



A USDOT University Transportation Center

New York University

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The City College of New York

## SEMI-ANNUAL PROGRESS REPORT

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

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## Table of Contents

<b><i>I. Accomplishments</i></b> .....	<b>3</b>
<b>A. Goals and Objectives</b> .....	<b>3</b>
<b>B. Accomplishments Under These Goals</b> .....	<b>3</b>
1. Center Administration .....	3
2. Research .....	3
3. Education .....	8
<b>C. Dissemination and Outreach</b> .....	<b>8</b>
1. Training and Tech Transfer Events.....	8
<b>Conference Presentations and Research Showcases</b> .....	<b>8</b>
2. Workshops.....	9
3. Industry and Public Agency Outreach.....	9
4. Webinars.....	10
5. Media Coverage and Public Outreach .....	11
<b>D. Plans for Next Reporting Period</b> .....	<b>12</b>
<b><i>II. Participants and Collaborating Organizations</i></b> .....	<b>12</b>
<b>A. Partner Organizations</b> .....	<b>12</b>
<b>B. Other Collaborators or Contacts</b> .....	<b>13</b>
1. Collaborations with Other Departments and Research Centers .....	13
2. Inter-University Collaboration .....	13
<b><i>III. Outputs</i></b> .....	<b>14</b>
<b>A. Publications, Conference Papers and Presentations</b> .....	<b>14</b>
1. List of Journal Publications .....	14
2. Books or Other Non-Periodical, One-Time Publications.....	15
3. Other Publications, Conference Papers and Presentations.....	15
<b>B. Websites</b> .....	<b>16</b>
<b>C. Technologies or Techniques</b> .....	<b>17</b>
<b>D. Industry/Agency Partners</b> .....	<b>17</b>
<b>E. Other Products</b> .....	<b>17</b>
<b><i>IV. Outcomes</i></b> .....	<b>18</b>
<b>A. Increased Understanding and Awareness of Transportation Issues</b> .....	<b>18</b>
<b>B. Increases in the Body of Knowledge</b> .....	<b>18</b>
<b>C. Improvement and Adoption of Processes, Technologies, Techniques and Skills in</b> <b>Addressing Transportation Issues</b> .....	<b>18</b>
<b><i>V. Impact</i></b> .....	<b>19</b>
<b>A. Effectiveness of the Transportation System</b> .....	<b>19</b>
<b>B. New Practices or Companies</b> .....	<b>19</b>
<b>C. Body of Scientific Knowledge</b> .....	<b>19</b>
<b>D. Transportation Workforce Development</b> .....	<b>20</b>
<b><i>VI. Changes/Problems</i></b> .....	<b>20</b>

## 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

In April 2021, C2SMART hired a project manager using non-federal grant sources to develop agency and industry partnerships ahead of outreach for the next planned round of funded proposals. The Center’s focus as it prepares to enter its next year of funding allocation is to continue to deepen and expand implementation opportunities. The new Center office space at NYU has reopened with COVID-19 safety protocols in place, though all Center programming and external activity remain online.

#### 2. Research

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

Urban Mobility and Connected Citizens	<b>Cooperative Perception of Road-Side Unit &amp; Onboarding Equipment with Edge Artificial Intelligence, UW</b>	The team developed a customized smart roadside unit, Mobile Unit for Traffic Sensing (MUST) with a customized Computer Vision (CV) algorithm, a cooperative perception method that realizes accurate 3D vehicle localization based on a single image for driving or parking assistance. As a result, the Vehicle Localization System can 1) provide more reliable vehicle localization information; 2) increase calculation efficiency to reduce the information delay; and 3) serve more vehicles in a more extensive sensing range.
	<b>Wearables to Command More Access &amp; Inclusion in a Smarter Transportation System, NYU</b>	The team employed novel mapping and localization in all public facing areas of the UN building footprint and the surrounding grounds, inclusive of entrances and courtyards. Using the NYU-VPR dataset that contains more than 200,000 images over a 2kmx2km area near the New York University campus, the team presented benchmark results that side views are significantly more challenging for current VPR methods while the influence of data anonymization is almost negligible.
	<b>Modeling &amp; Optimizing Ridesourcing Services in Connected &amp; Automated Cities, UW</b>	The team is conducting numerical simulations consisting of a joint modeling framework including four modes—taxi, ridesharing, taxi plus transit, and ridesharing plus transit—for commuters traveling from the UW district to downtown Seattle. The simulation study aims to reveal how different cost factors may influence the mode choices of commuters, and the resulting congestion effects on the network. It will also investigate the role of taxi and ridesharing in serving the first/last mile of transit, and how to best coordinate new mobility services and public transportation to better serve the urban mobility needs.

Urban Analytics for Smart Cities	<b>Urban Microtransit Cross-sectional Study for Service Portfolio Design, NYU</b>	<p>In partnership with Via, the team finalized a methodology to upscale data from the limited sources available to microtransit operators and to public agencies like the Federal Transit Administration at low cost. The team developed four typology classification models from Wikipedia data demonstrating city typology classification based on limited samples which can be scaled to up to 2000 cities across the world. This opens new opportunities to use text-based information for understanding city typologies, assisting diverse transportation and urban planning stakeholders, and reinforce existing studies utilizing crowd-sourced data, leading to advances particularly in data-scarce regions.</p>
	<b>Development of Level of Service Analysis Procedures &amp; Performance Measurement Systems for Parking, UTEP</b>	<p>This research developed a Level of Service (LOS) analysis procedure for off-street parking facilities. Transportation engineers now have three methods of observing parking search times for three types of off-street parking facilities, and guidelines on how smart garages should be designed to serve customers drivers. There are also now guidelines on how on-street parking performance management system (PMS) design can serve customers and a procedure for estimating the LOS for on-street parking zones. This research is the first to document the LOS analysis procedure for off-street parking facilities in the same format as the Highway Capacity Manual and opens a new approach for the analysis of on-street parking performance that can be linked to dynamic parking pricing.</p>
Resilient, Secure, and Smart Transportation Infrastructure	<b>Securing Intelligent Transportation Systems against Spoofing Attacks, NYU</b>	<p>This advanced theoretical research looked at the theory of diagnosis and secure routing for transportation networks subject to a rather broad class of random or strategic disruptions. Queuing networks modeling the behavior of transportation systems shows multiple regimes for equilibria dependent on the technological costs of attacking and of defending as well as the demand. An algorithm was developed that computes the equilibria of a game and quantifies the security risk.</p>
	<b>Energy Harvesting for Self-Powered Sensors for Smart Transportation Infrastructures, CCNY</b>	<p>This study proposed, prototyped, and field tested a new type of electromagnetic energy harvester (EMEH) in which planar arrays of permanent magnets have been employed as the magnetic field source to interact with the moving copper coil. It was found that the proposed EMEH can deliver the highest electrical power when the poles of permanent magnets alternate along the direction of motion. The Robert F. Kennedy Bridge suspension bridge in NY was selected for field testing of the proof-of-concept prototype due to its strong vibration induced by heavy daily traffic. The bridge frequencies are much larger than the frequency of the prototype which made it difficult to put the prototype EMEH into a resonant condition with the vibration of the bridge. A smaller sensor is being re-calibrated with the results from the field test for Phase 2 of the project.</p>

**Table 2: Updates on Ongoing Center-funded Research Projects**

Urban Mobility and Connected Citizens	<b>A MultiScale Simulation Platform for Connected &amp; Automated Transportation Systems, UW</b>	<p>This study improved the multiscale simulation platform vehicle-traffic-demand (VTD) running efficiency and memory usage by revising the SUMO-MATSim message-exchanging processor and removing flow analysis programs from MATSim (conducting the analysis separately). Using data provided by Washington DOT, Seattle DOT, and Bellevue DOT, the study cleaned up the Greater Seattle network to include the Metro routes and schedules, arterial speed factors, motorway speed factors, arterial capacity factors, and motorway capacity factors. The team also built the SUMO-MATSim-Unity integration for a testing intersection.</p>
	<b>Autonomous Vehicle Good Citizenry Standard, NYU</b>	<p>The team developed an invitation and fact sheet to send workshop participants, to be hosted in December 2021, and identified anchor participants for each of the three sessions. In addition, researchers have made progress in identifying the equity gaps in the proposed Mobility Data Specification (MDS) and collecting data that describe underserved groups in New York City to update the synthetic population of C2SMART's Multi-Agent Simulation Testbed (MATSim) with equity considerations.</p>

