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UTC Semi-Annual Progress Report

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Center for Regional and Rural Connected Communities

UTC Semi-Annual Progress Report

June 1, 2023 - September 30, 2023

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1601 E. Market Street, Greensboro, NC 27411

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Signature of Submitting Official Karimoddini

Ali Karimoddini, Ph.D.

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ACCOMPLISHMENTS

1. What are the major goals of the program?

The primary goal of *CR²C²* is to *"plan, implement, and evaluate an integrated research, education, workforce development, and technology transfer approach for providing innovative connected and coordinated multimodal technological solutions to enable and improve equitable, efficient, and effective mobility services for the movement of people and goods primarily, but not exclusively, in rural and underserved communities*."

To achieve this goal and support USDOT Innovation Principles, *CR²C²* will develop flexible and adaptable solutions for adopting emerging technologies in rural areas via competitive Research and Education Exploratory (REE) Grants and three intertwined, transformational, and multi-university Major Research Initiatives (MRIs):

- MRI 1: Integrating Emergent Technologies into **Transportation Planning** and Policy for Rural and Underserved Communities;
- MRI 2: **Technological Solutions** for Connected, Safe, Reliable and Secure Transportation Services in Rural and Underserved Communities; and
- MRI 3: Equitable **Mobility Services** for Goods and People in Rural and Underserved Communities.

The Center will also create a pathway toward developing future leaders for both students and faculty members, with a focus on underrepresented minorities, to help them become leaders and contributors to the field of transportation.

In addition, *CR²C²* aims to increase the existing pipeline of transportation professionals with the various skills required to develop a creative workforce for addressing transportation challenges in rural and underserved communities by integrating a wide range of education and workforce development components into the Center's daily activities.

Finally, *CR²C²* will provide leadership through technology transfer to stakeholders throughout the region and propose a sustainable and inclusive Technology Transfer and Collaboration (TTC) program to foster and support collaborative technology transfer efforts across all member institutions.

1.1. What was accomplished under these goals?

The Center started the activities effective June 1, 2023. Most activities have been around setting up collaborations, expectations, and team effort to execute the planned activities, establishing and initiating the processes, and executing subcontract agreements to bring all consortium members on board. All subcontract agreements with six subcontractors are executed. With the momentum that existed among team members, major accomplishments were achieved in Research, education, outreach, and technology transfer as detailed below:

1.2.1. Accomplishments under the Center Research

During the proposal development, we had already selected 8 projects based on the review feedback from stakeholders and the Center leadership. During this reporting period, for all projects, a steering committee was formed, and a separate kickoff meeting was organized. The project team provided the following documents:

- Project Summary (Exhibit D), which is posted online on the projects' website.
- Project Detail (Internal to the Center)
- Project alignment with USDOT RD&T strategic Plan

For each of the projects, a separate webpage is created. Also, the information about each project was uploaded to the Transportation Research Board's Research in Progress (RIP). Regular meetings were set up between team members of the projects, and the projects have started the activities and made progress as summarized in the below table:

Table 1: Progress of research planned activities.

Activity	Link to the Activity Website	Scheduled Start Date	Actual or Planned Start Date	Scheduled Completion Date	Actual or Planned Completion Date	Cumulative Percent of Completion
Project 1-1: Designing Tools for Assessing Readiness of Rural Communities for New Technologies	Project 1-1	8/1/2023	8/1/2023	7/31/2025	7/31/2025	5.25 %
Project 1-2: Rural Healthcare and Transportation Deployment Planning	Project 1-2	8/1/2023	8/15/2023	7/31/2025	7/31/2025	2.25 %
Project 1-3: Benefit-Cost Analysis of Rural CAV Deployment	Project 1-3	8/1/2023	8/1/2023	7/31/2025	7/31/2025	1.5 %
Project 2-1: Cost-Effective and Reliable Data and Communication Infrastructure for Enhancing Rural Transportation Safety and Efficiency	Project 2-1	8/1/2023	8/15/2023	7/31/2026	7/31/2026	2.1%
Project 2-2: A Data-Driven and Equitable Solution to Address Electric Vehicle Charging Needs in Rural and Underserved Communities	Project 2-2	8/1/2023	9/1/2023	7/31/2026	7/31/2026	0.5%
Project 2-3: Developing Connected Microtransit Vehicles for Equitable Mobility Service for Rural and Underserved Communities	Project 2-3	8/1/2023	8/1/2023	12/31/2027	12/31/2027	2.6 %
Project 3-1: Optimal and Safe Route for Freight Transportation in Rural Areas	Project 3-1	9/1/2023	10/1/2023	8/31/2025	8/31/2025	4.1%
Project 3-2: Community-Oriented and Data-Driven Mobility Modeling for Rural and Disconnected Communities	Project 3-2	8/1/2023	8/1/2023	12/31/2026	12/31/2026	5%

Highlights about achievements under these projects:

- **Conducting Literature Survey**: the team has reviewed the literature on topics related to the following topics:
    - Mobility and accessibility barriers faced by rural and disconnected communities in Region 4, such as transit deserts, food deserts, and healthcare shortage areas. The team has focused on how the terms are defined, ways for identifying them, and case studies for transit deserts in Region 4. As a result, the team has compiled a list of data sources available for the evaluation of mobility and accessibility barriers.
    - The needs of rural disadvantaged communities and strategies for implementing new transportation technologies in such communities. A few notable findings from the literature review are:

