggies' Autonomous Auto (A^3) team. This team of NC A&T students represents NC A&T in the Autodrive Challenge sponsored by GM and SME (Figure 1). In June 2019, the A^3 team used their autonomous vehicle to compete in four dynamic challenges and a mapping challenge. The team's accomplishments included placing 2nd in the traffic control sign challenge, intersection challenge, and Mcity challenge and 3rd in the pedestrian challenge and mapping challenge. They ranked 2nd overall (first among US teams) outranking Virginia Tech, Michigan Tech, Michigan State, Texas A&M, Waterloo University, and Kettering University. The award ceremony can be seen on YouTube (https://www.youtube.com/watch?v=NbYWDhdKxX0) and the NC A&T autonomous vehicle is currently featured on the SME website (https://www.sae.org/attend/student-events/autodrive-challenge/sponsor/equipment-suppliers).

Figure 1: Snapshots of the Autodrive Competition

Workforce Development and Outreach

CATM hosted the first Transportation Awareness Day at the BB&T Stadium on the campus of NC A&T on April 9, 2019. This event was held to bring awareness of the various modes of transportation, the importance of transportation in our society, and the numerous career opportunities in transportation. The event was free and open to the public but targeted middle school students. Over 3,000 K-12 students attended the event. During the event, students had the opportunity to board the electric bus from Greensboro Transit Authority and NCDOT's heavy highway equipment. They also experienced the process of designing a road intersection with consideration of pedestrians, bicyclists, and motorists; climbed inside Volvo's rig equipped with the latest technology; and learned about NC A&T's student designed autonomous vehicle (Figure 2). Students were able to touch the displays and ask the exhibitors probing questions to gain a deeper understanding of the transportation field. With this type of exposure, more students are expected to consider pursuing a degree or a career in a transportation-related field in the future.

Figure 2: K-12 students engaging in transportation activities and exhibits at the CATM Transportation Awareness Day

Fourteen rising high school juniors and seniors were selected to participate in the Summer High School Transportation Institute (STI) at NC A&T. During the STI program students participated

in the Garrett Morgan Youth Symposium sponsored by the Conference of Minority Transportation Officials (COMTO) in Tampa, FL at Florida Polytechnic University. They also participated in a Transportation Shark Tank competition as their final project.

ERAU hired three high school students as interns during the summer 2019. These students worked with the graduate students in related projects. In addition, the interns and two additional high school students participated in a research workshop conducted at ERAU.

Technology Transfer

On May 7, 2019, CATM hosted the first NCDOT Research & Innovation Summit (Figure 3). The purpose of this summit was to facilitate the sharing of information regarding current research, technology, and innovations among the public sector, private sector, and academia. The all-day event was held on the campus of NC A&T and was attended by 181 transportation professionals from NC and surrounding states. Approximately 35% of the participants were from the public sector and 65% came from the academic and private sectors. Speakers at the conference included the NC Secretary of Transportation.

Figure 3: Snapshots from the NCDOT Research & Innovation Summit

VTTI showcased their CATM funded research at the 5th International Symposium on Future Active Safety Technology toward Zero Accidents (FAST-zero-19). The audience included industry, university, and government professionals researching how automation can improve roadway safety.

NCDOT engineers have been involved in applying the technology for the Travelers' Rationality project. While this will be a long-term strategy, the publications resulting from this project have been reviewed by NCDOT engineers for potential application.

What opportunities for training and professional development has the program provided?

In addition to the students at each of the member institutions who are receiving research specific training and professional development as it pertains to their projects, the NCDOT Research & Innovation Summit served as a professional development opportunity for practitioners at the NCDOT. These individuals earned professional development hours for participating in the summit.

Have the results been disseminated?

Information about activities that took place within the center during the reporting period were disseminated through the CATM newsletter, which was sent to individuals on the center's newsletter distribution list and posted on the CATM website. In addition, the following is a list of dissemination activities that took place for individual research projects during the reporting period.

