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1. ACCOMPLISHMENTS

What are the major goals of the program?

The goals of the Center for Transportation, Environment, and Community Health (CTECH) are to pursue research and education innovations to support sustainable mobility of people and goods, while preserving the environment and improving community health. It leverages behavioral and economic sciences, information technology, and environmental and transportation sciences and technologies to address critical issues falling under the FAST Act's priority area of Preserving the Environment: greenhouse gas reduction, use of alternative fuels and energy technologies, environmentally responsible planning, and impacts of freight movement.

To address these challenges, the Center organizes its research activities through six thrusts: 1) Behavior, Active Transportation, and Community Health, which studies the links between travel behavior, active transportation, the built environment, and health; 2) New Transportation Technologies and Business Models, which explores how mobility-on-demand services can be used to improve environmental sustainability and human health; 3) Green Multimodal Transportation Systems, which leverages new mobility technologies to promote sustainable and health-enhancing modal integration; 4) Freight Transportation and Community Health, which explores new vehicle technologies and operation paradigms to reduce human exposure to truck exhaust; 5) Data-Driven Transportation-Health Informatics, which leverages Smart City and IoT (Internet-of-Things) technologies to develop community-based and personalized transportation-health indices for promoting healthy mobility choices; and 6) Energy, Technology and Policy Pathways, which studies the impact of different combinations of energy, technology and policy pathways on the environment and community health. The consortium, consisting of Cornell University (Cornell), University of California, Davis (UCD), University of South Florida (USF), and The University of Texas at El Paso (UTEP), aims to advance transportation sustainability in its broader human and environmental contexts through multi-level, multidisciplinary and cross-sector collaborations.

The Center leverages existing strengths of partner universities to create an innovative, multidisciplinary education program capable of training a workforce that will meet the complex challenges at the intersection of transportation, environment, and community health. Beyond the multidisciplinary curriculum designed in parallel with its research, the Center is developing programs to attract motivated undergraduates and high school students to transportation, particularly from underrepresented groups.

CTECH's research targets deliverables in the following areas:

- Advancing methods for the holistic representation of user behavior/response;
- Data-driven cyber-informatics modeling-management models/tools accounting for built environment-users and systems interactions;
- Computationally efficient algorithmic techniques for multimodal transportation systems management and community health;
- Scientific and engineering solutions for large scale integration of community health into transportation policy and planning; and
- Improved transportation-environment-community health nexus by linking fundamental scientific discovery with innovative practices.

The unique aspect of the work is that researchers focus on informing, influencing, and changing policy (i.e., legislation, regulations, programs, ordinances, and protocols) at the nexus of transportation, environment, and community health. Dissemination of research outcomes and education are critical components of technology transfer to subsequently influence policy and human behavior. The main products from our Center's research activities will be in the form of insights, knowledge, tools, and models that are instrumental to our stakeholders and practitioners as well as to policy development and

analysis. The development of technologies to license and/or commercialize can also be outcomes and is highly encouraged.

What was accomplished under these goals?

While providing critical services for the mobility, health, economic well-being, and security of communities, transportation presents challenges that also define modern society, with issues such as accessibility, air quality and energy efficiency, safety, health impacts, equity, and infrastructure vulnerability that must be confronted to sustain healthy living and economic growth. Successful solutions call for innovative cross-disciplinary research and education, and integrated technologies and approaches that meet goals in mobility alongside goals in environmental and health protection. In this reporting period, focused on FAST Act's priority area of Preserving the Environment, CTECH continued to use its fundamental research activities as the driving force to create downstream innovations, practices, and to enhance education programs for workforce development. The Center's activities are organized and the accomplishments reflected along three tracks: 1) the fundamental knowledge track comprises research activities, development of methodologies and tools, and collection and analyses of data; 2) new policy recommendations and innovative practical implications/guidelines that translate and promote research outcomes into transportation, environmental and community health practices/policies; and 3) education, outreach/engagement, and workforce development that trains students and professionals on the findings and insights of the research, as well as the tools used and lessons learned in best practices. We continued to engage stakeholders (government agencies, private industry, the public, etc.) in all of these processes to create broader impacts. Via accomplishments along these tracks, we progress towards our goal of building a unique platform for synergistic and multidisciplinary research and education at the nexus of transportation, environment, and community health, where new opportunities are explored to develop methods, tools, and technologies to support sustainable multi-modal transportation and promote healthy mobility choices.

Research projects accomplished during this reporting period cover topics such as environmental and health impacts of parking locations, mobility, and health impacts of COVID-19 in various communities, mobility and emissions in post-pandemic re-opening, and transportation system resilience facing sea level rise. In particular, the following research projects were completed.

- Mobility in Post-Pandemic under Social Distancing Guidelines: Congestion, Emission and Transit Contact Network
- The Impact of Mobility on the Spread of Infectious Diseases to and from High Risk Environments
- Improving immersive, highly realistic in-lab, cycling experiences for analyzing active travel
- Sustainable and Healthy Communities through Integrating Mobility Simulations in the Urban Design Process
- An Agent-based Travel and Charging Behavior Model for Forecasting High-resolution Spatio-temporal Battery Electric Vehicle Charging Demand
- Sea Level Rise Resilient Transportation Systems in Coastal Communities
- Assess the mobility and health impact of Covid-19 on diverse communities
- Modeling and Evaluating Multimodal Urban Air Mobility
- Analysis and Design of Pavement Surface Mixtures for Traffic Noise Reduction
- Vehicle-based Sensing for Energy and Emission Reduction
- Exploring the Influence of Carbon Footprint and Health Benefits in Parking Location Decisions
- Using Transit Vehicles as Probes to Monitor Community Air Quality and Exposure
- Exploring the Characteristics of Faculty and Staff Parking on University Campuses

Our education and workforce development missions are ongoing. We have encouraged, inspired, and supported CTECH students and post-docs in pursuing transportation engineering or related careers through comprehensive training programs. Below we highlight where some former CTECH graduate students/postdocs are now.

Dr. Hanjiro Ambrose worked with Miguel Jaller while at UC, Davis in Alissa Kendall's Group working toward his Ph.D. His dissertation was titled Life Cycle Modelling of Technologies and Strategies for Pollution Abatement: A Study of Heavy-Duty Vehicle Systems. He is now an engineer in the Environmental Justice Division's Office of Community Air Protection at the California Air Resources Board. He works on providing equitable access to low carbon energy and mobility while eliminating the disproportionate burden of pollution on disadvantaged communities, with focuses on Lithium Ion Batteries, Critical Energy Materials, Vehicle Electrification, Public Transit, and Transportation Policy.

Dr. Natalia Barbour was a Ph.D. student at USF supervised by Yu Zhang. Barbour developed statistical and econometric models studying adoption and usage patterns of new transportation systems such as bike-sharing, ride-sourcing, and shared automated vehicles. Furthermore, her research took health factors into transportation related modeling and explored the impact of health factors on the adoption and usage patterns of emerging transportation modes. She is now an assistant professor at TU Delft in the Netherlands.

Dr. Mayra Chavez was a Ph.D. student at UTEP supervised by Wen-Whai Li. Her dissertation addressed children's spatiotemporal exposures to transportation pollutants in bear-road communities. Chavez continued her research in transportation air quality and health related issues. She is currently a post-doctoral fellow in the Civil Engineering Department at UTEP and a co-PI on a TCEQ-sponsored project. The project addresses the air quality issues in the Paso del Norte region by strategically placing low-cost air sensors, requiring only a power outlet and Wi-Fi, near schools throughout El Paso, Texas and Juárez, Mexico.