        - The lack of accessible vehicles for people with disabilities in disadvantaged communities.
        - The lack of public and private investments in transportation programs.
        - Limited travel options, e.g., few public transportation routes, non-existent sidewalks, and scarcity of door-to-door transportation services.
    - Benefit-cost analysis of rural CAV deployment from three aspects: 1) synthesizing the benefits/impacts of CAV technologies on transportation systems, 2) learning the methods developed/adopted by other researchers to evaluate CAV benefits/impacts, and 3) exploring data sources from existing studies.
    - Safety applications and CAV challenges in rural areas, and sensing technologies and video-based scene understanding for rural road safety applications as well as transportation data and communication infrastructure. We also started reviewing the state-of-the-practice advanced technologies from the perspective of the feasibility of implementation in rural areas. The Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) provides a comprehensive framework for designing, defining, and integrating intelligent transportation systems. We have started studying this framework to be able to map the systems or applications we select to ARC-IT corresponding system architecture and functional requirements.
- **Analyzing rural disadvantaged communities in the Southeast region**. Using the recently released USDOT Equitable Transportation Community Data, the research team identified disadvantaged rural census tracts in the Southeast. The indicators used to identify such communities included Transportation Insecurity, Environmental Burden, Health Vulnerability, Social Vulnerability, and Climate and Disaster Risk Burden. The analysis revealed large clusters of disadvantaged communities in the rural Southeastern region.
- **Exploring the available resources**: The team compiled a list of publicly available data sources across Region 4 in 3 categories: (a) data on exogenous determinants of mobility and accessibility barriers, (b) data on derived transportation disadvantage indices, and (c) related data on mobility and behavior patterns.
- **Initial planning for development of advanced multimodal routing algorithms tailored to rural needs**: The team started developing algorithms aimed to enhance freight route planning, reduce travel distances, and optimize delivery schedules in rural areas, ultimately improving transportation efficiency and safety.
- **Upfitting a testbed microtransit vehicles**: A testbed of three self-driving GEM E6 Polaris at NCA&T was upfitted for deployment in public streets. This effort included the installation of new computing units and additional cameras and Lidar sensors in order to achieve an enhanced perception. Figure 1 shows part of the added sensors to enhance the perception of the system.

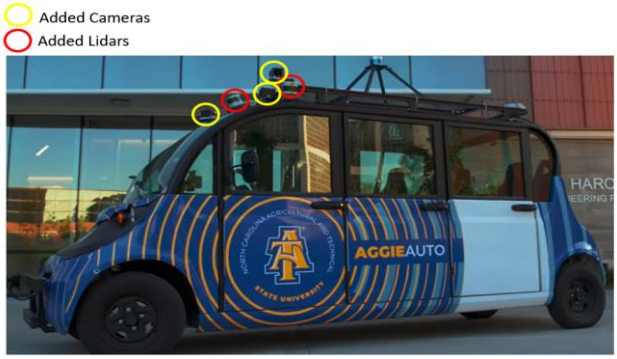

Figure 1. Added sensors to enhance the perception of the vehicles.

- **Developing an application software for live tracking of shuttles**: The autonomous shuttles at NCA&T were upfitted to be connected to the cloud and stream their location information. An early prototype of a software application was developed for vehicle tracking. Figure 2 shows a snapshot of the developed software application in which one of the vehicles (Vehicle 2) is captured.

Figure 2. A snapshot of the developed application software for live tracking of the autonomous microtransit vehicles.

- **Launching a pilot program for public deployment of microtransit vehicles**: A pilot program for public deployment of microtransit vehicles was kicked off in Sep 2023. This event was joined by FHWA Associate Administrator of Highway Policy Randall K Benjamin, II, NC Secretary of Transportation Eric Boyette, FHWA Special Administrator Yolonda Jordan, Greensboro Mayor Nancy Vaughan, and many other federal, state, and local leaders, during which CR^2C^2 researchers launched Aggie Autonomous Shuttles to serve the underserved community in East Greensboro by connecting the NCA&T neighboring area to downtown Greensboro. For more details, please refer to the NCA&T public release about this event: https://www.ncat.edu/news/2023/09/dtgso-aggie-auto.php. Figure 3 shows the ribbon cutting for the kickoff event for this pilot program.

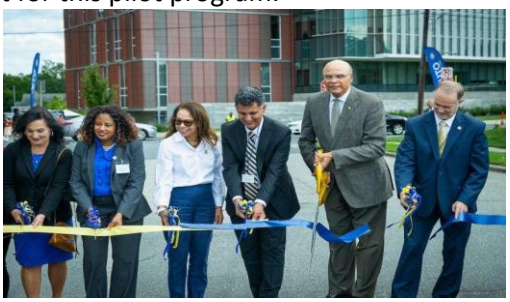

Figure 3. The ribbon cutting event for the pilot program for deploying autonomous microtransit vehicles between NCA&T neighboring area and downtown Greensboro.

The uniqueness of the implemented pilot program lies in:

1. The development of the shuttles' autonomy in-house.
2. The pilot program's route, which extends through the downtown area.
3. Its service coverage of the A&T neighboring area, identified as a food desert, and East Greensboro, an underserved community.
4. The utilization of a fleet of THREE self-driving shuttles in the pilot program.
5. The vehicle's speed, which is set at 25 mph.
6. A pivotal step towards the integration of microtransit vehicles into a multimodal transportation system. The stop in front of the Children's Museum is just a 7-minute walk from the Douglas Galyon Depot, the central hub for 22 buses and the train station. Additionally, the area is well-served by micro-mobility options, including e-bikes and e-scooters.

