CENTER FOR ADVANCING RESEARCH IN
Transportation Emissions, Energy, and Health
A USDOT University Transportation Center

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Signature of Submitting Official:	Haylee Yung

OVERVIEW

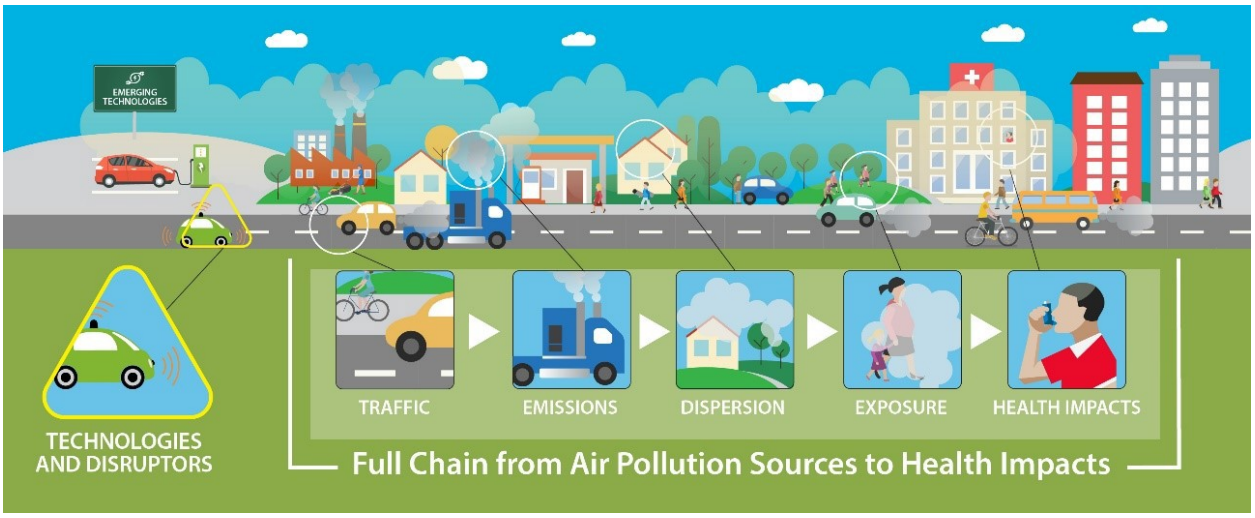
The Center for Advancing Research in Transportation Emissions, Energy, and Health (CARTEEH) has been highly productive during this reporting period as we continue to build on our successes of the last five years. The year four projects are winding down; however, and our year five competitive research projects and strategic initiatives are progressing well. We have initiated several technology transfer activities, which have received extremely positive feedback. At the end of this reporting period, we continue to be proud of our achievements and excited about upcoming activities in all our goal areas.

ACCOMPLISHMENTS

Major Goals of the Program

CARTEEH brings together experts from transportation and public health, two disciplines that have not traditionally worked together. CARTEEH's focus is to advance research on transportation emissions in a comprehensive manner, mapping the holistic tailpipe-to-lungs spectrum, as shown in Figure 1.

Figure 1: Tailpipe to Lungs Spectrum



CARTEEH's research focus areas were defined to cover this spectrum and are as follows:

- Transportation System
- Emissions and Energy Estimation
- Exposure and Health Impacts
- Data Integration
- Policy and Decision-Making

Progress in each CARTEEH goal area is detailed in the following sections:

CARTEEH Goal #1: Research Program

CARTEEH's research program includes collaborative research projects conducted jointly among consortium members, competitive program awards, and other initiatives that support our strategic research, education, and technology transfer goals. These are all included as part of our project portfolio in Table 1 below, though some initiatives are discussed further under the education and technology transfer sections of this report.

In the last reporting period, we kicked off fourteen new projects as part of our Fall 2020 competitive funding cycle as well as collaborative projects led by our consortium members. These projects were all aligned with CARTEEH's "SMART Infrastructure Initiative" that attempts to link health and health equity considerations into decision-making. These projects have progressed well over the past quarter and many are on track for completion in the next. Further, all CARTEEH consortium members initiated collaborative projects aligned with the SMART framework.

The majority of the research projects awarded in CARTEEH's third and fourth year have also been completed, and CARTEEH staff members are working with researchers to finalize their reports, upload their data to the CARTEEH Data Hub, and disseminate results.

Table 1: CARTEEH Project Portfolio

Project	Lead Institution	Principal Investigator
Transportation Emissions and Health Data Hub	TTI	Dr. Andrew Birt
Reconciles differences in characteristics of transportation and health data; develops a platform to house datasets		
Truck Emissions Exposure Study in Ports	GaTech	Dr. Michael Rodgers
Assesses pollutant emissions at selected major ports; evaluates the potential reduction of exposure using multiple methodologies		
Border Crossing Emissions Impact Study	TTI	Dr. Tara Ramani
Characterizes the emissions impact of border crossings and identifies population groups most affected by the emissions		
Healthy Living and Traffic-Related Air Pollution in an Underserved Community	UTEP	Dr. Wen-Whai Li
Quantifies traffic-related air pollution and the associated respiratory health for vulnerable school children in El Paso, Texas		
Development and Evaluation of Connected Vehicle Application for Alternative Fuel Trucks	UCR	Dr. Peng Hao