Dr. Rui Ma worked on several CTECH projects while he was a postdoctoral scholar at UC, Davis. In one project, he studied how ridesharing can influence the morning commute patterns, and based on the insights obtained from this study, developed ridesharing pricing schemes to reduce overall commuting costs. He also developed new traffic routing strategies that consider traffic safety as a major factor in people's route choices. Ma continues his research in ridesharing as an assistant professor at the University of Alabama at Huntsville, and credits his CTECH experience for helping sharpen his research focus.

Dr. Shuai Pan worked as a postdoctoral associate under H. Oliver Gao at Cornell University. He worked on assessing the air quality and health impacts of several mitigation strategies, including vehicle electrification in Houston in 2040, heavy-duty truck freight development in the U.S. in 2050, and lockdown during COVID-19 in California. Pan is now an assistant professor in the School of Atmospheric Physics at NUIST. Pan stated that the "system-level thinking", which he learned from the experience at CTECH, will help support tackling complex topics such as future mobility development, wildfires, and cleaner energy transition, and their associated impacts on air quality and health.

Dr. Chunfu Xin was a Ph.D. student at USF supervised by Qing Lu. He worked on two projects focusing on reducing life cycle cost and environmental impact of roadway pavement by improving the design of asphalt pavement. He is now an assistant professor at Inner Mongolia University in China.

Dr. Tingting Zhao was a postdoctoral scholar at USF under the supervision of Yu Zhang. She assisted with the evaluation and modeling of emerging urban air mobility. Zhao is now at the University of Maryland as an assistant research scientist. In addition to emerging transportation technologies, her research interests include Resilient Critical Infrastructure Systems, from the design, operational

optimization, and performance evaluation perspectives by leveraging transportation system modeling, multi-level simulation, data mining, machine learning, and optimization technologies.

How have the results been disseminated?
Formal research related oral presentations during the period are detailed below, followed by other dissemination activities.

> 4-22-21 Samaranayake, S., Northwestern University, **Algorithmic foundations for multi-modal transit systems**, Evanston, Illinois.
>
> 4-30-21 Stuart, A., Translational Research and Evaluation Seminar – USF Center of Excellence in Maternal and Child Health, **Adventures in urban design, air pollution exposures, and environmental equity**, Tampa, Florida.
>
> 5-12-21 Samaranayake, S., UC Irvine, **Algorithmic foundations for multi-modal transit systems**, Irvine, California.
>
> 6-1-21 Zhang, Y., University of Washington, **Studying the Association of Maternal Mental Health and the Built Environment Using Health Informatics**, Virtual.
>
> 8-23-21 Zhang, Y., Epic, **Putting HER in the EHR: Detecting women at risk for developing postpartum depression using artificial intelligence**, Verona, Wisconsin.
>
> 9-2-21 Samaranayake, S., University of Michigan, **Algorithmic foundations for multi-modal transit systems**, Ann Arbor, Michigan.
>
> 9-17-21 Zhang, Y., Southeast Florida FSUTMS Users Group Steering Committee, **Integrated Network Design and Demand Estimation for On-Demand Urban Air Mobility**, Virtual.

On May 20, 2021, Miguel Jaller participated in the STEPS Spring Symposium at UC, Davis. It is organized twice a year to provide research updates to sponsors, agencies, and other communities.

On August 22, 2021, Qing Lu organized and moderated a virtual International Association of Chinese Infrastructure Professionals' (IACIP) webinar on a Feasibility Study on the Intelligent Monitoring of Pavement Performance. Professor Jinxi Zhang from Beijing University of Technology introduced one case study of using mobile phone data to evaluate pavement performance.

H. M. Zhang was one of four in attendance at a virtual meeting on August 31, 2021, hosted by the Caltrans Office of Work Zones, to discuss Work Zone Safety.

For the past three decades or so, many major initiatives have been launched in the field of transportation, from smart roads to smart cities and automated highway systems to self-driving vehicles. On September 3, 2021, Yu Zhang organized a virtual event titled 'New Opportunities for Interactions between Individual Drivers and Traffic Control'. In this talk, the similarities and differences of those initiatives were identified, and lessons from them for assessing the new opportunities in utilizing cutting-edge technology in information and communication to achieve better efficiency in our transportation systems were discussed. In the AI world, "interaction" is the key feature and has been incorporated into many systems. The discussion was from a systems perspective, examining how the interaction between individual vehicles and system control can be realized to improve the efficiency of a transportation system in terms of cost reduction and an increase in system throughput, while at the same time protecting privacy and ensuring fairness.

Shared mobility—the shared use of a vehicle, bicycle, or other mode—is an innovative transportation strategy that enables users to gain short-term access to transportation modes on an "as-needed" basis. It includes various forms of carsharing, bikesharing, ridesharing, on-demand ride services, and microtransit. Smartphone "apps" are also part of this ecosystem and they aggregate and optimize these mobility

options, as well as "courier network services" that are seeking to disrupt the package and food delivery industry. A virtual presentation titled 'Is Sharing Caring? Understanding Shared Mobility Impacts', organized by Yu Zhang on September 10, 2021, explored the different models that have emerged in the shared mobility space and reviewed research that has quantified the environmental, social, and transportation-related impacts of these services. Questions addressed by this presentation included how shared mobility services contribute to social and environmental goals (and when they may not), what are the challenges and opportunities to this, and what could the future hold?

The City of Tampa is moving forward with many innovations in infrastructure and mobility. Some of the City's innovations include adding more green infrastructure to their stormwater projects, fostering new mobility with eBikes, seated, and stand-up scooters, integrating Vision Zero into all of their programs through Crosswalks to Classrooms and other high visibility projects, and tackling our aging infrastructure with new, proactive approaches. Thanks to Yu Zhang, the City's Administrator for Infrastructure and Mobility, Jean W. Duncan, P.E., discussed these innovations via a virtual presentation on September 27, 2021. It was titled 'Moving Florida Forward: Infrastructure, Innovations, and Beyond', showcasing how Tampa is a mid-size city making big-city moves.

What do you plan to do during the next reporting period to accomplish the goals?
No change.

2. PARTICIPATING AND COLLABORATING ORGANIZATIONS

Listed below are organizations that CTECH has partnered with during the reporting period.

Associated Asphalt	Tampa, FL	Other – materials provided for laboratory testing
Bikewalk Tompkins	Ithaca, NY	In-kind Support, Other – provided mailing list to recruit participants
Bird	Santa Monica, CA	Collaborative Research
Boeing	Seattle, WA	Financial Support
C2SMART	New York, NY	Collaborative Research
California Air Resources Board	Sacramento, CA	In-kind Support, Other - dissemination
California Department of Public Health	Sacramento, CA	Personnel Exchanges
California Department of Transportation (Caltrans)	Sacramento, CA	Financial Support, Collaborative Research, Personnel exchanges, Other - dissemination
Center for Urban Transportation Research (CUTR)	Tampa, FL	Financial Support, Facilities, Collaborative Research
Chattanooga Area Regional Transportation Authority	Chattanooga, TN	Collaborative Research
ChemCo Systems	Redwood City, CA	In-kind support
City of El Paso	El Paso, TX	In-kind Support, Facilities, Collaborative Research
City of El Paso Parks and Recreation Department	El Paso, TX	In-kind Support, Facilities, Other – data source, feedback
City of Ithaca	Ithaca, NY	Other – task giver, data source, feedback, potential implementer
City of St. Petersburg	St.Petersburg, FL	Collaborative Research In-kind Support, Other – feedback, potential implementer
City of Tampa	Tampa, FL	In-kind Support, Collaborative Research, Other – provide information on their green infrastructure implementation plan and policymaker advisory support
City of Temple Terrace	Tampa, FL	Other – provided stormwater GIS data for the Temple Terrace area

