NC STATE UNIVERSITY | Duke | FAYETTEVILLE STATE UNIVERSITY | NORTH CAROLINA AGRICULTURAL AND TECHNICAL STATE UNIVERSITY | THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

NCDOT Center of Excellence on Mobility and Congestion

Project 1

Deep Learning Software for Traffic State Prediction

March 18, 2021 Year 1 meeting

Project Team

- Principal Investigator – **Sambit Bhattacharya, Ph.D.**
  - Professor of Computer Science – Fayetteville State, Dept of Math & Computer Science
  - Director – Intelligent Systems Lab (ISL)
- Co-Principal Investigators
  - **Ali Hajbabaie, Ph.D.** – NC State, Assistant Professor in the Department of Civil, Construction, and Environmental Engineering
  - **Noel Greis, Ph.D.** – NC State, Research Full Professor, Poole College of Management
  - **Hyoshin (John) Park, Ph.D.** – NC A&T, Assistant Professor in the Department of Computational Science & Engineering
- Senior Researchers
  - **Murat Adivar, Ph.D.** – Fayetteville State, Associate Professor, Broadwell College of Business & Economics
  - **George List, Ph.D.** – NC State, Professor in the Department of Civil, Construction, and Environmental Engineering
  - **Thomas Chase, Ph.D.** - NC State, Research Associate in the Institute for Transportation Research and Education

Project Goals

- Develop edge computing and deep learning software to **improve estimation of traffic state parameters** on arterials by fusing video, loop detector and Bluetooth sensor data
- Test software with traditional signal control and a CV-enabled signal control algorithm in VISSIM
- These capabilities will assist in
  - improved performance measures for integration into existing tools like ATSPM
  - temporary deployment for signal retiming or loop detector calibration
  - driver information through connected vehicle applications

Methodology

- Deep/machine learning AI approach to prototype software design
- Steps include –
  - Data collection on real and simulated traffic
  - Develop single stream video analytics
  - Develop multi stream video analytics
  - Develop data fusion methods
  - Test hypothesis that advanced traffic signal control algorithm performs better optimization with this traffic state estimate

Project Schedule and Progress to Date – Task 1 to Task 5

Project Activities	Monthly (February 2020 - July 2022)																													
	Academic Year 1						Academic Year 2												Academic Year 3											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
Task 1: Literature Survey																														
Task 2: Data Collection																														
Task 3: Ground Truth Collection																														
Task 4: Data Collection from Simulation																														
Task 5: Develop Single Video Stream Analytics																														
Task 6: Develop Multi-stream Video Analytics																														
Task 7: Develop Data Fusion Methods																														
Task 8: Hypothesis Testing																														
Task 9: Final Report and Deliverables																														

Lit. Survey (Task 1): Challenges and opportunities in using machine learning for traffic state estimation

- Computer Vision
  - Vehicle detection
  - Sim2real gap
  - Vehicle re-identification
  - … and more …
- Data Fusion
  - Video
  - Bluetooth
  - … and more …
- Simulation
  - Traffic
  - … and more …
- Existing Applications
  - Traffic signal control
  - Active traffic management
  - … and more …

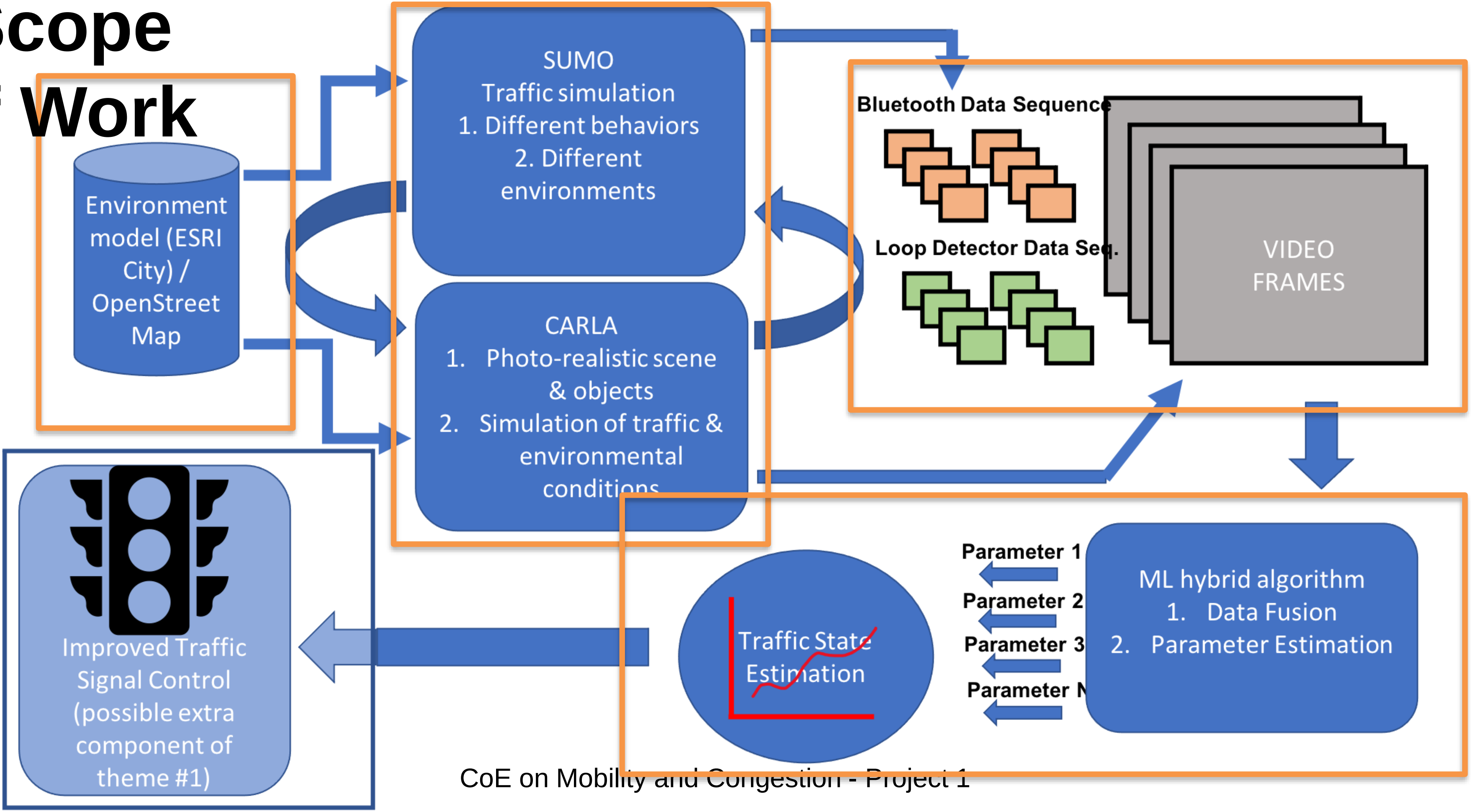
Tasks 2 to 5: Modeling & Software Development