- **Utilizing advanced transportation technology developed in-house to serve the underserved communities of East Greensboro**: One of the main objectives of this project is to identify service gaps and currently unmet demands that could be addressed by the deployment of advanced transportation technologies such as microtransit vehicles. The above-mentioned pilot program involved autonomous microtransit vehicles to connect disconnected communities in Greensboro: N.C. A&T State University and its neighboring area in District 2, an underserved community with businesses and establishments in downtown Greensboro in District 3. The location of the implemented pilot program has one of the most diverse populations in Greensboro. Figure 4 shows the route being used for this pilot program in red overlapped with the demographic index in EJScreen, which combines the percent low-income and percent minority factors explicitly named in the Executive Order 12898 on Environmental Justice for the area the route passes through. Nearby District 3 encompasses the downtown area and includes numerous businesses and establishments. Therefore, this pilot program demonstrated that autonomous microtransit vehicles could create a significant impact by offering a new, more flexible shared mobility option to an underserved community, connecting residents to job opportunities, services, and resources in the downtown area**.**

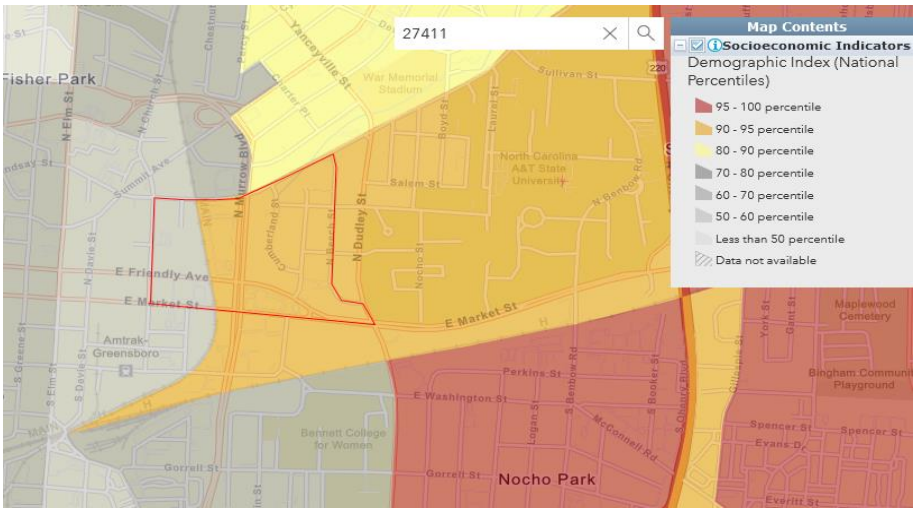

Figure 4. The socioeconomic indicators for the area where the pilot program is implemented. Data source: Environmental Justice mapping and SCREENing (EJScreen) tool.

- **Data collection for assessment of public perception and trust on autonomous microtransit vehicles:** Pre- and post-ride survey instruments have been developed and are currently being used to assess the public perception and trust in autonomous transit vehicles through the public deployment of Aggie Auto Self-Driving shuttle September 18 through October 13, 2023. The results from this will help us further refine the survey and create the interview and focus group questions for this project.

Research and Education Exploratory (REE) Grants: The *CR²C²* Center started the process of providing REE Grants through a competitive process. These competitive seed grants will be available to faculty, researchers, and professionals within the consortium to conduct projects on emerging concepts and novel approaches to addressing transportation challenges in rural and underserved communities. One of the awarded projects will be dedicated to equity and must be aligned with the objectives of the Equity 360 program of *CR²C²* or equity-focused research on technological solutions for rural transportation or increasing the involvement of underserved minorities in research, education, and technology transfer activities. The process has two major steps:

1. Selection of project ideas (white papers)
2. Selection of full proposals

The call for project ideas was released on Aug 1, which is available at https://www.cr2c2.com/research/call-for-project-ideas-2023. Top proposals were selected for the next round (full proposal) based on a peer-review process involving three review reports, at least one of which was obtained externally from stakeholders.

1.2.2. Accomplishments under the Center Education and Workforce Development (EWD)

Several initiatives started within the *CR²C²* Center toward Education and Workforce Development as listed in Table 2.

Table 2: Progress of EWD planned activities.

Abbreviated Task Title	Link to the Activity Webpage	Scheduled Start Date	Actual or Planned Start Date	Scheduled Completion Date	Actual or Planned Completion Date	Cumulative Percent of Completion
Supporting the Summer High School Transportation Institute (STI)	*CR²C²* Support for STI	6/1/2023	6/1/2023	5/31/2028	5/31/2028	20%
Autonomy Graduate certificate	Certificate programs	6/1/2023	6/1/2023	5/31/2028	5/31/2028	5%
Supply Chain Management graduate certificate	Certificate programs	6/1/2023	6/1/2023	5/31/2028	5/31/2028	5%
Minority-Serving Institutions (MSI) Outreach Program	MSI Outreach program	8/1/2023	9/1/2023	5/31/2028	5/31/2028	2%
Transportation core skills gap analysis	NA	8/1/2023	8/1/2023	4/1/2024	4/1/2024	25%
Undergraduate Minority Internship Program	UG Minority Internship	6/1/2024	6/1/2024	5/31/2028	5/31/2028	15%
Supporting the Autodrive Challenge	Autodrive Challenge	6/1/2023	6/1/2023	5/31/2026	5/31/2026	8%

