# C2SMART

## CONNECTED CITIES WITH SMART TRANSPORTATION

A USDOT University Transportation Center

# SEMI-ANNUAL PROGRESS REPORT

Submitted to the Office of the Assistant Secretary for Research and Technology

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| **Federal Grant Number** | 69A3551747124 |
| **Project Title** | C2SMART Tier I University Transportation Center |
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| **Submitting Official** | Center Director |
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Signature: *Kaan Ozbay*

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# I. Accomplishments

## A. *Goals and Objectives*

C2SMART is the first Tier 1 University Transportation Center (UTC) in New York City, led by the New York University (NYU) Tandon School of Engineering. The mission of C2SMART is to build a solution-oriented research center that uses resources from consortium members' cities as a decentralized but comprehensive living laboratory. The Center brings together a unique combination of strengths and resources in urban informatics, connected technologies, behavioral informatics, and city partners. Its research approach is based on a system-of-systems (SoS) perspective that integrates roads, transport services, energy grids, financial information, and other urban networks.

**Research** — C2SMART will study challenging transportation problems and field test novel solutions in close collaboration with end-users, city agencies, policy makers, private companies, and entrepreneurs. We are focused on developing innovative solutions based on emerging disruptive technologies and their impacts on transportation systems. Our three main research areas are: Urban Mobility and Connected Citizens; Urban Analytics for Smart Cities; and Resilient, Secure, and Smart Transportation Infrastructure.

**Education** — As an academic institution, C2SMART is focused on training the workforce of tomorrow to deal with new mobility problems in ways that are not covered in existing transportation curricula.

**Dissemination and Outreach** — C2SMART aims to overcome institutional barriers to innovation and hear and meet the needs of city and state stakeholders, including government agencies, policy makers, the private sector, non-profit organizations, and entrepreneurs. The Center is also working to make it possible to safely share data to equip transportation decision-makers with the best information available.

## B. *Accomplishments Under These Goals*

### 1. Center Administration

C2SMART continues to work to be compliant with USDOT's data management requirements. The most-viewed repository is again the "Freeway Inductive Loop Detector Dataset for Network-wide Traffic Speed Prediction" project which has 520 views and 130 downloads at the time of reporting. The Common Innovation Platform (CIP) collaborative research and project tracking platform developed by C2SMART serves as a repository for all datasets, code, publications, and reporting documents for center-funded projects. C2SMART Center's [Annual Report](#) was released in December 2020 to disseminate center activities. The COVID-19 pandemic continues to play in role in center programming, but most administrative processes and core research work conducted at the Center continued unabated. University funds were used to meet remote-working technological needs, and staff continue to meet regularly via tele-/video-conference.

### 2. Research

**Table 1: Projects Completed During this Reporting Period**

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| **Urban Mobility and Connected Citizens** | **Work Zone Safety: Behavioral Analysis with Integration of VR and Hardware in the Loop,** NYU | This project used hardware-in-the-loop (HIL) to examine worker behaviors that affect work zone safety. Workers operated in virtual reality (VR) environments which emulate real-world scenarios (for example, cutting the road and installing sensors). The next phase of the project will introduce user testing with eye tracking. |
| | **Learning to Drive Autonomously,** NYU | Using reinforcement learning and adaptive dynamic programming techniques to achieve optimal control of connected vehicles in mixed traffic, this project created an autonomous driving algorithm. The next phase of the project will focus on validation of the algorithm under different driving scenarios in the CARLA simulator. |
| | **Urban Connector: Year 3 Field Tests,** UTEP | This project's original scope had planned for user tests in senior centers. Since these were unable to take place given the COVID-19 pandemic, this project's scope was modified to forego user tests, and all source code for the Urban Connector app, and the proposed survey, were uploaded to the C2SMART Center repository. |

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| | **Research and Field Testing of Vehicle-traffic Control with Limited-capacity Connected/Automated Vehicles,** UW | The team finalized its Vehicle-In-the-Loop (VIL) platform to reduce the costs of testing algorithms in the real-world, and tested these under two traffic environments with data from Inrix. The model allows researchers to track a vehicle to observe the traffic system at a microscopic to sub-microscopic perspective. |
| Urban Analytics for Smart Cities | **Development and Tech Transfer of an Integrated Robust Traffic State and Parameter Estimation and Adaptive Ramp Metering Control System,** NYU | Researchers developed an automatic, robust, mode-switching supervisory observer to enhance traffic flow. They achieved adaptive ramp metering control through a reinforcement learning approach and assessed the performances of the adaptive traffic control by simulations. |
| Resilient, Secure, and Smart Transportation Infrastructure | **Street-level Flooding Platform: Sensing and Data Sharing for Urban Accessibility and Resilience,** NYU | In this first phase of the project, the team published open-source technical documentation for its hyperlocal flood sensors. They generated a fourth dataset, including two recorded floods, and one snowstorm. The next phase of the project expands this deployment to more locations around NYC and will create a public-facing dashboard for use by the public and agencies. |
| | **Development of Advanced Weigh-In-Motion (A-WIM) System for Effective Enforcement of Overweight Trucks to Reduce their Socioeconomic Impact on Major Highways,** Rutgers | Analysis showing that bridge damage associated with permit trucks is approximate 1/3 of all infrastructure damages, valued at 20% higher than the permit fee. The team also formalized a methodology to estimate pavement temperature based on ambient temperature to calibrate WIM sensors more accurately. |

Table 2: Updates on Ongoing Center-funded Research Projects

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| Urban Mobility and Connected Citizens | **Modeling and Optimizing Ridesourcing Services in Connected and Automated Cities,** UW | The team completed the data collection and network construction for a virtual network of downtown Seattle. It will help simulate the commuting scenario from UW and surrounding areas to downtown Seattle via driving, carpooling, and transit. |
| | **Urban Microtransit Cross-sectional Study for Service Portfolio Design,** NYU | Researchers used 6 U.S. cities (Salt Lake City, Sacramento, Cupertino, Columbus, Jersey City, and Austin) to calibrate a day-to-day adjustment model of industry partner VIA operations with parameters such as maximum walking distance limit and dwell time per stop. The team also continued formulation of human behavioral factors such as safety, convenience, time savings and cost. |
| | **Wearables to Command More Access and Inclusion in a Smarter Transportation System,** NYU | The team improved the image-based place recognition system's graphical user interface (GUI), which will allow non-experts to easily generate image-based place recognition. Based on new data and partner interest, the test scope area was shifted to 3D map all public-facing areas of the United Nations Headquarters, and construction of a UN 'digital twin'. They are now in the process of developing a low-cost wearable data collection kit. |
| | **Cooperative Perception of Roadside Unit and Onboard Equipment with Edge Artificial Intelligence for Driving Assistance,** UW | The team has conducted tests of different scenarios to determine camera calibration algorithm parameters. Next, they will apply the algorithm to an IOT device for real-time vehicle location and improve the accuracy of sensor location and the model. |
| | **C2SMART COVID-19 Data Dashboard,** NYU, Rutgers, UW | The C2SMART COVID-19 Data Dashboard continued to evolve with the addition of new data sources and visualizations. Aggregated pedestrian density and social distancing trends are now quantified at both intersection and city level. The dashboard now includes results from a survey conducted to explore the impact of COVID-19 on different demographics, such as individuals with disabilities. |