Urban Analytics for Smart Cities	<b>Lane Changing of Autonomous Vehicles in Mixed Traffic Environments, NYU</b>	This study investigated the decision-making model for the lane changing of autonomous vehicles (AV), considering the safety distance between the AV, the preceding vehicle and the following vehicle. The team will develop a learning-based algorithm to optimally change the lane of an AV. In order to improve the comfort of passengers, reduce energy consumption, and accelerate the lane changing process, they utilized a learning-based adaptive optimal control method. They will use SUMO simulation for validation.
	<b>Evaluating Remote Repositioning for Shared Scooters, UW</b>	The team worked with Boise and Spin to develop performance milestones for its scooter rollout and conditions for introducing new remote repositioning functions, including developing plans for user training, publicity and program rollout, and the data fields available for analysis and protocols. The project has been delayed because the global chip shortage has delayed the delivery of T-60 e-scooters to be used in the pilot. The team is targeting the spring of 2022 for data collection and surveys.
	<b>Collaborative Driving, Ramp Metering &amp; Mean-field Controls, Rutgers</b>	Towards a mean-field multi-scale model for collaborative driving, the team designed a control algorithm and tested in highway simulations with heterogeneous traffic. They will extend the model to a different level of heterogeneous traffic, study the case for ramp-metering using numerical tests, and study disruption scenarios such as an accident on the downstream of a work zone that requires a lane change.
	<b>C2SMART COVID-19 Data Dashboard, NYU, Rutgers, UW</b>	The research team integrated additional public data sources into the dashboard including subway ridership from four cities in China; yellow and green taxis; and For-Hire Vehicle (FHV) trip-related data in 2020, monthly vehicular traffic at Port Authority Tunnels and Bridges and a social distancing safety rate and temporal distributions of pedestrian, car and cyclist charts have been uploaded.
	<b>Quantifying &amp; Visualizing City Truck Route Network Efficiency Using a Virtual Test Bed, NYU</b>	The team has been meeting monthly with NYCDOT to explore moving away from data visualization towards an app for urban truck routing, which is currently manually performed via hotline calls from truck drivers. The team has met with different city agencies to acquire data that will be tied together and processed and will develop a truck tour algorithm in app form to present to NYCDOT.
	<b>Utilizing Social Media Data for Estimating Transit Performance Metrics in a Pre- &amp; Post-COVID-19 World, CCNY</b>	Various keywords, hashtags, and Twitter handles were used to build a model that can estimate relevance of tweet and to classify the tweet by category. An estimate of the sentiment from these tweets is also being developed. Transit data will be analyzed to estimate performance metrics on delays, service alerts and other station-related metrics for the time period after COVID-related lockdown. They have finalized the reward function for the reinforcement learning model specific to each alarm event.
	<b>Calibration of Safety Notifications through Reinforcement Learning and Eye Tracking, NYU</b>	The team has continued to develop VR models for additional scenarios by adding realistic, SUMO-controlled vehicles. They have further developed data analysis methods for visualizing data on measures of alarm response and have begun developing a process for generating synthetic data for the reinforcement learning model's training environment, using statistical inference on human participants to simulate worker behavior.
<b>Exploring AI-based Video Segmentation /Saliency to Optimize Imagery-Acquisition from Moving Vehicles, NYU</b>	The team developed the Entity Relationship Aware (ERA) framework, which utilizes graph convolutional networks to extract pure visual features concentrating on the interaction among objects/entities alongside a model called IntentVizor through which users can input visual/text features for evaluation. They are currently developing a crowd counting algorithm using a novel technique to count pedestrians from videos mounted on the cars moving along streets.	
<b>Digital Twin Tech. for Interactions between Transportation &amp; Other Civil Infr. Systems, UTEP</b>	The team combined and augmented ground scans of the UTEP campus to create a digital twin infrastructure model. They have created a 2D network in VISSIM of the road network of the area of interest, created digital models of the transportation network inventory, created pavement marking models, and transformed the 2D network into a 3D network. They met with researchers at Czech Technical University to discuss its digital twin in Europe.	

Resilient, Secure, and Smart Transportation Infrastructure	<b>Implementation &amp; Effectiveness of Autonomous Enforcement of Overweight Trucks in an Urban Infrac. Environment,</b> Rutgers	The team collaborated with NYCDOT and industrial partner, Kistler, to develop the WIM site qualification testing RFP to evaluate the pavement condition for future enforcement systems at the 2nd testbed. The team provided technical support to NYCDOT for the selection of the proposals, and with development of the drawing of the 2nd testbed for the Quartz sensor and ALPR camera installation. The WIM sensor and ALPR camera layouts were optimized based on various field constraints. The team and Kistler proposed new sensor layouts to validate the weighing accuracy and repeatability in the urban area. The team then continuously collected WIM data of 5 lanes at the testbed.
	<b>Field Application of a High-Power Density Electromagnetic Energy Harvester to Power Wireless Sensors in Transp. Infrastructures,</b> CCNY	The team completed the initial design of a modified electromagnetic energy harvester which uses linear arrays of permanent magnets and for this reason has a smaller volume compared to the initial device design. An analytical model was developed in MATLAB to optimize the generation of power. The next step is to design a dynamic magnifier for the device to amplify the output power. The PI carried out an optimization study on the analytical model of the device. The results show that the device in the resonant frequency can generate electric power of about 1 W.
	<b>Equitable Access to Residential (EQUATOR) EV Charging,</b> NYU	The team developed metrics pertaining to environmental and public health benefits of installing EV charging stations. They have evaluated these metrics to infer neighborhood-level social costs of local pollutants in NYC and have developed a multi-objective optimization problem for designing electricity tariffs that expedite EV adoption and incentivizes investments in EV charging infrastructure.
	<b>Comprehensive Analysis of Air Quality in the NYC Subway System,</b> NYU	Preliminary air quality data was collected at NYC subway stations from Jay Street MetroTech to Union Square station using rapid and robust sampling techniques. Optimization will involve the use of a dynamic magnifier in the device to launch a full campaign of data collection. IRB approval has been granted to add a health measurement component to the project, and physiological data will be collected from the data sampling teams in collaboration with researchers from NYU Langone School of Medicine.
	<b>Deployment &amp; Tech Transfer of a Street-level Flooding Platform: Sensing &amp; Data Sharing for Urban Accessibility &amp; Resilience,</b> NYU	Four newly designed and improved flood sensors were assembled and deployed, incorporating city agency input. The FloodNet flood alert system was refined following Hurricanes Henri and Ida incorporating feedback by city agency and researcher beta testers. The team will hold additional user tests and advisory sessions and a beta flood data dashboard will be produced. FloodNet sensors were included as an initiative by NYC's Extreme Weather Task Force which may lead to city investment in the next phase.
	<b>Advanced Weigh-in-Motion System for Autonomous Enforcement of Overweight Trucks,</b> Rutgers	The team worked with NYCDOT to install fiberoptic sensors. The asphalt pavement was removed to reveal a bare concrete surface and concrete deck condition was assessed. The team found various defects on the concrete surface, such as, hard roughness, bumps, exposed aggregate, exposed rebars, and excessive water. The team will continue working with NYCDOT to instrument various SHM sensors.