- In July 2023, *CR²C²* supported the **Summer Transportation Institute** and hosted a record of 20 participants. The participants were rising juniors and seniors hailing from North Carolina, South Carolina, Georgia, Florida, New York, Texas, Maryland, and Virginia. https://www.cr2c2.com/education-and-outreach/k-12-outreach-programs/summer-transportation-institute-sti
- Two graduate certificate programs, including **Autonomy Certificate and Supply Chain Management Certificate** were offered starting from Fall 2023. Courses are planned to be offered as a part of this program and students' enrolment will be tracked. https://www.cr2c2.com/education-and-outreach/student-engagement-opportunities/offered-courses-and-learning-modules
- Planning started for implementing the **MSI outreach program** through which MSI faculty and students in transportation-related disciplines will visit *CR²C²* facility allowing them to learn more about *CR²C²* transportation research programs. Attendees will also engage in activities to help

them develop their own transportation research programs and network with other researchers interested in transportation. Also, initiated outreach to HBCUs/MSIs within the UTC program to identify ways we can support their efforts to improve their transportation programs. https://www.cr2c2.com/education-and-outreach/outreach-programs/msi-outreach

- Planning started for implementing the **Undergraduate Minority Internship Program** through which we will work with industry collaborators to provide transportation industry internships for minority undergraduate students. Furthermore, we met with potential industry sponsors and started planning for and finalized student/industry pairings for the undergraduate minority internship program. https://www.cr2c2.com/education-and-outreach/student-engagement-opportunities/undergraduate-minority-transportation-industry-internships
- *CR²C²* faculty supported the NCA&T Aggie Auto Autonomous (A3) team to participate in the AutoDrive national competition which involves ten universities from North America, including Canada. Since June 2023, the team began preparing for year three by improving the vehicle's perception, specifically in Lidar-Camera fusion, as well as mapping, navigation, motion planning, and controller development. The team also attended the Year 3 kickoff event to discuss the rulebook and CAN messaging/scoring requirements. The team also met engineers from General Motors (GM). Other sponsors, such as Intel, Hexagon, and Cepton showcased their products. GALLUP provided guidance on using their strength assessment tools. https://www.cr2c2.com/education-and-outreach/student-engagement-opportunities/autodrive-challenge

In addition to the above-listed initiatives, education and outreach activities have been undertaken to reach members of communities who may not be necessarily aware of advanced transportation technology research programs. These programs' activities played an important role in enhancing public understanding and increasing interest in transportation careers.

- In June 2023, around 40 high school students and teachers from Eastern North Carolina toured the *CR²C²* facility. The Saunders Science Scholars Program was modeled after Morehead's family science enrichment program, which encourages young people and their families to get more involved with science. The program is part of outreach initiatives that address gaps in STEM education across North Carolina, specifically in rural communities such as Gates County. https://www.cr2c2.com/news-and-events/science-scholars-program
  - In Sep 2023, *CR²C²* Researchers and NCDOT organized a workshop for first responders to discuss the incident management plan for autonomous vehicles https://www.cr2c2.com/news-and-events/firstrespondersworkshopreport

1.2.3. Accomplishments under Technology Transfer and Collaboration (T2C)

Several initiatives started within the *CR²C²* Center toward Technology Transfer and Collaboration Development as listed in Table 3.

Table 3: Progress of EWD planned activities.

Abbreviated Task Title	Link to the Activity Webpage	Scheduled Start Date	Actual Start Date	Scheduled Completion Date	Actual-Planned Completion Date	Cumulative Percent of Completion
CR²C² Research Seminars	Research Seminars	6/1/2023	6/1/2023	5/31/2028	5/31/2028	5%
CR²C² Annual Meeting		6/1/2023	6/1/2023	5/31/2028	5/31/2028	5%

- We started planning for ***CR²C²* Seminars**, planned for the second Thursday of each month with the following two planned talks:
    - Oct 12, 2023: "Measuring Accessibility to Destinations: National trends, local application" by Andrew Owen and Saumya Jain from Center for Transportation Studies at the University of Minnesota
    - Nov 9, 2023: NCDOT's vision for mobility in North Carolina, by Sarah Searcy, Senior Advisor for Innovation, Integrated Mobility Division (IMD), North Carolina Department of Transportation
- Received a Technology Transfer funding from NCDOT to pilot the deployment of autonomous shuttles. https://connect.ncdot.gov/projects/research/Pages/ProjDetails.aspx?ProjectID=2023-35
- Planning started for *CR²C²* Annual Meeting, which is tentatively set for April 17-18. Details of the agenda and other logistics will be planned during the next few months.
- Collaborating with stakeholders and leveraging the *CR²C²* funding, several projects were awarded to be used as a cost-share for increasing the impact of *CR²C²* activities, including:
    - Collaborated with industrial partners including General Motors, VOLVO, Verizon, RTI, Google, Waymo, and Intel during the development of technological solutions for transportation problems.
    - *CR²C²* researchers at FAU co-organized a workshop on Smart Freight Transportation: Last - Mile Logistics Challenges in the "New Normal" at 26th IEEE International Conference on Intelligent Transportation Systems ITSC 2023 that took place in September 2023 in Bilbao Bizkaia, Spain. https://www.cr2c2.com/news-and-events/itsc2023