Closing the Sim2real gap

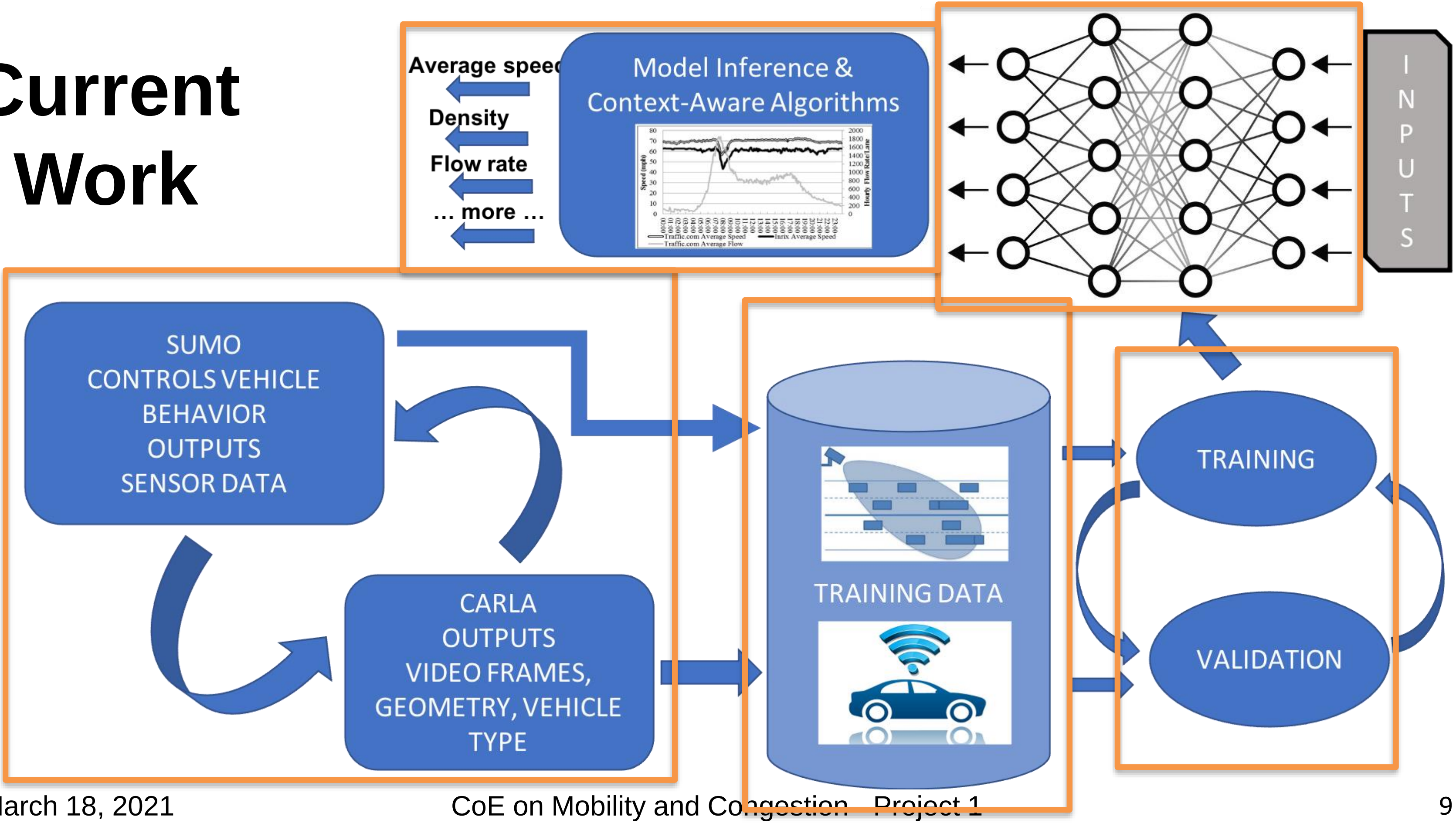
- Major barrier: availability of labelled data
- Solution, step 1: synthetic data
- Challenge: real-world is more complicated
- Solution, step 2: Domain Randomization

- Task 2: Data Collection
  - Procedural variation of conditions
- Task 3: Ground Truth Collection
  - Procedural geometric and other labels
- Task 4: Data Collection from Simulation
  - Accelerated collection with co-simulation
- Task 5: Develop Single Video Stream Analytics
  - ML models which will work in the real world

Scope of Work



Current Work



Video Demo

Problems and Deviations to Date

- In general, the problem is the uncertainty that is caused by the COVID-19
- None to date

Work Planned in the Next Year

- Develop multi-stream video analytics
- Develop data fusion methods
- Hypothesis testing
- Final Report and Deliverables

Problems and Deviations Anticipated

- Real world data collection may be disrupted due to pandemic
- We have flexibility in our plans to address this disruption

NCDOT Support Needed

- Technical advice and feedback from stakeholders

Students

Catherine Spooner (FSU)

Niharika Deshpande (NC A&T)

Daniel Rundell (FSU)

Ramin Niroumand (NCSU)

Thank you!