C2SMART is preparing for its next request for proposals for Center-funded research projects and initiatives. This year, different from prior years, C2SMART will emphasize real-world implementation by first deriving research needs directly from agency and industry partners. The RFP will then call for four main tracks of proposals to prioritize funding for projects to address the following key areas of importance for C2SMART, its partners, and USDOT. This revised format for this year's additional round of funding seeks to enhance or improve upon the original stated goals off C2SMART:

- Track 1: Research to Implementation projects
- Track 2: Student-led projects and initiatives such as research and entrepreneurship
- Track 3: Non-traditional research activity such as workshops, training, and workforce development
- Track 4: Short-term NSF-style "High Risk" projects in USDOT priority areas, or synthesizing previous years of C2SMART project activity

**Table 3: Matching or Complementary-funded Projects to C2SMART-funded Projects**

Urban Mobility and Connected Citizens	NYC Connected Vehicle Deployment – Mobile Accessible Pedestrian Signal System Application	USDOT/ NYCDOT/JHK
	NYC Connected Vehicle Deployment – Cooperative Driving	Engineering
	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
	Accessibility and Energy Productivity Impacts of Micromobility	USDOE
	Statewide Open-Source Advanced Traffic Management System (ATMS) Software Research and Pilot	NYSDOT
	Statewide Mobility Services Program Strategic Procurement Planning	NYSDOT
	Effects of Vulnerable Road Users on Driver Inattention & Multitasking	FHWA
	U.S. Mexico Interdisciplinary Research for Smart Cities	NSF
	Pathways to Success in Graduate Engineering: Understanding and Supporting the Critical Transition from Undergraduate to Graduate Engineering Studies (PASSE)	NSF
	COVID-19 Hazards Prevention for Non–English Speaking and Vulnerable Construction and General Workers in The Greater El Paso, Texas, and Surrounding	USDL (FED)-Amer. Rescue Plan Act
	Extreme Heat Hazards Prevention for Non–English Speaking and Vulnerable Construction Workers in The Greater El Paso, Texas, and Surrounding Areas	USDL (FED)-OSHA Susan Harwood Training Program
	Urban Analytics for Smart Cities	Algorithms to Convert Basic Safety Messages into Traffic Measures
Intelligent Transportation Systems (ITS) Deployment Evaluation Program Data Collection and Information Synthesis Support		FHWA/Noblis
Application of Multimodal Indicators in Design Process		WSDOT
Measuring and Mapping Interference with Transit by other Road Users		Challenge Seattle / Mobility Innov. Ctr.
Promises of Data from Emerging Technologies for Transportation Applications: Puget Sound Region Case Study (Phase I & Phase II)		FHWA/WSDOT
Scenario Modeling of Return to Work after Covid-19		Challenge Seattle
Predictive Real-time Traffic Management in Large-Scale Networks Using AI		FHWA
Privately Collecting & Analyzing V2X Data for Urban Traffic Modeling		NSF
Resilient, Secure, and Smart Transportation Infrastructure	AASHTO and NBI (National Bridge Inventory) Element Deterioration Rates for Bridge Management System	NYSDOT
	Bridge Resource Program	NJDOT
	Capital Program Resource Model	NYSDOT
	Public Investment in EV Charging	WSDOT/USDOT
	Travel Behavior Modeling for Emerging Transportation Technologies	Argonne National Lab/USDOE
	Effects of Electrifying High-mileage Vehicles	Uber / Mobility Innovation Center
	Development of a Continuous for Live Load Prefabricated Steel Accelerated Bridge Construction (ABC) Unit for Texas Bridges	TxDOT
	Green Technology Innovation and Entrepreneurship for Engineers	VentureWell
	Surveillance for SARS-CoV-2	NYCDEP
	Modeling Strategic Regulators in Network Infrastructure Planning	NSF
	A Peer-to-Peer Approach to Electricity Supply	NSF

Engineering Research Center for the Electrification of the Chemical Industry (CECI)	NSF
RETrofitting RESiliency AgainsT COVID-19! (RETREAT COVID-19!)	NSF
Quantification of Contingency Reserve Requirements Considering Risk	Electric Power Research Institute
Decarbonization of Chemical Manufacturing (DC-MUSE)	Alfred Sloan Fdtn.
Toward a Utility-less Electricity Future: Understanding and Overcoming Information Asymmetry in Smart Grids	Alfred Sloan Fdtn.
Energy (ARPA-e), "Risk-Aware Power System Control Dispatch and Market Incentives	DOE ARPA
Real-Time Flood Monitoring Dashboard	NYSEDF

### 3. Education

- 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: MATSim-NYC Workshop Learning Series; Applied Data Science with Python Specialization; Introduction to Machine Learning; How to Collect Useful Data to Support Transportation Research
- NYU Tandon has relaunched its transportation management program to address the rapidly changing needs of the transportation workforce, featuring courses in Intelligent Cities, Informatics and Data Visualization, Big Data, Machine Learning, and Technology, and Urban Science.
- PI Sarah Kaufman began to teach a course to NYU Civil Engineering graduate students called “Intelligent Cities: Technology, Policy, and Planning,” cross-listed with NYU’s Wagner School.
- UTEP is offering the Dual Master Degree Program in Smart Cities Science & Engineering jointly with Czech Technical University (CTU) in Prague, Czech Republic. This program is co-hosted by the College of Engineering at UTEP, and the Faculty of Transportation Sciences at CTU. Students who have completed one year of study at UTEP and another year of study at CTU under this program will earn two degrees: Master of Science in Engineering at UTEP and Master of Engineering at CTU.
- The Institute of Transportation Engineers (ITE) and Intelligent Transportation Society (ITS) student chapters, supported by the C2SMART Center, continued to meet virtually during the reporting period and look forward to a return to in-person activities during the 2021-2022 academic year.
  - The NYU student chapter was awarded the ITE Northeastern District Student Chapter Award during the District’s virtual conference on May 13, 2021. This award was given in recognition of the outstanding services the organization provided to its members this year.
- NYU PhD candidate Suzana Duran Bernardes, shared her experience with the ITE Spotlight newsletter of mentoring high school students who are conducting research on the effect of car proximity on the stress level of cyclist.

### C. Dissemination and Outreach

#### 1. Training and Tech Transfer Events

##### Conference Presentations and Research Showcases

- Together with the PacTrans UTC, C2SMART co-organized the 8th International Symposium on Dynamic Traffic Assignment from June 28 to June 30, 2021, led by Associate Director Jeff Ban of UW. The theme of DTA2020 was “Modeling Multi-Modal Dynamic Transportation Network Systems in Smart Cities in the Era of Connectivity, Automation, and Sharing.” NYU student Ding Wang, C2SMART Director Kaan Ozbay, Deputy Director Joseph Chow, Yubin Shen and alumnus Yueshuai He also presented.
- Professor Hani Nassif, along with Tanvi Pandya, NYCDOT and Jess Helmlinger, presented their work on the BQE Urban Roadway Testbed to the Truck Size and Weight Committee at the Commercial Vehicle Safety Alliance (CVSA) on August 31, 2021.



- Professor Ban delivered a keynote speech at Harbin Institute of Technology, Network Traffic Control with CAVs, one of the keynote speeches at the Computational Transportation Science Annual Conference, July 29, 2021.
- Professor Chow delivered a webinar titled "Overview of MATSim-NYC and Application to COVID", for Lawrence-Berkeley National Laboratory, on May 5, 2021 and "Planning towards shared, electric, modular automated mobility" to the University of South Florida, on April 2, 2021.
- Sarah Kaufman and Joseph Chow were part of a panel called "Keeping Micromobility Safe as Cities Reopen" with Revel at NYU's Rudin Center for Transportation Policy on, June 10, 2021.
- Professor Henaff's team delivered a presentation to the NYC Department of Transportation GIS working group on September 24, 2021.
- The FloodNet team is part of regular NYC Interagency Flood Working Group Meeting and delivered a presentation called Living with Water: Using Qualitative and Quantitative Data on Flooding to Engage with Communities and Agencies on April 30, 2021. They delivered a presentation to the NYNJ Harbor Estuary Program Water Quality Work Group on May 11, 2021.
- Professor Don Mackenzie spoke at the Norwegian University of Science & Technology on "ChargEval: An agent-based tool for evaluating EV charging network changes" on May 27, 2021 and at Chalmers University of Technology, "What can today's mobility services today tell us about travel demand with tomorrow's autonomous vehicles?" on May 18, 2021.
- NYU Research Associate Jingqin Gao and PhD student Ding Yang presented, "Mobility in Post-Pandemic Economic Reopening under Social Distancing Guidelines: Congestion, Emissions, and Contact Exposure in Public Transit" to ITS-NY on June 23, 2021.
- Professor Hani Nassif presented on Fiber-Reinforced High-Performance Concrete at the Metro New York local chapter of International Concrete Repair Institute International on April 14 and 15, 2021.
- Sarah Kaufman was included on a panel on "Advancing Equity in Transportation: A Data-Driven Approach" at the Open Mobility Foundation on September 23, 2021.
- C2SMART Director Kaan Ozbay presented "Rethinking Traffic Flow with Connected and Autonomous Vehicles" at the 2021 MIT Mobility Forum.
- Rae Zimmerman presented "Flexible & Adaptable Infrastructure for a Post-Covid World" at the 2021 ASCE Metropolitan Section Infrastructure Group June Seminar.
- Yury Dvorkin presented "Risk- and Variance-Aware Pricing in Wholesale Electricity Markets" at Princeton University on June 14, 2021.
- Zhong-Ping Jiang delivered virtual invited talks at the Electrical and Systems Engineering Department at Washington University at Saint-Louis on Friday, April 23, 2021, the School of Data Science, City University of Hong Kong, April 28, 2021 ("Learning-based Control in the Era of AI and Autonomous Vehicles") and at the University of Agder, Norway on June 15, 2021.