1.3. How have the results been disseminated*?*

- The center website was launched at https://www.cr2c2.com to disseminate the Center projects' outcomes. Each project has a dedicated page under the project. The center also started an active presence in social media, including:
    - LinkedIn https://www.linkedin.com/company/cr2c2/
    - Twitter: https://twitter.com/CR2C2UTC
    - YouTube: https://www.youtube.com/@CR2C2UTC
- The projects' information was uploaded to the Transportation Research Board's Research in Progress (RIP).
- A public repository was created https://digital.library.ncat.edu/cr2c2/ using Aggie Digital Collections, the repository platform, Digital Commons, is managed by the F.D. Bluford Library and hosted by bePress.
- The research outcome of the project was disseminated via 14 peer-reviewed journal and conference papers (See Section 3 for details). Also, the research results of the research team were presented at 6 conferences.
- In Sep 2023, *CR²C²* researchers launched Aggie Autonomous Shuttles to serve the underserved community in East Greensboro by connecting the NCA&T neighboring area to downtown Greensboro. https://www.cr2c2.com/news-and-events/launchshuttles
- In Sep 2023, *CR²C²* team developed a documentary about deployment of microtransit vehicles to serve underserved communities https://www.youtube.com/watch?v=vPznZwcn1Us
- In Sep 2023, worked with PBS Carolina about the effort of *CR²C²* researchers to develop autonomous cars and address the challenges for deployment in rural roads. https://www.cr2c2.com/news-and-events/av-rural-pbs
- The kickoff event for public deployment of the Aggie Autonomous Shuttles was well attended by more than 150 transportation professionals on the first day (Sep 18), and then it was open to the public from Sep 19-Oct 13. This brought so much excitement to the community and was well covered by media outlets some of which are listed below:
    - University press release: https://www.ncat.edu/news/2023/09/dtgso-aggie-auto.php

- ABC45: ttps://abc45.com/news/local/at-opens-autonomous-shuttle-service-for-the-public
- Winston Salem Journal: https://journalnow.com/news/local/the-future-of-transportation-nc-a-t-develops-launches-trial-of-driverless-electric-shuttles/article_5c4a29a4-5672-11ee-b017-a7336a8b0949.html
- News & Record: https://greensboro.com/news/local/self-driving-shuttles-an-nc-a-t-pilot-program-should-begin-later-this-year/article_8a37974c-b2f4-11ed-91bb-df408342e124.html
- North State Journal: https://nsjonline.com/article/2023/09/nc-at-unveils-fleet-of-driverless-cars-to-connect-campus-to-downtown/
- Spectrum News: https://spectrumlocalnews.com/nc/charlotte/news/2023/09/19/nc-a-t-autonomous-vehicles
- WFMY News 2: https://www.wfmynews2.com/article/news/education/north-carolina-at-launches-aggie-auto-shuttle-pilot-program-self-driving-cars-campus-to-downtown/83-89cd32f1-9058-49cf-a56f-c83cd6a44a9f
- NCDOT Press Release: https://www.tarpo.org/2023/09/ncdot-supports-new-autonomous-shuttle-pilot-at-university/
- Automoblog: https://www.automoblog.net/nc-at-self-driving-shuttles/
- Yes! Weekly: https://www.yesweekly.com/education/beep-beep-nc-a-t-su-offers-a-free-autonomous-shuttle/article_7332c312-57bf-11ee-910c-6b281a4ae981.html
- WFDD: https://www.wfdd.org/story/nc-ats-self-driving-shuttles-are-making-pilot-runs-downtown-greensboro
- WXII12: https://www.wxii12.com/article/greensboro-partners-with-nc-aandt-for-autonomous-shuttle-route/45218497

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

- We will continue the literature review, refine the developed algorithms, and improve the autonomous shuttle platforms. Some areas of focus of the next phase of the literature survey include searching for diversity criteria and metrics for diversity in communities and transportation systems; gaps in current charging infrastructure, Rural Electric Vehicle Behavior, Charging Station Optimization, electric vehicle-related routing problems; scheduling for a fleet of microtransit vehicles using artificial intelligence and optimization based methods; vehicle passenger cooperation to identify optimal pickup and drop-off locations
- We will collect further data resources and will clean and organize the collected data in order to develop a database by the complete synthesis of a “data lake” for the projects including (a) what data, (b) resolution, (c) geospatial elements, (d) link for download, (e) sample data/data-dictionary/metadata.
- We will complete the data collection for public perception and trust in autonomous shuttles and will analyze the collected data to determine if additional modifications are needed.
- Additionally, we will engage with stakeholders on how to conduct performance evaluations and validation tests to ensure the system's reliability and effectiveness in improving rural public transportation and freight transportation.
- We will collect sociodemographic and disadvantaged communities’ data and conduct spatial analytics to explore differences among rural communities in terms of various indicators over space and time.
- We will look at the HRSA data on healthcare provider shortages (HPSA and IMU scores) and document the transit and mobile health clinic status in the counties of four states (KY, NC, AL, FL).
- We will identify regions, case studies, and current/planned study communities where mobility models can be tested and where our Autonomous Shuttle testbed can be deployed. We will use a systemic method, e.g., by creating a decision matrix for discussion and selection of study areas. Once the areas are selected, in the future phases, we will collect transportation supply data for the selected study

areas. The team will start the process for IRB approval to meet with community leaders and local officials.