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| **Urban Analytics for Smart Cities** | Development of Level of Service Analysis Procedures and Performance Measurement Systems for Parking, UTEP | The research team completed the analysis of street parking data from the City of Los Angeles, CA. The team has received a set of new data from the City of El Paso and has nearly completed the process of analyzing the newly received data. |
| | Utilizing Social Media Data for Estimating Transit Performance Metrics in a Pre- and Post-COVID-19 World CCNY | MTA performance metrics were obtained and analyzed for trends in delay, incidents, construction, and signal problems during the study's designated pre-COVID time period. These were compared to trends from social media data and showed that there is a correlation between number of tweets and public transit events. |
| **Resilient, Secure, and Smart Transportation Infrastructure** | Energy Harvesting for Self-Powered Sensors for Smart Transportation Infrastructures, CCNY | An optimization study showed that the team's built device can generate more than 1W electrical power when out into the resonance with the external excitation. The team is currently in the process of fabricating a prototype of the device for field study. |
| | Securing Intelligent Transportation Systems Against Spoofing Attacks, NYU | The team finalized work on the security of dynamic routing for parallel networks and initiated a novel direction for secure routing for general networks. They used game theory to study network resiliency and designed a diagnosis scheme to recover the spoofed data fully or partially. |
| | Feasibility of Autonomous Enforcement Approach Using Advanced Weigh-in-Motion (A-WIM) System to Reduce Rehabilitation Cost of Infrastructure, Rutgers | A legislative executive order based on this project's outcome by the Mayor of NYC was established to ensure that all weight restrictions on the BQE are strictly enforced. The team analyzed WIM data from the BQE testbed site for periods before and after the enforcement executive order and the Stay-at-Home order due to COVID-19. |
| | Implementation and Effectiveness of Autonomous Enforcement of Overweight Trucks in an Urban Environment, Rutgers | The team diagnosed sensors installed at the testbed and found one damaged. Given the unique conditions at the BQE testbed, such as high traffic volumes, Overweight trucks, and limited access, the team proposed a pilot/scoping study to NYCDOT to apply a structural health monitoring (SHM) and non-destructive testing and evaluation (NDT/E). |

## 2021 C2SMART Request for Proposals and Peer Review Process

Over the course of this reporting period, C2SMART issued a request for proposals for its next round of Center-funded research projects. The RFP call specified two main tracks of proposals to prioritize funding for projects to address the following key areas of importance for C2SMART, its partners, and USDOT:

- **Track 1: Implementation or Demonstration of a Prior C2SMART Research Effort**
  Projects that build off prior research conducted at the center towards real-world implementations or demonstrations of research outcomes with heavy agency or industry partner involvement. Proposals under this track were given higher priority to emphasize technology transfer.
- **Track 2: Advanced Research Project within Center Themes**
  Proposals that advance center research under a multi-disciplinary perspective, targeted at new PIs and partnerships across different disciplines to diversify C2SMART research. Research themes:
  - *Topic Area 1:* Big Data and Urban Analytics in Smart Cities.
  - *Topic Area 2:* Connected and Autonomous Mobility.
  - *Topic Area 3:* Microtransit, Micromobility, and Shared Mobility.
  - *Topic Area 4:* Safety of Pedestrians and Mobility Systems.
  - *Topic Area 5:* Resilient, Secure, and Smart Transportation Infrastructure.
  - *Topic Area 6:* Equity & Accessibility for Under-represented Groups in Transportation.
  - *Topic Area 7:* Adaptative Transportation Solutions in a Post-Pandemic World

The RFP solicitation process consisted of 3 steps: 1st, PIs were invited to submit project abstracts detailing proposed research goals and methods, as well as any partners or targets of dissemination/ outreach. 24 abstracts were received, which the Center's executive team reviewed for research merit, alignment with the RFP and Center themes, and feasibility of implementation, funding, timeline, and cost-share requirements. 18 submissions were invited for full proposals submission, and 16 full proposals, with scope, budget, and data management plan, were received: 10 under Track 1 and 6 under Track 2.

In the 2nd step, the received proposals were submitted to anonymous reviewers from a group of academic and industry experts. A minimum of 2 reviewers were assigned to each proposal from a panel of reviewers consisting of 25 different individuals: 3 from C2SMART Center's Advisory Board, 4 from industry, and 21 from academia. Reviewers were asked to rate each proposal based on a set of 10 review questions, provide comments for proposal improvement, and provide their assessment of whether the proposal should be funded. Finally, these and Center comments were transmitted to submitters for revised submissions – which each proposal undergoing 2-5 iterations to address all comments. Ultimately, 14 proposals were recommended and selected for 2021. awarded to commence in March 2021:

Table 3: Year 5 Awarded Projects

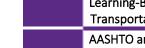| | | |
|---|---|---|
| **Urban Mobility and Connected Citizens** | **A Multiscale Simulation Platform for Connected and Automated Transportation Systems,** UW | This project will establish a multiscale vehicle-traffic-demand (VTD) simulation platform for connected and automated transportation systems (CATS) with a goal to improve the control and management of CATS with varying penetration of connected/automated vehicles. |
| | **Autonomous Vehicle Good Citizenry Standard,** NYU | This project seeks to establish a Responsible Autonomous Mobility (RAM) Framework to evaluate safety, inclusion, accessibility, and equity in transit modes as New York City expands its network of autonomous transit vehicles. |
| | **Quantifying and Visualizing City Truck Route Network Efficiency Using A Virtual Testbed,** NYU | This project seeks to develop a citywide model of truck network flows to visualize truck routes and evaluate system performance and develop a score for truck routes based on established performance indicators to address the rapid growth in e-commerce. |
| | **Evaluating Remote Repositioning for Shared Scooters,** UW | Self-repositioning scooters offer a promising path to increasing micro-mobility utilization and lowering costs and emissions. This project evaluates the effects of remote-repositioning capabilities on shared scooter systems from the first US deployment of Segway Ninebot T-60 e-scooters in a pilot project in Boise, Idaho. |
| | **Collaborative Driving, Ramp Metering and Mean-Field Controls,** NYU | This project explores a macroscopic and network-level approach to collaborative driving through multi-scale models and control algorithms.  It will look at a study case for ramp-metering for congestion decrease, safety, and disruption scenarios. |
| | **Lane Changing of Autonomous Vehicles in Mixed Traffic Environments: A Reinforcement Learning Approach,** NYU | To guarantee the safety of autonomous vehicles, improve passenger comfort, and increase traffic efficiency, this project aims to develop innovative learning-based control methods for lane changing of connected and autonomous vehicles in mixed traffic by the combined use of reinforcement learning and optimal control. |
| **Urban Analytics for Smart Cities** | **Equitable Access to Residential (EQUATOR) EV Charging,** NYU | This project will focus on accessibility of EV charging infrastructure with decision-support procedures and tools to determine electricity rates (tariffs) and additional incentives to promote investments in EV charging infrastructure. Project outreach will include coordination with the New York Public Utility Commission. |
| | **A Comprehensive Analysis of The Air Quality in The NYC Subway System,** NYU | This project will draw statistically robust conclusions on the nature of exposure to particulate matter across the NYC subway system. This includes the development of a data product incorporating real-time measurements, to be used by owners and agencies. |

| | Project | Description |
|---|---|---|
| **Resilient, Secure, and Smart Transportation Infrastructure** | AI-Based Video Segmentation and Saliency Computation to Optimize Imagery-Acquisition from Moving Vehicles, NYU | This project seeks to employ machine learning techniques to create adaptive sampling profiles and a data-driven, opportunistic approach to data acquisition from moving sensors to cut down the cost of deploying video and image sensors. |
| | Digital Twin Technologies Towards Understanding the Interactions between Transportation and other Civil Infrastructure Systems, UTEP | The project is focused on developing a digital twin (DT) model of the UTEP campus transportation infrastructure. The goal is to demonstrate the usefulness of the DT technology to optimize civil infrastructure design and management and visualize impacts of construction project schedule on surrounding infrastructure. |
| | Tech Transfer of a Street-Level Flooding Platform: Sensing and Data Sharing for Urban Accessibility and Resilience, NYU | Building on the FloodSense project's previous work, this phase of the project will expand the ultrasonic flood sensor network, develop a public-facing data dashboard to transfer flood data to stakeholders, and evaluate the feasibility of new sensor modalities. |
| | Integration and Operation of An Advanced Weigh-In-Motion (A-WIM) System for Autonomous Enforcement of Overweight Trucks, Rutgers | This project will support NYCDOT in establishing the legislation to operate an autonomous overweight enforcement system and extend the service life of the BQE corridor. The team will utilize its testbeds on the BQE corridor to develop the guidelines and specifications for the operation of the OW enforcement system. |
| | Field Application of a High-Power Density Electromagnetic Energy Harvester to Power Wireless Sensors In Transportation Infrastructures, CCNY | This project is the implementation-focused second phase to fabricate and field test a high-power density electromagnetic energy harvester (EMEH) to provide a power source for conventional sensors installed on transportation infrastructures. |
| | Work Zone Safety III: Calibration Of Safety Notifications Through Reinforcement Learning And Eye Tracking, NYU | The third phase of this work zone safety project aims to calibrate the frequency, timing, and modality of alarms through the introduction of an eye-tracking component to the existing VR platform, and the introduction of a reinforcement learning-based model to optimize the calibration of alarms. |

The following projects are externally funded underway at the Center that match the goals of C2SMART-funded projects. Combined with C2SMART-funded research, these projects enable larger, more impactful, efforts that have benefits for state/local agencies as well as other users.