- Last Mile project: In response to a VTTI press release, interviews were conducted with the TV stations WSLS, WDBJ, WFXR, WSET and the Roanoke Times in May and June 2019. The links to the articles are below:
  - https://vtnews.vt.edu/articles/2019/05/053019-vtti-autonomousshuttle.html?fbclid=IwAR09t4KxmEH-A9Hc--nhtfjqjyz-xXWZK0FXpCct4vOdX5OokDIfw5N_0QE
  - https://www.wdbj7.com/content/news/Virginia-Tech-researchers-testing-autonomous-shuttle-510684421.html
  - https://www.roanoke.com/news/nrv/no-steering-wheel-no-problems-researchers-testing-autonomous-shuttle-service/article_68a03e05-078b-5d41-ae45-04bbd47fef9a.html
  - https://wset.com/news/local/virginia-tech-releasing-a-new-autonomous-vehicle-for-research
  - https://www.masstransitmag.com/alt-mobility/autonomous-vehicles/press-release/21082984/virginia-tech-transportation-institute-lowspeed-ahead-meet-vttis-automated-shuttle
  - https://www.wric.com/news/local-news/vt-researchers-test-self-driving-shuttles-to-expand-campus-transportation/2044374332
  - https://newssmart.info/technologi/self-driving-bus-is-rolling-at-virginia-tech/
- Emergency project: Team members gave a presentation about the research to a general audience at Transportation Camp, FL and outreach presentations about the research at a high school student workshop. They also submitted and presented a poster at the UTC Spotlight Conference on May 14, 2019. The final project report, CATM-2019-R3-NCAT, was completed and posted on the CATM website during the reporting period.
- DRONETIM project: Team members submitted a paper that was accepted for the TRB2020 annual meeting proceedings. The paper is expected to be presented during the conference.
- Travelers' Rationality project: A total of seven papers directly related to this project were generated. Two papers were published in a journal, one paper for the proceedings in IEEE SoutheastCon 2019, one paper for the TRB 2020 proceedings, and three papers were presented at conferences and workshops.

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.

- Conduct proposal review process for Year 4 internal grant competition
- Develop autonomous vehicle webinar
- Review and post final reports for completed projects
- Continue research project specific activities
- Prepare and submit application for NC A&T's 28th Summer High School Transportation Institute
- Recruit students for NC A&T's 28th Summer High School Transportation Institute
- Hold the 3rd Annual CATM Symposium at ERAU
- Plan 2020 Transportation Awareness Day activities
- Apply for the 2020-21 Eisenhower Fellowship Scholars local competition
- Solicit applications for the 2020-21 TRB Fellowship Scholars and 2020-21 CATM Scholars
- Participate in the 2020 UTC Conference for the Southeastern Region
- Create and distribute the Spring 2020 newsletter

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 and 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 Economics	Greensboro, NC	Collaborative Research	Ryoichi Sakano, Ph.D.	NC A&T
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
Dept. of Human Development	Blacksburg, VA	Collaborative Research	Carolyn Shivers	Virginia Tech
Dept. of Psychology	Birmingham, AL	Collaborative Research	David Schwebel, Ph.D. & Despina Stavrinos, Ph.D.	UAB - Birmingham

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.; Richard Prazenica, Ph.D.	ERAU
North Carolina DOT	Raleigh, NC	In-Kind Support	Ted Baker	
North Carolina DOT	Raleigh, NC	Financial Support	Neil Mastin, Curtis Bradley, Ph.D.	
Florida DOT	Tallahassee, FL	In-Kind Support	Larry Ringers	
NASA JPL	Pasadena, CA	Collaborative Research	Hiro Ono	

Other collaborators or contacts involved

Maranda McBride and Hyoshin Park worked with researchers at NC State University and UNC-Chapel Hill on separate proposals that were submitted to the NCDOT's Transportation Centers of Excellence grant competition.