## 2. Workshops

- Professor Benedetto Piccoli helped organize the FIRST CIRCLES workshop on Traffic and Autonomy on September 23 and 24, 2021.
- The FloodNet team hosted a workshop for NYC Department of Environmental Protection, facilitated by NYC Mayor's Office of Climate and Resiliency on September 17, 2021.
- Professor Jiang delivered an IFAC Workshop series themed "Control Systems and Data Science towards Industry 4.0" to the Hong Kong Institute for Data Science on July 9, 2021.
- The C2SMART Center joined the New York City Economic Development Corporation for a Concept Showcase to define the opportunity for a new bike access model in NYC on September 29, 2021.

## 3. Industry and Public Agency Outreach

- NYMTC have provided Prof. Chow's research team with truck trip data, network data, and guidance on the goals and direction of the truck routing application being developed for NYCDOT needs.

- C2SMART has formally joined NYCDOT’s Joint Venture team to conduct Structural Health Monitoring on the Brooklyn Queens Expressway (BQE) in New York City. This is the result of USDOT-funded implementation of and analysis from Weigh-in-Motion (WIM) sensors on a portion of the BQE.
- The Autonomous Vehicle Good Citizenry Standard project invited the following organizations to participate in stakeholder workshops:
  - NYC Department of Transportation
  - Metropolitan Transportation Authority
  - NYC Economic Development Corporation
  - NYC Taxi and Limousine Commission
  - NYS Department of Transportation
  - The Port Authority of NY&NJ
  - Star City Group
  - Data & Society
  - Urban-X
  - Center for Independence of the Disabled
  - World Economic Forum
  - Ford Mobility
  - Cruise
  - Waymo
  - Nuro
  - Zoox
  - Uber
  - Lyft
  - Via
- The FloodSense project is actively collaborating with the Mayor’s Office of Resiliency, the Mayor’s Office CTO, Voltaic, The Things Network, New York State Empire State Development, New York City Department of Transportation, New York City Department of Environmental Protection (DEP) Bureau of Water and Sewer Operations for consultation on deployment locations in flood-prone areas key to validating their stormwater models; the Department of NYC Emergency Management for feedback on sensor data representation, alerting system, and data needs; and the National Weather Service for feedback on sensor data representation and data needs.
- Professor Ban has met with Washington Department of Transportation to provide data about freeway travel times and traffic flows, the Seattle Department of Transportation to provide traffic data collected on arterial streets in Seattle, and the City of Bellevue to provide traffic data.
- The City of El Paso Streets and Maintenance Department provided the UTEP research team with the traffic count data and signal timing plans necessary for the coding of the VISSIM simulation model.
- The following are industry and agency partners for the BQE Urban Roadway Testbed: NYCDOT, providing in-kind support through a testbed to implement various advanced structural health monitoring (SHM) and non destructive testing and evaluation (NDT/E) technologies; the Triple Cantilever Design Joint Venture (TDJV), providing in-kind logistical support, including lane closure, bucket trucks, etc., for various fieldwork to perform SHM and NDT/E; ThermalStare, LLC, Leesburg, VA, providing technical support and implementing IR-UTD technology to quantify structural deficiency. The team also collaborated with industrial partner, Kistler, to develop the WIM site qualification testing specification.
- The CIDNY Multimodal Construction Management Tool, developed to enhance coordination of construction projects citywide, is ongoing in collaboration between CCNY, NYU and NYSDOT.
- Zhong-ping Jiang is working on a DOE subcontract through Oak Ridge National Lab (ORNL), titled “AI-based Modeling and Control for Traffic Flow Systems”.

#### 4. Webinars

- AI-based Navigation for Accessible Cities: Challenges and Opportunities, Chen Feng, NYU Tandon School of Engineering, John-Ross (JR) Rizzo, NYU Langone Medical School, April 22, 2021.
- Leveraging Bicycle Safety through Emerging Data Collection Technologies, Suzana Duran Bernardes, NYU Tandon School of Engineering, April 28, 2021.
- A Data-driven Optimization-based Control Model for Cooperative Adaptive Cruise Control Under Uncertainty, Kuilin Zhang, Michigan Technological University, May 13, 2021.
- Proactive Safety Monitoring: A Functional Approach to Detecting Safety-related Anomalies Using Unmanned Aerial Vehicle Video Data, Di Yang, NYU Tandon School of Engineering, May 26, 2021.

- Listening Session: Analysis of Socioeconomic Factors in Distribution of Electric Vehicle Charging Stations in New York City, Yury Dvorkin, NYU Tandon School of Engineering, June 17, 2021.
  - Harvesting Energy from Traffic-Induced Vibrations of Transportation Infrastructure: Development of a High-Power Density Electromagnetic Energy Harvester, Mohsen Amjadian, The City University of New York (City College), June 23, 2021
  - Toward Smart Highway Work Zones: When Highway Workers Meet AI and AR, Hamed Tabkhivaygh, UNC Charlotte; Omid Shoghli, UNC Charlotte, July 20, 2021.
  - Traveler Behavior and Public Transport in the Age of COVID-19 Sanmay Shelat, TU Delft Smart Public Transport Lab Data Analytics and Traffic Simulation Lab, August 11, 2021.
  - Developing a multiscale vehicle-traffic-demand (VTD) simulation platform, Xuegang “Jeff” Ban, UW, August 25, 2021.
  - Incentive Design for Promoting Ridesharing, Neda Masoud, Univ. of Michigan, September 8, 2021.
  - Parking for Smart Cities: Level of Service and Performance Measurement Systems for Parking, Ruy Long “Kelvin” Cheu, UTEP, September 28, 2021.
5. Media Coverage and Public Outreach
- PIs Sarah Kaufman and Mitchell Moss were recognized by [City & State's Transportation Top 100](#).
  - Sarah Kaufman was also featured in [“The end of the line for gender-based violence,”](#) Thinking Cities; [Jobs for the City of Tomorrow](#), The Wall Street Journal; [“Can Tech Make the Roads Safer?,”](#) The New York Times; [“How Can New York City Prepare for the Next Ida? Here’s a To-Do List,”](#) The New York Times; [“Is There Room for E-Scooters in New York City?”](#) Bloomberg CityLab; [“What will it take to keep NYC’s subway running after tropical downpours?”](#) NPR Marketplace; [“Subway system struggles to recover after major flooding stops service” in NY1](#); [How the city is preparing for the arrival of self-driving cars”](#) Crain's New York Business; [“Warming Climate Threatens Subway Systems,”](#) the Weather Channel; [“Pipeline companies are trying to avoid regulation, despite major hack,”](#) NPR Marketplace; [“Micromobility surges amid pandemic as city plans e-scooter share pilot program,”](#) in NY1; and [“Climate Crisis Turns World’s Subways Into Flood Zones,”](#) The New York Times; [“Meet Sarah M. Kaufman”](#) Qualite de Villes.
  - Professor Don Mackenzie’s project was covered by the [Sightline Institute](#) and [The Verge](#), along with [Automotive World](#) and [Smart Cities Dive](#); he was also featured in Transport Topics for the article, [“Rise of Electric Vehicles Presents Questions About Transportation Funding”](#).
  - Professor Yury Dvorkin was featured in [“Cyberattack on US pipeline could affect gas prices, expert warns, as FBI, DHS, DOE investigate,”](#) FOX Business; [“Why the first big U.S. ocean wind farm is a big deal,”](#) Mashable; [“Crude oil prices rise after Colonial Pipeline cyberattack,”](#) Fox Business; [Cyber attack on US Colonial Pipeline,](#) Fox News LIVE; [“So Long, Indian Point Nuclear Plant. Hello, More Fossil Fuels,”](#) Gothamist; [Colonial Pipeline hack highlights grid disruption risks even with IT-focused cyberattack analysts say,](#) Utility Dive; [The Gas Pipeline Hack Could Mess With Your Vacation,](#) Inc; [“Here's why empty office buildings aren't so hot at saving much electricity,”](#) Crain’s NY Business.
  - Professors Henaff and Silverman were interviewed for an article on with NY1: [“Flooding shows risks to city posed by increasing storm deluges”](#).
  - Professor Chow and the C2SMART Center were featured in IEEE Spectrum [NYU Researchers Pave the Way for Future Shared Mobility](#); Professor Chow was also interviewed in the Wall Street Journal’s [New York City Installs First Curbside Electric-Vehicle Charging Station.](#)
  - Prof. Ergan was interviewed for comment in the [Commercial Observer on the use of embedded systems and property technology and their role in the operations and maintenance of buildings.](#)
  - Co-PI Dr. Burçin Ünel authored [“Ending the snipe hunt for buyer-side power in PJM and other capacity markets”](#) in Utility Dive.
  - Professor Anil Agrawal comments were featured in [“Five Bridges that Show How Technology Is Changing,”](#) Technology Review.