Table 4: Matching or complementary funded projects to C2SMART-funded projects

| | Project | Funder |
|---|---|---|
| **Urban Mobility and Connected Citizens** | NYC Connected Vehicle Deployment – Mobile Accessible Pedestrian Signal System Application | USDOT/ NYCDOT/JHK Engineering |
| | NYC Connected Vehicle Deployment – Connected Driving | |
| | Multi-Agency/Multimodal Construction Management Tool to Enhance Coordination Projects City-Wide During Planning and Operation Phases to Improve Highway Mobility and Drivers Experience | NYCDOT/ NYSDOT |
| | Smart Social Connector: An Interdisciplinary, Collaborative Approach to Foster Social Connectedness in Underserved Senior Populations | NSF |
| | Statewide Open Source Advanced Traffic Management System (ATMS) Software Research and Pilot | NYSDOT |
| | Statewide Mobility Services Program Strategic Procurement Planning | NYSDOT |
| | Transportation Gaps and Disability-Related Unemployment: Smarter Cities and Wearables combating Commuting Challenges for the Visually Impaired | NSF |
| | U.S. Mexico Interdisciplinary Research for Smart Cities | NSF |
| **Urban Analytics for Smart** | Algorithms to Convert Basic Safety Messages into Traffic Measures | NCHRP/Noblis |
| | Intelligent Transportation Systems (ITS) Deployment Evaluation Program Data Collection and Information Synthesis Support | FHWA/Noblis |
| | Development of Reconfigurable Environmental Intelligence Platform | NSF |

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| | Data-driven Real-time Prediction and Multi-level Coordinated Control for Smart Transportation | NSF |
| | Learning-Based Fault-Tolerant Traffic Management Algorithms for Intelligent Transportation Systems | NSF |
| Resilient, Secure, and Smart Transportation Infrastructure | AASHTO and NBI (National Bridge Inventory) Element Deterioration Rates for Bridge Management System | NYSDOT |
| | AI-powered and Robot-assisted Manufacturing for Modular Construction | NSF |
| | Bridge Resource Program | NJDOT |
| | Capital Program Resource Model | NYSDOT |
| | Enable Elastic Capacity for Transportation Infrastructure through a Transmodal Modular Autonomous Vehicle System | NSF |
| | Technical Support Services for the Maintenance Department | NJ Turnpike Auth. |
| | Update of Highway Capacity Manual: Merge, Diverge, and Weaving Methodologies | NCHRP |
| | Real-Time Flood Monitoring Dashboard | NYSEDF |

## 3. Education

- C2SMART continues to support the **Vertically Integrated Projects (VIP)** program at NYU, a multi-year approach to learning that emphasizes project-based, innovative, research-active education for undergraduate students The Clean Fleet Team, advised by Deputy Director Joseph Chow, has conducted research that led to a paper currently under review, and code used to analyze the largest fast charging hub in the U.S., operated by Revel. Revel met with the team to adopt their technology.

- The **Institute of Transportation Engineers (ITE) and Intelligent Transportation Society (ITS) student chapters** participated in and hosted a variety of events over the past year which has led to increased visibility and profile among the professional transportation community in NYC. These events focused on development of both technical and leadership capabilities, diversity and inclusion, and applying knowledge learnt from ITE presentations, and included: assisting with hosting and organizing **Transportation Camp NYC 2020** the third **Women in Transportation Panel Discussion,** a **Tech & Careers Talk** series event, a jointly hosted webinar titled **"Running Successful Student Chapters" with Cal Poly SLO**, and an **ITE International Virtual Student Leadership Summit**.

- The **C2SMART Learning Hub**, open to all students attending C2SMART Consortium Universities, has offered free courses on applicable skills for students since its launch in September 2020. The classes are taught by doctoral students in transportation programs at Consortium schools, providing teaching and curriculum development experience. The following classes were offered during this period:
  - o Applications of Virtual Reality for Work Zone Safety
  - o SUMO-Urban Traffic Simulation Workshop (3 sessions)
  - o Storytelling with Data: Learn Data Visualization
  - o Open-source Simulation of Transit operation systems in MATLAB
  - o Fundamentals of Structural Health Monitoring of Bridges – Creating and Analyzing a Simple Model in Abaqus

- **The transportation program at NYU** led by Associate Director for Education, Prof. Semiha Ergan, underwent two changes: the MS in Transportation Management curriculum was modified to revise the required course to lean more heavily on emerging technologies and smart cities. This change will take place in Fall 2021. Second, NYU now offers an undergraduate minor in transportation.

- Dr. Kelvin Cheu at UTEP added Parking as a new lecture topic in **UTEP's CE4340 Transportation Engineering** course in the Fall 2020 semester, in synergy with his research projects. Professor Jeffrey Weidner has also integrated research efforts into classroom curriculum: two groups of senior design students (10 students) started projects on converting a campus parking lot into a student center.

## C. Dissemination and Outreach

### 1. Training and Tech Transfer Events

#### Conference Presentations and Research Showcases

- C2SMART was well represented at the [100th Annual Meeting of the Transportation Research Board](#), presenting 53 presentations with a wide variety of research during virtual lectern and poster sessions, as well as presiding over several workshops and committee meetings. [Full C2SMART activity at TRB](#)

- On March 19, 2021, PI *Rae Zimmerman* presented in a workshop titled *Identifying Data Guideline Needs for Community and Regional Resilience Modeling* at the NIST Center of Excellence for Risk-Based Community Resilience Planning.

- Prof. *Joseph Chow* presented *Enlarging Infrastructure- based Public Services with Integrated Frameworks for Risk Reduction and Equity for Severe Weather, Climate Change and Pandemics* at the NYU Urban Initiative 2021 Urban Research Day on March 5, 2021. He also presented *Abrupt Transformations of Food Supply and Demand Networks and Interconnected Water and Energy in the COVID-19 Pandemic* at the 2nd Food Energy Water Nexus conference on February 10, 2021.

- On March 12th, 2021 Prof. Elizabeth Henaff's team participated in [NYC Open Data Week](#). On March 6, 2021, her team participated in NYU Urban Research Day with 20 in attendance; on March 26, 2021 they presented to members of the Marron Institute for Urban Research at NYU; and on March 19, 2021, the team presented to the Gowanus Canal Conservancy for its "Lunch and Learn"

- On October 28th, 2020, Professor Semiha Ergan delivered "Integration of Virtual Reality, Wearable Sensors and Hardware in the Loop for Construction Work Zone Safety" at Rutgers University.

- The "Enlarging Infrastructure-based Public Services with Integrated Frameworks for Risk Reduction and Equity for Severe Weather, Climate Change and Pandemics," presentation took place at the NYU Urban Initiative 2021 Urban Research Day on March 5, 2021.

- On December 4, 2020, Director Kaan Ozbay gave a presentation at *The NY Metropolitan Transp/ Council's (NYMTC) Metropolitan Area Planning (MAP) Forum* titled "The Future of Commutation."

- Prof. Joseph Chow presented "Advances Toward Mobility-as-a-Service: from Traveler to Operator and Platform Perspectives" at the *UC Irvine Institute of Transportation Studies* on October 23, 2020.

