University
Transportation
Centers Program

ANNUAL REPORT TO CONGRESS

for 2019

Office of the Assistant Secretary for Research and Technology
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

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ABSTRACT

This Annual Report to Congress for 2019 under the University Transportation Centers (UTC) Program is submitted to Congress in accordance with Section 6016 of the Fixing America's Surface Transportation Act (FAST Act, P.L. 114-94) codified at 49 U.S.C. §5505. This report highlights ongoing or recently completed University Transportation Center research projects through fiscal year 2019 by 37 UTCs. It discusses a requirement for a Regional Center to address transportation safety, congestion, connected vehicles (CVs), connected infrastructure, and autonomous vehicles (AVs). The report outlines the technology transfer (T2) plan and reporting requirement[1][2][3] which guide the University Transportation Centers' technology transfer activities. It summarizes UTC program-wide performance indicators measuring productivity at individual UTCs.

INTRODUCTION

The UTC Program funds Federal grants for university-based transportation centers to conduct research, education and workforce development, and technology transfer activities. This report documents the hallmarks of progress in each of these areas. UTC grant funds continue to advance surface transportation research coupled with technology transfer opportunities and priorities. This program facilitates collaboration and coordination between government, academia, and industry to advance technologies and expand research capabilities through required matching contributions from non-federal sources.

The United States Department of Transportation (USDOT) staff in the Office of the Assistant Secretary for Research and Technology (OST-R) in Washington, D.C. manage and administer UTC grants.

FAST ACT REQUIREMENTS:

The FAST Act provides long-term funding for surface transportation infrastructure planning and investment. Section 6016 of the FAST Act authorizes the Secretary of Transportation to establish and operate UTCs --

- *to advance transportation expertise and technology in the varied disciplines that comprise the field of transportation through education, research, and technology transfer activities;*
- *to provide for a critical transportation knowledge base outside the Department of Transportation; and*
- *to address critical workforce needs and educate the next generation of transportation professionals leaders.*[4]

The FAST Act authorized $72.5 million for fiscal year 2016, $75 million for fiscal years 2017 and 2018, and $77.5 million for fiscal years 2019 and 2020 for up to 35 competitive grants for UTCs.[5] These grants have a termination date of September 30, 2022, and September 30, 2023, for Regions 1, 2, and 3 grants that were awarded late due to a recompete of those regions. Additional funding for two new National Centers in congestion research and infrastructure research was provided through the Consolidated Appropriations Act, 2018 (P.L. 115-141).

[1] USDOT, Assistant Secretary for Research and Technology, Technology Transfer Plans Memorandum, April 16, 2018.
[2] UTC FAST Act General Provisions, https://www.transportation.gov/utc/fast-act-general-provisions-grants-utcs.
[3] UTC FAST Act Grant Deliverables and Requirements, https://www.transportation.gov/utc/2019-grant-deliverables-and-requirements-utcs.
[4] 49 U.S.C. §5505(a)(2).
[5] FAST Act, 49 U.S.C. §5505, as amended by P.L. 114-94, Sec. 6002(a)(5).

RESEARCH AND TECHNOLOGY: For necessary expenses related to the Office of the Assistant Secretary for Research and Technology, $23,465,109, of which $2,618,000 shall remain available until September 30, 2020, and of which $15,000,000, to remain available until expended, is for new competitive grants under 49 U.S.C. 5505 to a national center for congestion research and a national center for infrastructure research…[6]

The Department selected the University of South Florida's National Institute for Congestion Reduction to focus on reducing congestion and the University of Washington's National Center for Transportation Infrastructure Durability and Life Extension to focus on improving the durability and extending the life of transportation infrastructure. Both Centers commenced activity on July 1, 2019, and will conduct its research until its termination date of September 30, 2023. The appropriated fiscal year funding totaling $7,500,000 was awarded to each Center over two fiscal years (2019 and 2020).

To view the 2018 Grant Solicitation for National Center for Congestion Research and National Center for Infrastructure Research, visit https://www.transportation.gov/utc/utc-national-comp-nofo. The full list of the 37 FAST Act UTCs can be found on the UTC website, https://www.transportation.gov/utc/2016-utc-grantees.