Columbia University	New York, NY	Collaborative Research
Cornell Atkinson Center for a Sustainable Future	Ithaca, NY	Collaborative Research
Cornell University – Transportation, Facilities, and Campus Services	Ithaca, NY	Other – task giver, data source, feedback, potential implementer
Downtown Ithaca Alliance	Ithaca, NY	Other – task giver, data source, feedback, potential implementer
El Paso Metropolitan Planning Organization	El Paso, TX	Collaborative Research
Englander Precision Medicine Institute	New York, NY	Collaborative Research
Environmental Defense Fund (EDF)	Washington, DC	Collaborative Research, Personnel exchanges
Florida Department of Health	Tampa, FL	Other – project contributions
Florida Department of Transportation Central Office	Tallahassee, FL	In-kind Support
Florida Department of Transportation District 7	Tampa, FL	Other – project contributions
Ford Motor Company	Dearborn MI	Financial Support, Collaborative Research
Hillsborough Area Regional Transit Authority (HART)	Tampa, FL	In-kind Support, Other – data source, feedback
Hillsborough County MPO	Tampa, FL	In-kind Support, Collaborative Research
Hillsborough County Public Works Department	Tampa, FL	Other – provided GIS data and input on the modeling process
Joint Advisory Committee for improving the air quality in El Paso Sunland Park, and Ciudad Juárez	El Paso, TX	Personnel Exchanges, Other – data source, feedback, potential implementer
King County Metro	Seattle, WA	Collaborative Research
Kohn Pederson Fox Architects	New York, NY	Collaborative Research, Personnel exchanges
Lime	San Francisco, CA	Collaborative Research, Other – data sharing agreement, participant recruitment
Lyft	San Francisco, CA	Collaborative Research, Other – data sharing agreement, participant recruitment
New York City Department of Citywide Administrative Services	New York, NY	Other – data sharing agreement
New York City Department of Transportation Design Group	New York, NY	Collaborative Research
New York Metropolitan Transportation Council (NYMTC)	New York, NY	Collaborative Research, Other – data source,
NewYork-Presbyterian Hospital	New York, NY	Collaborative Research
Optimus Technologies	Pittsburgh, PA	Collaborative Research
Pinellas Suncoast Transit Authority (PSTA)	St.Petersburg, FL	Collaborative Research, In-kind Support, feedback, potential implementer
Qualtrics	Salt Lake City, UT	Collaborative Research
San Francisco Transportation Authority	San Francisco, CA	In-kind Support, Personnel Exchanges
Spin	San Francisco, CA	Collaborative Research, Other – data sharing agreement, participant recruitment
Superpedestrian	Cambridge, MA	Collaborative Research, Other – data sharing agreement, participant recruitment
Tampa Bay Area Regional Transit (TBARTA)	Tampa, FL	In-kind Support
Tampa Pavement Constructors/Lakeland Paving	Tampa, FL	Other – provide aggregate samples for laboratory testing

Texas A&M Transportation Institute	College Station, TX	In-kind Support, Other – consultative support
Tompkins Consolidated Area Transit (TCAT)	Ithaca, NY	Other – task giver, data source, feedback, potential implementer
Uber	San Francisco, CA	Collaborative Research, Other – data sharing agreement, participant recruitment
USF Water Institute	Tampa, FL	Other – data exchanges and technical support
UTEP	El Paso, TX	Financial Support, In-kind Support, Facilities
Weill Cornell Medical	New York, NY	Collaborative Research
Wood PLC	Tampa, FL	Other – advice on drainage system modeling

Other collaborators or contacts with involvement in CTECH are listed or described below.

CARTEEH	College Station, TX	Partner (UTEP)
Cornell-Unibo Center for Vehicle Intelligence	New York, NY	H. Oliver Gao is Co-PI of Cornell-Unibo Center
John Swanson	The Villages, FL	Donor – Biodiesel Project

H. Oliver Gao will be serving as a judge for NYSERDA's Clean Transportation Prize project evaluations.

H. Oliver Gao collaborated with Monika M. Safford of Weill Cornell Medicine in New York City, and Lara Skinner of Cornell's School of Industrial and Labor Relations, on a NYSERDA proposal for transportation electrification in New York State.

H. Oliver Gao collaborated with K. Ozbay at C2SMART on research related to the impact of the pandemic on mobility and traffic emissions during and post-pandemic.

Chen-Nee Chuah collaborated on the topic of preserving privacy of mobility data with both Jane Macfarlane at the University of California, Berkeley and Sean Peisert at the Lawrence Berkeley Lab in Berkeley, California. Jane provided access to trajectory data and Sean provided an internship for a Ph.D. student.

Timur Dogan collaborated with Neil Gagliardi, Director of Urban Design NYC DOT. They meet via Zoom bimonthly to discuss how Urbano.io can be used by the NYC DOT. Together they applied for funding from the Cornell Atkinson Center for Sustainability and were awarded $130K. Timur Dogan also interacts frequently with Luc Wilson of Kohn Pederson Fox in NYC to discuss how to use Urbano.io, developed with support from this USDOT UTC award.

Samitha Samaranayake collaborated with Daniel Work at Vanderbilt University and Benedetto Piccoli at Rutgers Camden on an NSF funded project entitled Managing Epidemics by Managing Mobility.

Qing Lu collaborated with Rasim Guldiken, Associate Professor in the Department of Mechanical Engineering at USF. Guldiken provided inputs and support toward Lu's development of noise testing equipment.

3. OUTPUTS

The Covid-19 pandemic has significantly impacted the lives of communities in many dimensions. In a project assessing the mobility and health impact of Covid-19 on diverse communities, CTECH research team led by PI H. M. Zhang at UC Davis relies on traffic data (both vehicular and non-motorized traffic) collected during and after the pandemic to assess how transportation is affected, and its role in response and recovery in a selected number of communities in California, paying particular attention to equity. The research team collected Apple mobility data to see how the pandemic has affected mode share between driving, transit, and walking relative to a pre-pandemic baseline volume. The data shows a shift in mode choice towards driving away from transit and walking during the pandemic. However, to further explore the impacts of Covid-19 on a community scale, the research team collected Bay Wheels data for bikeshare trips made in San Francisco, California. Bay Wheels operates a bikeshare service in the Bay Area in California, and trips made from 2019 to present in San Francisco were studied for changes in ridership during and after the pandemic compared to pre-pandemic levels. Aggregated daily ridership data collected indicated a drop in ridership following March 2020 and the slow recovery to pre-pandemic ridership is evident (Figure 1). With this output, the research team aims to study ridership changes with the demographics of the city to determine if communities were affected by these changes equally. To identify these community characteristics, U.S. Census Bureau data was collected about household income and race for each census block group. Trips were aggregated for these census block groups over different time intervals, such as per month. Outputs from the study will help find ways to improve transportation services that promote robust response to future pandemics and other disasters in equitable ways.