- PI Sarah Kaufman was a panelist at a *CoMotion event titled "New Administration, New Priorities: the Transportation Infrastructure That Will Power the Roaring Twenties"* on February 10, 2020. She was also a panelist on *MOVE America*'s "Pouring the Foundation: Examining the Essential Role of Equity in Mobility" on December 3, 2020. She was the *MegaRegion Transportation Policy Symposium*'s Keynote Speaker, titled "Programming Equity into Our Mobility Future" on Thursday, October 1, 2020.

- Director Kaan Ozbay was a panelist at the *ITE Metropolitan Section's Annual Meeting*, covering the topic of "Adapting to COVID-19: A Paradigm Shift in Transportation" on November 12, 2020.

### 2. Workshops

- The C2SMART Center played a key role in organizing and facilitating the three-day virtual program for the *27th ITS-NY Annual Meeting and Technology Exhibition* on December 9-11, 2020, for over 200 attendees. C2SMART created and maintained the online virtual conference environment, delivered presentations, and participated in sessions at the conference.

- Associate Director of C2SMART *Hani Nassif* presented at a C2SMART webinar titled *Development of Cost-Effective UHPC and FR-HPC for Bridge Deck Applications* on March 24, 2021 with 65 attendees.

- On October 9, 2020, C2SMART hosted a joint day-long symposium between Tongji University in Shanghai, China, on *"Smart Cities in the Pandemic Era,"* sharing COVID-19 related-research between universities including C2SMART's COVID-19 Transportation Dashboard and related findings.

- Professor Anil Agrawal delivered a webinar "Performance Based Design for Bridge Piers Impacted by Heavy Trucks" to an audience of 100 for Municipal Engineers of New York on February 24, 2021.

- **Transportation Camp NYC 2020** virtually returned to C2SMART and NYU on October 17, 2020, co-directed by C2SMART Postdoctoral Associate Jingqin Gao, and NYU student Suzana Duran Bernardes,.

261 people were in attendance across 22 sessions. Scholarships were awarded to Nicholas Hudanich, C2SMART undergraduate student researcher, and Abhinav Bhattacharya, a doctoral student at NYU.

- On December 16, 2020 C2SMART PI Zhong-Ping Jiang organized and chaired a session titled *Advances on Finite-Time Control and Consensus* with co-Chair Professor Z. Zhao at the 2020 Virtual IEEE Conference on Control and Decision (CDC).
- Deputy Director Joseph Chow was the Transportation Science and Logistics Cluster Chair for the 2020 INFORMS Annual Meeting and helped organize the conference.
- On November 13, 2020, Director Kaan Ozbay was the Distinguished Speaker as part of the *C2M2 UTC's Webinar Series* with a presentation titled Understanding Mobility and Policy Impacts of COVID-19 Pandemic in New York City through the use of Big Data and Machine Learning.
- Deputy Director Joseph Chow delivered the "Design of cyberphysical autonomous mobility platforms" workshop for the *UCLA IPAM Workshop: Large Scale Autonomy: Connectivity and Mobility Networks*, part of the Long Program Mathematical Challenges and Opportunities for AV, on November 16, 2020.
- Professor Rae Zimmerman was an Invited panelist and presenter of "Identifying Data Guideline Needs for Community and Regional Resilience Modeling Workshop" in Fort Collins, CO at the *NIST Center of Excellence for Risk-Based Community Resilience Planning* on March 19, 2021.

3. Industry and Public Agency Outreach

- Professor Anil Agrawal of CCNY is in the process of contacting local agencies such as New York State Department of Transportation (NYSDOT), New Jersey Department of Transportation (NJDOT), New York City Department of Transportation (NYCDOT) and the Port Authority of New York and New Jersey to seek permission for a field implementation of his energy harvester.
- Professor Ban of UW continues to meet regularly with Microsoft Research about related research ideas; the team is facilitating the weekly meeting between UW Transportation Services and MSR on a possible pilot study using the MSR app to help the commute of UW essential workers. Professor Ban has also met with UW CoMotion, Challenge Seattle, PSRC, UW Transportation Services, and Microsoft Research on designing surveys to collect data related to commuting of employees and customers.
- The UTEP team has been participating in monthly meetings with the City of El Paso Parking Committee., responsible for operating and managing metered parking stalls in the downtown area of El Paso. The City of El Paso International Bridges Department has also provided parking data at downtown of El Paso (from the city's contractor).
- Professor Henaff's team has met monthly with agency partners including NYCDOT as part of the FloodSense project. They've also held regular stakeholder meetings with Gowanus civic groups, integrating these findings to understand the technology interventions that can be meaningful and provide a more useful and impactful solution for stakeholders to become aware of flooding concerns.
- The Rutgers team continues to work with NYCDOT, who provide support to develop the testbed on the Brooklyn Queens Expressway. Kistler Instrument Crop continues to provide technical support as collaborative research to develop an integrated system for direct Overweight truck enforcement.
- Professor Wang's UW team installed customized mobile units for sensing traffic (MUST) sensors in a field test bed provided by the City of Bellevue for curbside monitoring. This partnership was established in a previous research effort between UW and the City of Bellevue.
- Professor Rizzo's team is working with the United Nations. The team has been invited to conduct mapping of the headquarters to aid the UN's accessibility efforts.
- Profs. Joseph Chow and Rae Zimmerman of NYU continue to collaborate closely with Via on their joint study on microtransit optimization in New York City.

4. Webinars

As part of the C2SMART's Webinar Series, Center faculty, students and visiting researchers present their work to a live audience virtually due to the COVID-19 pandemic. All webinars are archived for viewing on the Center's YouTube channel. The following webinars took place during this reporting period:

- 10/15 - Development of a Mobile Web App for Micromobility Parking Management, *Don MacKenzie*
- 10/29 - New Degradation Models Based on Pre-Cracked Bridge Deck Rebars to Better Address Infrastructure Corrosion, *David W. Coit*
- 11/20 - Public Traffic Cams and Computer Vision to Analyze Social Distancing Trends, *Jingqin (Jannie) Gao, Yubin Shen & Fan Zuo*
- 11/16 - Protecting Traffic Infrastructure with Weigh In Motion (WIM), *Christoph Klauser*
- 11/24 - Edge Computing for Safer and Smarter Transportation Applications, *Yinhai Wang*
- 12/4 - FloodSense – Longitudinal Remote Urban Flood Monitoring, *Elizabeth Henaff, Andrea Silverman, Charlie Mydlarz, & Tega Brain*
- 12/8 - Autonomous Driving and Energy-Efficient Traffic Smoothing, *Benedetto Piccoli*
- 12/15 - Adaptation of Weigh-In-Motion (WIM) Standards for Autonomous Enforcement on the BQE Smart Urban Roadway Testbed, *Hani Nassif & Chaekuk Na*
- 2/16 - Extracting Horizontal Alignment Information from Geographic Information Systems (GIS) Maps: A Clustering Approach, *Bekir Bartin*
- 3/2 - Learning-based Control: A Tool for Autonomous Driving, *Zhong-Ping Jiang*
- 3/18 - Understanding the Role of Microtransit in a Multi-modal Ecosystem, *Joseph Chow, Rae Zimmerman and Saar Golde, Chief Data Scientist, Via*