- In July 2021 C2SMART Center Research was featured in the [UTC Spotlight Newsletter](#).
- The Mayor’s Expert Panel, which includes C2SMART Center Director Kaan Ozbay, and PI Hani Nassif, was included in a [press release issued by the New York City Mayor’s Office](#), and referenced the weigh-in-motion sensors the team installed on the Brooklyn Queens Expressway (BQE). The BQE panel’s recommended 2 lane configuration was also [featured in CBS Local](#).

#### D. Plans for Next Reporting Period

- C2SMART is launching a new event series called “State of the Field,” to take a deep dive on the latest advances in transportation engineering research through a series of thematically-tied events aimed explicitly at agency and industry audiences. The first event in this series will be on Structural Health Monitoring, the current state of the industry, the challenges of monitoring physical infrastructure and several case studies. This planned series will include a return of the annual “Freight Forum,” and a webinar on Weigh-in-Motion (WIM) technology.
- In a continued effort to explicitly build in transportation equity considerations into C2SMART’s sixth year of funding, the Center has invited a panel of speakers to focus in on the question of: What problems of equity are UTCs best positioned to solve with application of research dollars? The answers from this panel will feed directly into a dedicated Equity track in the C2SMART’s request for proposals.

## II. Participants and Collaborating Organizations

### A. Partner Organizations

Table 4: C2SMART Active Partnerships with Updates during this Reporting Period

Organization Name	Location	Financial Support	Contribution	
			In-kind Support	Collaborative Research
CarbonCure	Dartmouth, Canada		X	
Carrera	Brooklyn, NY		X	
City of Bellevue	Bellevue, WA		X	
City of El Paso	El Paso, TX		X	
Gowanus Canal Conservancy	Brooklyn, NY			X
Gowanus By Design	Brooklyn NY			X
Intelligent Transportation Society of NY	New York, NY		X	
King County Metro	Seattle, WA			X
Kistler Instrument Corp.	Buffalo, NY		X	
The Lighthouse Guild	US (various)		X	X
National Weather Service	US (various)			X
Nexar	New York City, NY			X
NEXT	Silicon Valley, CA			X
NJ Turnpike Authority	Woodbridge, NJ	X		
NJDOT	Newark, NJ	X		
NYC Department of Environmental Protection	New York City, NY			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		
Port Authority of NY&NJ	New York City, NY	X		
Precast Systems Engineering	Exmore, VA			X
Puget Sound Regional Council	Seattle, WA		X	

Revel	New York City, NY			X
Science and Resiliency Institute	Jamaica Bay, NY			X
Texas Department of Transportation	Austin, TX		X	
Thermalstare LLC	Leesburg, VA		X	
The Things Network	Amsterdam, Neth.		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

## 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.

- CCNY Professor Kamga collaborated on an NSF Medium: Collaborative Research: Spatial Data and Trajectory Data Management on GPUs with the CCNY Department of Computer Science.
- NYU Professor Henaff collaborated with Professor Semiha Ergan on a seed-grant-funded project to study microbial impacts on building facade integrity.
- NYU Professor Jiang is working on an NSF CMMI project with Professor Maurizio Porfiri from NYU's Mechanical and Aerospace Engineering Department.
- The FloodSense project has grown to include CUNY ASRC and the Science and Resiliency Institute at Jamaica Bay, providing collaborative research on sensor development.
- Professor Piccoli connects his C2SMART project with his existing participation in the [CIRCLES consortium](#) of university, government and car manufacturers. The team discussed the project's tasks and existing SUMO simulations with CIRCLES partners.
- Professor Weidner is working on "Development of a Continuous Live Load Prefabricated Steel Accelerated Bridge Construction (ABC) Unit for Texas Bridges," funded by Texas Department of Transportation via Texas A&M.
- NYU Professor Ghandehari added a physiological evaluation component to his subway air quality analysis in collaboration with the Department of Environmental Medicine, NYU Langone as partners. Their students David Luglio and John Adragna are also collaborating on the project.
- UTEP Professor Weidner is working on a funded NSF project titled "Pathways to Success in Graduate Engineering: Understanding and Supporting the Critical Transition from Undergraduate to Graduate Engineering Studies (PASSE)" with other UTEP collaborators.
- NYU Professor Ergan is collaborating with Dr. Chen Feng of the Civil Engineering department on EASEEbot, Robotic Envelope Assessment System for Energy Efficiency and an NSF funded project on modular construction.
- NYU Professor Dvorkin of Electrical and Computer Engineering collaborated with Dr. Joseph Chow of Civil Engineering and Pacific Northwest National Laboratory (PNNL) colleagues to submit a DOE proposal, which partially correlates with the topic of Dvorkin's C2SMART project.

### 2. Inter-University Collaboration

- C2SMART has expanded its network of colleges with access to the Student Learning Hub to include NYC Community Colleges, widening impact beyond original scope based on program success.
- Professor Nassif worked on the NJDOT Bridge Resource Program with Rutgers Civil/Environmental Engineering, NYU Civil/Urban Engineering, and Stevens Civil/Environmental/Ocean Engineering, and partnered with NYU on: New Jersey Turnpike and Garden State Parkway Maintenance Snow Program and Improvements to Lane Closure Application Program, Implementation and Effectiveness of Autonomous Enforcement of Overweight Trucks in an Urban Infrastructure Environment, Integration

and Operation of an Advanced Weigh-in-Motion (A-WIM) System for Autonomous Enforcement of Overweight Trucks, and the Capital Program Resource Model. Professor Nassif is also part of AASHTO and NBI Element Deterioration Rates for Bridge Management System with Professor Agrawal, CCNY.

- Professor Ban’s Multiscale Simulation Testbed project at UW is based off of Professor Chow’s project at NYU and the two are frequently collaborating. Professors Chow and Ban discussed progress of respective projects and will be meeting next quarter to go over freight components of MATSim.
- Professor Weidner’s team at UTEP is leveraging an existing relationship with faculty at the Czech Technical University, who have established similar capabilities for Digital Twin and Augmented/Virtual Reality combined with deep expertise in transportation modeling and logistics and an operational DT model for the city of Prague.