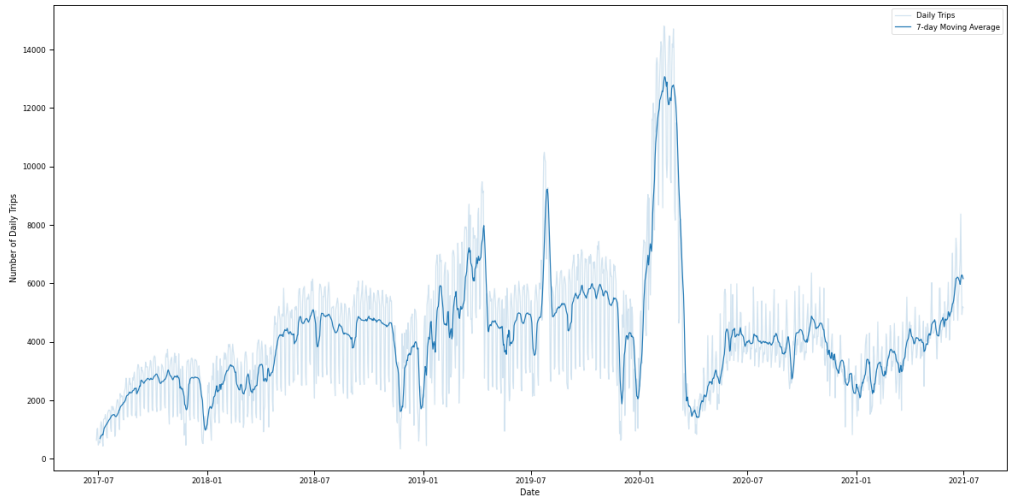

Figure 1: Total number of Bay Wheels trips per day in San Francisco with a 7-day moving average.

While the pandemic hit hard on transit ridership and travelers' mode choices, the wide distribution of transit system makes transit vehicles to be possible probes for monitoring locally representative community air quality and exposure. A recently completed project led by CTECH researchers Wen-Whai Li, Kelvin Cheu at UT El Paso conducted on-road air quality measurements of transportation related air pollutants (TRAPs) using a transit vehicle traveling on a fixed route, and off-road TRAP measurements using two near-road fixed locations along the route. Traffic counts were collected at two locations along the routes using pneumatic tube traffic counters concurrent to the air monitoring campaign to generate vehicle emissions factors and emissions inventory using MOVES3 emission model. Continuous on-road measurements of three criteria pollutants (ozone, nitrogen dioxide, and particulate matter (PM) including PM2.5 and PM10 for particulate less than 2.5 µm and 10 µm in aerodynamic diameter, respectively) were processed in conjunction with GPS locations using ArcGIS and Python for data visualization and statistical analyses. More specific outputs include:

- Traffic data: hourly volume, speed, and classification at two locations for 14 consecutive days.

- Air quality data: On-road NO2, PM2.5, PM10 and O3 concentrations were measured within US. EPA federal equivalent method (FEM) certified devices for a total of 282 trips resulting in around 60 hours of validated data, or approximately 216,000 records of 1-second data, for each TRAP with GPS locations. Off-road FEM air quality data of the same TRAPs were measured concurrently with the on-road measurements.
- A manuscript, entitled "Evaluation of Near-road Exposure Using On-road Air Monitors", was submitted for a presentation at the 2022 TRB Annual Meeting and a publication on TRR.

Publications

Journal publications

1) Nadafianshahamabadia, R., Tayarani, M., Gao, H.O., Impacts of Transportation Emissions on the Risk of Mortality: Findings from the Literature and Policy Implications, *Medical Research Archives, European Society of Medicine*, 2021, Volume 9, DOI: 10.18103/mra.v9i8.2502.
2) Wang, D., Tayarani, M., He, B.Y., Gao, J., Joseph, Y., Chow, J., Gao, H.O., Ozbay, K., Mobility in post-pandemic economic reopening under social distancing guidelines: Congestion, emissions, and contact exposure in public transit, *Transportation Research Part A: Policy and Practice*, 2021, Volume 153, Pages 151-170, DOI: 10.1016/j.tra.2021.09.005.
3) Zhang, Y., Tayarani, M., Wang, S., Liu, Y., Sharma, M., Joly, R., RoyChoudhury, A., Hermann, A., Gao, H.O., Pathak, J., Identifying urban built environment factors in pregnancy care and maternal mental health outcomes, *BMC Pregnancy and Childbirth*, 2021, Volume 21, DOI: 10.1186/s12884-021-04056-1.
4) Wu, Z., Zhang, Y., Integrated Network Design and Demand Forecast for On-Demand Urban Air Mobility, *Engineering*, 2021, Volume 7, Issue 4, Pages473-487, DOI: 10.1016/j.eng.2020.11.007.
5) Mahmoodian, V., Charkhgard, H., Zhang, Y., Multi-objective optimization based algorithms for solving mixed integer linear minimum multiplicative programs, *Computers and Operations Research*, 2021, Volume 128, Page 105178, DOI: 10.1016/j.cor.2020.105178.
6) Mahmoodian, V., Zhang, Y., Charkhgard, H., Hybrid Rebalancing with dynamic hubbing for free-floating bike sharing systems, *International Journal of Transportation Science and Technology*, Awaiting Publication, DOI: 10.1016/j.ijtst.2021.08.002.
7) Guo, Y., Zhang, Y., Understanding factors influencing shared e-scooter usage and its impact on auto mode substitution, *Transportation Research Part D: Transport and Environment*, 2021, Volume 99, Awaiting Publication, DOI: 10.1016/j.trd.2021.102991.
8) Han, X., Yu, Y., Gao, Z., Zhang, H.M., The value of pre-trip information on departure time and route choice in the morning commute under stochastic bottleneck capacity, *Transportation Research Part B: Methodological*, 2021, Volume152, Pages 205-226, DOI: 10.1016/j.trb.2021.08.006.
9) Haydari, A., Zhang, H.M., Chuah, C-N., Adversarial Attacks and Defense in Deep Reinforcement Learning (DRL)-Based Traffic Signal Controllers, *IEEE Open Journal of Intelligent Transportation Systems*, 2021, DOI: 10.1109/OJITS.2021.3118972.
10) Dogan, T., Kastner, P., Mermelstein, R., Surfer: A fast simulation algorithm to predict surface temperatures and mean radiant temperatures in large urban models, *Building and Environment*, 2021, Volume 196, Page 13, DOI: 10.1016/j.buildenv.2021.107762.
11) Klein, N., Subsidizing Car Ownership for Low-Income individuals and Households, *Journal of Planning Education and Research*, 2021, DOI: 10.1177/0739456X20950428.
12) Lu, Q., Xin, C., Alamri, M., Alharthai, M., Development of pourous asphalt mixture with bio-based epoxy asphalt, *Journal of Cleaner Production*, 2021, Volume 317, Page 128404, DOI: 10.1016/j.jclepro.2021.128404.
13) Barbour, N., Menon, N., Mannering, F., A statistical assessment of work-from-home participation during different stages of the COVID-19 pandemic, *Transportation Research Interdisciplinary Perspectives*, 2021, Volume 11, Page 100441, DOI: 10.1016/j.trip.2021.100441.
14) Kocak, T. K., Gurram, S., Bertini, R. L., Stuart, A., Impacts of a metropolitan-scale freeway expansion program on air pollution and equity, *Journal of Transport and Health*, 2021, Volume 22, Pages 10114 (1-11), DOI: 10.1016/j.jth.2021.101114.

Books or other non-periodical, one-time publications

Nothing to report.

Other publications, conference papers, and presentations

1) Haydari, A., Zhang, H.M., Chuah, C-N., Ghosal, D., Impact of Deep RL-based Traffic Signal Control on Air Quality, IEEE 93rd Vehicular Technology Conference – A Virtual Event, April 25, 2021 – May 19, 2021, DOI: 10.1109/VTC2021-Spring51267.2021.9448639.
2) Rivera-Royero, D., Jaller, M., Impacts of Precautionary and Opportunistic Buying Behaviors on Supply Chain Resilience During the COVID-19 Pandemic, *Transportation Research Record*, Under Review.

Policy Papers

1) Pan, S., Fultonc, L., Royd, A., Junge, J., Choi, Y., Gao, H.O., Shared use of electronic autonomous vehicles: energy, air quality, and health impacts of future mobility in the United States, *Renewable and Sustainable Energy Review*, 2021, Volume 149, Page 111380, DOI: 10.1016/j.rser.2021.111380.