Andy Alden of VTTI collaborated with Hyoshin Park of NC A&T on three grant proposals. Two proposals related to use of unmanned aerial vehicles for support of ground traffic operations including emergency vehicles and one proposal focused on the implementation of a low speed autonomous vehicle in a retirement community to link with nearby transit and other important destinations such as healthcare facilities. Two of these proposals were selected for funding.

Three NC A&T faculty members continued their service as Dwight D. Eisenhower Transportation Fellowship faculty research mentors for the NC A&T Eisenhower Fellows.

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
<u>Journals</u>
- Chen, J., Liu, D., Namilae, S., Lee, S., Thropp, J. E., & Seong, Y. (2019). Effects of Exit Doors and Number of Passengers on Airport Evacuation Efficiency Using Agent Based Simulation. International Journal of Aviation, Aeronautics, and Aerospace, 6(5), published, acknowledgement of federal support: yes.
- Dekkata, S. & Yi, S. (2019). Steering control for autonomous vehicles using model predictive control, Journal of Mechatronics and Robotics, 3, 378-388, published, acknowledgement of federal support: yes.
- Derjany, P., Namilae, S., Liu, D., & Srinivasan, A. (submitted). Multiscale model for the optimal design of pedestrian queues to mitigate infectious disease spread, Plos One 2019, under review, acknowledgement of federal support: yes.
- Liu, D., Guo, S., Namilae, S., & Thropp, J. (submitted). Effect of strategy on the efficiency of evacuation process using agent-based simulation model, Human Factors and Ergonomics in Manufacturing & Service Industries, under review, acknowledgement of federal support: yes.

Books and Non-Periodical, One-Time Publications
- Nothing to report

Other Publications, Conferences, and Presentations
- Alden, A. (2019). Low-Speed Autonomous Vehicle Research presentation, NHTSA FMVSS compliance division visiting VTTI, acknowledgement of federal support: yes.
- Alden, A. (2019). Congressional Briefing presentation on Weather Impacts on Automated Vehicles, acknowledgement of federal support: yes.
- Alden, A. (2019). Automated Shuttle Research at VTTI, presented to FAA, CUTR, Volpe, and Pearce Transit, acknowledgement of federal support: yes.
- Alden, A. (2019). VTTI Overview on AV Research, presented to the Virginia Unmanned Systems Advisory Board, acknowledgement of federal support: yes.
- Alden, A. (2019). CATM Last Mile Project Autonomous Shuttle, demonstration and presentation on related activities for Nissan Corp., acknowledgement of federal support: yes.
- Assery N, Yuan X, Almalki S, Roy K, & Qu X, (2019). Comparing learning-based methods for identifying disaster-related Tweets, accepted by the 18th International Conference on Machine Learning and Applications (ICMLA 2019), acknowledgement of federal support: no.
- Chilukuri, D. (2019). Computer vision based mobility assistance system for vulnerable road user safety, presented at 8th NC A&T Annual COE Graduate Poster Presentation Competition, acknowledgement of federal support: yes.
- Chilukuri, D., Yi, S., & Seong, Y. (2019). Mobility assistance for vulnerable road users using machine learning, presented at IEEE Southeastcon 2019, acknowledgement of federal support: yes.
- Darko, J., Acquaah, Y., Folsom, L., Park, H., & Alden, A. (submitted). DRONETIM: Dynamic Routing of Unmanned-aerial and Emergency Team Incident Management, Proceedings of the 99th Annual Meeting of TRB2020, #20-02283, 2020, acknowledgement of federal support: yes.
- Darko, J., & Park., H. (2019). Vulnerable Road Users-Personalized, Optimum, and Dynamic (VRU-POD) Routing. Poster presentation for 2019 NCDOT Innovation Summit, NCAT Alumni-Foundation Event Center, acknowledgement of federal support: yes.
- Darko, J., & Park., H. (forthcoming). A dynamic transit model for vulnerable road users. Poster presentation at the 2019 INFORMS Annual Meeting, acknowledgement of federal support: yes.
- Dekkata, S.C. & Chilukuri,, D.M. (2019). Control of autonomous vehicles using MPC and machine vision with artificial intelligence, presented at 2019 Automated Vehicles Symposium, acknowledgement of federal support: yes.
- Folsom, L., Darko, J., Pugh N., & Park, H. (2019). Travelers' rationality in anticipatory online emergency response, presented at 2019 Safe Systems Summit, acknowledgement of federal support: yes.
- Guo, S., Liu, D., et al, (2019). Effect of strategies on the efficiency of airport emergent evacuation, Proceedings of the 2019 IISE Annual Conference, acknowledgement of federal support: yes.
- Islam, S., Parr, S., Liu, D., Prazenica, R., & Namilae, S. (2019). An epidemiological modeling approach to fuel shortages during hurricane evacuations, 2019 INFORMS Annual Meeting, acknowledgement of federal support: yes.
- Mhatre, S., Qu, X., & Davis, L. (2019). A MILP model for road restoration after a natural disaster, Proceedings of the 2019 IISE (Institute of Industrial and Systems Engineers) Annual Research Conference, acknowledgement of federal support: yes.
- Milner, M. N., Winter, S. R., Rice, S., Rice, C., Ragbir, N., & Baugh, B. (2019). Identifying influencing factors affecting pedestrians' willingness to interact with driverless vehicles. Presentation at the 10th International Conference on Applied Human Factors and Ergonomics, Washington, D.C., published, acknowledgement of federal support: yes.