The FAST Act provides for the periodic review and evaluation of the UTC Program. This report assesses, among other things, 1) selection of a Center to address connected infrastructure and automated vehicle research, 2) select UTC research projects addressing FAST Act research priorities along with "nonexclusive candidate topic areas"[7], 3) progress made to advance technological development, 4) the reporting metrics used to assess the performance of FAST Act grant recipients, and 5) overview of the repository for all research projects conducted by UTCs.

- ***Focused Research:*** The FAST Act also requires that one of the Regional UTCs selected address the field of comprehensive transportation safety, congestion, CVs, connected infrastructure, and AVs (49 U.S.C. 5505(c)(3)(E)). The Regional University Transportation Center selected for funding is the Center for Connected Automated Transportation led by University of Michigan in Standard Federal Region 5. This report discusses this Center's focused research activity, see page 7.

- ***Project Description Examples Addressing Research Priorities:*** The FAST Act specified six research priorities[8] that UTCs selected through the competition must address:
    - Improving Mobility of People and Goods;
    - Reducing Congestion;
    - Promoting Safety;
    - Improving the Durability and Extending the Life of Transportation Infrastructure;
    - Preserving the Environment; and
    - Preserving the Existing Transportation System.

  In addition, the FAST Act charges the Secretary of Transportation with establishing "nonexclusive candidate topic areas" within these priorities, see Table 2 on page 9. This report also contains detailed project descriptions submitted by all FAST Act grant recipients and results to date for projects active during fiscal year 2019.

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[6] P.L. 115-141, Title I of Division L.
[7] 49 U.S.C. §5505(b)(4)(A).
[8] 49 U.S.C. §6503(c).

- ***Technology Transfer:*** This Administration is committed to advancing technological development and conducting research and development to promote emerging technologies, empower Americans to innovate, and defend American technologies abroad.[9] Within the past year, OST-R has led USDOT efforts to increase the effectiveness of T2 activity to promote transportation safety and efficiency. This report discusses USDOT's new requirement for UTCs to develop Technology Transfer Plans to advance technological development and research and spur the commercialization of market-ready transportation technologies.

- ***Performance Metrics:*** This report contains UTC Program-wide performance indicators used to measure productivity in meeting the research, technology transfer, education, and outreach goals at individual UTCs and for the UTC Program. This is required by 49 U.S.C. 5505(b)(4)(B)(viii), as amended by the FAST Act.

- ***Research Repositories:*** The FAST Act requires the Secretary to disseminate results of UTC research through an online clearinghouse.[10] In response, the FAST Act grant recipients submit current and recently completed research projects to Research in Progress (RiP) and Transportation Research International Documentation (TRID) databases. These databases provide access to more than 1.25 million transportation research records. This report contains a summary of submissions to Research in Progress and Transportation Research International Documentation since 2013.

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[9] Office of Science and Technology Policy, Science & Technology Highlights in the First Year of the Trump Administration.
[10] 49 U.S.C. §5505(d)(1)(B).

FOCUSED RESEARCH: A LOOK AT THE CENTER FOR CONNECTED AND AUTOMATED TRANSPORTATION

The FAST Act requires one of the ten selected Regional UTCs to address the fields of comprehensive transportation safety, congestion, connected vehicles, connected infrastructure, and autonomous vehicles [49 U.S.C. 5505(c)(3)(E)].

The Center for Connected and Automated Transportation (CCAT) focuses its research efforts in those designated areas. CCAT is USDOT's Standard Federal Region 5 UTC. This consortium includes the University of Michigan at Ann Arbor in partnership with Purdue University, University of Illinois at Urbana-Champaign, University of Akron, Central State University and Washtenaw Community College.

CCAT emphasizes technology evaluation and deployments in realistic testing environments to address research questions in a comprehensive and accelerated manner. CCAT tests emerging technologies and concepts by using the Ann Arbor Connected Vehicle Test Environment—a unique 'living laboratory' that has instrumented urban streets and highways, thousands of connected vehicles, motorcycles, bicycles, and smartphones. It also leverages Mcity, a state-of-the-art off-roadway facility for connected and autonomous vehicle testing and evaluation developed at the University of Michigan.