Vehicle electrification, automation, and shared mobility – also referred to as the transportation three revolutions (3Rs) – are the emerging trends in future mobility. This paper highlighted a study that performed a comprehensive integrated analysis to investigate the potential future development of passenger transportation in the United States. A technical-economic mobility model, a chemical transport model, and a health impact assessment tool were utilized. This study first adopted several assumptions for vehicle sales under the impact of the 3Rs, and made projections to 2050 for vehicle stocks, distance travel, energy use, and carbon dioxide (CO_2) emissions. This study then quantified the impacts of changing emissions on concentrations of fine particulate matter and associated health benefits. Compared to a projected 2050 business-as-usual case, the wide use of electrification could lead to reductions of ~50% in petroleum consumption and ~75% in CO_2 emissions, and obtain health benefits of 5,500 prevented premature deaths, corresponding to $58 billion annually. The net energy impacts of automation are highly uncertain, and the improved efficiency from automation might be offset by an increase in travel. Sharing would bring additional benefits. The combination of the 3Rs could maximize the energy savings, carbon mitigations, and health benefits. The results of this study suggest that policies/incentives are needed to promote the transition from single-occupied conventional vehicles to shared electric vehicles.

Website(s) or other Internet site(s)

Websites http://ctech.cee.cornell.edu/, https://urbano.io/, and https://www.hbuddy.org/ are continuously being updated.

New methodologies, technologies, or techniques

For emerging Urban Air Mobility (UAM), Yu Zhang's Group studied the network design of UAM on-demand service, with a particular focus on the use of integer programming and a solution algorithm to determine the optimal locations of vertiports, user allocation to vertiports, and vertiport access- and egress-mode choices, while considering the interactions between vertiport locations and potential UAM travel demand. For demonstration of the new methodologies and algorithms, a case study was performed based on simulated disaggregate travel demand data of the Tampa Bay area in Florida. Candidate vertiport locations of this area were obtained by analyzing a three-dimensional (3D) geographic information system (GIS) map developed from lidar data of Florida and physical and regulation constraints of eVTOL operations at vertiports. The outcomes of the integrated model provided optimal locations for vertiports, allocation of passengers to vertiports and their access/egress modes, as well as total diverted traffic to area UAMs.

Ricardo Daziano's Research Group developed a solution that provided a realistic VR biking experience to the user. Building from content and feedback from previous studies, they were able to successfully utilize the technologies at hand to build a strong foundation for future VR bike simulations. Although TwinMotion may be the desired rendering engine for architects, their technological exploration proved that Unity is an easily adoptable rendering engine that provides further levels of customization, levels that

are necessary when considering the extensive user input that is necessary for developing a realistic and engaging VR experience.

Miguel Jaller's Group developed a methodology based on textual analysis, dictionary-based word clustering, and causality relationship regression to use information contained in media posts to analyze the impact of different factors on supply chain resilience during the COVID-19 pandemic.

For managing the supply-demand imbalance in free-floating bike sharing systems, Yu Zhang's research group proposed dynamic hubbing (i.e., geofencing areas varying from one day to another) and hybrid rebalancing (combining user-based and operator-based strategies) to solve the problem with a novel multi-objective simulation optimization approach.

H. Michael Zhang's Research Group developed a new traffic control algorithm for signal-controlled intersections based on the distributed backpressure control technology, which takes into account both, queues and arrival patterns at intersections. This new control algorithm was shown to have better performance than the original backpressure control algorithm through high fidelity traffic simulation.

R. Kelvin Cheu developed a base price model for faculty and staff parking at university campuses, which was a result of the year five project titled, '*Exploring the Characteristics of Faculty and Staff Parking on University Campuses'*.

Qing Lu's Research Group developed the prototype of a low-cost test device to measure the sound absorption of pavement specimens in the laboratory. The device requires further work to perfect it.

Timur Dogan's Group developed a fast simulation algorithm to predict surface temperatures and mean radiant temperatures in large urban models. It predicts exterior surface temperatures and MRT in an arbitrarily complex urban 3D model. The algorithm utilizes K-Means clustering to reduce simulation times by a factor of 80. They report an RMSE of 1.8°C for surface temperature predictions of a full year. The importance of long-wave radiation exchange is analyzed. Lastly, the largest heterogeneity in external surface temperature is reported for horizontal clusters close to obstacles and south-facing clusters.

Samitha Samaranayake's Research Group developed an agent based SEIR model (software package) for university campuses, which can be accessed at https://github.com/MAS-Research/SEIR-Campus.

Jia Li developed an equilibrium model of mixed autonomy traffic, which establishes the theoretical connections between macroscopic traffic equilibria and characteristics of individual traffic agents, i.e., automated vehicles and human-driven vehicles. These connections lay a foundation for designing automated vehicle behaviors in mixed autonomy environments. They demonstrated the complex behaviors of mixed autonomy traffic under different infrastructure settings and endowed agent behaviors. They also proposed a class of speed policies that guarantees the Pareto efficiency of mixed autonomy traffic.

Inventions, patents, and/or licenses

Other products, such as data or databases, physical collections, audio or video products, application software or NetWare, analytical models, educational aids, courses or curricula, instruments, equipment, or research material

- Code for the VR implementation described above code was developed.
- The Jaller Group developed word dictionaries for data analysis, and algorithms for text analysis for the methodology described above.

- YiYe Zhang worked with Bustle Digital Media in New York City to develop patient education articles on health and wellbeing.
- Yu Zhang reorganized the content of USF's Sustainable Transportation course and added multimodal components and transportation equity into the syllabus.
- Frances Vanek collaborated with Professors Dave Dillard and Michael Ellis at Virginia Tech on the publication of the fourth edition of the textbook "Energy Systems Engineering" from McGraw-Hill. The updates included sections on transportation energy, meaning that students have access to more current information about efforts to reduce emissions from travel. Ideally, greater knowledge from a more up-to-date textbook should have a positive impact on engineers' practice regarding transportation and community health, although the textbook is just one among many sources of information that seeks to achieve this goal.
- Frances Vanek developed video lectures for Cornell's Sustainable Transportation Systems Design course, which are now available via Cornell's online classroom learning management system, Canvas.
- Qing Lu incorporated environmental impacts in teaching the design of roads and streets in the USF course Capstone Geotechnical Transportation Design.
- Miguel Jaller added research findings about the health implications of new vehicle technologies, the impacts of truck traffic on vulnerable communities, and the COVID impacts on supply chain resilience and consumer demand to the UC, Davis course Sustainable Freight Systems, and into COSMOS, a program for K-12 students.
- Jia Li developed the curriculum for a graduate course in Civil Engineering at UC, Davis, Exploring Data from Built Environment Using R. It is also a core course in data science for the Transportation Technology and Policy (TTP) Program at UC, Davis.
- Two new project videos highlighting UTEP projects, *Exploring the Influence of Carbon Footprint and Health Benefits in Parking Location Decisions* and *Exploring the Characteristics of Faculty and Staff Parking on University Campuses*, were created and added to the CTECH website at https://ctech.cee.cornell.edu/project-videos/.

T2 Plan Output One – dissemination activities – Number of seminars and/or webinars – goal of 8 annually.

CTECH's Impacts of Transportation and Urban Systems on Health and the Environment Webinar Series hosted the following webinars this period.