Evaluates benefits of battery-electric trucks and plug-in hybrid electric trucks over conventional diesel trucks		
Health Risk Characterization for Transportation Users	JHU	Dr. Mary Fox
Develops a cumulative exposure and risk profile for transportation workers and/or system users considering chemical and other stressors		
Assessing Regulatory Compliance and Community Air Pollution Impacts of Crude Oil by Rail (CBR) Transport in Baltimore City, Maryland	JHU	Dr. Genee Smith
Delivers evidence-based characterization of emissions impacts of CBR within Baltimore City, Maryland		
PM Exposure for Paratransit Transport	GaTech	Dr. Alex Samoylov
Characterizes exposure to PM faced by sensitive populations using paratransit transport		
Traffic-Related Air Pollution and Childhood Asthma in the United States: A Burden of Disease Assessment	TTI	Dr. Haneen Khreis
Conducts a burden of disease estimate of childhood asthma attributable to traffic-related air pollution within the US		
Characterizing In-Cab Air Quality in Heavy-Duty Diesel Construction Equipment	TTI	Dr. Phil Lewis
Analyzes air quality and driver exposure inside the cabs of heavy-duty diesel construction equipment		
Dockless Mobility: Addressing Safety, Emissions, and Gaps in Policy Making	TTI	Dr. Suriya Vallamsundar
Examines emissions exposure on dockless mobility users in Dallas, Texas		
Quantifying Bioavailable Metals and Potential Dust Emissions from Highway-Related and Desert Sediments at Lordsburg Playa, New Mexico	UTEP	Dr. Thomas Gill
Scopes the presence of bioavailable metals and potential dust emissions from highway-related and desert sediments in New Mexico		
Secondary Particulate Matter Exceed Primary Emissions from Current Gasoline Vehicles: Air Quality and Public Health Implications	UCR	Dr. Georgios Karavalakis
Assesses emissions from gasoline direct injection and multipoint injection vehicles when operated under different driving cycles		
Quantifying Traffic Congestion-Induced Change of Near-Road Air Pollutant Concentration	UCR	Dr. Jill Luo
Develops a statistical model to quantify the contribution to the ambient air quality degradation due to traffic congestion		

Transportation and Health - Conceptualization and Quantification	TTI	Dr. Haneen Khreis
Addresses the transportation-health nexus beyond air quality and emissions; develops a comprehensive conceptual "pathways" model		
Urban Policy Interventions and Their Effectiveness in Reducing Traffic Emissions and Traffic-Related Air Pollution	TTI	Dr. Haneen Khreis
Identifies policy interventions to effectively reduce traffic emissions and traffic-related air pollution from on-road mobile sources		
Technology Landscape and Future Direction for Transportation Emissions, Energy, and Health	TTI	Dr. Yanzhi (Ann) Xu
Develops a technology roadmap for transportation emissions, energy, and health		
Curriculum for Transportation Emissions and Health	TTI	Dr. Haneen Khreis
Development of a unique, cross-disciplinary course titled "Traffic-Related Air Pollution: Emissions, Human Exposures, and Health.", which can be used for undergraduate, graduate, and practitioner education.		
Transportation Emissions and Health Literature Library	TTI	Dr. Haneen Khreis
Downloadable spreadsheet resource tabulating and categorizing literature on transportation emissions, energy, and health.		
Innovative Data Applications using CARTEEH's Data Hub	TTI	Dr. Yanzhi (Ann) Xu
Use of CARTEEH's data hub infrastructure for data integration applications, including the development of a national emissions map		
Development of an Emission-Based Selection Algorithm to Optimize Variable Message Signs Location *(student project)*	TTI	Ms. Farinoush Sharifi
Develops an algorithm to identify locations of variable message signs to maximize emissions savings in situations of nonrecurring congestion		
Real-World Data Measurement of Factors Affecting Air Quality for Nonroad Diesel Equipment Operators	TTI	Dr. Phil Lewis
Characterizes the various factors affecting equipment operators' exposure to poor air quality, using real-world data and measurements.		
Trace Metals in Airborne Particulate Matter and Genomic Characterization of Associated Microorganisms: Insights into Health Effects from an Industrialized, Near-Roadway Site in Houston	TTI	Dr. Shankar Chellam
Investigates vehicular contributions of PM10, and its elemental components and microorganisms, to understand health effects and implications.		
Making New Mobility a "Win" for Public Health	JHU	Dr. Johnathon Ehsani
Investigates the use of new mobility options as a public health intervention, through simulation of scenarios and validation with real-world data.		

Improved Vehicle Emissions and Near-Road Dispersion Modeling Tool for Project Evaluation: Integrating MOVES-Matric, the FEC, and AERMOD	GaTech	Dr. Haobing Liu
Developing a tool to streamline and integrate transportation emissions modeling and dispersion modeling for a more straightforward assessment of air quality impacts.		
Modeling Air Quality Impacts of Pollution Mitigation Scenarios at a Multimodal Inland Port	GaTech	Dr. Franklin Gbologah
Assessment of Nox and PM emissions and dispersion for various pollution control scenarios in an inland port.		
Association of Traffic and Related Air Pollutants on Cardiorespiratory Risk Factors from Low-Income Populations in El Paso, TX.	UTEP	Dr. Jsoyoung Jeon
Studies linkages between cardiorespiratory risk factors and levels of traffic-related air pollutants.		
Onboard Sensing, Analysis, and Reporting (OSAR): Expanded Field Demonstrations and Development of Associated Visual Aids	UCR	Dr. Kent Johnson
Develops the capability for spatial and temporal visualization of emissions from the OSAR on-board emissions measurement system.		
Development of Full-Chain Transportation Emissions, Exposure and Health Modeling Platform	TTI	Dr. Yanzhi (Ann) Xu
Models the "full-chain" between transportation and health, building on an advanced transportation emissions modeling platform developed by CARTEEH researchers		
Transportation as a Disease Vector - a Modeling Approach	TTI	Dr. Joe Zietsman
Investigates the role of transportation vehicles and infrastructure in the spread of disease.		
Runners air pollution exposure assessment using Low-cost Wearable (LCS) Sensors	TTI	Benjamin Ettelman
The study attempts to bridge a gap in the literature by employing emerging low-cost sensor technology.		
Feasibility Analysis and Infrastructure Requirements of Affordable, Shared, and Electric Mobility	TTI	Dr. Yanzhi (Ann) Xu
Study assesses the feasibility of providing electric shared EV service to middle- and low-income households that live in multi-unit communities in Texas.		
Economic Impacts of Electric Vehicle Infrastructure Expansion on Texas Metros	TTI	Jacqueline Kuzio
This research project will produce a tool that utilizes both benefit-cost and economic impact modelling to show the benefits that could arise with an increased investment in electric vehicle infrastructure.		
Effects of COVID-19 Lockdown on Air Quality and Mortality across Continental United States – A Data Driven Approach	TTI	Rohit Jaikumar
Study aims to integrate observational air quality data from EPA and other state agencies monitoring networks with satellite data and epidemiological studies to quantif the health benefits of the lockdown measures imposed in response to the COVID-19 pandemic.		
Developing a SMART Framework and Practitioner Toolkit to Enhance the Public Health Benefits of Transportation Infrastructure	TTI	Benjamin Ettelman