Sambit Bhattacharya

Professor in Computer Science,

Fayetteville State University

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NCDOT Center of Excellence on Mobility and Congestion

Project 2

Smart Connected and Automated Vehicle Fleet Management: Developing Regional Dispatch Decision Support for Congestion Mitigation

March 18th, 2020 Center Update

Project Team

- Principal Investigator – **Mary "Missy" Cummings, Ph.D.**
  - Professor – Duke University
    - Department of Electrical and Computer Engineering
    - Department of Computer Science
    - Duke Robotics
    - Duke Institute for Brain Sciences
  - Director – Humans and Autonomy Lab (HAL)
- Co-Principal Investigators
  - **Eleni Bardaka, Ph.D.** – NC State, Assistant Professor in the Department of Civil Construction and Environmental Engineering
  - **Raghavan "Srini" Srinivasan, Ph.D.** – UNC-CH, Senior Transportation Research Engineer at the Highway Safety Research Center
- Senior Researcher – **Nagui Rouphail, Ph.D.** – NC State, Professor in the Department of Civil Construction and Environmental Engineering

Project Goals

- Develop a supervisory capability for AVs in a regional dispatch center
- Provide state and/or local authorities with monitoring of and direct communications with traditional, connected, and autonomous vehicles
- These capabilities will assist dispatcher/operators in –
  - Developing mitigation actions to reduce congestion
  - Managing planned and urgent/emergent scenarios

Duke Underlying Research Questions

- Can we adapt network optimization theory to represent connected vehicle communications?
  - Is this better than traditional optimization approaches?
  - The presence of uncertainty in the form of traditional vehicles
- How can a decision support tool based on this algorithm aid dispatchers?
  - Planning: How many and where should Road Side Units (RSUs) be located to ensure appropriate coverage/metrics?
  - Real-time: Where and when should CVs be redirected to reduce congestion?
  - Three exemplar scenarios: Minor accident at an interstate exit, major accident at interstate exchange, medical emergency in CV.

Prototype “Sketch”

- https://www.youtube.com/watch?v=q3AFo2dmgEk
  - Figma

Prototype v1.0

- Very early in development

Thank you!

Missy Cummings
Professor and Director,
Humans and Autonomy Lab,
Duke University
m.cummings@duke.edu

NCSU Outline of Efforts

- Freeway Capacity Sensitivity Tool in mixed CAV, AV and TV traffic

- Surrogate safety measures (SSMs) in mixed traffic
  - Why Use them?
  - Review of Literature
  - SSM and Car-following Analysis using Real-World AV and TV trajectories in Mixed Traffic

- Future work: calibrating simulation model (SUMO) open source simulation code --- in mixed traffic

Freeway Capacity Sensitivity Tool

Enter Market Penetration Rate (%)	CAV	AV	TV
	30	30	40

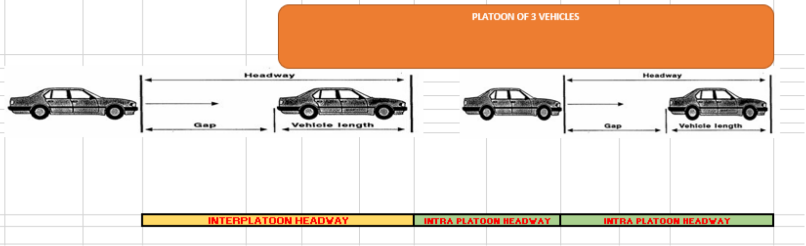
PER LANE CAPACITY FOR INDICATED MPR

OEM OR USER SETTINGS CAV Time Gap (Sec.)	OEM or USER SETTINGS FOR AV Time Gap (Sec.)												
	0.50	0.63	0.75	0.88	1.00	1.13	1.25	1.38	1.50	1.63	1.75	1.88	2.00
0.400	4,105	3,676	3,362	3,123	2,936	2,785	2,660	2,555	2,466	2,390	2,324	2,265	2,213
0.550	4,009	3,579	3,265	3,026	2,839	2,688	2,563	2,458	2,369	2,293	2,227	2,168	2,116
0.700	3,944	3,514	3,200	2,962	2,774	2,623	2,498	2,393	2,305	2,228	2,162	2,103	2,052
0.850	3,897	3,468	3,154	2,915	2,728	2,577	2,452	2,347	2,258	2,182	2,116	2,057	2,005
1.000	3,863	3,433	3,119	2,880	2,693	2,542	2,417	2,312	2,224	2,147	2,081	2,022	1,971

Mixed Capacity (pcphpl)
0 to 999
1000 to 1999
2000 to 2999
3000 to 3999
4000 to 4999
5000 to 5999
6000 to 6999

User DATA Entries

	CAV	AV	TV
Average Free Flow Speed (mph)	50	60	50
Average Vehicle Length (ft)	15	15	15
Time Gap Upper Bound (seconds)	1	2	
Time Gap Lower Bound (seconds)	0.4	0.5	
Platoon Size (vehicles)	10		
Inter Platoon Headway Multiplier	1		
Average Headway for TV (Seconds)			1.64



Why Use Safety Surrogate Measures (SSM)?