- We will continue the development of the testbed of autonomous microtransit vehicles. In particular, a new computing system will be installed and configured to enhance the onboard computing of autonomous shuttles to handle more sensors and more advanced perception algorithms.
- We will produce a tool that brings clarity to the planning process resulting in more rural, small urban, and underserved areas being considered for new technological solutions, e.g., ICT. Using this tool, we will assess the emerging technology readiness of rural and disadvantaged communities.
- To accelerate and enhance the application of the new tools, a training course will be developed and offered through the Local Technical Assistance Program (LTAP).
- We will assess the collected data during the public deployment of Aggie Autonomous Shuttles in the underserved communities of East Greensboro to identify technical challenges to be addressed in the next prototypes. This includes adding new vehicles that can handle rail crossing, adding more computing resources, enhancing the perception of vehicles for better detection of objects, enhancing the autonomy level of autonomous shuttles, and better situational awareness for intersection handling. This will help us to develop a roadmap for future developments to address these technological gaps.
- We will select new REE Grants and kick them off in January 2024.
- We will continue monitoring the progress of the existing projects on a quarterly basis.
- We will continue the education and workforce development efforts by offering Autonomy and Supply Chain Management graduate certificates; conducting transportation core skills gap analysis; Implementing the Undergraduate Minority Internship Program by student/industry pairing, supporting the Autodrive Challenge, implementing Minority-Serving Institutions (MSI) Outreach Program by reaching HBCUs/MSIs within the UTC program to identify ways we can support their efforts to improve their transportation programs. We also started several new initiatives, including:
    - Transportation Diversity Scholarship https://www.cr2c2.com/education-and-outreach/student-engagement-opportunities/transportation-diversity-scholarships
    - Equity Council https://www.cr2c2.com/equity-360
- We will continue the technology transfer and collaboration efforts by offering seminar series and planning for transportation events including the *CR²C²* annual event. We also started new initiatives, including:
    - The Demonstration and Deployment Forum (DDF)
    - Minority-focused Entrepreneurship and Commercialization Forum (MECF)

2. PARTICIPANTS & COLLABORATING ORGANIZATIONS

Partnerships with stakeholders, industry partners, and university collaborators were extended as summarized in the below table:

		Contributions from partners				
Organization Name	Location of organization	Financial Support	In-Kind Support	Facilities	Collaborative Research and Education	Staff exchanges, technical input, engagement, visit
NCDOT	NC	X			X	X
FHWA	DC	X				X
City of Greensboro	Greensboro, NC			X	X	X
Downtown Greensboro Inc.	Greensboro, NC	X			X	X
Google	CA	X				X
Waymo	CA	X				
VOLVO	NC	X				X
Verizon	NC	X				X
Intel		X				
General Motors					X	
SAE International		X				
Sandia National Lab		X			X	X
Center for Advanced Transportation Mobility	Greensboro, NC	X	X		X	
Morgan State University					X	
Howard University					X	
Prairie View A&M University					X	
UNC Chapel Hill					X	
NC State University					X	
The Southern Alliance for Clean Energy (SACE)	Knoxville, TN		X		X	

3. OUTPUTS

3.1. Publications, conference papers, and presentations

3.1.1 Journal publications

[1] Islam, Muhammad Mobaidul, Abdullah Al Redwan Newaz, Li Song, Benjamin Lartey, Shih-Chun Lin, Wei Fan, Ali Hajbabaie Abdullah Homaifar, Ali Karimoddini, "Connected autonomous vehicles: State of practice." Applied Stochastic Models in Business and Industry (2023), 1-17. DOI: 10.1002/asmb.2772

[2] Yan, X., Sarkar, M., Lartey, B., Gebru, B., Homaifar, A., Karimoddini, A. and Tunstel, E., 2023, “An Online Learning Framework for Sensor Fault Diagnosis Analysis in Autonomous Cars,” IEEE Transactions on Intelligent Transportation Systems, DOI: 10.1109/TITS.2023.3305620

[3] Muhammad Mobaidul Islam, Abdullah Al Redwan Newaz, Tesfamichael Getahun, Michael Dejene Azage, Ali Karimoddini, Abdollah Homaifar, and Samuel Labi, “Information Fusion for Pedestrian Detection for Autonomous Vehicles,” IEEE Transactions on Intelligent Transportation Systems,

submitted.

[4] Tesfamichael Getahun, Ali Karimoddini, “An Integrated Vision-based Perception and Control for Lane Keeping of Autonomous Vehicles”, IEEE Transactions on Intelligent Vehicles, submitted.

[5] Nhat Le, Brennan Borlaug, Matthew Bruchon, Tim Jonas, Hieu Nguyen, “Electrifying Education: Insights into Charging Electric School Buses in the United States," IEEE Innovative Smart Grid North America, 2024, submitted.

[6] Jose Matute, Milad Khaleghi, Ali Karimoddini, Automatic Fault Diagnosis in Automotive Brake Systems using a Decentralized Most Permissive Observer Architecture, IEEE Transactions on Vehicular Technology, submitted.

[7] Liu, D., Kaisar, E., Yang, Y., Yan, P., Physical Internet-enabled E-grocery Delivery Network: A Load-dependent Two- echelon Vehicle Routing Problem with Mixed Vehicles. International Journal of Production Economics. 2022, Vol 254, Article No.108632. SCI (IF: 11.251, TOP, 3 / 216)

[8] Liu, D., Yan P., Deng, Z., Wang Y. Kaisar, E., Sustainable Two Echelon Vehicle and Autonomous Delivery Robots Routing for E-Grocery Operations. Transportation Research Part C: Emerging Technologies. Under review.

3.1.2 Books or other non-periodical, one-time publications

[1] Thesis: Tienake Phuapaiboon, Development of a Testbed of Connected Autonomous Vehicles, 2023 (NCA&T).

3.1.3. Other publications, conference papers, technical reports, articles, etc.

[1] Latif, A. S. Usman, I. Mahdinia, A. Khattak. Framework to Assess Readiness of Intelligent Mobility Technologies Needs and Results of a Readiness Survey. Accepted for Presentation at the Transportation Research Board Annual Meeting, Washington D.C., 2024.