Identify a range of qualitative and quantitative metrics for transportation-health pathways.		
Drayage Truck Electrification Feasibility and Benefit Analysis	TTI	Dr. Yanzhi (Ann) Xu
The goal of this study is to assess the feasibility of truck fleet and equipment electrification at POH.		
Drayage Truck Electrification Feasibility and Benefit Analysis	TTI	Tara Ramani
The goal of this study is to assess the feasibility of truck fleet and equipment electrification at POH.		
Instant COVID-19 Diagnostic Devices on the Go to Improve Transportation Safety	UTEP	Xiujun Li
This project aims to develop an "on-the-Go" COVID-19 quantitative diagnostic microdevice.		
Understanding Modal Shift during the Pandemic and Quantifying its Public Health Impact	JHU	Michelle Duren
The goal of the study is to provide useful insights for policymakers in transportation and health departments on travel behavior changes during the pandemic.		
Locational Marginal Emission Evaluation for Electric Vehicle Charging Facility Planning	UTEP	Yuanrui Sang
Develop a framework for hazardous gas LME evaluation and EV environmental impact mitigation.		
Impacts of COVID-19 Induced Active Transportation Demand on the Built Environment and Public Health	TTI	Bahar Dadashova
Develop data-driven tools and recommendations for implementing a bicycle- and pedestrian-friendly infrastructure to meet and maintain this new demand.		
Develop a performance metric to quantify the inhalation of traffic-related air pollutants at both mesoscale and macroscale	UCR	Ji Luo
Develop a performance metric to quantify the inhalation of traffic-related air pollutants at both mesoscale and macroscale.		
Quantifying the Environmental and Health Impacts of Curbside Management for Emerging Multi-modal Mobility Services	UCR	Guoyuan Wu
The research aims to investigate how curbside management strategies may help address traffic bottlenecks on roads and sidewalks due to intensive pick-up/drop-off activities.		
Children's Exposure to Traffic Pollution in Texas School Districts: Analyzing Social Disparities and Adoption of Mitigation Strategies	UTEP	Jayajit Chakraborty
This project seeks to analyze social disparities in exposure of school-aged children to vehicular air pollution and examine the adoption of mitigation strategies for reducing school exposure to vehicular pollution, across public school districts in Texas.		
Quantification of traffic-related emissions and exposures at US-Mexico Border Crossings using real-time mobile sensors	UTEP	Mayra Chavez
Exposure to traffic emissions related to border crossing occurs while people are waiting in line or on foot to cross the border.		
Supporting Health-Transportation Education in Schools	TAMU	Joanne Olson
This project supports CARTEEH's SMART Infrastructure initiative project by demonstrating how carefully designed educational STEM contents can promote a greater understanding and engagement of stakeholders in public schools (K-12 level).		

Research Results Disseminated

CARTEEH researchers continued to disseminate their research results through various venues, including presentations at conferences, paper submittals to journals, and in meetings and outreach to stakeholders. Key research findings and final reports are also disseminated through the CARTEEH website. CARTEEH's 2nd Transportation Air Quality and Health Symposium (discussed later in this report) also provided a platform for dissemination of several CARTEEH research projects.

Plans for Next Reporting Period to Accomplish Research Goal

In the next reporting period, CARTEEH leadership will continue working with the principal investigators of the ongoing projects to ensure the success of their projects and the development of impactful results. We plan to continue to build upon our SMART Infrastructure initiative. We expect to leverage our research results for further education and technology transfer activities, with an emphasis on stakeholder engagement and in line with our technology transfer plan.

CARTEEH Goal #2: Education and Workforce Development

CARTEEH research projects are catalysts for CARTEEH student involvement, with the number of students involved with CARTEEH increasing each semester.

Texas A&M University College of Education Collaboration

During this reporting period, CARTEEH formalized its collaboration with Texas A&M University's College of Education by kicking off a project to demonstrate how carefully designed educational STEM contents can promote a greater understanding and engagement of stakeholders in public schools (K-12 level). The purpose of this project is to design and publish a digital open access Proof of Concept curriculum model that reinforces several of CARTEEH's 14 pathways to health. The products from this project can serve as a framework for future CARTEEH educational support materials for classroom educators. To ensure global access to the CARTEEH SMART Infrastructure educational materials.

Curriculum Course Development

CARTEEH' completed the development of a cross-disciplinary course titled "*Traffic-Related Air Pollution, Human Exposures, and Health*." The course materials, which include a course outline and lectures which can be adapted for various teaching purposes can be found posted on the CARTEEH website.

A modified version of the course was piloted to undergraduate students at Georgia Tech as a special topics course in the Spring of 2019 and Spring of 2020. The course focused on the relationship between human health outcomes and the transportation system including operations, construction, and maintenance. The health outcomes that are being considered will focus on the air quality impacts for both users and the general population, including sensitive populations, as well as occupational exposure (e.g. truck and transit drivers, maintenance workers dock workers, etc.) for those directly employed in transportation. Dr. Michael Rodgers served as the primary instructor and was aided by four other instructors. This course has been approved as a permanent course at Georgia Tech for the Fall 2021 semester.

CARTEEH Summer Internship Program

In conjunction with two other University Transportation Centers (UTCs), CARTEEH held its annual summer internship program from May to July of this year. CARTEEH selected three summer interns, who worked remotely and on site with mentors on research projects and delivered a final research paper and presentation. Students participated in weekly virtual events over the course of the internship, which ran from May 24 to July 31, 2021. One of the CARTEEH interns, a Texas A&M University student, has stayed on with CARTEEH as an undergraduate student worker for the Fall 2021 semester.