1) April 6, 2021 **An Electric Future for Transportation**, Regan Zane, David G. and Diann L. Sant Endowed Professor, Director, NSF ASPIRE ERC, Utah State University. Zane discussed how electric vehicles (EVs) offer tremendous opportunity to both reduce the emissions and stabilize and reduce the cost of transportation. However, significant challenges remain, particularly in charging infrastructure. Now is the time, as our nation considers major investments in aging infrastructure, to build for a future designed to support widespread electrification of all vehicle classes. This talk introduced the ASPIRE ERC and their mission to improve health and quality of life by catalyzing sustainable and equitable electrification in transportation.
2) April 9, 2021 - **Dynamic Driving and Routing Games for Autonomous Vehicles on Networks: A Mean Field Game Approach,** by Xuan (Sharon) Di, Associate Professor, Department of Civil Engineering and Engineering Mechanics, Smart Cities Center, Data Science Institute, Columbia University in the City of New York. As this era's biggest game-changer, autonomous vehicles (AV) are expected to exhibit new driving and travel behaviors, thanks to their sensing, communication, and computational capabilities. However, a majority of studies assume AVs are essentially human drivers but react faster, "see" farther, and "know" the road environment better. Di addressed their belief that AVs' most disruptive characteristic lies in its intelligent goal-seeking and adapting behavior. Building on this understanding, they propose a dynamic game-based control leveraging the notion of mean-field games (MFG). She introduced how MFG can be applied to the decision-making process of a large number of AVs. To illustrate the potential advantage that AVs may bring to stabilize traffic, she introduced a multi-class game where AVs are

modeled as intelligent game-players and HVs are modeled using a classical non-equilibrium traffic flow model. Last but not the least, she talked about how the MFG-based control is generalized to road networks, in which the optimal controls of both velocity and route choice need to be solved for AVs, by resorting to nonlinear complementarity problems.

3) April 16, 2021 - **The Various Silver Linings of the Impacts of the Pandemic on Traffic** by Fraser Shilling, Co-Director, Road Ecology Center, University of California, Davis, Shilling addressed that the U.S. mitigation of the spread of COVID-19 has been implemented by cities', counties', and governors' offices through "shelter-in-place" and "stay-at-home" orders and related actions. The Road Ecology Center carried out three primary types of investigation into the traffic reduction that resulted from these orders and the corresponding "silver linings" that emerged for driver safety, climate change, and nature.
Using observations of reported traffic incidents in our real-time "California Highway Incident Processing System" (CHIPS), the Road Ecology Center found a ~50% reduction in injury and non-injury crashes, on state highways and rural roads that resulted from Governor Newsom's "shelter-in-place" order, from ~1,000 crashes and ~400 injury/fatal crashes per day to 500 and 200 per day, respectively. These reductions have resulted in a savings to the public of about $40 million/day, or $1 billion since the order went into effect. In the U.S., transportation, including personal vehicles, releases about 29% of the greenhouse gas (GHG) per year. We found that estimated emissions had declined by >50% following the various government stay-at-home orders. This puts the U.S. on track to meet its annual goals for GHG reduction under the Paris Climate Accord. Impacts to High traffic volume is a primary contributor to wildlife-vehicle conflict (WVC) and wildlife mortality on roads. Using traffic and collision data from four states (California, Idaho, Maine, and Washington), they found a 34% reduction in WVC. This reduction in mortality would potentially equate to tens of millions fewer vertebrates killed on U.S. roadways during one month of traffic reduction, representing an unintentional conservation action unprecedented in modern times.
4) April 30, 2021 – **Deployable Decentralized Routing Strategies using Envy-Free Incentive Mechanisms for Connected and Autonomous Vehicle Environments** by Srinivas Peeta, Frederick R. Dickerson Chair and Professor, School of Civil and Environmental Engineering, H. Milton Stewart School of Industrial and Systems Engineering, Georgia Institute of Technology. He presented on routing strategies using dynamic traffic assignment that have been proposed in the literature to optimize system performance. However, challenges have persisted in their deployability and effectiveness due to inherent strong assumptions on traveler behavior and availability of network-level real-time traffic information, and the high computational burden associated with computing network-wide flows in real-time. To address these gaps, this study proposes an incentive-based decentralized routing strategy to nudge the network performance closer to the system optimum in a traffic system with connected and autonomous vehicles (CAVs). The strategy consists of three stages, incorporating a local route switching dynamical system to approximate the system optimal route flow in a local area based on vehicles' knowledge of local traffic information, optimizing the route for each CAV by considering individual heterogeneity in traveler preferences (e.g., the value of time) to maximize the utilities of all travelers in the local area, and leveraging an expected envy-free incentive mechanism to ensure that travelers in the local area can accept the optimal routes determined in the second stage. They prove that the incentive mechanism is expected individual-rational and budget-balanced. The study analytically showed that the proposed incentive-based decentralized routing strategy can enhance network performance and user satisfaction in a connected and autonomous traffic environment.
5) May 7, 2021 - **Traffic Flow Smoothing at Scale** by Daniel B. Work, Associate Professor, Civil and Environmental Engineering, Electrical Engineering and Computer Science, Institute for Software Integrated Systems, Vanderbilt University. He discussed that the majority of the best-selling cars in the U.S. are now available with SAE level-one automated driving features such as adaptive cruise control. As the penetration rate of these vehicles grows on the roadways, it is now possible to consider controlling the bulk human-piloted traffic flow by carefully designing these driver-assist features. This talk discussed modeling, simulation, and field demonstration advancements that are needed to control automated vehicles to stabilize traffic flow at scale. Prior work on a closed course established that automated vehicles can eliminate human-generated phantom traffic jams that seemingly occur without cause, reducing fuel consumption by up to 40%. The talk highlighted research challenges and progress towards demonstrating traffic flow smoothing with a fleet of connected and automated vehicles on the I-24 Smart Corridor in Tennessee, as part of the CIRCLES Consortium.
6) May 21, 2021 - **Prediction/Causality Tradeoffs and Data Size Issues in Transportation Modeling: The Example of Highway-Safety Analysis** by Fred Mannering, Associate Dean for Research, College of

Engineering, Professor of Civil and Environmental Engineering, University of South Florida. Mannering discussed how the analysis of transportation data is largely dominated by traditional statistical methods (standard regression-based approaches), advanced statistical methods (such as models that account for unobserved heterogeneity), and data-driven methods (machine learning, neural networks, and so on). In the analysis of highway safety data, these methods have been applied mostly using data from observed crashes, but this can create a problem in uncovering causality since individuals that are inherently riskier than the population as a whole may be over-represented in the data. In addition, when and where individuals choose to drive could affect data analyses that use real-time data since the population of observed drivers could change over time. This issue, the size of the data (which can often influence the analysis method), and the implementation target of the analysis imply that analysts must often tradeoff the predictive capability (dominated by data-driven methods) and the ability to uncover the underlying causal nature of crash-contributing factors (dominated by statistical and econometric methods). However, the selection of the data-analysis method is often made without full consideration of this tradeoff, even though there are potentially important implications for the development of safety countermeasures and policies. This talk provided a discussion of the issues involved in this tradeoff with regard to specific methodological alternatives, and presented researchers with a better understanding of the trade-offs often being inherently made in their analysis.

7) September 24, 2021 - **Prediction/Causality Tradeoffs and Data Size Issues in Transportation Modeling: The Example of Highway-Safety Analysis Paradigm shift towards smart and healthy cities —systems innovation at the nexus of transportation, environment, and public health** by H. Oliver Gao, Professor, Director, Center for Transportation, Environment, and Community Health, Cornell University. He presented on transportation-related air pollution, GHG emissions and energy problems that are a significant issue in the U.S. and across the world. The World Health Organization estimates that urban air pollution causes 200,000 deaths per year worldwide. How do we meet the mobility needs in urban transitions without sacrificing environment sustainability and global health? Dr. Gao explains their systems approach to study the nexus of transportation and environment/health systems, examining the broad spectrum and necessary depth of models, tools, and insights for trans-disciplinary systems research in support of integrative transportation, environment, and health systems planning and finance/policy innovation such as public private partnership.