## 5. Media Coverage and Public Outreach

- C2SMART's email communications averaged 30% opens and 3% click-throughs respectively, exceeding the 23% open and the 2% click-through rate averages for other mailing lists in education and training reported by MailChimp. During this period, the center's YouTube channel accumulated 2,409 views, an increase of slightly more than 1,000 views over the last reporting period.
- C2SMART has gained 70 followers to its Twitter account (@C2SMARTNYU), used to promote its research, webinars, and other events and news, since last reporting period. The account produces at least 2 tweets or retweets per day, on average.
- Dot.LA, a Los Angeles-centered technology outlet quoted Jingqin Gao, C2SMART research associate, in "Santa Monica Will Test Surveillance Tools to Monitor Its New Drop-Off Zone"
- The Wall Street Journal Featured the C2SMART Center's research on pandemic traffic trends, quoting Director Kaan Ozbay in "New York City Traffic Picks Up, but It Still Isn't What It Once Was"
- GovTech covered the FloodSense project and interviewed the team in "Data Project May Drive Policy for Hyperlocal Flooding in NYC"
- Deputy Director Prof. Joseph Chow was quoted in the Wall Street Journal in an article titled "Electric-Vehicle Charging Hub to Park Itself in New York City"
- C2SMART Center Director Kaan Ozbay was interviewed for Transport Topics "Traffic Volumes Continue to Climb Amid Pandemic" after his TRB presentation, drawing an attendance of over 400
- The Queens Chronicle covered the joint project between Professor Henaff and the FloodNet team, and the Science and Resilience Institute at Jamaica Bay
- Prof. Mackenzie was quoted in "Electric vehicle revolution is coming fast – and North Carolina isn't ready" in WRAL TechWire, and in "To Save the Planet, Get More EVs Into Used Car Lots," in Wired.
- Professor JR Rizzo spoke about his work on sensory substitution to help people with vision impairments on the Lighthouse Guild podcast, On Tech & Vision with Dr. Cal Roberts.
- The publication Automotive World cited C2SMART PI Sarah Kaufman's research on Revel Mopeds in "Invers: Deconstructing the gender gap in shared micromobility usage"
- Prof. Andrea Silverman was quoted in the NYTimes' "What NYC's Sewers Reveal About the Virus"
- The BQE Expert Panel, which includes Profs. Hani Nassif and Kaan Ozbay, was referenced in "Stalled Highway Project Could Get Lift from New NYC Transportation Chief" in the Wall Street Journal.

## D. *Plans for Next Reporting Period*

- C2SMART will expand two monthly webinars to also highlight student research across the Consortium
- The Center will organize a virtual Technology Transfer Day with an audience of agency and industry partners to facilitate connection between active research and partners for implementation or pilots.
- C2SMART looks forward to holding its annual Advisory Board Meeting in Summer of 2021.

# II. Participants and Collaborating Organizations

## A. *Partner Organizations*

Table 5: C2SMART partner organizations

| Organization Name | Location | Contribution | | |
| --- | --- | --- | --- | --- |
| | | Financial Support | In-kind Support | Collaborative Research |
| 6-t Bureau de Recherche | Paris, France | | | X |
| Abu Dhabi DOT | Abu Dhabi, UAE | | X | |
| Alliance for Downtown New York | New York City, NY | | X | |
| Arcadis | New York, NY | | X | |
| Bestmile | San Francisco, CA | | X | |
| BMW ReachNow | Seattle, WA | | X | |
| Calstart | Various, USA | | | X |
| CarbonCure | Dartmouth, Canada | | X | |
| Carmera | Brooklyn, NY | | X | |
| Castrol | Various | | X | |
| Clayton Concrete | Lakewood, NJ | | X | |
| Central Japan Railways | Tokyo, Japan | X | | |
| City of El Paso | El Paso, TX | | X | |
| Conway Marine Construction, Inc. | Long Island, NY | | X | |
| Cuebiq | New York, NY | | | X |
| Daidone Electric, Inc. | Newark, NJ | | X | |
| Drive Engineering | Blue Bell, PA | | | X |
| ETH Zurich | Zurich, CH | | | |
| Euclid Chemical | Cleveland, OH | | X | |
| Federal Transit Administration | Washington, DC | X | | |
| Foundation for the Future | Brooklyn, NY | | | X |
| Gowanus Canal Conservancy | Brooklyn, NY | | | X |
| Gowanus By Design | Brooklyn NY | | | X |
| Ikos Lab | Europe (various) | | | X |
| Intelligent Transportation Society of NY | New York, NY | | X | |
| International Parking & Mobility Institute | Alexandria, VA | X | | |
| King County Metro | Seattle, WA | | | X |
| Kistler Instrument Corp. | Buffalo, NY | | X | |
| Korea Expressway Corporation | Korea | | X | |
| The Lighthouse Guild | US (various) | | X | X |
| Nexar | New York City, NY | | | X |
| NEXT | Silicon Valley, CA | | | X |
| NJ Turnpike Authority | Woodbridge, NJ | X | | |
| NJDOT | Newark, NJ | X | | |
| NYC Mayor's Office of the CTO | New York City, NY | | | X |
| NYC Mayor's Office of Resilience | New York City, NY | | | X |
| NYC Mayor's Office for People of Disabilities | New York City, NY | | X | |
| NYC Dept. of Citywide Admin. Services | New York City, NY | | X | X |

| | | | | |
|---|---|---|---|---|
| NYC Dept. of Transportation | New York City, NY | X | X | |
| NY Metro. Transportation Council | New York City, NY | | | X |
| NY State Dept. of Transportation | Albany, NY | X | X | X |
| NYSERDA | Albany, NY | X | | |
| Parkofon | Alexandria, VA | | X | |
| Populus | San Francisco, CA | | | X |
| Port Authority of NY&NJ | New York City, NY | X | | |
| Precast Systems Engineering | Exmore, VA | | | X |
| Puget Sound Regional Council | Seattle, WA | | X | |
| Red Hook Initiative | Brooklyn, NY | | X | |
| Revel | New York City, NY | | | X |
| Science and Resiliency Institute | Jamaica Bay, NY | | | X |
| SHARE NOW | Seattle, WA | | | X |
| Silvi Concrete | Fairless Hill, PA | | X | |
| Sound Transit | Seattle, WA | | | X |
| Texas Department of Transportation | Austin, TX | | X | |
| Toyota | Various | | | X |
| The Things Network | Amsterdam, Neth. | | X | |
| TrafficCast International | Middleton, WI | | X | |
| Transpod | Toronto, Canada | | | X |
| Trust for Governor's Island | New York City, NY | | X | |
| US-China Clean Energy Research Center | Various | | | X |
| United Nations | New York City, NY | | | X |
| Via | New York City, NY | | X | |
| Voltaic | Brooklyn, NY | | X | |
| Washington State DOT | Olympia, WA | | X | X |
| Zendrive | San Francisco, CA | | | X |

### B. *Other Collaborators or Contacts*

### 1. Collaborations with Other Departments and Research Centers

C2SMART continues to promote inter-departmental research projects, renewing collaborations between Depts. of Civil/Environmental Engineering, Computer/Electrical Engineering, Computer Science, Urban Planning & Policy, School of Medicine, and the Center for Urban Science and Progress at NYU. New collaborations were initiated during the latest round of funded proposals this period with the School of Law at NYU and the Dept. of Math at Rutgers-Camden.

### 2. Inter-University Collaboration

- C2SMART continues to collaborate the PacTrans and CTECH UTCs on its response to COVID-19 related research, sharing data sources that feed into the C2SMART Center Transportation Data Dashboard.
- Professor Henaff's team continues to collaborate with CUNY Advanced Science Research Center (ASRC) and with the Science and Resiliency Institute at Jamaica Bay on flood sensor development.
- Professor Ergan's research team recently began discussing a joint research effort with faculty members from University of North Carolina Charlotte (UNCC), who have a similarly scoped project.

### 3. Other Collaborations

- NYCDOT has continued to provide support for C2SMART's Urban Roadway testbed on the BQE.
- C2SMART continued to work with NYCDOT on USDOT's NYC Connected Vehicle Project, including finalizing the safety assessment in the Performance Measurement and Evaluation Support Plan (PMESP) and updating project design for the application for visually impaired pedestrian navigation.

## III. Outputs

C2SMART is exceeding its targeted performance metrics in each of the areas identified in its Technology Transfer Plan, identified in Table 5.