- Limited crash data available for AVs or CAVs
- Evaluate conflicts in the absence of limited crash data
- Conflict: observable situation in which two or more road users approach each other in time and space such that there is risk of collision if their dynamics remain unchanged.
- Use of conflict data for safety evaluation and car following rules

Review of SSM Literature and OEM Settings

Review of Surrogate Safety Measures (SSMs) in Mixed Traffic

Safety Surrogates	Abbreviation	Application
Time to Collision	TTC	Rear End Crash
Post Encroachment Time	PET	Right angle and Merging/Diverging Crashes
Deceleration Rate to Avoid Crash	DRAC	Rear End Crash
Time Integrated Time to Collision	TIT	Rear End Crash
Time Exposed Time to Collision	TET	Rear End Crash
Time Exposed Rear-End Crash Risk Index	TERCRI	Rear End Crash
Deceleration Rate to Avoid Crash	DRAC	Rear End Crash and Merging/Diverging Crashes
Driving Volatility (Speed/Acceleration)		Rear End Crash and Merging/Diverging Crashes

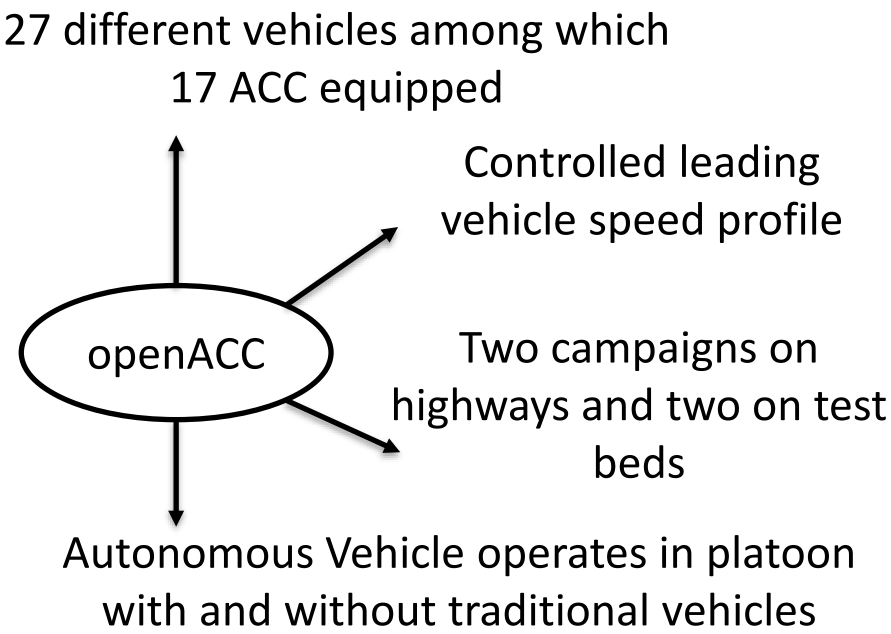
Review of OEM Autonomous Vehicle Dynamics Parameters

Make/Model	Distance Levels	Range	Minimum speed	Technology
Volvo	1-5	1-2.5 seconds	20mph	Adaptive Cruise Control
Tesla	1-7	Not specified	45mph	Traffic aware cruise control
Honda	1-4	1.1-2-9seconds	25mph	Adaptive Cruise control
Mercedes	1-5	Not specified	15mph	Distronic plus
BMW	1-4	Not specified	20mph	Active Cruise Control
Hyundai	1-4	82 -172 feet at 60mph	0mph	Smart Cruise control
Ford	1 to 4	82 to 150 ft at 62 mph	20 mph	Advanced Driving Assistance System
Cadillac	1 to 3	1.1 to 2.5 s	Not specified	Adaptive Cruise Control
Chevrolet	1 to 3	Up to 360 feet Lower limit not specified	25 mph	Adaptive Cruise Control
Chrysler	1 to 4	Not specified	25 mph	Adaptive Cruise Control

Analyze Real World Trajectories: TV/ AV Mix

openACC

- Database of car-following experiments involving **vehicles with Adaptive Cruise Control systems (ACC)**.
- ACC behavior and detailed vehicle dynamics (speed/headway/accel.) tracked
- Database contains **vehicle trajectories** under different car-following experiments.
- Sites in Italy, Sweden and Hungary



To access the Data Base: https://data.jrc.ec.europa.eu/dataset/9702c950-c80f-4d2f-982f-44d06ea0009f/resource/ecf3de9e-0370-431f-80ed-019b8912197f

NCDOT Center of Excellence on Mobility and Congestion

Project 3

Transit and MaaS Role in Improving Economic and Healthcare Access for Underserved Populations

March 18, 2021 Center Update

Project Team

- **Kai Monast, MRP,** Director, Public Transportation Group – NCSU/ITRE
- **Noreen McDonald, Ph.D.** – Thomas Willis Lambeth Distinguished Chair, UNC-CH, Department of City and Regional Planning
- **Hyoshin (John) Park, Ph.D.** – Assistant Professor, NC A&T, Department of Computational Science and Engineering
- **Burcu Adivar, Ph.D.** – Associate Professor, Fayetteville State University, Broadwell College of Business and Economics
- **Trung Tran, Ph.D.** – Assistant Professor, Fayetteville State University, Department of Intelligence Studies, Geospatial Sciences, Political Science, and History
- **Jeremy Scott, MS,** –Research Associate, Public Transportation Group – NCSU/ITRE
- **Abigail Cochran, Ph.D** – Postdoctoral Research Associate, UNC-CH, Department of City and Regional Planning