- Namilae, S., Derjany, P., Liu, D., & Srinivasan, A. (forthcoming). Computational modeling framework for the study of infectious disease spread through commercial air-travel, accepted for IEEE Aero Conference, acknowledgement of federal support: yes.
- Namilae, S. & Islam, S. (2019). Is hurricane fuel shortage an epidemic? Transportation Camp, invited presentation, acknowledgement of federal support: yes.
- Park, H. (2019) Dynamic Transit Modeling. Oral presentation for 2019 NCDOT Innovation Summit, NCAT Alumni-Foundation Event Center, acknowledgement of federal support: yes.
- Pugh, N., Derjany, P., Park, H., Namalie, S., & Liu. D. (forthcoming). Deep adaptive learning for safe and efficient navigation of pedestrian dynamics - airport evacuation, accepted for Proceedings of the 99th Annual Meeting of TRB2020, #20-02081, acknowledgement of federal support: yes.
- Pugh, N., Derjany, P., Park, H., Namalie, S., & Liu. D. (forthcoming). Deep adaptive learning for safe and efficient navigation of pedestrian dynamics - airport evacuation, accepted for 2020 INFORMS Annual Meeting, acknowledgement of federal support: yes.
- Pugh, N., Derjany, P., Park, H., Namilae, S. & Liu, D. (submitted). Deep adaptive learning for safe and efficient navigation of pedestrian dynamics-airport evacuation, Transportation Research Record, acknowledgement of federal support: yes.
- Pugh, N., & Park, H. (2019). Prediction of secondary crash likelihood considering incident duration using high order Markov model, IEEE SoutheastCon 2019, acknowledgement of federal support: yes.
- Pugh, N., & Park, H. (submitted). High-order markov model for prediction of secondary crash likelihood considering incident duration. Transportation Research Board 2020 Annual Meeting, acknowledgement of federal support: yes.
- Qu, X., Davis, L., Mhatre, S., & Glass, C. (2019). Integrated decision-making model for the restoration of air and road transportation systems after a hurricane, Poster presentation at the UTC Spotlight Conference, acknowledgement of federal support: yes.

Websites or other internet material
- CATM Website: https://www.ncat.edu/cobe/transportation-institute/catm/index.php
- CATM Spring 2019 Newsletter: https://www.ncat.edu/cobe/transportation-institute/_files/pdfs/spring2019newsletterada.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/_files/pdfs/stibrochure2020ada.pdf https://www.ncat.edu/cobe/transportation-institute/summer-high-school-transportation-institute.php
- Website for Dr. Hyohsin (John) Park's research: https://johnpark.club/2019/10/14/park-lab-ncat-newsletter/

Technologies or techniques
- Technology for a predictive model for fuel shortages during hurricanes. Techniques described in papers. Working with FDOT officials to inform them of this approach.