In addition, the following collaborative research projects are active across universities:

- Professor Camille Kanga at CCNY worked on a Metrofreight project involving the University of Southern California (USC) and Hofstra University.
- Professor Chow, NYU, continues his NSF project with USF on modular vehicles.
- NYU Professor Silverman collaborated with professors at Arizona State University (Norovirus review paper), Stanford University (Enveloped virus meta-analysis,) University of Wisconsin, Notre Dame University, CUNY Queens College, and Queensborough Community College (SARS-CoV-2 Surveillance).
- Professor Henaff, NYU, collaborated with professors at Yale University School of Architecture, School of Engineering and School of Public Health on a bioaerosol monitoring project; with professors at Weill Cornell Medicine on bioremediation of a SuperFund site.
- NYU Professor Masoud Ghandehari is part of active NSF projects "A socio-technical framework to enhance community resilience", with CUNY and ASU and "City as a Lab: for the study of nexus of food-energy-water" with NYIT, CUNY, and ASU.
- Professor Jiang is part of an active NSF DMS project with Louisiana State University "Collaborative Research: Designs and Theory for Event-Triggered Control with Marine Robotic Applications"
- Professor Silva is working closely with Eric K. Tokuda, a researcher from University of Sao Paulo on the exploration of video summarization approaches as well as crowd counting.
- Professor Piccoli worked on an NSF project titled "Managing Epidemics by Managing Mobility" with Cornell University Samaranayake School of Engineering. He also worked on a U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy (EERE) award with Electrical Engineering and Computer Science faculty at UC Berkeley, Vanderbilt. University of Pennsylvania, Arizona University, and Temple University.
- Professor Ergan is working on "Future of Manufacturing Program: ARM4MOD: AI-powered and Robot-assisted Manufacturing for Modular Construction" an NSF funded project on modular construction is in collaboration with the University of Michigan.

### III. Outputs

C2SMART is exceeding its targeted performance metrics in each of the areas identified in its Technology Transfer Plan, identified in Table 5. The following research outputs are produced with C2SMART Center support.

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

##### 1. List of Journal Publications

- Ergan, S., Ozbay, K., Zou, Z., Bernardes, SD., Shen, Y. Developing an Integrated Platform to Enable Hardware-in-the-loop for Real Time VR, Traffic Simulation and Sensor Interactions. Advanced Engineering Informatics 2021.

**Table 5: Output Performance Measures**

Performance Measures	Annual Goal	Achieved (current period)
Peer-reviewed papers	20	62
Conference presentations	10	41
Joint proposals/projects with industry/agency partners	10	42
Website analytics	5,000 unique pageviews	18,015

- Amjadian, M., Agrawal, A. K., Silva, C., Dyke, S. Magneto-solid Damper: Modeling, Fabricating, and Testing. *Journal of Mechanical Systems and Signal Processing* 2020.
  - Truszkowska, M., Thakore, L., Zino, S., Butail, E., Caroppo, Jiang, Z.P., Rizzo, A., Porfiri, M. Designing the Safe Reopening of US Towns through High-resolution Agent-based Modeling. *Advanced Theory in Simulations* 2021.
  - Mazenc, F., Malisoff, M., Barbalata, C., Jiang, Z.P. Event-triggered Control using a Positive Systems Approach. *European Journal of Control* 2021.
  - Tan, X., Abu-Obeidah, A., Bao, Y., Nassif, H., Nasreddine, W. Measurement and Visualization of Strains and Cracks in CFRP Post-tensioned Fiber Reinforced Concrete Beams using Distributed Fiberoptic Sensors. *Automation in Construction* 2021 Vol. 124.
  - Dakic, I., Yang, K., Menendez, M., Chow, J.Y.J. 2021. On the Design of an Optimal Flexible Bus Dispatching System with Modular Bus Units: Using the Three-dimensional Macroscopic Fundamental Diagram. *Transportation Research Part B* 148, 38-59.
  - Lee, M., Chow, J.Y.J., Yoon, G., He, B.Y. 2021. Forecasting e-scooter Substitution of Direct and Access Trips by Mode and Distance. *Transportation Research Part D* 96, 102892.
  - Li, M., Chow, J. Y. J. 2021. School Bus Routing Problem with Mixed Ride, Heterogeneous Fleet, and Mixed Load. *Transportation Research Record* 2675(7), 467-479.
  - Correa, D., Chow, J.Y.J., Ozbay, K. 2021. Spatial Dynamic Matching Equilibrium Models of New York City Taxi and Uber Markets. *Journal of Transportation Engineering Part A: Systems* 147(9), 04021048.
  - Li, L., Pantelidis, T. P., Chow, J. Y. J., Jabari, S. E. 2021. A Real-time Dispatching Strategy for Shared Automated Electric Vehicles with Performance Guarantees. *Transportation Research Part E SI: ISTTT24*, 152, 102392.
  - Liu, B., Bade, D., Chow, J.Y.J. 2021. A Bike Count Forecast Model with Multimodal Network Connectivity Measures. *Transportation Research Record* 2675(7), 320-334.
  - Pantelidis, T., Li, L., Ma, T.Y., Chow, J. Y. J., Jabari, S. E. 2021. Node-charge Graph-based Online Carshare Rebalancing with Capacitated Electric Charging. *Transportation Science*.
  - Xu, S. J., Chow, J. Y. J. 2021. Online Route Choice Modeling for Mobility-as-a-Service Networks with Non-separable, Congestible Link Capacity Effects. *IEEE Transactions of ITS*.
  - Wang, D., Tayarani, M., He, B. Y., Gao, J., Chow, J. Y. J., Gao, H. O., Ozbay, K. 2021. Mobility in Post-pandemic Economic Reopening under Social Distancing Guidelines: Congestion, Emissions, and Contact Exposure in Public Transit. *Transportation Research Part A SI: COVID-19*, 153, 151-170.
2. Books or Other Non-Periodical, One-Time Publications
- Kelvin Cheu has authored and published “Transportation Engineering FE+: An Introduction of Transportation to Civil Engineering Students”
  - Benedetto Piccoli has co-authored “A Holistic Approach to the Energy-efficient Smoothing of Traffic via Autonomous Vehicles”, a chapter of “Intelligent Control and Smart Energy Management: Renewable Resources and Transportation,” Springer Optimization and Its Applications, 2021.
3. Other Publications, Conference Papers and Presentations
- Amjadian, M., Agrawal, A. Feasibility of Using a High-Power Electromagnetic Energy Harvester to Power Structural Health Monitoring Sensors and Systems in Transportation Infrastructures. *SPIE Conference* 2021.
  - Chow, J., Kaufman, S.M., Liu, C.B. Equitable Commute Project NYC 2025 Policy Project 2021.
  - Albeaik, S., Bayen, A., Chiri, M.T., Gong, X., Hayat, A., Kardous, N., Keimer, A., McQuade, S.T., Piccoli, B., You, Y. Limitations and Improvements of the Intelligent Driver Model. (IDM) *SIAM SIADS* 2021.
  - Hayat, A., Piccoli, B., Truong, S. Dissipation of Traffic Jams using a Single Autonomous Vehicle on a Ring Road *SIAM SIAP* 2021.
  - Wu, G., Lin, J., Silva, C., Vizor, I. Towards Generic Query Guided Interactive Video Summarization Using Slow-Fast Graph Convolutional Networks. *AAAI* 2022.
  - Zimmerman, R. Small Changes, Large Effects: Interconnected Infrastructure Networks in Food Supply Chain Disruptions and Multi-Modal Transportation Solutions. *ASCE International Conference on Sustainable Infrastructure* 2021.
  - Abu-Obeidah, A., Nassif, H. Serviceability of Beams Prestressed with Hybrid (Steel/CFRP) Tendons. *American Concrete Institute* 2021.