CARTEEH Webinar Series

CARTEEH continued its webinar series with two very successful webinars in this reporting period. The first webinar was held on April 27, 2021, presented by Dr. Haneen Khreis of TTI. It focused on the 14 key linkages between transportation and health. Transportation facilitates the movement of people and goods and is key to the growth of cities, the transfer of knowledge and the exchange of cultures and ideas. Transportation affects health in several positive ways, including increasing physical activity through active transportation modes, such as walking and biking, and access to social networks and opportunities for people to improve their health and well-being. The second webinar was held on June 21, 2021. It featured a presentation by Dr. Kari Watkins on a CARTEEH-funded research project that investigated cyclists' exposure to air pollution through the use of air pollutant sensors.

Materials and recordings from the webinars can be accessed and viewed at the CARTEEH website.

Plans for Next Reporting Period to Accomplish Education Goal

During the next reporting period, the current education initiatives will continue, and CARTEEH will look for additional opportunities for education and workforce development growth. CARTEEH is scheduled to participate in STEM related activities as part of the collaboration with the College of Education, and we will also work to recruit our next group of summer interns.

CARTEEH Goal #3: Technology Transfer

CARTEEH views technology transfer as a vital part of the research process, and one that must be integrated with our activities at all stages and in a cross-cutting manner. We value stakeholder engagement, as well as emphasizing information dissemination and the creation of open-access tools and methods that enable practical application of cutting- edge research findings. Several technology transfer activities are underway and progressing. The CARTEEH technology transfer activities aim to make research results and knowledge available to the research community and beyond.

Transportation, Air Quality, and Health Symposium

The 2nd Transportation, Air Quality, and Health Symposium was held May 18-20, 2021, as a virtual event. This Symposium followed on our very successful inaugural symposium held in Austin and was held online due to COVID-19 concerns. We had 166 registrants for the event, which TTI and UC-Riverside served as the main organizers of. Our keynote speaker was Liane M. Randolph, Chair of the California Air Resources Board. She spoke about air quality public policy and her experience working at a state agency. The event was highly successful, and involved students, researchers, and university faculty or staff, as well as transportation professionals. In future symposia, we will continue

to advance research on healthy transportation planning and policy by bringing together different disciplines working in the distinct areas of transportation systems, emissions, energy, air pollution, exposures, and public health.

Transportation Emissions and Health Dashboards and Data Hubs

One of the competitive research projects selected in year five has created an online geospatial dashboard for exploring and visualizing children's exposure to vehicular pollution in Texas school districts. A draft version of this GIS-enabled dashboard is available at: https://tinyurl.com/CCVPTXSD. This dashboard allows users to browse and examine interactive maps and datasets related to traffic pollution exposure and socio-demographics of children at the school district level (information compiled in Phase 1 of this project). This resource will yield societal benefits by providing school administrators, school board members, families of school children, residents, transportation planning agencies, and various other stakeholders with convenient access to selected project-related outputs. We continue to expend and improve our CARTEEH DataHub with new data from competitive projects and other data repositories.

CARTEEH Literature Library

The CARTEEH literature library continues to develop on the CARTEEH website. This tool is intended as a resource for students, researchers and practitioners interested in the area of transportation and health, especially the impact of transportation emissions and air pollution on human health. It currently contains a reference list of over 1,000 scientific studies addressing the full-chain of events between transportation pollution sources and health impacts, in addition to technologies and disruptors. The literature library tabulates several attributes for each study, including the citation details, the publication type, topic area(s), and type(s) of study. This reference list will be periodically updated to include new studies as they become available.

Technology Transfer Results Disseminated

All Center activities are posted to the CARTEEH website, with several updates made to the site following this reporting period. While earlier research projects are just coming to completion, a significant number of abstracts have been submitted, as well as presentations made.

Plans for Next Reporting Period to Accomplish Technology Transfer Goal

We plan to continue the implementation of the Technology Transfer Plan, engaging with stakeholders, and developing tools and project outputs that can directly aid practitioners in their work.

PARTICIPANTS AND COLLABORATING ORGANIZATIONS

CARTEEH is made up of a consortium of five institutions: TTI is a member of the Texas A&M University System and home to the Center. Faculty and students from other colleges, such as the Texas A&M Health Science Center, are also involved. Johns Hopkins University, Georgia Tech, University of Texas-El Paso, and the University of California, Riverside, complete the partnership.

Partner Organizations and Other Significant Collaborators

CARTEEH's focus areas cross multiple disciplines, bringing opportunities for a unique collaborative effort with institutions and individuals. These partners are essential to the success of the Center.

Organizations and individuals in the following tables have directly supported or collaborated on Center activities.

Table 2: CARTEEH Partner Organizations

Organization Name	Location	Contribution
Air Alliance Houston	Houston, Texas	Collaboration
American Thoracic Society	New York	Collaboration
Atlanta Bicycle Council	Atlanta, Georgia	Collaboration, In-kind support
Atlanta Bike Coalition	Atlanta, Georgia	In-kind support
Atlanta Regional Commission	Atlanta, Georgia	Data, Collaboration
Breathe Easy Dallas	Dallas, Texas	Collaboration
Broadway Services	Baltimore, Maryland	Access to facilities and data
California Air Resources Board	Sacramento, California	In-kind support
California Energy Commission	Sacramento, California	In-kind support
Cherry Hill Neighborhood	South Baltimore, Maryland	Collaboration
Chesapeake Climate Action Network	Takoma Park, Maryland	Collaboration
City of Austin Department of Transportation	Austin, Texas	Collaboration
City of Carson	Carson, California	Personnel
City of Dallas	Dallas, Texas	Collaboration
City of Los Angeles	Los Angeles, California	Data
Clean Water Action	Washington, D.C.	Collaboration
Dallas Independent School District	Dallas, Texas	Access to facilities
El Paso Independent School District	El Paso, Texas	Facility and student access
El Paso Health Department	El Paso, Texas	Data sharing
El Paso Metropolitan Planning Organizatoin	El Paso, Texas	Data sharing
Emory University	Atlanta, Georgia	Personnel, Collaboration
Environmental Defense Fund	Austin, Texas	Collaboration
George Mason University	Fairfax, Virginia	Collaboration, data
Georgia Department of Transportation	Atlanta, Georgia	Data
Georgia Ports Authority	Savannah, Georgia	Data, access to facilities, in-kind support
Georgia Tech Research Institute	Atlanta, Georgia	Data, personnel, access to facilities
Health Effects Institute	Boston, Massachusetts	Collaboration
Houston-Galveston Area Council	Houston, Texas	Collaboration
Institute for Healthy Living at the University of Texas at El Paso	El Paso, Texas	Collaboration, facility and student access
Kelly Burt Dozer	College Station, Texas	In-kind support
Larry Young Paving	College Station, Texas	In-kind support