### A. *Publications, Conference Papers and Presentations*

#### 1. List of Journal Publications

**Table 6: Output Performance Measures**

| Performance Measures | Annual Goal | Achieved (current period) |
|---|---|---|
| Peer-reviewed papers | 20 | 46 |
| Conference presentations | 10 | 20 |
| Joint proposals/projects with industry/agency partners | 10 | 16 |
| Website analytics | 5,000 unique pageviews | 25,570 unique pageviews |

- Xie, Q. & Jin, L. Stability of model data-independent control of queuing networks. IEEE Transactions on Control of Network Systems. Submitted.
- Zou, Z., Bernardes, S. D., Zuo, F., Ergan, S., & Ozbay, K. An Integrated Approach to Enable Hardware-in-the-loop for Realtime VR, Traffic Simulation and Sensor Interactions: An Application in Work Zone Safety. Journal of Advanced Engineering Informatics, 2021. In preparation.
- Zhou Y., Ozbay K., Kachroo P., & Zuo F. Ramp Metering for a Distant Downstream Bottleneck Using Reinforcement Learning with Value Function Approximation. Journal of Advanced Transportation. October 2020. Published.
- H. Chang, A. Pallathadka, J. Sauer, N. Grimm, R. Zimmerman, C. Cheng, D.M. Iwaniec, Y. Kim, R.Lloyd, T. McPhearson, B. Rosenzweig, T. Troxler, C. Welty, R. Brenner, & P. Herreros-Cantis. Assessment of Urban Flood Vulnerability Using the Social-Ecological-Technological Systems Framework in Six US cities. Sustainable Cities and Society. Accepted.
- Zhou Y., Ozbay K., Kachroo P., & Chung E. A supervised switching-mode observer for traffic state and parameters and application to adaptive ramp metering. Transportmetrica A: Transport Science 2021. Published.
- Liu, B, Pantelidis, T.P., Tam, S., Chow J.Y.J.; An electric vehicle charging station access equilibrium model with M/D/C queueing. Under Review.
- Xu S.J., Xie Q., Chow J.Y.J., Xintao Liu. An Empirical Validation of Network Learning With Taxi GPS Data From Wuhan, China. IEEE Transportation Magazine. December 2020. Published.
- Yoon G., Chow J.Y.J.; Dmitriyeva A., Fay D., Effect of Routing Constraints on Learning Efficiency of Destination Recommender Systems in Mobility-on-Demand Services. IEEE Transactions on Intelligent Transportation Systems. December 7 2020. Published.
- Yang D., Xie K., Ozbay, K., Yang. H. Fusing crash data and surrogate safety measures for safety assessment: Development of a structural equation model with conditional autoregressive spatial effect and random parameters. Accident Analysis & Prevention. March 2021. Published.
- Yueshuai B.H., Chow J.Y. J. Impact of COVID-19 Behavioral Inertia on Reopening Strategies for New York City Transit,Gravity Model of Passenger and Mobility Fleet Origin–Destination Patterns with Partially Observed Service Data. Transportation Research Record: Journal of the Transportation Research Board. February 10, 2021. Published.
- Xie K., Ozbay K., Yang, D., Xu, C. Yang, H. Modeling bicycle crash costs using big data: A grid-cell-based Tobit model with random parameters. Journal of Transport Geography. February 2021. Published.
- Bian Z., Zuo F., Gao, J. Chen Y., Venkata S.S.C.P, Bernardes S.D., Ozbay K., Ban, X.J., Wang J., Time lag effects of COVID-19 policies on transportation systems: A comparative study of New York City and Seattle. Transportation Research Part A: Policy and Practice. Published.
- Huang, M., Cui, L., Ozbay, K., & Jiang Z. Learning-Based Adaptive Optimal Control for Connected Vehicles in Mixed Traffic: Robustness to Driver Reaction Time. IEEE Transactions on Cybernetics. November 2020. Published.

#### 2. Books or Other Non-Periodical, One-Time Publications

- Doctoral student Chloe Bingqing Liu and Prof. Joseph Chow shared their analysis of the impact of Revel's megahub on EV charging accessibility in NYC using a tool developed for NYC DCAS as part of the NYU VIP "NYC Clean Fleet" The tool is freely available on the BUILT lab's Github portal, and arXiv.
- Professor Chow also published an all-in-one reference guide for those interested in the various efforts produced by his MatSIM validation and application to congestion pricing.

3. Other Publications, Conference Papers and Presentations

- C2SMART presented 53 presentations with a wide variety of research during virtual lectern and poster sessions, as well as presiding over several workshops and committee meetings, at the 100th Annual Meeting of the Transportation Research Board in January 2021. Full C2SMART activity at TRB.

- Sheng D., Chai Y., Li X., Feng C., Lin J., Silva C., Rizzo J. NYU-VPR: Long-Term Visual Place Recognition Benchmark with View Direction and Data Anonymization Influences. International Conference on Intelligent Robots and Systems 2021. Under Review.

- Professor Jiang was the keynote speaker at the 3rd International Symposium on Electrical, Electronics and Information Engineering (ISEEIE 2021), Feb. 19-21, 2021, Seoul, South Korea. Learning to Control Dynamic Systems: Stability and Robustness.

- Professor Jiang was a plenary speaker at the 2021 International Workshop on Smart Energy and Optimal Control, January 15-17, 2021, Jinan, Shangdong. Learning-Based Optimal Control: A New Direction in Control Theory. He was also Plenary speaker at the 4th International Symposium on Autonomous Systems (ISAS), Guangzhou, December 7-8, 2020, where he presented Learning-Based Control: A New Direction in Control Theory.

- Yoon, G. Reinforcement Learning-based Transit Operation Design: From Line Planning To Operation Policy. 2020 INFORMS Annual Meeting. November 13, 2020. Presented.

- Briones, F., Weidner, J. and Cheu, R. L. (2021). Smart Parking Garage: Concept of Operations and User Benefits. Submitted.

- L. Cui, K. Ozbay and Z. P. Jiang, Combined Longitudinal and Lateral Control of Autonomous Vehicles based on Reinforcement Learning. 2021 American Control Conference. Accepted.

- Xie, Q., Jin, L. Stabilizing Queuing Networks with Model Data-Independent Control. In preparation.

- De la Garza, X. J., Weidner, J. and Cheu, R. L. (2021). Locations and Length of Entrances and Exits of an Automated Truck Lane on a U.S. Freeway. IEEE Smart City Symposium in Prague (SCSP2021). Under Preparation.

- Gurbuz, O. and Cheu, R. L. (2021). Zoning and Zone Permit Pricing Methodology for Smart Parking Management at University Campuses. IEEE Smart City Symposium in Prague (SCSP2021). Under Preparation.

- Yoon, G., Simulation Approach to Plan Demand Responsive Transport (DRT) - Relevant study: FTA Project., 2020 IATR Virtual Conference. Presented.

- Bernardes, S.D. Performance Assessment of Major Connectors In New York City Using Virtual Sensors, INFORMS Virtual 2020 Annual Meeting. Presented.

- Xiong, X., Vehicle Platooning Coordination in Networks: A Multi-agent Reinforcement Learning Approach. INFORMS Virtual 2020 Annual Meeting. Presented.

- Yiyuan Lei, Y., A robust analysis of the long-term impacts of the stay-at-home policy on taxi and Citi bike usage: A case study of Manhattan, International e-Conference on Pandemics and Transport Policy (ICPT2020). Presented.

- Gao J., Ozbay K., Hotspot Identification, Ranking and Impact Estimation of Illegal Parking Using Spatial Association and Queueing Model, hEART 2020: 9th Symposium of the European Association for Research in Transportation. Presented.

B. *Websites*

The **C2SMART website** (c2smart.engineering.nyu.edu) continues to be used for disseminating information about the Center's activities and research and had 25,570 unique page views during this reporting period, up from 20,124 unique pageviews last reporting period, and once again exceeding its annual goal of 5,000 pageviews. The COVID-19 mobility dashboard hosted on the C2SMART website since April 2020 continues to generate a lot of interest and inquiries. The landing page and dashboard on this research were the first and second most visited webpages during this reporting period with 2,336 unique visitors and 1,357 respectively, and 4,684 total page views for the two combined. In addition, the Sustainable Transportation Lab site is used to disseminate information about research at the University of Washington, including C2SMART-funded work on shared electric vehicle systems. The Rudin Center site shares information about research and workforce development, and the Rutgers Infrastructure Monitoring and Evaluation Group (RIME) site provides regular updates on the group's activities.