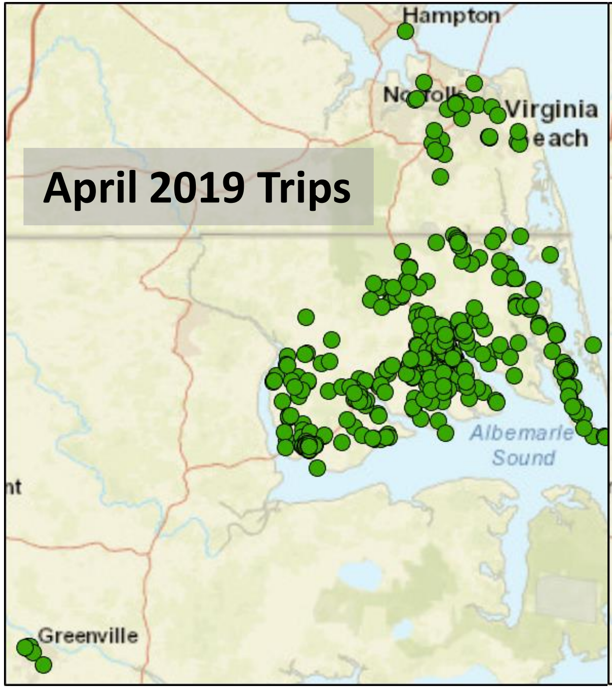
Project Goals

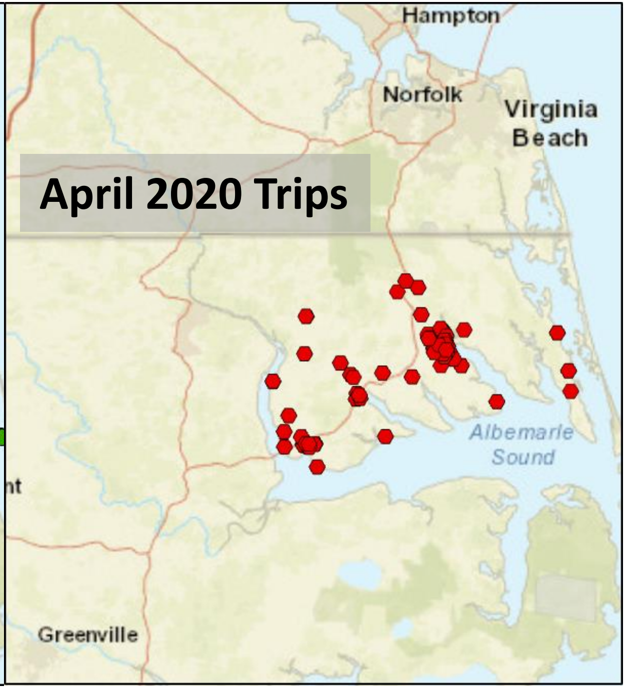
- How changes in health care policy (e.g. Medicaid Transformation) and transportation service delivery (e.g. Mobility as a Service- MaaS) impact:
  - Individuals
  - Health systems
  - Public transportation
- How transport system innovation impacts health care access by:
  - Modeling existing services
  - Developing operational scenarios
  - Analyzing patient travel preferences based on the scenarios
  - Assessing information needs for patients and care managers
  - Building a decision support tool