Inventions, patent applications, and/or licenses
- Nothing to report

Other products
Software
- Software for optimal resource allocation to address fuel shortage (also models fuel shortage as an epidemic).

- Python modules developed to solve the deterministic optimization model for airline flights rescheduling, the network optimization models for road restoration after a hurricane, and the integrated decision-making model for optimal restoration decisions for a multi-mode (air and road) transportation system disrupted by a hurricane.

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 acquisition, setup, mapping, and training required to make the EasyMile shuttle operational has given the team an understanding of the difficulties in testing autonomous shuttle technologies. These issues with testing are amplified for real-world deployments in more complex environments.
- Emergency project: The findings from this study have demonstrated the effect of queue structure, group travel, and instruction on the efficiency of the evacuation process, understanding the effect of the variable factors, human factors, and environmental factors on the impact of evacuation efficiency. The data obtained through this project is increasing awareness and understanding of the importance of transportation systems and the impact of a natural disaster on transportation systems.
- Disability Survey project: The findings of this survey will provide both increased knowledge of the barriers facing people with disabilities in the academic community as well as directly support improved responsiveness to the needs of the disability community in the companion VRU-MAP project.
- Multiscale Model project: High-volume mass evacuations have led to fuel shortages lasting several days during several recent hurricanes. While news reports mention fuel shortages in many past hurricanes, the crowdsourced platform Gasbuddy has quantified the shortages in the recent hurricanes. Analysis of this data suggests the characteristics of an epidemic. The research team has developed an epidemiological model for hurricane fuel shortage and devised an optimal control strategy to mitigate the epidemic. Results show a direct correlation between evacuation traffic volume and fuel shortages. The control strategy is effective in estimating the level and duration of intervention required to mitigate the fuel shortage epidemic.
- Multi-agent project: The work performed for this project has increased the understanding of the pedestrian dynamics associated with path planning for airport evacuation processes and the results can be used to improve evacuation time in the case of an emergency.
- DRONETIM project: Successful use of UAVs will lead to quicker deployment of ERVs to emergency sites. This will lead to more lives saved, reductions in secondary crash occurrences, and reductions in delays affecting vulnerable road users.
- VRU-POD project: This study is increasing the understanding of the importance of preference and dynamically changing environments for VRUs and dynamic transit modeling.
- Real-Time project: This project is providing data that can be used to better understand the role of Intelligent Transportation Systems (ITS) in the response of a natural disaster.

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: This research is expected to identify gaps in ADA current guidance, which did not consider driverless automated vehicles when issued. The research is also expected to identify new policies that could facilitate testing and deployment of automated shuttle technologies in the future. VTTI team members hosted NHTSA FMVSS compliance division staff members on May 22, 2019 to demonstrate the EasyMile vehicle and associated safety protocols.

- Emergency project: Results from this study will provide insights for developing the training and management policies for emergency responses, including designing layout, planning, practice, and training strategies for improving the effectiveness of the pedestrian evacuation process under emergency.
- Multi-agent project: The developed evacuation policy and regulation will create new strategies to safely and efficiently evacuate pedestrians during evacuation.
- DRONETIM project: The application of UAVs has increased with the relaxation of Federal Aviation Administration (FAA) rules, technological advances, and battery efficiency improvements. UAVs also have been actively used for crash scene reconstruction as well as fire and rescue operations. However, there has been a lack of application of UAVs to assist in the deployment of ERVs in freeways and arterial roadways, which is important for the mobility of citizens in critical circumstances. This study is providing data to help fill this gap.
- VRU-POD project: The results of this study are expected to provide data that will assist public transit designers to create transportation systems that will accommodate VRUs in a more user-friendly manner.