- Liu, T., Cui, L., Pang, B., Jiang, Z.P. Learning-Based Control of Multiple Connected Vehicles in the Mixed Traffic by Adaptive Dynamic Programming. 3rd IFAC Conference on Modelling, Identification, and Control of Nonlinear Systems (MICNON2021) 2021.
- Wu, G., Lin, J., Silva, C. ERA: Entity–Relationship Aware Video Summarization with Wasserstein GAN. The British Machine Vision Conference 2021.
- Mazenc, F., Malisoff, M., Barbalata, C., Jiang, Z.P. Event-Triggered Control for Discrete-Time Systems Using a Positive Systems Approach. IEEE Control Systems Letters & 2022 American Control Conference.
- Mazenc, F., Malisoff, M., Barbalata, C., Jiang, Z.P. Event-triggered Control for Linear Time-varying Systems using a Positive Systems Approach. Systems and Control Letters June 2021.
- Pang, B., Jiang, Z.P. Robust Reinforcement Learning for Stochastic Linear Quadratic Control with Multiplicative Noise. The 19th IFAC Symposium on System Identification (SYSID 2021) 2021.
- Briones, F., Weidner, J., Cheu, R. L. 2021. Smart Parking Garage: Concept of Operations and User Benefits. IEEE Smart City Symposium 2021.
- De la Garza, X. J., Weidner, J., 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 2021.
- Jiang, Z.P. Control Systems and Data Science towards Industry 4.0. Hong Kong Institute for Data Science. IFAC Workshop.
- Rizzo, J.R., Feng, C., Riewpaiboon, W., Mongkolwat, P. A Low-Vision Navigation Platform for Economies in Transition Countries. IEEE Digital Health as a Service Symposium (DHAASS 2020).
- Sheng, D., Chai, Y., Li, X., Feng, C., Silva, C., Lin, J., Rizzo, J.R. NYU-VPR: Long-Term Visual Place Recognition Benchmark with View Direction and Data Anonymization Influences. IROS 2021.
- Abu-Obeidah, A., Nasreddine, W., Nassif, H., Meng, W. Performance of Fiber Reinforced Ferrocement and UHPC in Flexural Repair of Concrete Beams. 13th International Symposium on Ferrocement and Thin Fiber Reinforced Inorganic Matrices.
- Abu-Obeidah, A., Ortiz, D., Nassif, H. Early Age Bond Characteristics of Ferrocement-Concrete Interface under Thermal Curing. 13<sup>th</sup> International Symposium on Ferrocement and Thin Fiber Reinforced Inorganic Matrices.
- Cruz, H., Raheem, A., Nazarian, S. Digital Twin Technology Applications for Transportation Infrastructure – A Survey-based Study. ASCE 2021 International Conference on Computing in Civil Engineering (i3CE 2021).
- Liu, C., Yang, H., Cui, Z., Sun, W., Wang, Y. 3D Structural Information Sensing System (3D-SISS) based on Car Keypoints Detection with Single Monocular Surveillance Camera. 2022 TRB Annual Meeting.
- Cui, L., Ozbay, K., Jiang, Z.P. Combined Longitudinal and Lateral Control of Autonomous Vehicles based on Reinforcement Learning. American Control Conference 2021.
- Dvorkin, Y. 2021. Power Systems Planning and Economics in the Age of Energy Transition. Argonne National Laboratory Center for Energy, Environmental, and Economic Systems Analysis.
- Dvorkin, Y. Cybersecurity of Urban Power Grids: Mitigating Demand-Side Vulnerabilities from Electric Vehicles Panel.
- Dvorkin, Y. Examining Current Trends in the Cybersecurity Research Environment. U.S. Civilian Research and Development Foundation (CRDF) Panel.
- Dvorkin, Y. 2021. Examining Current Trends in the Cybersecurity Research Environment.
- Dvorkin, Y. Socially-Cognizant Optimal Tariff-Making for Smart Grids: A Case of Electric Vehicles. 31st European Conference on Operational Research.
- Dvorkin, Y. Strategic Regulatory Pathways for Decarbonizing the Power Sector via Complementarity Modeling. IISE Annual Conference and Expo 2021
- Piccoli, B. 2021. Introduction to Mean Field Games and Applications. IMSI University Chicago.
- Nassif, H. Early Age Performance of Fiber Reinforced Ferrocement and UHPC in Flexural Repair of Concrete Beams. 13<sup>th</sup> International Symposium on Ferrocement and Thin Fiber Reinforced Inorganic Matrices.
- 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. May 27, 2021.
- Nassif, H. Early Age Bond Characteristics of Ferrocement-Concrete Interface under Thermal Curing. 13<sup>th</sup> International Symposium on Ferrocement and Thin Fiber Reinforced Inorganic Matrices.
- Chow, J. Mobility Operator Fleet-sharing Contract Design to Risk-pool Against Network Disruptions. INSTR 2021.

## B. Websites

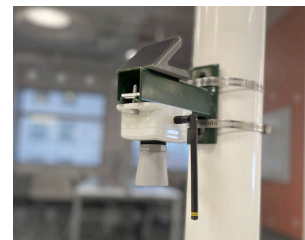
The [C2SMART website](#) disseminates information about the Center’s activities and research, with 18,015 unique page views during this reporting period, exceeding its annual goal of 5,000 pageviews. The [COVID-19 mobility dashboard](#) continues to generate a lot of interest and inquiries and received 3,990



total page views. The data produced from the Weigh-in-Motion (WIM) sensors on the Brooklyn Queens Expressway (BQE) Urban Roadway Testbed is saved to [NYC's Open Data Portal](#) and has been downloaded 100 times.

### C. Technologies or Techniques

- The FloodSense team has designed, implemented and tested a new version of the ultrasonic flood sensor. This development board incorporates solar charging circuitry, thereby reducing the sensor size, and additional components and cost. The new design requires less skill and time to assemble and will enable scaling up the number of sensors produced.
- Professor Jiang developed and disseminated a 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.
- The Rutgers team provided the final SOW to evaluate the current structural performance and capacity of the triple cantilever section of the BQE. The SOW consists of new and novel sensor technologies and non-destructive testing technologies.



**Figure 1: FloodSense Sensor**

### 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 team at NYU & Rutgers worked on Low Carbon Concrete Capture for the Port Authority of New York & New Jersey.
- 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

### E. Other Products

- Open-source libraries, sensor hardware tutorials, and code resources have been built and are housed on the [FloodSense Github page](#).
- C2SMART's MATSim-NYC model has been downloaded by researchers in from ETH Zurich, Argonne National Laboratory, Carnegie Mellon, University of Kentucky, Tongji University, Berkley Labs, Inner Mongolia University and George Mason University.
- Professor Nassif and his team publish Weigh-In-Motion data collected from PVDF sensors at the testbed near Pearl St. in Brooklyn, NY to [NYC's Open Data portal](#).
- Professor Weidner's team collected a detailed database of transportation assets for the UTEP campus via a vehicle-mounted camera. The database provides a powerful dataset for training machine learning algorithms to identify signage and pavement markings and enhance the extraction process.
- The initial version of Professor Silva's Entity–Relationship Aware algorithm is uploaded to the [C2SMART Zenodo repository](#).

## IV. Outcomes

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

- The FloodNet alert system successfully warned agencies of mobility-impairing levels of water during Ida and Henri. The project’s monthly meetings with NYCDOT and civic groups have pushed to develop useful and impactful technology interventions. Meetings with the DEP have led to understanding of how flood sensor data can be used to benchmark their predictive stormwater flood models.
- Professor Dvorkin conducted a data-driven analysis of the intersection of transportation/demographical data and EV charging infrastructure, alongside the environmental and public health implications, to develop metrics which provide better understanding of the social implications of electric transportation policies and opens avenues for designing interventions to alleviate social inequities.
- The NYCDOT accepted the Rutgers’ team proposal to implement advanced Structural Health Monitoring (SHM) and non-destructive testing and evaluation (NDT/E) to extend the service life of the BQE triple cantilever section until complete replacement or rehabilitation can take place.