Los Angeles County Metropolitan Transportation Authority	Los Angeles, California	In-kind support
Maryland Institute College of Art	Baltimore, Maryland	In-kind support
Metropolitan Atlanta Rapid Transit Authority	Atlanta, Georgia	Collaboration, in-kind support
Mississippi State University	Starkville, Mississippi	Collaboration
Mount Winans Community Association	Baltimore, Maryland	Collaboration, facility access
Nashville Metropolitan Transit Authority	Nashville, Tennessee	Collaboration, in-kind support
National Weather Service	Santa Teresa, New Mexico	Information/data sharing, collaboration
New Mexico Department of Environment	Santa Fe, New Mexico	Data, collaboration
New Mexico Department of Health	Santa Fe, New Mexico	Data, collaboration
New Mexico Department of Transportation	Santa Fe, New Mexico	Data, collaboration, access to facilities (field site)
North Central Texas Council of Governments	Arlington, Texas	Collaboration
Oak Ridge National Laboratory	Oak Ridge, Tennessee	Computer models
Port of Galveston	Galveston, Texas	Facilities
Port of Houston	Houston, Texas	Facilities
Port of Long Beach	Long Beach, California	Facilities
Port of Los Angeles	Los Angeles, California	Personnel
South Baltimore Go! Pilot Project	South Baltimore, Maryland	Collaboration
South Coast Air Quality Mgmt. District	Diamond Bar, California	Data, equipment, and facilities
Tampere University of Technology	Tampere, Finland	Collaboration, personnel exchange, in-kind support
TAMU Department of Construction Science	College Station, Texas	Facilities
Texas Department of Transportation	Austin, Texas	In-kind support, collaboration
The City of Dallas	Dallas, Texas	Collaboration
The Nature Conservancy	Austin, Texas	Collaboration
U.S. Department of Agriculture	Big Spring, TX and Fort Collins, CO	Collaboration, in-kind support, data, equipment, student access
U.S. Geological Survey	Reston, Virginia	Data, in-kind support, access to equipment
University of Delaware	Newark, Delaware	Collaboration
University of Miami	Miami, Florida	Collaborative research
University of Southern California	Los Angeles, California	Collaboration
University of Texas, El Paso Department of Public Health	El Paso, Texas	Data sharing
University of Texas Houston School of Public Health	Houston, Texas	Collaboration and student access
University of Washington	Seattle, Washington	Collaboration

USDA Agricultural Research Service	Big Spring, Texas	In-kind support, equipment, collaboration
USDA Agricultural Research Service	Fort Collins, Colorado	In-kind support, equipment, collaboration
USDA Agricultural Research Service	Las Cruces, New Mexico	Equipment, collaboration
WeGo Public Transit	Nashville, Tennessee	In-kind support, access to facilities
Sun Metro	El Paso, Texas	Project Stakeholder
El Paso County Transit	El Paso, Texas	Project Stakeholder
City of El Paso	El Paso, Texas	Project Stakeholder
Camino Real Regional Mobility	El Paso, Texas	Project Stakeholder
Center for Disease Control and Prevention	Atlanta, Georgia	Next Generation Sequencing
Children's Hospital Los Angeles	California	Collaboration
El Paso Electric Company	El Paso, Texas	Provided sample survey questions
Texas Commission on Environmental Quality	Houston, Texas	Sampling and logistics
LINK Houston	Houston, Texas	Collaboration
City of Riverside	California	In-kind support
Norfolk Southern Railway	Atlanta	Personnel, Collaboration
Ray C. Anderson Foundation	Atlanta	Data, Personnel

Table 3: CARTEEH Collaborators

Name	Affiliation	Contribution	Country
Dr. Ananya Roy	Environmental Defense Fund	Collaboration	USA
Dr. Andrea Polidori	University of California - Riverside	In-kind contributions	USA
Dr. Bakeyah Nelson	Air Alliance Houston	Collaboration	USA
Dr. Cassandra Gaston	University of Miami, Miami, FL	Contact/Collaboration/data sharing/leveraging	USA
Dr. Chanam Lee	Texas A&M University	Collaboration	USA
Dr. Daniel Tong	NOAA, Washington DC	Contact/leveraging	USA
Dr. David Cocker	UCR, Department of Chemical and Environmental Engineering	Experimental Design and Data Analysis	USA
Dr. David Dubois	Office of the State Climatologist, Las Cruces, NM	Collaboration	USA
Dr. Dongjoo Park	University of Seoul	Collaboration	Korea
Dr. Ellen MacKenzie	Dean, JHU Bloomberg School of Public Health	Collaboration	USA
Dr. Eun Sug Park	TTI – Mobility Analysis Program	Collaboration	USA
Dr. Gabriel Ibarra-Mejia	The University of Texas at El Paso, Department of Public Health	Collaboration, Data, Faculty	USA
Dr. George Delclos	University of Texas Health Science Center at Houston	Collaboration	USA