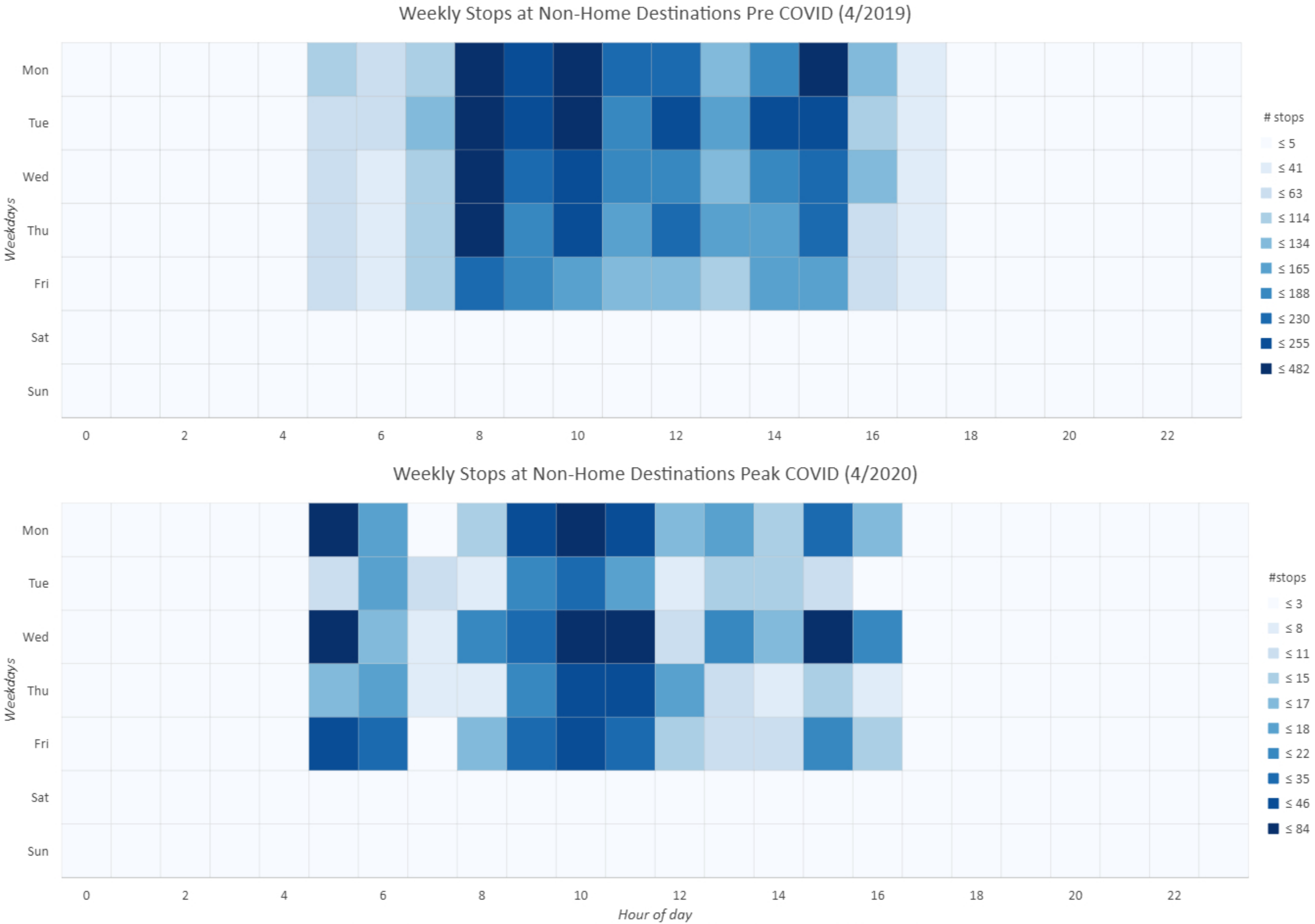
Methodology

- Mixed methods research focusing on people and institutions in the Elizabeth City area as they experience disruptions
    - COVID-19
    - Medicaid Transformation
    - Mobility-as-a-Service Technology and Access Enhancements
- Spatial and Tabular Data analysis
- Surveys and interviews of individuals and healthcare providers
- Modeling to assist with implementing accessibility improvements