### B. *Increases in the Body of Knowledge*

- The double flood profile captured by FloodNet during Tropical Storm Henri yielded a new insight as to the pattern of floods experienced in NYC, and the relationship with precipitation patterns.
- Professor Piccoli’s research has shown that much fuel can be saved in actual vehicles. It has yet to be applied on an actual highway with AVs acting on traffic.
- Professor Dvorkin’s proposed metrics for availability and affordability of EV charging stations, associated environmental degradation and public health impacts, and application to zip code-level demographical data of NYC can be used to design holistic frameworks that ensure a just allocation of energy and transportation resources, along with equitable distribution of costs and benefits.
- Pls JR Rizzo and Chen Feng enhanced understanding of an image-based infrastructure independent localization system using visual place recognition methods, and its potential for improving accessibility in complex urban environments.
- IR-UTD is a new technology for imaging subsurface damage in concrete and is well-suited to this high-traffic structure because data are obtained without any lane closures. Based on the measurements performed on portions of the BQE, IR-UTD can be effectively used to: monitor cantilever soffits, provide written documentation of defect size and location, minimize impact on traffic, and provide an accurate technology to quantify existing damage, outperforming other non-destructive evaluation.
- The research findings of Professor Jiang’s project 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.

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

- Professor Chow is working to improve the NYCDOT’s process for freight truck routing with the development of a faster, more reliable routing app.
- The FloodNet alert system offers an opportunity to alert drivers and city agencies of flooded streets in real time and have been included as an initiative by the NYC Extreme Weather Task Force.
- The NYCDOT accepted four advanced sensor technologies proposed by Rutgers to monitor the BQE’s cantilever sections to develop long-term SHM specifications and plan to prolong its service life with minimum repair requirements.

**Table 6: Outcomes Performance Measures**

Performance Measures	Annual Goal	Achieved (current period)
Media interviews, mentions, coverage	10	34
Workshops, webinars, and seminars	10	19

- Professor Dvorkin developed metrics for the availability and affordability of EV charging stations to ensure a just allocation of energy and transportation resources in the society.
- The CIDNY Multimodal Construction Management Tool, developed to enhance coordination of construction projects citywide, is ongoing in collaboration between CCNY, NYU and NYSDOT. The team continued to develop an automated algorithm to map individual work zone projects with corresponding traffic state information (e.g., traffic speed, travel time), extracted three-year work zone project data and traffic mobility information and finished pre-processing.

## V. Impact

### A. Effectiveness of the Transportation System

- C2SMART’s Covid-19 data dashboard continues to capture data and feeds to monitor transportation networks. It shows the temporal and spatial trends of pedestrian density at 68 locations in New York City. The object detection algorithm is currently being extended to perform vehicle tracking, counting, and turn counts and is also included in a draft case study for the ITSJPO Deployment Evaluation Database, including applications for lane occupancy, illegal parking and bus lane detection.
- The FloodSense project received permission by NYCDOT to deploy flood sensors on city infrastructure and was positioned as a use case during heavy rain from the recent Hurricanes Ida and Henri. The project sensors detected the presence of water accumulation hours before the city’s flood alert system. The FloodSense project shared its internal flood monitoring dashboard and alerts with agency partners at the DOT and DEP and is incorporating its feedback during dashboard development. This success has led to proposed expansion of the Flood Sensor program in a New York City Major’s Office recent report on the city’s climate change preparedness efforts.
- The Brooklyn Queens Expressway (BQE) partnership between the C2SMART Center and NYCDOT was formalized as C2SMART was added to NYCDOT’s Joint Venture team to monitor and rehabilitate the BQE for the next 2 years. C2SMART’s long-term goal is to advance the original project into a comprehensive overweight truck detection, enforcement and structural health monitoring system that can be scaled to transportation agencies around the United States.

### B. New Practices or Companies

- Professor Cheu’s team is potentially the first to use the new parking features in VISSIM to conduct research as part of his Development of Level of Service Analysis Procedures and Performance Measurement Systems for Parking project.

### C. Body of Scientific Knowledge

- Professor Joseph Chow joined the Editorial Board of Transportation Research Part C and has been nominated to the editorial board for Transportation Research Part B.
- Professor Zhong-Ping Jiang received “Best Paper Award” from the International Journal "Control Theory and Technology for "Adaptive Dynamic Program for Finite-Horizon Optimal Control of Linear Time-Varying Discrete-Time Systems."
- For their work in advancing transportation research, Professors Claudio Silva and Joseph Chow recognized as Institute Associate Professors; Professor Zhong-Ping Jiang was elected to the Academy of Europe; Sarah Kaufman won the Dr. Louis J. Pignataro Memorial Transportation Education Award; Zhengbo Zou’s dissertation received an Outstanding Dissertation Award from NYU; Di Yang was

**Table 7: 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	5
Partnerships/collaborative relationships with companies or transportation agencies established or renewed	10	15

selected for the Institute of Transportation Engineers Northeastern District Daniel B. Fambro Student Paper.

#### **D. Transportation Workforce Development**

- Professor Nassif presented “Analysis of Overweight Truck Permit Policy” at the NJDOT Lunchtime Tech Talk webinar series for NJ AICP and PE credits.
- C2SMART Center provided Professional Development Hours for Intelligent Transportation Society of New York (ITS-NY) events on May 19, 2021 and June 23, 2021
- Pls Kaan Ozbay, Claudio Silva, Andrea Silverman, Yury Dvorkin, Semiha Ergan, Chen Feng, Joseph Chow and their graduate students provided mentorship for a total of 9 NYC high school students as part of NYU Tandon’s Applied Research Innovations in Science and Engineering (ARISE) program.
- Pls Andrea Silverman, Charlie Mydlarz, Joseph Chow, Semiha Ergan, Tega Brain, Chen Feng and their graduate students mentored 9 students as part of NYU’s Undergraduate Summer Research Program.
- C2SMART alumni Zhengbo Zou graduated in May 2021 and has accepted a tenure track assistant professor position at University of British Columbia.
- Chintan Pathak received a PhD from UW and is working at [a startup company](#) that he co-founded during his time at UW.

## **VI. Changes/Problems**

### **Funded Research Projects:**

- The data used by Professor Ban’s Modeling and Optimizing Ridesourcing Services in Connected and Automated Cities project experienced issues which caused the numerical simulation model to be too slow to converge, delaying to the project schedule. The team thus requested a 3-month extension.
- Professor Mackenzie’s Evaluating Remote Repositioning for Shared Scooters project has been further delayed because the global chip shortage has delayed the delivery of T-60 e-scooters to be used in the pilot until October 2021. The team is targeting the spring of 2022 for data collection and surveys.
- Professor Kamga’s project requires a 4 month extension due to delay in acquiring social media data.

### **Center Goals:**

With the authorized 6<sup>th</sup> year of funding, USDOT asked Centers to look back on planned accomplishments at the start of the Center versus successes and opportunities for changes. C2SMART has exceeded expectations for a new Tier 1 Center in many areas, though growth in some areas has proven challenging:

- The nature of research has not lent itself towards the development of patents, spin-off companies, or other commercial endeavors, as envisioned. With the push in the transportation community, following federal and state-level organizations’ interest in open-source technology, developing commercialized products has not been a goal of the Center’s research. Instead, open-source software and data projects funded by UTC sources has resulted in significant outputs, such as the COVID-19 dashboard, MATSim-NYC model, FloodSense dashboard, and various open datasets and code.
- Cross-university educational programs has proven to be a challenge due to institutional constraints of universities. Instead, C2SMART has focused on its own programming such as the Student Learning Hub that is accessible to all consortium students and recently expanded to public colleges. The sixth year will feature shorter duration and innovative education projects at local sites.
- The Center planned to have dedicated entrepreneurial support and mentoring for students with incubation and new startup opportunities. While the Center supports numerous students on projects and has student-led projects, its “student entrepreneurship grant competition” launched in 2020 did not attract much interest mainly due to the pandemic. With the 6<sup>th</sup> year of funding, C2SMART will dedicate more specific funding for student entrepreneurship and student-led projects.
- There will also be limited funding for NSF-style “high-risk projects” based on USDOT priorities such as equity and sustainability components. These will be short duration collaboration projects including innovative ideas, hands-on meetings, and interactive report/presentation of the findings.