<u>T2 Plan Output Two</u> – breadth of researchers' engagement with stakeholders – number of CTECH researchers on stakeholder committees and/or boards – goal of 8 annually.

16 CTECH faculty researchers hold positions on 47 committees and/or boards.

4. OUTCOMES

Design Autonomous Vehicle Behaviors in Heterogeneous Traffic Flow: The advent of autonomous vehicles (AVs), while revolutionizing the transportation landscape, can also create complications for traffic operations, due to the different characters of AVs and human-driven vehicles (HVs). CTECH researchers Jia Li and Michael Zhang developed a game theory-based equilibrium model of mixed autonomous traffic. As the key outcome of the project, the model encapsulates the interactions of two classes of agents as a bargaining game, where the lateral road space is divided between them. Their model thoroughly characterizes the equilibrium properties of mixed autonomous traffic when AVs and HVs are endowed with different driving behaviors. An intriguing finding is that the traffic agents, even when their behaviors are the same, can reach to different equilibriums. Among all these equilibriums, Pareto efficient equilibriums always exist, which are the desired ones from both agent and system perspectives. They also propose a class of speed policies that guarantee such equilibriums are always attainable. Numerical examples show the different equilibrium flow structures when AV behaviors vary, and lane policies are imposed.

Influence of Carbon Footprint and Health Benefits in Parking Location Decisions: In parking location decisions, the cost of parking and walking time to the final destination are the decision criteria. From the viewpoints of sustainability, parking location affects the carbon footprint of a vehicle's trip. In

addition, walking between the parked vehicle and final destination has health benefits. This project surveys students at The University of Texas at El Paso. A questionnaire survey was performed online. Prior to the conduct of the survey, significant efforts were made to estimate the carbon footprints and measures of health benefits at alternative parking locations. The online survey attracted responses from 430 students. With the information of MHBs and MCFs provided when purchasing permits, 46% of the respondents changed their parking zones. These changes were estimated to cause a 3.88% reduction in total calories burned per year (from all the commuter students), a 2.10% reduction in total CO_2 emissions per year (contributed by all the students on campus), combined with a 1.15% reduction in student permit sales revenue.

Additional outcomes include:

- Chen-Nee Chuah's team studied deep reinforcement learning (DRL) based algorithms at the traffic signal control (TSC) and the vulnerabilities of these DRL-TSC algorithms in the presence of black-box and white-box adversarial attacks. Their results showed that the performance of DRL learning agent decreases in both settings, resulting in higher levels of traffic congestion. They then proposed an ensemble model to perform sequential anomaly detection of the adversarial attacks. Their model minimizes detection delay and achieves lower false alarm rates due to cumulative anomaly inspection. Application of their models can lead to reduced emission and improved travel delay at intersections thanks to deep reinforcement learning (DRL) based traffic signal controller (TSC). The algorithms also help protect DRL-TSC against adversarial attacks, resulting in better safety.
- Conditional logit models are proposed to model the stated choices of respondents that participated in an online survey. Significant negative estimate of price proves respondents' preferences for lower prices of bike sharing systems. It has been recognized that among all bike sharing attributes tested, the highest valued feature is for the system being dockless. Respondents' willingness-to-pay for dockless bike sharing system is $10.53 on average, which is very high even compared with the price of daily passes. On the contrary, other features seem to be less attractive. Respondents showed some interest in e-bikes, while they do not care about time included and extra time fees. This information has the potential to impact decisions on which kind of bike sharing systems to implement in cities across the United States.
- Timur Dogan was able to set up a funded collaboration with the NYC DOT Design group. They anticipate deep integration of Urbano.io workflows into the NYC DOT's upcoming design projects.
- Dillon Fitch's model has improved our chances of accurately measuring the VMT reductions, and the downstream health and safety benefits, that can be attributed to micromobility services. This has increased the body of knowledge specific to micromobility service impacts on the transportation sector and beyond.
- Qing Lu finalized empirical models that may be used to predict the acoustic performance of asphalt mixtures used for pavement, which increased the body of knowledge in addressing the noise issue from the pavement facility perspective.
- The concept of an alternative approach to reuse old asphalt pavement materials in new pavement was proposed and shared with industrial collaborators. Laboratory testing to validate the approach was initiated during this period.
- An increased understanding of the e-scooter sharing pilot program in the City of Tampa, including the inequity impacts.
- Increased knowledge about precarious car ownership among low-income households and the effect of this precocity on their economic and social wellbeing.

T2 Plan Outcome One* – *cited works – Number of reports in media – goal of 8 annually.

With the support of Yu Zhang's (USF) Ph.D. student, Hualong Tang, their research titled "Design of an automated advanced air mobility flight planning system (AAFPS)" was selected to receive the Amazon Research Award (ARA). They were among the 101 recipients of the 2020 Amazon Research Awards, who represent 59 universities in 13 countries. Each award is intended to support the work of one to two graduate students or postdoctoral students for one year, under the supervision of a faculty member. Proposals were reviewed for the quality of their scientific content, their creativity, and their potential to impact both the research community, and society more generally.

Timur Dogan's research was highlighted in an article in *Gothamist* with an article entitled Longer NYC Commutes, Household Crowding Linked to Higher COVID-19 Rates. https://gothamist.com/news/longer-nyc-commutes-household-crowding-linked-higher-covid-19-rates and also highlighted in the Cornell Chronicle https://news.cornell.edu/stories/2021/09/long-commutes-home-crowding-tied-covid-transmission.

Amy Stuart was interviewed on a Podcast Panel in the Environmental Health, Climate Change, and Advocacy Series, on April 29, 2021. The podcast was entitled Advocation – Change it up! https://anchor.fm/advocation/episodes/%20Environmental-Health--Climate-Change--and-Advocacy-eprb05.

Former CTECH Ph.D. student, and UTC Student-of-the-Year, Hanjiro Ambrose, occasionally hosts the podcast on energy issues on Watts Radio.

We recently learned that Nicholas Klein's research was highlighted in Fast Company in October 2020, https://www.fastcompany.com/90562174/should-we-be-subsidizing-cars-for-low-income-families.

T2 Plan Outcome Two* – *stakeholder support – Number of stakeholders that collaborated with researchers on projects – goal of 8 annually.

The following 22 stakeholders have worked collaboratively with us on research projects.

- Bird
- Caltrans
- Chattanooga Area Regional Transit Authority
- City of El Paso
- City of St. Petersburg
- City of Tampa
- El Paso Metropolitan Planning Organization
- Englander Precision Medicine Institutute
- Environmental Defense Fund (EDF)
- Ford Motor Company
- Hillsborough County Metropolitan Planning Organization
- King County Metro
- Kohn Pederson Fox Architects
- Lime
- Lyft
- NYMTC
- Optimus Technologies
- Pinellas Suncoast Transit Authority

- Qualtrics
- Spin
- Superpedestrian
- Uber

5. IMPACTS

Agent-based Travel and Charging Behavior Model for Battery Electric Vehicle Charging Demand: The expansion of the battery electric vehicle (BEV) market is expected to require considerable changes in the supply of electricity to fulfill the charging demand. Meanwhile, understanding the spatio-temporal distribution of BEV charging demand at a micro-level is crucial for optimal electric vehicle supply equipment (EVSE) planning and electricity generation. CTECH researchers at Cornell (Yuechen Sophia Liu, Mohammad Tayarani, and H. Oliver Gao) propose an integrated travel and charging behavior model to study the high-resolution distribution of charging demand. An agent-based travel behavior model is applied to simulate daily travel patterns and charging demand at fine spatial resolution. A novel charging choice model is proposed which considers the effect of the agents' risk sensitivity, range buffer, and preference to charging rate. The results of a case study for the Atlanta metropolitan area imply that high demand is more likely to appear at popular travel destinations such as airports and universities, suggesting that placing work/public EVSE at popular areas increases the chance of serving more demand. Charging behavior has a significant impact on the demand share at each location as well as charging mode. In particular, a high-risk sensitivity leads up to 50% higher peak power demand. Similarly, disfavoring fast charging decreases direct-current fast charging (DCFC) demand by 17%. These behaviors would affect the maximum number of work/public EVSE needed to satisfy demand at each location. Meanwhile, some results are robust to a range of behaviors; DCFC takes the largest portion (more than 69%) of work/public demand in all scenarios. However, a large amount of DCFC doubles the variance of power demand, especially when users are high-risk sensitive, thus creating challenges to electricity generation.