[2] Jose Matute, Mario Rodriguez-Arozamena, Joshue Perez, and Ali Karimoddini, “*Sensor Fusion-Based Localization Framework for Autonomous Vehicles in Rural Forested Environments*”, 26th IEEE International Conference on Intelligent Transportation Systems ITSC 2023, Spain September 2023.

[3] Tesfamchael Getahun, Ali Karimoddini, GPS-guided Vision-based Lane Detection for Autonomous Vehicles, 26th IEEE International Conference on Intelligent Transportation Systems ITSC 2023, Spain September 2023.

[4] M. M. Islam, A. A. Redwan Newaz, T. Getahun, and A. Karimoddini, Enhancing Pedestrian Detection in Autonomous Vehicles through Multimodal Information Fusion, TRB 2024, submitted.

[5] M. M. Islam, A. A. Redwan Newaz, T. Getahun, and A. Karimoddini, Enhancing Pedestrian Detection in Autonomous Vehicles through Multimodal Information Fusion, TRB 2024, submitted.

[6] Tesfamichael Getahun, Ali Karimoddini, Vision-based Lane Detection using Map Information as a Prior, TRB 2024, submitted.

[7] Tienake Phuapaiboon, Jose Matute, Daniel Tobias, Tesfamichael Getahun, Ali Karimoddini, Development of a Testbed of Connected Autonomous Vehicles. TRB 2024, submitted.

[8] Jose Matute, and Ali Karimoddini, “A Framework for Localization of Autonomous Vehicles in Rural Forested Environments using Sensor Fusion”, TRB 2024, submitted.

[9] Dan Liu and Evangelos I. Kaisar, “Improving the Sustainability of an E-grocery Delivery Network by Integrating Autonomous Delivery Vehicles,” 26th IEEE International Conference on Intelligent Transportation Systems ITSC 2023, Spain September 2023.

[10] Liu, D., Zhou Y., and E. Kaisar, Assessing ADR as an Enabler of Resiliency for Urban Grocery Delivery: A Chance-Constraint Model, accepted for presentation at 103 Annual Meeting of the Transportation Research Board, Washington, D.C., January 2024.

3.1.4. Presentations

[1] Jose Matute, Mario Rodriguez-Arozamena, Joshue Perez, and Ali Karimoddini, "*Sensor Fusion-Based Localization Framework for Autonomous Vehicles in Rural Forested Environments*", 26th IEEE International Conference on Intelligent Transportation Systems ITSC 2023, Spain September 2023.

[2] Nhat Le, Brennan Borlaug, Matthew Bruchon, Tim Jonas, Hieu Nguyen, "*Electrifying Education: Insights into Charging Electric School Buses in the United States*," North America Power Symposium 2023.

[3] Tesfamchael Getahun, Ali Karimoddini, GPS-guided Vision-based Lane Detection for Autonomous Vehicles, 26th IEEE International Conference on Intelligent Transportation Systems ITSC 2023, Spain September 2023.

[4] N. Stamatiadis, C. Pope, R. Souleyrette, and T. Fields, "*Identifying work-related crashes through crash narrative mining, 11th International Congress on Transportation Research*" (ICTR 2023), Crete, September 2023.

[5] Daria Korostina, Nikiforos Stamatiadis, Teng Wang, and Reginald Souleyrette, "*Evaluation of a Scoring Approach for Pedestrian and Bicycle Projects*," 11th International Congress on Transportation Research (ICTR 2023), Crete, September 2023.

[6] Dan Liu and Evangelos I. Kaisar, "Improving the Sustainability of an E-grocery Delivery Network by Integrating Autonomous Delivery Vehicles," 26th IEEE International Conference on Intelligent Transportation Systems ITSC 2023, Spain September 2023.

3.2. Website(s) or other Internet site(s)

- *CR²C²* website: https://www.cr2c2.com
- Aggie Autonomous Shuttles: https://www.aggieauto.com/

3.3. Technologies or techniques

- We developed a new method for Sensor Fusion-Based Localization Framework for Autonomous Vehicles in Rural Forested Environments. One major hurdle for the deployment of autonomous vehicles in rural environments is achieving accurate localization in areas with tree-canopied roads or outdated point cloud maps. The presence of limited visibility and high variability renders standalone sensor localization unreliable in such situations. To tackle these issues, we developed a sensor fusion-based localization framework that integrates data from GNSS, LiDAR, INS, and vehicle odometry. The developed approach uses a loosely coupled Extended Kalman Filter for sensor fusion and a weighted gate approach for accurate state estimations. Compared to a state-of-the-art technique, the proposed method achieves a reduction of around 71% in maximum lateral deviations. This method successfully enables safe and reliable localization in challenging scenarios that are frequently found in the rural and inter-urban sectors.

3.4. Inventions, patent applications, and/or licenses

Nothing to report.

3.5. Other products

- During the pilot program for public deployment of autonomous microtransit vehicles from Sep 18-Oct. 13, we collected survey data from the riders, the camera data recording inside and surrounding of vehicles, the number of riders and number of trips and total miles driven autonomously, number and sources of autonomy disengagement. The analysis of this information will be conducted in the next quarter.
- We developed an application software for live tracking of autonomous microtransit vehicles.

- We developed training materials for AV incident management for first responders.
- We are working on collecting and assembling data in various spatiotemporal resolutions and creating visualization tools. We are also identifying public data sources for generating synthetic population and travel demand data that can be used to support advanced mobility modeling.
- A spreadsheet database with resources identified in Gap Analysis inventory is being developed.