## C. Technologies or Techniques

- PI Cheu and his UTEP co-PI have approached the Office of Technology Commercialization (OTC) in UTEP on filing an invention disclosure for the completed Urban Connector application. The OTC has evaluated the Urban Connector and confirmed the possibility of commercializing the Urban Connector. The OTC is consulting with the advisor in The University of Texas System on the possible ways forward (such as copyright, patent), arrangement (such as licensing) as this project involved NYU and the City of El Paso, and the Urban Connector is linked to 3rd party applications.
- PI Henaff and her team have made a complete sensing unit bill of material and its construction procedure available online (see Sec. 3d below), including full modular code stack for edge sensor.
- PI Jiang's novel vehicle control technology that integrates advances in reinforcement learning, adaptive dynamic programming, and modern control theory, for real-time control of connected vehicles in mixed traffic with robustness to human reaction time continue to be used and cited.

## D. Industry/Agency Partners

Table 5 lists all current active or renewed collaborations with agency and industry partners. C2SMART is actively pursuing new funding opportunities to complement or continue center-funded research to expand upon the initial research into implementation projects.

- The C2SMART proposal (NYU & Rutgers) in response to the Port Authority of New York & New Jersey's RFP for Academic Institutions to Advise on Best Practices in Low Carbon Concrete Capture was accepted for partial funding, to commence in the next period.
- The C2SMART Center continues to work with NYC-area agencies on USDOT's NYC Connected Vehicle Project, including an application for visually impaired and a cooperative driving task.
- C2SMART is actively working with the New York State Department of Transportation on four research proposals under its long-term consortium agreement. These projects are:
  - SR-20-02 Statewide Mobility Services Program Strategic Procurement Planning
  - SR-20-03 Capital Program Resource Model
  - SR-20-04 Statewide Open Source Advanced Traffic Management System (ATMS) Pilot
  - SR-20-05 AASHTO and NBI Element Deterioration Rates for Bridge Management System
- NYS Empire State Development has awarded funding for the data backend of the FloodSense project.
- C2SMART also submitted proposals in response to RFP's for the following:
  - FHWA Intelligent Transportation Systems (ITS) Deployment Evaluation Program Data Collection and Information Synthesis Support with partner Noblis
  - NJDOT Technology Transfer and Implementation Program
  - NJDOT Bridge Research Program
  - Department of Energy (DOE) Fiscal Year 2021 Research Funding Opportunity Announcement

## E. Other Products

C2SMART researchers have produced various datasets, models, mobile applications, and summaries during this reporting period, located on the center's Zenodo Data Repository. In addition:

- PI Cheu's research team downloaded and processed Los Angeles downtown parking data from the LA Express Park website. The parking data for downtown El Paso was provided by the city.
- PI Nassif's research team generated a dataset regarding the effect of COVID-19 Pandemic Effect on Implementation and Effectiveness of Autonomous Enforcement of Overweight Trucks in an Urban Infrastructure Environment. The team also created a comparison dataset of BQE weigh-in-motion (WIM) data before and after enforcement.
- PI Nassif's team utilizes the NYCDOT Data Repository to publish the WIM data collected from PVDF sensors at the testbed near Pearl St. in Brooklyn, NY. It can be accessed at NYCDOT
- PI Henaff's team have built open source libraries, sensor hardware tutorials, and code resources and housed them on the C2SMART Github. 6 Datasets have been uploaded for each deliverable:: the canal sensor data and the street sensor data

- Using the reinforcement learning, adaptive/approximate dynamic programming, and control theory, Professor Jiang has developed a new class of learning-based algorithms for control of connected vehicles in the mixed traffic and autonomous driving with perception in the loop.

## IV. Outcomes

### A. Increased Understanding and Awareness of Transportation Issues

- The recent Future of Road Transport report produced by the European Commission cited Deputy Director Joseph Chow's Informed Urban Transport Systems: Classic and Emerging Mobility Methods toward Smart Cities

**Table 7: Outcomes Performance Measures**

| Performance Measures | Annual Goal | Achieved (current period) |
|---|---|---|
| Media interviews, mentions, coverage | 10 | 9 |
| Workshops, webinars, and seminars | 10 | 20 |

- Through the monthly meetings with C2SMART researchers, members of the City of El Paso Parking Advisory Committee are now aware of smart parking and performance measurement system. The committee has uploaded El Paso downtown parking data, the first time the public will have access.
- PI Nassif's research team has been providing the updated WIM data that summarizes the effect of NYCDOT overweight enforcement that was implemented in February 2020. Due to the pandemic, the effect of the enforcement was not distinct from the WIM data. Now that traffic volumes have returned to pre-pandemic levels, the team will be able to isolate the effect of NYCDOT enforcement.
- PI Nassif's team has proposed a scoping study to the NYCDOT for immediate action to be taken to repair significantly deteriorated segments of the BQE to maintain the bridge for several years until full replacement or rehabilitation to accommodate the future traffic volume and weight demands.
- PI Henaff's research team has monthly meetings with agency partners in NYC, and stakeholder meetings with Gowanus civic groups. The team's discussions with NYCDEP engineers have identified 6 locations for sensor deployments to inform and calibrate hydrological models.
- PI Jiang's research team has progressed development of advanced vehicle control technologies that can address safety and energy efficiency issues for mixed traffic transportation environments to reduce the congestion and improve safety and energy efficiency.
- Members of PI Cheu's research team, Dr. Weidner and Dr. Gurbuz, continued to attend the monthly meeting of Parking Advisory Committee as committee members.

### B. Increases in the Body of Knowledge

- PI Ban's work modeling ride-hailing services and their integration with transit have expanded understanding of how disparate elements of urban transit operate together.
- PI Cheu's work has shown the manner and degree to which different cities have different levels of smart parking implementation. The different types of data available for this project will require the development of new analysis procedures to meet this challenge.
- PI Ergan's team has identified that Hardware in the Loop (HIL) is a key technique for increasing the realism of the VR experiments, as it can adapt data from the physical environment it to the VR environment to better reproduce work zone scenarios and improve the spatial awareness of participants. The research team also identified the suitable types of sensors to be used for future implementations in work zone safety monitoring. Four main technologies have thus been adopted:
  - o VR Technology for visually reproducing real work zone environments into immersive 3D.
  - o Traffic simulation integrated to the VR environment to reproduce real traffic conditions.
  - o Feedback from VR environments to influence traffic patterns caused by worker behaviors.
  - o Using HIL to create a virtual boundary of a VR work zone based on physical dimensions of a lab.

- PI Henaff's research team captured two floods and one snowfall with the sensor mounted on Hoyt Street in Gowanus, demonstrating that ultrasound-based sensors are effective in determining the height of hyper-local precipitation over the sidewalk. Additionally, the frequency of data measurements enabled sensors to identify the flood profile, or pattern of water accumulation and decay time, which enables differentiation between snow and water accumulation.
- The findings of PI Jiang's project contributed to the development of a new theory to design advanced vehicle technologies by combined use of interdisciplinary tools and methods from machine learning, control theory, and transportation. The research findings contribute to the development of a new theory to design advanced vehicle technologies by combined use of interdisciplinary tools and methods from machine learning, control theory, and transportation.
- PI Nassif's team have proposed a scoping study to NYCDOT to demonstrate new bridge deck evaluation technology, Infrared Ultra Time Domain (IR-UTD) measurement system and to determine if it is well-suited for measurements in urban areas with very high traffic.
- Based on a composite citation index (Ioannidis et al. (2020)), Professor Joseph Chow, C2SMART Deputy Director was among the [top 2% of scientists in the Logistics and Transportation subfield](#) in 2019. Professor Kelvin Cheu also made the list.