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: In addition to the documentation of how hands-on experience with automated technology can impact user attitudes and acceptance, this research will uncover how vulnerable road users prefer to utilize an autonomous shuttle.
- VRU-MAP project: Several papers detailing the knowledge obtained throughout the duration of this study have already been published and presented at multiple conferences including IEEE Southeastcon and the Automated Vehicle Symposium.
- Emergency project: In addition to providing decision-making models for road restoration and flight rescheduling for disaster management, this project demonstrates the effects of individual factors on evacuation efficiency is not well understood. This study examined these effects by combining data from field observation, past literature, and using an agent-based simulation approach to investigate the effect (including the interaction effect) on the time for evacuation. Three journal papers documenting the results were submitted during this reporting period.
- Disability Survey project: The final report and anticipated journal article describing this project will provide a significant increase in the body of knowledge surrounding the transportation-related barriers for people with disabilities.
- Multiscale Model project: This research will result in publications, a new approach to model fuel shortages, and aid in hurricane evacuation processes.
- Multi-agent project: This is the first effort to integrate models from the two different fields: social force model and route optimization.
- DRONETIM project: This work will improve processes associated with route searching and providing traffic information using UAVs in traffic incident management.
- VRU-POD project: Data collected for this project will enable VRU preferences to be incorporated into the design of the VRU-MAP app.

The following projects are expected to result in improved processes, technologies, techniques and skills in addressing transportation issues:
- Last Mile project: This research will identify how communication, outreach, and training practices can improve adoption in the real world. Specifically, the research will study the effectiveness of hands-on experience with automation in shaping rider opinion and adoption.
- Multiscale Model project: This study will result in a model to facilitate optimal resource allocation to address fuel shortages and help in hurricane evacuation.
- Multi-agent project: Previous transportation models have ignored either pedestrian dynamics or routing, but this work will improve the design of integrated evacuation planning.
- DRONETIM project: This project will result in a new line of research in UAV-guided ERV routing.

- VRU-POD project: This study will result in dynamic optimization, programming, and modeling for last mile transit options.

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 for the EasyMile shuttle vehicle.
- Research projects: Students engaged in the various research projects are expanding their knowledge of the transportation industry and obtaining the domain specific knowledge associated with their projects. These students are being trained at several educational levels and in various specialties so they can contribute to the field of transportation and transportation safety in the future.
- NCDOT R&I Summit: This event brought together transportation practitioners, researchers, and students in a forum that facilitated information sharing and candid conversations about the current state and future direction of the transportation industry.
- STI Program: The high school students who participated in the STI program were exposed to each mode of transportation using hands-on experiences and demonstrations. Most of these students come into the program with no real idea of the vast nature of the transportation industry; however, all walk away with a better understanding of how broad the field truly is. Several of these students who did not indicate any specific interested in pursuing a career in transportation expressed an interest at the end of the program.

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

- Last Mile project: In addition to the best practices in training and outreach on automated vehicles that are likely to result from this study, the training and outreach involved may in turn lead to new deployment initiatives.
- Multiscale Model project: A new model for hurricane-related fuel-shortages as an epidemic has been created and will be presented to transportation officials for consideration.
- DRONETIM project: With MPO planners and state DOT engineers as targeted users, the research team will also focus on how to better construct network-wide day-to-day and seasonal travel time/on-demand databases by locating and routing mobile sensors to better characterize both mean and uncertainty of end-to-end path travel time in a regional network.
- VRU-POD project: This project will result in the ability to model specific user preferences using exponential functions.

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	0

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	24
		Number of peer-reviewed journal papers published	2	8
		Number of newsletter articles, conference papers, and technical reports published	10	16

5. IMPACTS:

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

- Emergency project: The optimization models and corresponding Python modules developed for airline recovery and road restoration will improve the effectiveness and efficiency of response activities in local and regional transportation systems during and after a hurricane.
- DRONETIM project: Partial knowledge about the traffic condition is typically available from various traffic sensors, but it needs to be complemented with additional observations from UAV on-board sensors. This project focuses specifically on determining how UAVs should behave to assist ERVs in the autonomous execution of tasks.

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?