4. OUTCOMES

The major outcome of the Center for this reporting period was the public deployment of Aggie Autonomous Shuttles to serve the underserved communities of East Greensboro. Other outcomes include publications, presentations, creating training, and workforce development opportunities, whose impact is provided in the next section.

5. IMPACTS

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

- The implemented pilot program created a significant community impact. The project location is in District 2 of Greensboro, which is an underserved community. On the other hand, it has one of the most diverse populations in Greensboro. Nearby District 3 encompasses the downtown area and includes numerous businesses and establishments. This project offered a new, more flexible shared mobility option to an underserved community, connecting residents to job opportunities, services, and resources in the downtown area. Assessment data for this pilot program is collected, and we will report it after analyzing the collected data.
- We started the investigation into how technology can address the mobility needs of specific groups in rural communities, e.g., older and lower-income populations.
- The research findings from the literature review conducted thus far pinpoint transit deserts and health equity issues, guiding targeted interventions for a more inclusive and sustainable transportation system. Implementing data-driven strategies will enhance efficiency, mitigate environmental impact, and improve access to medical care, positively impacting overall system effectiveness.

5.2. What is the impact of technology transfer on industry and government entities, on the adoption of new practices, or on research outcomes which have led to initiating a start-up company?

- We have started developing a tool or set of tools for assessing the readiness of small urban and rural communities for new transportation technologies. The tools may consist of survey instruments for gathering data, procedures for implementing assessments, checklists to aid implementation, and/or assessment instruments.
- Technology transfer also includes the development of short training-oriented courses and the presentation of results at national forums, such as the Transportation Research Board.
- Center researchers received Technology Transfer funding from NCDOT for $172K to implement a pilot program to identify the sociotechnical challenges in terms of the adoption of autonomous microtransit vehicles.
- Engagement with stakeholders continued resulting in pilot programs, securing external matching funds, and securing new funds by leveraging center activities, as summarized in the below table:

Number of regional pilot programs or projects co-funded/cost-shared by regional organizations	Amount of external matching funds	Amount of new funds leveraged for the Center
4	**$2,337,508**	**$1,494,942**

- Technology transfer also includes organizing transportation events, contributing to transportation-related committees and organizations, and organizing seminars and workshops as summarized in the below table:

Number of regional and national events organized by the Center members	Number of Transportation-related short courses, seminars, workshops, and training programs offered by the Center members	Number of committees, transportation organizations contributed by the Center members
35	**22**	**35**

5.3. What is the impact on the body of scientific knowledge?

- One of the Center's projects aims at identifying gaps in transportation access and healthcare disparities in order to advance strategies for inclusive, sustainable systems. This work not only informs current practices through data-driven methods but also lays a foundation for future interdisciplinary studies in improving community well-being through enhanced transportation and health policies.
- We developed a new technique for Sensor Fusion-Based Localization Framework for Autonomous Vehicles in Rural Forested Environments. To date, most of the work on the deployment of autonomous vehicles and localization challenges is focused on urban or highway environments, having limited research on rural areas, particularly when there are dense forests along the roadside. These environments pose greater challenges due to the presence of a canopy of trees and changing vegetation, which leads to limited visibility and high variability, increasing the risks of losing vehicle localization. Addressing these challenges, we developed a novel localization framework that sequentially fuses observations from various sensors. It is designed to perform effectively under GNSS- and LiDAR-limited environments to enhance robustness and accuracy. We also validated the proposed approach in realistic conditions, driving an autonomous vehicle in a rural forested canopied road that blocks line-of-sight with satellites, and having zones that lack point cloud data from mapping.

Figure 5. The self-driving shuttle used for navigation in rural roads.

- The Center researchers also contributed to the body of knowledge and actively disseminate the research outcomes through peer-reviewed publications, presentations, and other mechanisms which are summarized in the below table:

Number of peer-reviewed Journal papers	Number of peer-reviewed conference papers	Number of research-related presentations	Tech reports	Inventions/patent applications/licenses	Total
8	**10**	**6**	**0**	**0**	**24**

5.4. What is the impact on transportation workforce development?

- The program has provided valuable opportunities for researchers in transportation and related disciplines. The Center's activities contributed to the development and enhancement of the transportation workforce by offering educational opportunities, skill development, and exposure to transportation-related concepts and technologies. The impact of these training and workforce development opportunities is summarized in the below table:

Transportation-related courses offered by faculty and/or teaching assistants who are associated with the UTC		Transportation-related short courses, seminars, workshops, and training programs		Transportation-related education, workforce development, or outreach activities	
Number of courses	Participants	Number of programs	Participants	Number of Activities	Participants
32	**757**	**22**	**363**	**13**	**1032**

- The students and researchers involved in the Center's activities were exposed to multidisciplinary research in advanced transportation technologies particularly in rural and underserved communities. The impact of the engagement of students and researchers is summarized in the below table:

Number of students participating in transportation research projects funded by this grant			Number of students supported by this grant who received degrees		Number of faculty and non-student researchers involved in the Center activities
PhD	**MS**	**UG**	**PhD**	**MS**	
27	**14**	**7**	**0**	**1**	**42**

- To accelerate and enhance the application of the new tools resulting from the Center's activities training courses will be developed and offered through the Local Technical Assistance Program (LTAP).

6. CHANGES/PROBLEMS

- Changes in approach and reasons for change: None
- Actual or anticipated problems or delays and actions or plans to resolve them: None
- Changes that have a significant impact on expenditures: None
- Significant changes in use or care of animals, human subjects, and/or biohazards: None

7. SPECIAL REPORTING REQUIREMENTS

None.