Dr. George Thrushton	New York University School of Medicine	Collaboration	USA
Dr. Jennifer Horney	University of Delaware	In-kind support	USA
Dr. Jenny Mindell	University College London	Collaboration	The U.K.
Dr. Jeremy Sarnat	Emory University	Collaboration, Faculty	USA
Dr. Joan Reibman	New York University School of Medicine	Collaboration	USA
Dr. Joao Ferreira-Pinto	The University of Texas at El Paso, Department of Public Health	Collaboration, Data, Equipment, In-kind, Faculty	USA
Dr. John Tatarko	USDA Agricultural Research Service, Fort Collins, CO	Collaboration	USA
Dr. John Wright	Bradford Institute for Health Research	Collaboration	The U.K.
Dr. Jorma Keskinen	Tampere University of Technology	In-kind contributions	Finland
Dr. Julian Marshall	University of Washington	Collaboration	USA
Dr. Kai Zhang	University of Texas Health Science Center	Collaboration	USA
Dr. Karen Lucas	University of Leeds	Collaboration	The U.K.
Dr. Kees de Hoogh	Swiss Tropical and Public Health Institute	Collaboration	Switzerland
Dr. Kent Johnson	University of California, Riverside	Data	USA
Dr. Kyuok Kim	Korea Transport Institute	Collaboration	Korea
Dr. Leah Whigham	University of Texas Houston Health Center	Collaboration, Data, Equipment, In-kind, Faculty	USA
Dr. Lixin Jin	The University of Texas at El Paso	Collaboration, Data, Equipment, In-kind, Faculty	USA
Dr. Liz York	Centers for Disease Control and Prevention	Collaboration	USA
Dr. Mark Benden	TAMU Health Science Center	Collaboration	USA
Dr. Mark Burris	TAMU – Civil Engineering	Collaboration	USA
Dr. Michael de Miranda	TAMU - College of Education	Collaboration	USA
Dr. Mark Nieuwenhuijsen	Barcelona Institute for Global Health	Collaboration	Spain
Dr. Martina Klose	Barcelona Supercomputing Center, Barcelona, Spain	Contact/ data sharing	Spain
Dr. Michael Jerett	University of California, Los Angeles	Collaboration	USA
Dr. Nicholas Webb	USDA Agricultural Research Service, Las Cruces, NM	Collaboration	USA
Dr. Nick Duffield	Texas A&M Institute of Data Science	Collaboration	USA
Dr. Qi Ying	TAMU – Civil Engineering	Collaboration	USA
Dr. R. Scott Van Pelt	USDA Agricultural Research Service, El Paso, TX	Collaboration	USA
Dr. Rashid Shaikh	Health Effects Institute	Collaboration	USA
Dr. Rob Scott McConnell	The University of Southern California, Keck School of Medicine	Collaboration	USA
Dr. Robin Autenreith	TAMU – Civil Engineering	Collaboration	USA
Dr. Roya Bahreini	UCR, Environmental Sciences	In-kind contributions	USA
Dr. Shams Tanvir	University of California, Riverside	Personnel	USA

Dr. Susan Anenberg	Environmental and Occupational Health, George Washington University	Collaboration	USA
Dr. Susan Chrysler	TTI – SAFE-D UTC Assistant Director	Collaboration	USA
Dr. Tom Durbin	University of California, Riverside	Data	USA
Dr. Wei Li	TAMU – Landscape Architecture and Urban Planning	Collaboration	USA
Dr. Yunlong Zhang	TAMU – Civil Engineering	Collaboration	USA
Mr. Brandon Feenstra	South Coast Air Quality Management District	Data, In-kind support	USA
Mr. David Ederer	Centers for Disease Control and Prevention	Collaboration	USA
Mr. Douglass Mann	Maryland Institute College of Art	Data collection access	USA
Mr. Hugh Pocock	Maryland Institute College of Art	Data collection access	USA
Mr. Iyasu Eibedingil	The University of Texas at El Paso	Collaboration, Data, Equipment, Student	USA
Mr. John Smart	Advanced Vehicles - Idaho National Lab	Collaboration	USA
Mr. Juan Aguilera	Institute for Healthy Living at the University of Texas at El Paso	Collaboration, Data, Equipment, Student	USA
Mr. Marcos Mendez	The University of Texas at El Paso	Collaboration, Data, Equipment, Student	USA
Mr. Mathew Bechle	University of Washington	Data	USA
Mr. Michael Garber	Emory University	Collaboration	USA
Mr. Zhiming Gao	Oak Ridge National Laboratory	In-kind support	USA
Ms. Niina Kuittinen	Tampere University of Technology	Collaboration	Finland
Ms. Victoria DeGuzman	University of Southern California/ METRANS UTC	Collaboration	USA
Mr. Trent Botkin	New Mexico Department of Transportation	Collaboration	USA
Mr. William Hutchinson	New Mexico Department of Transportation	Collaboration	USA
Mr. Michael Baca	New Mexico Environment Department	Collaboration	USA
Dr. Sarah Hayes	U.S. Geological Survey	Facilities, Equipment, Data	USA
Dr. Robert Wunderlich	Center for Transportation Safety, TTI	Data	USA
Dr. Jothikumar Narayanan	Centers for Disease Control and Prevention	Next Generation Sequencing	USA
Stephen Paciotti	Texas Commission on Environmental Quality	Collaboration	USA
Dr. Shankar Chellam	TAMU	Collaborator	USA
Jennifer Dien Bard	Children's Hospital Los Angeles	Collaboration	USA
Kevin Hall	TTI	Data	USA
Jacob Aun	Socio-Environmental and Geospatial Analysis Lab, UTEP	Data collection access	USA
Ernesto Ortiz	El Paso Independent School District	Access	USA
Jacob Burns	Institute for Medical Information Processing, Biometry and Epidemiology	Collaboration	Germany
Anthony D. May	Institute for Transport Studies	Collaboration	The U.K.
Shams Tanvir	California State Polytechnique, San Luis Obispo	Collaboration	USA

Tom Durbin	University of California at Riverside	Data	USA
Cesunica Ivey	University of California at Riverside	Equipment	USA
Akura Ventakram	University of California at Riverside	Equipment	USA
Nanpeng Yu	University of California at Riverside	Data	USA
Ran Wei	University of California at Riverside	Data	USA
Amy Moore	Oak Ridge National Laboratory	Data, In-Kind Support	USA
Mary Katherine Watson	The Citadel	Collaboration	USA
Andrew Danneberg	University of Washington	In-Kind Support, Collaboration	USA
April Willis Rodgers	Samford University	Collaboration, In-Kind Support	USA
Daniel Rochberg	Emory University	In-Kind Support, Collaboration	USA
Dr. Teresa Penbrooke	GP RED and GreenPlay, LLC	Collaboration	USA

OUTPUTS

We have successfully met several of our outcome performance measures, such as the number of attendees at seminar and outreach events, and the number of visitors to the website, literature library, and Data Hub. For this six-month reporting period, we had over 300- attendees to our webinar and outreach events and 2,162 visits to our website and are on track to meet our yearly goals for these metrics.