## C. *Improvement and Adoption of Processes, Technologies, Techniques and Skills in Addressing Transportation Issues*

- PI Ban's work on the interconnectedness of urban transit modes has furthered our understanding of how ride-hailing can help solve transportation issues.
- PI Cheu's research team is developing a LOS analysis procedure to improve downtown parking based on search time.
- PI Ergan's research team extended on the previous SUMo-VR information loop to include hardware in the loop component, where work zone safety hardware can be tested in a realistic environment with real-time traffic simulated in VR and real-time worker behavior feedback from VR to SUMo. The proposed approach can fundamentally change the way of testing work zone safety technologies with a more realistic traffic in VR from SUMo simulations.
- PI Henaff's research team's experiments show that ultrasound-based sensors can be used to detect water levels, and the ongoing work will determine their validity in street-level flooding. Understanding drainage patterns can improve transportation by predicting how long a flood will persist based on prior profile information at that location to result in an accurate and resilient solution for urban flood monitoring.
- C2SMART researchers working with PI Nassif have proposed several advanced sensor technologies to monitor the BQE's cantilever sections to develop a long-term SHM specifications and plan to prolong its service life with minimum repair requirements. NYCDOT has accepted C2SMART's proposal to implement various new sensors, including:
  - Infrared Ultra Time Domain (IR-UTD) Test to quantify the concrete deterioration,
  - Distributed Fiber Optic Sensors to measure continuous strain, temperature, etc.,
  - Accelerometers to measure the acceleration to check the change in natural frequency,
  - Tiltmeters to measure the tilt at the cantilever tip, and
  - Laser Distance Sensor to measure the deflection of the cantilever tip.
- The Rutgers team is also evaluating the performance of the Weigh-In-Motion (WIM) and Automatic License Plate Recognition (ALPR camera) for direct Overweight Truck enforcement.

## V. Impact

### A.  Effectiveness of the Transportation System

- C2SMART's work on COVID-19-related data will significantly inform the state of transportation systems during recovery from the pandemic. Its dashboard collection of various mobility data sources is the only known consolidated tool of these data sources, and its low-cost social monitoring using feeds from traffic cameras and survey data is available for use by planners and policymakers.
- The FloodSense team's work will regularly inform residents, advocacy groups, and agencies such as NYCDOT of hyperlocal flooding issues, filling the need for data that is not currently not collected.
- The Rutgers team's work with NYCDOT is critical to the health and safe operation of the BQE, a critical link in the NYC highway network. An automated overweight truck enforcement bill based on the Rutgers' team's research efforts at the BQE Testbed under review by NYS Senate.

**Table 8: Impacts Performance Measures**

| Performance Measures | Annual Goal | Achieved (current period) |
|---|---|---|
| Instances of software, tools, research results, or guidelines adopted by transportation agencies leading to operational improvements | 5 | 14 |
| Partnerships/collaborative relationships with companies or transportation agencies established or renewed | 10 | 20 |

### B. New Practices or Companies

C2SMART's Student Entrepreneurship Grant Competition resulted in selection of 2 teams. The students are developing a prototype, investigating the market, and preparing the business plan for the topic with the aid of a faculty mentor. At the end of the spring semester, students will report out on their progress and their future plans for advancing and sustaining the business to an audience that includes identified industry stakeholders, and/or potential investors and clients.

### C. Body of Scientific Knowledge

C2SMART's work in connected vehicles and cities continues to generate significant scientific knowledge in this area prior to full-scale deployment. C2SMART researchers were recognized for their contributions which the following awards:

- Two C2SMART Center students received recognition for their graduate theses: Junaid Farooq, who previously worked on a C2SMART Center project with PI Quanyan Zhu, was awarded top honors in the Technology and Applied Science subcategory for "Cyber-Physical Dynamic Decision Mechanisms for Large Scale Internet of Things Systems & Networks," and Zhengbo Zou, Professor Ergan's Graduate Research Assistant was awarded for "Towards Emotionally Intelligent Buildings: An Integrated Approach to Quantify Human Emotions in Designed Spaces" from among all entries in the "Urban" category.
- The NYU Institute of Traffic Engineers (ITE) Student Chapter Traffic Bowl Team won the 2020 ITE Northeastern Collegiate Traffic Bowl, an annual trivia competition using transportation planning and engineering topics. This year's winning team, represented by ITE president Logan Wagner, former ITE president Bruno Cunha and C2SMART Student Researcher Nicholas Hudanich, competed in the Traffic Bowl Grand Championship on October 22, placing second.
- At the 27th ITS-NY Annual Meeting, C2SMART Center was recognized for its participation in USDOT's Connected Vehicle Pilot in the New York City Area. The NYC CV Pilot Deployment project was also awarded a 2020 ACEC NY Engineering Excellence Silver Award.
- The C2SMART Center-funded FloodSense project, generating hyperlocal flooding data from sensors installed in the Gowanus neighborhood, was included in "Innovation of the Month" by MetroLab Network. The research team sat down with Gov Tech News for an interview.
- The Federal Highway Administration (FHWA) has awarded C2SMART student Haoran Su a Research Fellowship for an estimated $41,500.00 as part of the 2020 Dwight D. Eisenhower Transportation

Grant Research Fellowship (DDETP GRF). He will research "Artificial Intelligence (AI) Applications for Vehicle Tracking Using Loop Signature Matching Technology."

- "A Bike Count Forecast Model with Multimodal Network Connectivity Measures", was selected by the Transportation Research Board's Bicycle Transportation Committee as the Best Paper Award – Highest Overall Score for the 2021 Annual Meeting. The Bicycle Committee accepted nearly 60 papers for presentation at this year's Annual Meeting.

### D.  *Transportation Workforce Development*

- C2SMART has made an impact on transportation workforce development through classes taught by Center faculty, support of students involved in transportation research projects, funding for masters and Ph.D. students, and opportunities for undergraduate students. It also continues to provide Professional Development Hours assessments for credits towards PE licensure, most recently at the ITS-NY annual meeting workshops.

- The C2SMART Center Learning Hub Workshop series has an explicit emphasis on workforce development and career skills. Instructors are selected from current Consortium graduate students, providing them curriculum development and teaching preparation, while coursework is designed to provide in-demand simulation, engineering, programming, and data analysis skills, and expose students to new areas of transportation planning and engineering.

- During this reporting period, the C2SMART Center initiated support for another year of PI Sarah Kaufman's "Emerging Leaders in Transportation" program, a three-day program that brings together early-career transportation professionals for networking, panels, workshops, and leadership activities designed to enhance their professional toolkit and expose them to diverse issues in transportation.

- The C2SMART Center has selected Dan McCabe, a master's student in the Transportation Engineering at University of Washington, as its 2020 Outstanding Student of the Year. Dan has demonstrated leadership by developing an original idea (originating in a NSF GRFP proposal) into a funded research project with the guidance of his advisor, Professor Jeff Ban. Both research projects to which Dan contributed during his first year as a graduate student resulted in papers, one as first author, that were recently accepted to the 2021 TRB Annual Meeting.

## VI.  Changes/Problems

The COVID-19 pandemic continues to affect several projects, due in large part to a combination of partner agencies operating at limited capacity and reduced ability to conduct in-person data collection.

- The Cooperative Perception of Road-Side Unit and Onboard Equipment with Edge Artificial Intelligence for Driving Assistance project could not conduct field tests.
- The Work Zone Safety: Behavioral Analysis with Integration of VR and Hardware in the Loop project was unable to conduct in-person user studies of the VR environment. This task has been integrated into the next phase of the project, which began in March 2021.
- Implementation and Effectiveness of Autonomous Enforcement of Overweight Trucks in an Urban Infrastructure Environment, conducting a large-scale implementation with heavy involvement by NYCDOT, has been delayed as NYCDOT was not able to provide enough support for the testbeds due to COVID-19 pandemic, delaying field work.
- Researchers working on the Modeling and Optimizing Ridesourcing Services in Connected and Automated Cities project team encountered delays in accessing the network and other data for the case study in Seattle due to COVID-19.
- Wearables to Command More Access and Inclusion in a Smarter Transportation System initially proposed the creation of ethograms of Manhattan that would assist peiple with Visual Impairments with navigation. Given complications related to the pandemic and a connection with the United Nations, the team has modified its scope to focus on AI-based assisted navigation through mapping the UN headquarters, with a focus on the "handoff" between indoor and outdoor environments.