Influence of Carbon Footprint and Health Benefits in Parking Location Decisions: To study influence of carbon footprint and health benefits in parking location decisions, a walking survey was conducted on the UTEP campus to estimate the Measure of Health Benefits (MHBs), which had been identified as number of calories burnt. The MHBs ranged from 5,880 to 25,938 calories/student/year. The actual value is dependent on the gender, body weight, distance between the parking zone and the centroid of the campus and elevation gained. The CO2 emission had been identified as the Measure of Carbon Footprint (MCF). The research teams found out that this survey had increased the respondent's awareness of a healthy lifestyle and environmental sustainability. After the presentation of the MHB data, the proportions of respondents who stated that MHB was "very important" and "important" in parking permit purchase decisions increased from 79.7% to 87.5%. After the MCF data was shown to the respondents, the proportions of respondents who stated that MCF was "very important" and "important" in parking permit purchase decisions increased from 66.1% to 75.5%. When selecting the parking locations, the permit cost, last-mile travel time and ease of finding a parking sport remained as the first, second and third most important factors. They are followed immediately by MHB and MCF.

Additional impacts include:

- The funded collaborative research with NYC DOT titled "A New Data-Driven Approach to Re-designing Sustainable, High-Density Urban Environments Through the Lens of Pandemic Resilience" will build on the achievements and modeling capabilities introduced by the Urbano.io project. The current COVID-19 crisis revealed the vulnerability of urbanizing societies where cities are the focal points of the current pandemic. Therefore, long-standing planning paradigms that promote urban density to enhance social life, increase efficiency, and sustainability must be re-evaluated using a data-driven approach. While U.S. transportation emissions dropped ~10% in 2020 as millions of workers stopped driving to work, the use of mass transportation may have

accelerated the outbreak in specific locales like New York City. This suggests that sustainability, pandemic resilience, and the design of our built environment are closely linked. To better understand how urban design attributes such as urban density, housing, demographic and building use mix, mobility infrastructure, walkability, and bike-ability of a city relate to the spreading and containment of pathogens, new collaborative research efforts at the nexus of urban design, policymaking, and epidemiology are needed. As a multi-disciplinary team from Cornell Architecture, Public Health, Weill Cornell Medicine, and the NYC Department of Transportation's Urban Design directorate we aim to combine emerging data on COVID-19, urban geospatial data, state of the art mobility simulations, and epidemiological modeling to develop a new data-driven tool that will help urban designers and planners to transform our cities into healthy and sustainable urban environments. The team will test, validate and apply the tool in two real-world case studies to help enhance the NYC Open Streets initiative and support DOT's $50 million capital project on Jerome Avenue in the Bronx.

- YiYe Zhang is working with Epic Corporation to integrate the risk prediction algorithm into the electronic health record system. Once implemented, patients who are predicted to be at risk for postpartum depression may be identified early and referred to the appropriate next steps for prevention and/or management.
- The modeling group at NYMTC continues to use the web-based emissions post-processing software, CU-PPS, developed by the Gao Research Group, for their transportation conformity analysis.

***T2 Plan Impact One* –impact on practice – number of research recommendations implemented – goal of 7 annually.**

H. M. Zhang's findings and recommendations with respect to travel time data acquisition accuracy and cost contributed to the formulation of Caltrans' data acquisition policies. This resulted from our year one project entitled *Evaluation of Freeway Traffic Data Acquisition: Technology, Quality and Cost*.

Y. Zhang's year four project entitled *Understand usage patterns of e-scooter sharing and policy implications* led to the implementation of equity into a shared micromobility program in the City of Tampa.

***T2 Plan Impact Two* –software applications – number of practitioners – goal of 6 annually.**
***T2 Plan Impact Three* –software applications – number of researchers – goal of 7 annually.**

The Urbano.io software can be downloaded for free and is used to integrate mobility simulation and urban data processing into the urban design process.

Urbano.io had approximately 4,000 practitioner downloads to-date by twelve organizations, including AECOM, KPF, Ramboll, SOM, Buro Happold, Henning Larsen, Transsolar, SidewalkLabs, AS+P, Graphisoft, Link, HKS, and Perkins + Will.

Urbano.io had approximately 2,000 researchers downloads to-date from seven institutions including MIT, Harvard, Columbia, Carnegie Mellon, TU Berlin, TU Delft, and Technion.

6. CHANGES/PROBLEMS

Across all four partner institutions, some COVID-19 challenges continue, e.g., continued delays and/or inability to do experiments, acquire data, recruit for surveys, and/or engage public participants. Field and laboratory work continue to be hindered due to limitations on college campuses. Interactions with state and local agencies have been delayed because of their high workloads. Feedback indicated that the

publication review process seems to have slowed down. There are issues with current students that are unable to leave their home countries to return to their degree programs in the U.S., as well as difficulty in recruiting new students virtually. Inefficiencies working from home and managing child care also continue to negatively affect productivity. The opportunities for in-person collaborations and to participate in conferences, meetings, or events remain limited. Also, there is an inability to organize student related professional opportunities/events. Newly reported this period were slowdowns that resulted from faculty and student health conditions.

On the positive side, COVID-19 exposed Timur Dogan's Group to new research directions in which Urbano.io can be leveraged.

7. SPECIAL REPORTING REQUIREMENTS

CTECH Specific Metric: Overarching goals of the Center include the development of a metric for community health that incorporates mobility and health indicators; mobility on-demand models including environmental sustainability indicators; large-scale models to promote environmental sustainability, community health, and environmental justice. Urban Air Mobility (UAM) is an emerging concept proposed in recent years that uses electric vertical take-off and landing vehicles (eVTOLs), which is expected to offer an alternative way of transporting passengers and goods in urban areas with significantly improved mobility by making use of low-altitude airspace. Previous studies answered planning questions in terms of optimal vertiport locations and estimation of diverted demand from ground transportation by developing an integrated network design and travel mode choice model. Few studies investigated possible environmental impacts of emerging UAM. CTECH project "Modeling the Environmental Impact of Urban Air Mobility: Case Study of Tampa Bay Region" develops a modeling framework to assess environmental impacts of emerging UAM, focusing on assessing air pollutant emissions. The objectives of the project include (1) collect the data of power sources for electricity generation and calculate corresponding greenhouse gas emissions of electricity consumption; (2) calculate and compare the difference of air pollutant emissions of diverted demand from ground transportation to multimodal UAM; (3) apply sensitivity analysis to test how the parameters in the modeling will affect the research outcomes. This study fills in the gaps in existing UAM literature and improves the impact analysis of this emerging transportation mode. The project has been selected to be presented during Business of Automated Mobility Forum: Flight Path to UAM/AAM, a virtual event organized by Association for Unmanned Vehicle Systems International (AUVSI) that will be held on November 2 & 3, 2021. The attendees of these conference/forum will include researchers from academia, practitioners from public and private sectors, and general public.