Presentations

Name: Wan Zhou, James Li
Event: Pittcon Conference
Title: Gold Nanoparticles Aggregation-Induced Quantitative Photothermal Biosensing Using a Thermometer

Name: Tara Ramani
Event: CARTEEH Symposium 2021
Title: Advancing a Research Agenda for Transportation Emissions, Health and Beyond

Name: Kristen Sanchez
Event: ISEE Conference 2021
Title: Urban Policy Interventions to Reduce Traffic Emissions and Traffic-Related Air Pollution: A Systematic Evidence Map

Name: Soheil Sohrabi
Event: CARTEEH Symposium 2021
Title: Transportation, Technology and Public Health: Assessing the Health Impacts of Automated Vehicles

Name: Farinoush Sharifi
Event: CARTEEH Symposium 2021
Title: Regional Assessment of Implementing Autonomous Vehicle Dedicated Lanes on Transportation Congestion and Emissions

Name: Phil Lewis
Event: CARTEEH Symposium 2021
Title: In-Cab Pollutant Measurements for Nonroad Diesel Equipment

Name: Evan Williams
Event: COURI Spring 2021 Virtual Symposium, April 26th- 30th, 2021.
Title: Assessing Ambient Air Quality Using Real-time Air Monitors Mounted on a Transit Vehicle

Name: Mayra Chavez
Event: 79th meeting of the Joint Advisory Committee (JAC) for the Improvement of Air Quality in the Ciudad Juárez, Chihuahua / El Paso, Texas / Doña Ana County, New México Air Basin
Title: Low-Cost Air Sensor Study in the Paso del Norte

Name: Leonardo Vazquez-Raygoza
Event: COURI Spring 2021 Symposium
Title: The application of low-cost sensors for assessing PM air pollution in The El Paso del Norte Region

Name: Kenji Santacruz
Event: 2021 Texas Undergraduate Research Day at The Capitol
Title: Tracking Renewable Energy Consumption in an Electricity Market

Name: Mayra Chavez, Leonardo Vazquez
Event: Technical Exchange on Air Sensor Networks along the Mexico-U.S. border region
Title: Low-Cost Air Sensor Study in the Paso del Norte

Name: Kenji Santacruz
Event: UTEP COURI Spring 2021 Symposium
Title: Tracking Renewable Energy Consumption in an Electricity Market

Name Kanok Boriboonsomsin, University Lead, UCR
Event: University of California's Clean, Renewable Energy, and Decarbonization Workshop (May 6, 2021)
Title: Overcoming Operational Barriers to Adoption of Medium-Duty and Heavy-Duty Electric Vehicles

Name Kanok Boriboonsomsin, University Lead, UCR
Event: 2nd Transportation, Air Quality, and Health Symposium (May 18, 2021)
Title: Improving Public Health in Disadvantaged Communities Near Ports through Truck Electrification

Name Kanok Boriboonsomsin, University Lead, UCR
Event: Transportation Electrification Partnership's Goods Movement Working Group Meeting (August 17, 2021)
Title: Heavy-Duty Truck Electrification Research at CE-CERT, University of California-Riverside

Name: Mary Fox, Johns Hopkins University Bloomberg School of Public Health
Event: Transportation, Air Quality, and Health (TAQH2021) Symposium (May 18-20, 2021)
Title: Public Health Methods for Decision Making in Communities

Name: Mary Fox, Johns Hopkins University Bloomberg School of Public Health
Event: Transportation, Air Quality, and Health (TAQH2021) Symposium (May 18-20, 2021)
Title: Development of a Consumer Cumulative Risk Profile

Name: Andrew Patton, Johns Hopkins University Bloomberg School of Public Health
Event: Transportation, Air Quality, and Health (TAQH2021) Symposium (May 18-20, 2021)
Title: Benzene Exposure and Cancer Risk from Commercial Gasoline Station Fueling Events Using a Novel Self-Sampling Protocol

Conference Papers, Conference Papers, and Journal Articles

Sanchez, K. A., Foster, M., Nieuwenhuijsen, M. J., May, A. D., Ramani, T., Zietsman, J., & Khreis, H. (2020). Urban policy interventions to reduce traffic emissions and traffic-related air pollution: Protocol for a systematic evidence map. *Environment International*, *142*, 105826. https://doi.org/10.1016/j.envint.2020.105826

Chakraborty J. 2022. Children's Exposure to Vehicular Pollution: Environmental Injustice in Texas, USA. ***Environmental Research*** (ISI impact factor = 6.498). Volume 204, Part A, 112008. Available at: https://doi.org/10.1016/j.envres.2021.112008.

Fu, G.; * Hou, R.; Mou, X.; **Li, X.*** Integration of 3,3',5,5'-tetramethylbenzidine (TMB)-probed ELISA-like systems in a photothermal bar-chart microfluidic chip for multiplexed visual immunoassay, *Anal Chem* 2021, In Press. (IF 7.0)

Zhang, X.; Wang, L.; Li, X. C.; * **Li, X., *** AuNP aggregation-induced quantitative colorimetric aptasensing of sulfadimethoxine with a smartphone. *Chin Chem Lett* 2021, In Press. DOI: 10.1016/j.cclet.2021.09.061. (IF 6.8)

Zhou, W.;[+] Dou, M.;[+] Sanjay, S. T.;[+] Xu, F.; * **Li, X.*** Recent innovations in cost-effective polymer and paper hybrid microfluidic devices, ***Lab Chip*** 2021, 21, 2658-2683. DOI: 10.1039/D1LC00414J. (Invited. IF 6.8).