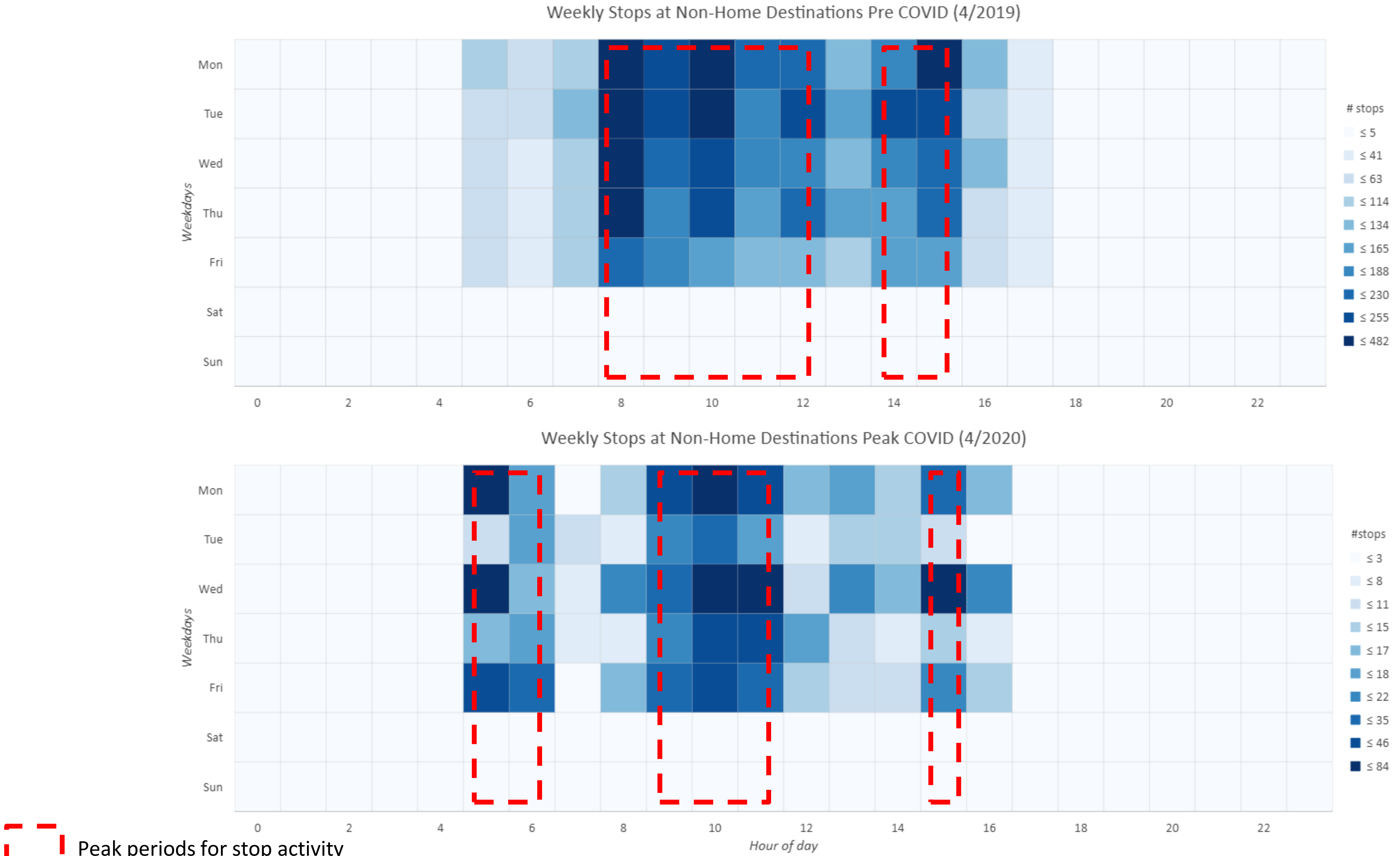
Spatial and Temporal Data Analysis





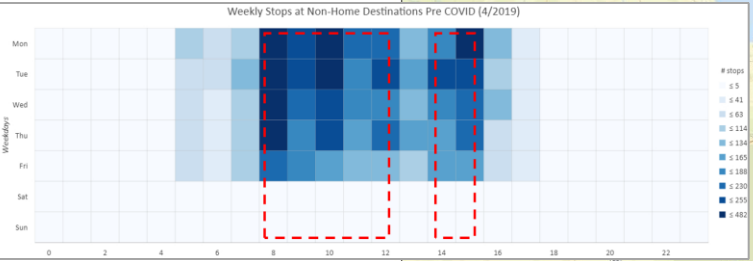


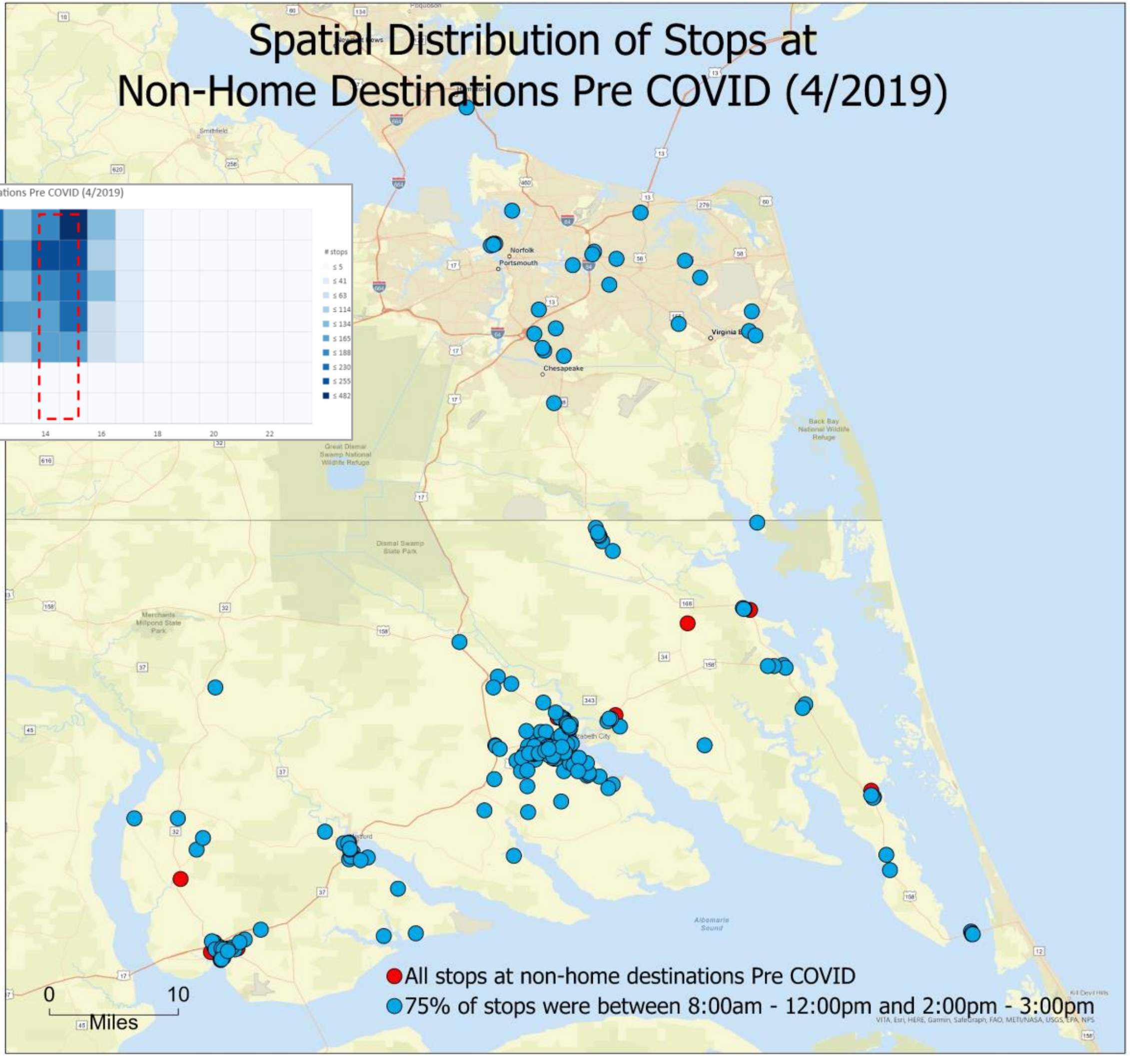
Note: Class breaks were done by quintile classification. Every class has 10% of all destinations.