- Last Mile project: Feedback provided by this team is being used by EasyMile to improve their autonomous vehicle products.
- VRU-MAP project: Upon completion of the project, it is anticipated that the prototype navigation system developed will serve as the foundation for a commercial technology that will greatly improve the ability of people with disabilities to navigate through the world.
- Emergency project: The Python modules developed for flights rescheduling and road restoration after a hurricane can be used by government agencies to support their decision making during disaster management.
- Disability Survey project: The output of this project, in the form of prioritization of transportation-related barriers for people with disabilities, will inform the design of a prototype navigation application which may eventually be commercialized or form the foundation for a commercialized application.
- Multiscale Model project: An optimal control methodology for resource allocation to reduce fuel shortages was developed along with codes for on-the-fly analysis. The methodology and codes were tested for the beginning stages of fuel shortage during the recent Hurricane Dorian. Both

can be used to aid hurricane evacuation by transportation and emergency management organizations.

- Multi-agent project: The resulting model will be utilized to determine intermediate goals for each pedestrian particle, which is a key input for the time-based evolution of pedestrian trajectories.
- Real-Time project: Factors affecting drivers' choice of evacuation routes will be identified along with the factors and actions of the current NC ITSs that can benefit a hurricane evacuation. The contributing factors will support the NC government's efforts to organize an effective emergency evacuation.

What is the impact on the body of scientific knowledge?

- VRU-MAP project: The outcomes of the VRU-MAP project will improve the body of knowledge of disability studies and psychology, with direct impacts on the understanding of ways to improve mobility and safety for people with disabilities.
- Emergency project: This work will provide quantitative tools for decision-making of road restoration and flight rescheduling in emergency situations.
- Disability Survey project: The data from this project speak directly to the psychology-related needs of the Persons With Disabilities (PWD) community, including their thoughts and opinions related to transportation, as well as individual and structural barriers to transportation for that community.
- Multiscale Model: A model for hurricane-related fuel shortages was developed treating the shortage as an epidemic. Parameter estimation methods were used including Kalman filters to obtain dynamic parameters for the model. A correlation between evacuation traffic and fuel shortages was developed and utilized to create a predictive model. All of these results have been, or will be, presented in journals and conference papers to impact the knowledge base in transportation.
- Multi-agent project: The project outcome will lead to a multidisciplinary computational framework for understanding and modeling the human decision-making process and resulting actions in emergency evacuations.
- Real-Time project: The factors identified for drivers' choice of evacuation routes will be used to develop driver behavior models under emergency. The factors for rescheduling airline passengers will be used in developing the model of airline passenger rescheduling. The factors and actions of the NC ITSs for a hurricane evacuation will be used to develop a simulation testbed for NC government agencies to evaluate traffic control plans/policies during a hurricane evacuation.

What is the impact on transportation workforce development?

- VRU-MAP project: This project has funded numerous undergraduate and graduate students. It is providing foundational experience associated with doing scientific research as well as experience presenting data verbally and via the written word.
- Emergency project: Three graduate students and one undergraduate student have been involved in the project during this reporting period. Half of these students are female. Working on this project prepares them with a better understanding of the importance of transportation systems and the impact of a natural disaster on transportation systems.
- Disability Survey project: Three undergraduate students have been involved throughout the research project, allowing them to experience and participate in a transportation-related research study from initiation through planning, conduct, and conclusion.
- Multiscale Models project: Two of the master's degree students working on this project are nearing completion of their studies. These students are expected to accept jobs in the transportation industry. Three high school interns worked with the grad students on related projects. A high school research workshop was conducted with 5 participants using content associated with this project. Some methods linked to this project were developed as a part of the research used in course work.

- Real-Time project: Four graduate students (2 females) and one female undergraduate student have been involved in the project. Working on this project prepares them with a better understanding of ITS and the role of an ITS in the response of a natural disaster.

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	4 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:

Progress for several projects were delayed slightly due to the late distribution of the Year 3 funding.

7. SPECIAL REPORTING REQUIREMENTS

Nothing to report for this period.