Zhou, W.;[+] Fu, G.;[+] **Li, X.*** Detector-free photothermal bar-chart microfluidic chips (PT-Chips) for visual quantitative detection of biomarkers, ***Anal Chem*** 2021, 93, 7754-7762. DOI: 10.1021/acs.analchem.1c01323. (IF 7.0)

Ma, L.; Abugalyon, Y.; **Li, X.*** Multicolorimetric ELISA Biosensors on a Paper/Polymer Hybrid Analytical Device for Visual Point-of-Care Detection of Infection Diseases, *Anal Bioanal Chem* 2021, 413, 4655-4663. DOI: 10.1007/s00216-021-03359-8.

Vallamsundar S, Uwak I, Jaikumar R. Ramani T, Johnson NM, Aguilera JA, Li W-W, 2020. Personal Exposure to Air Pollution near the US-Mexico Border Crossings: A Case Study of School Teachers in El Paso, TX, submitted to the *Journal of Transport & Health*

Uwak I, Vallamsundar S, Jaikumar R, Ramani T, Aguilera J, Li W-W. 2020. Personal Exposure to Polycyclic Aromatic Hydrocarbons in the Vicinity of the U.S.-Mexico Border Crossings, a pilot study of School Teachers in El Paso, Texas submitted to *Journal of Environmental Research and Public Health (IJERPH)*.

Rangel A, Raysoni AU, Chavez M, Jeon S, Aguilera J, Whigham L, Li W-W, 2020, Assessment of Traffic-Related Air Pollution (TRAP) at Two Near-Road Schools and Residence in an Arid, High Altitude West Texan City, submitted to *International Journal of Environmental Pollution*.

Aguilera J, Jeon S, Chavez M, Ibarra-Mejia G, Ferreira-Pinto J, Whigham L, **Li W-W**, 2020. Short-term effects of traffic related air pollution on cardiorespiratory outcomes among low-income residents from a US-Mexico border community, submitted to the *Journal Air Quality, Atmosphere, and Health*.

Aguilera J, Jeon S, Chavez M, Ibarra-Mejia G, Ferreira-Pinto J, Whigham L, **Li W-W**, 2020. Land use regression modeling to assess effects of long-term transportation data on metabolic syndrome risk factors of low-income communities in El Paso, Texas. *Transp Research Record July, 2021.* https://doi.org/10.1177/03611981211021853

Chakraborty J. Children's Exposure to Vehicular Pollution: Environmental Injustice in Texas, USA. Environmental Research (ISI impact factor = 6.498). STATUS: in review; submitted June 22, 2021.

Van Pelt, R.S., Tatarko, J., Gill, T.E., Chang, C., Li, J., **Eibedingil, I.G**., and **Mendez, M**., 2020. Dust emission source characterization for visibility hazard assessment on Lordsburg Playa in Southwestern New Mexico, USA. *Geoenvironmental Disasters*, 7(1), 34.

Eibedingil, I.G., Gill, T.E., Van Pelt, R.S., and Tong, D.Q., 2021. Combining Optical and Radar Satellite Imagery to Investigate the Surface Properties and Evolution of the Lordsburg Playa, New Mexico, USA. *Remote Sensing*, 13, 3402.

Andrew Glazener, Kristen Sanchez, Tara Ramani, Josias Zietsman, Mark J. Nieuwenhuijsen, Jennifer S. Mindell, Mary Fox, Haneen Khreis, Fourteen pathways between urban transportation and health: A conceptual model and literature review, Journal of Transport & Health, Volume 21, 2021, 101070, ISSN 2214-1405, https://doi.org/10.1016/j.jth.2021.101070. (https://www.sciencedirect.com/science/article/pii/S2214140521001006)

Media References

https://health.gov/news/202102/carteeh-and-healthy-people-addressing-transportations-impact-health

Entrepreneur Yanzhi "Ann" Xu Co-Creates Start-Up Company to Commercialize Electric Vehicle Charging Demand Software — Texas A&M Transportation Institute (tamu.edu)

"$30k Grant Helps UTEP Tracks Traffic Related Air Pollution Near Regional School Zones," *El Paso Herald Post,* October 15, 2020.

Website

The CARTEEH website continues to be the face of our Center and is regularly updated with the latest center activities. It also provides access to the Transportation Emissions and Health Data Hub, as well as the literature library and videos from CARTEEH seminars. From April 1, 2021, through September 30, 2021, the CARTEEH website had a total of 5,668 page views and a total of 2,900 unique visitors.

Technologies

Dr. Ann Xu of CARTEEH co-founded ElectroTempo, Inc., a Delaware corporation, to commercialize the charging demand simulator technology that was developed as part of CARTEEH-funded research in the area of transportation electrification and energy. ElectroTempo, Inc. is a software-as-a-service (SaaS) company with a mission to accelerate transportation electrification. ElectroTempo, Inc. is licensing the technology from the Texas A&M University System and productizing the technology to serve market needs. Currently, ElectroTempo, Inc.'s software platform based on the UTC funded

technology has been selected to support EVolve Houston in its Regional Infrastructure Strategy for Electrification (RISE) initiative for Houston's charging infrastructure planning.

Inventions

None to report for this period

Other Products

None to report for this period

OUTCOMES

We have successfully met several of our outcome performance measures, such as the number of attendees at seminar and outreach events, and the number of visitors to the website, literature library, and Data Hub. Our target measure for the number of attendees to the seminar, webinar, and outreach events is 150 per year; we are meeting that goal.

A second performance measure is the number of visitors to the CARTEEH website, literature library, and Data Hub. Our target number is 700 per year. We are continuing to exceed this goal each year.

IMPACT

We are continuing to see the impacts of our work, ranging from the successes of our students and interns to the dissemination of our research results and technology transfer activities, including the establishment of a successful spin-off venture that builds on CARTEEH research. We continue to engage several transportation agencies and work with them collaboratively on solutions that can maintain and enhance the functioning of the transportation system while also promoting health. Our outputs continue to impact the body of existing scientific knowledge, with publications and conference presentations reaching a scientific audience, as well as the local media. We hope to continue outreach to stakeholders with a view of increasing our impact in the coming reporting period.

CHANGES/PROBLEMS

None

SPECIAL REPORTING REQUIREMENTS

No special reporting requirements.