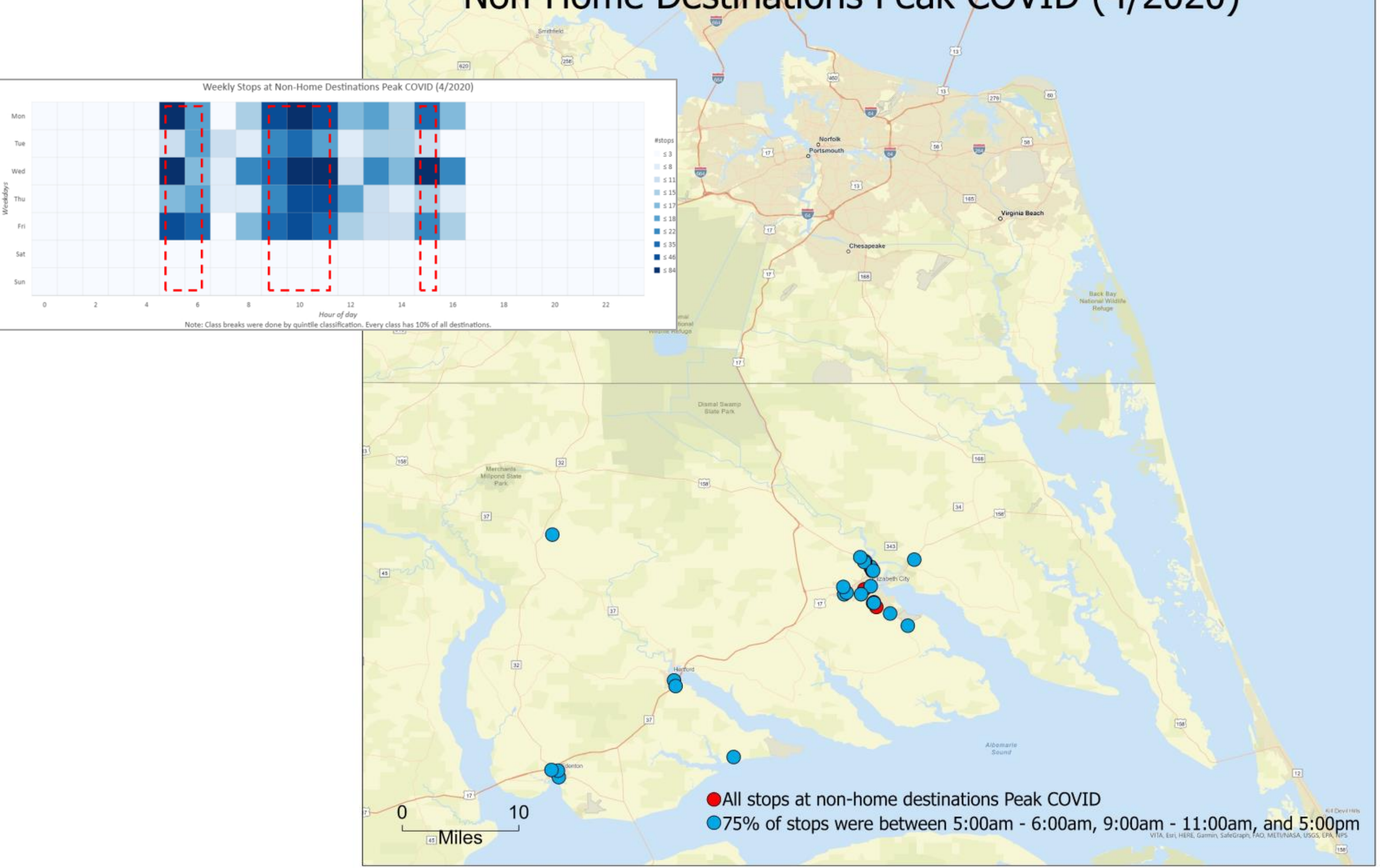
Note: Class breaks were done by quintile classification. Every class has 10% of all destinations.

Spatial Distribution of Stops at Non-Home Destinations Pre COVID (4/2019)





Spatial Distribution of Stops at Non-Home Destinations Peak COVID (4/2020)



Surveys and Interviews

Addressing Transportation Barriers to Health Care During the COVID-19 Pandemic

Between October and November 2020, in-depth interviews were conducted with sixteen (16) nurses, social workers, and other professionals in North Carolina who help address health-related social needs. The interviews identified the transportation barriers to health care that individuals have encountered during the pandemic, and solutions medical systems have used to address these challenges. This infographic summarizes the key findings.

EXISTING TRANSPORTATION BARRIERS EXACERBATED

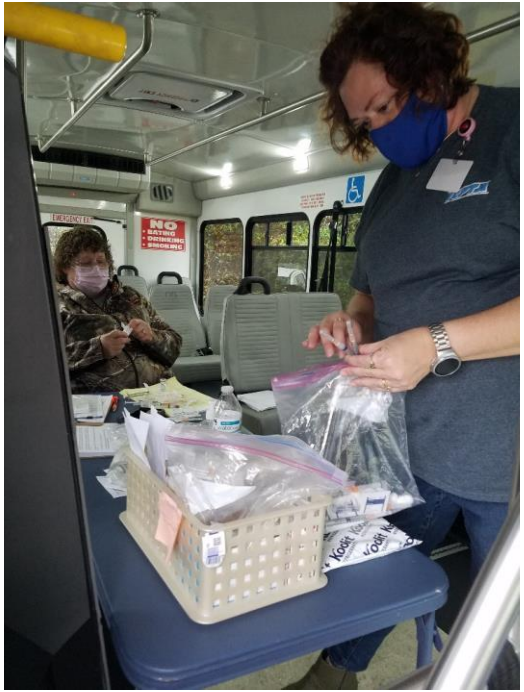
Financial strain and transportation service changes built upon existing transportation barriers (e.g., cost and availability of transportation options, etc.).

PANDEMIC CREATED NEW BARRIERS

Concerns emerged about COVID-19 exposure while traveling with strangers, particularly public transportation use and ride-hailing.

“At times, [riders] may have social anxiety… with COVID, folks do have a little increased anxiety about riding public transportation.”

- Care Coordinator in Albemarle Region



Modeling

- Baseline model development
- Develop assumptions
- Integration of Medicaid trip data and Transmodeler simulation
- Analyze the spatiotemporal patterns of service performance

Next Steps

- Continue to develop analytical tools
- Continue surveying individuals and healthcare providers
- Finalize model data and parameters
- Conduct pre- and post-analyses for all time periods
- Develop service alternatives
- Conduct stated-preference surveys of the alternatives
- Publications, presentations, and final report

Questions?

- **Kai Monast** – NCSU/ITRE, kai_monast@ncsu.edu
- **Noreen McDonald** – UNC-CH, noreen@unc.edu
- **Hyoshin (John) Park** – NC A&T, hpark1@ncat.edu
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- **Trung Tran** – FSU, ttran1@uncfsu.edu
- **Jeremy Scott** – NCSU/ITRE, jscott@ncsu.edu
- **Abigail Cochran** – UNC-CH, acochran@unc.edu