The Ann Arbor Connected Vehicle Test Environment aims to be the largest operational, real-world deployment of connected vehicles and infrastructure in the world. It has expanded to encompass the entire City of Ann Arbor – 29 square miles. It has 70 infrastructure sites to include three curve speed warning sites, four pedestrian crosswalks, eight freeway sites, one roundabout, five staging/testing sites, and 49 intersections that are instrumented. More than 2,650 cars, commercial trucks, and transit vehicles are equipped with global positioning systems and dedicated short-range communications. All devices pass industry certification testing and use production security.

Mcity at University of Michigan Ann Arbor

Mcity is a simulated city providing safe, repeatable, off-roadway testing of advanced connected and automated technologies and system concepts. Occupying 32 acres on the University of Michigan Ann Arbor campus, the facility simulates a broad range of urban and suburban environments. This test environment includes four lane-miles of roads with intersections, roundabouts, roadway markings, simulated buildings, pedestrians and obstacles such as construction barriers that are designed to replicate the most challenging scenarios for connected and automated vehicles.

The University of Michigan, in collaboration with the Michigan Department of Transportation, established the American Center for Mobility. Built on 335+ acres of existing infrastructure at Willow Run, and employing under-utilized state roadway infrastructure, it provides a comprehensive range of realistic road and weather scenarios in a concentrated and fully-instrumented and professionally-operated test facility.

CENTER PROJECT HIGHLIGHTS

The following are detailed descriptions of the research projects submitted by the current 37 FAST Act grant recipients. For each research project in this section, this report provides the project name, grant recipient name, Center's name, research priority, a detailed project description, outputs, outcomes, impacts, funding amount, and end date. Information is categorized by center type (National, Regional or Tier 1). The seven National, ten Regional, and twenty Tier 1 Centers must focus their efforts on national transportation issues as identified by the FAST Act's six research priority areas on page 8. The ten Regional Centers are located in each of the ten standard Federal regions listed in Table 1 below. They are distinct from the National and Tier 1 Centers in that they must also address regional needs. A National or Tier 1 Center may be based in any region and may form a consortium with universities that are not located in its region.

Table 1. Standard Federal Regions[11]

Standard Federal Regions	
Region 1	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
Region 2	New Jersey, New York, Puerto Rico, U.S. Virgin Islands
Region 3	Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia
Region 4	Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee
Region 5	Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin
Region 6	Arkansas, Louisiana, New Mexico, Oklahoma, Texas
Region 7	Iowa, Kansas, Missouri, Nebraska
Region 8	Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming
Region 9	Arizona, California, Guam, Hawaii, Nevada
Region 10	Alaska, Idaho, Oregon, Washington

Section 6503(c) of the FAST Act specifies six research priorities (Table 2, next page) that the competitively selected UTCs must address: improving mobility of people and goods, reducing congestion, promoting safety, improving the durability and extending the life of transportation infrastructure, preserving the environment, and preserving the existing transportation system.

In addition, the FAST Act charges the Secretary of Transportation with establishing "nonexclusive candidate topic areas" within these priorities. The foundation for the chosen topics is *Beyond Traffic –2045: Trends and Choices* released in February 2015. This report supports a continuing dialogue about the state of the U.S. transportation system, and identifies current and emerging challenges to the system in coming years. The full report is available at https://www.transportation.gov/policy-initiatives/beyond-traffic-2045-final-report.

Funding identified for each research project includes both Federal and matching funds.

[11] 49 U.S.C. §5505(c)(3)(A).

Table 2. FAST Act Research Priorities[12]

<table>
<tr><th colspan="2">Research Priority Areas</th></tr>
<tr><td colspan="2">1. Improving mobility of people and goods:</td></tr>
<tr><td>Increase access to opportunities that promote equity in connecting regions and communities, including urban and rural communities;
Smart cities;
Innovations to improve multi-modal connections, system integration, and security;
Assistive technologies for those with physical or cognitive disabilities;</td><td>Data modeling and analytical tools to optimize passenger and freight movements;
Innovations in multi-modal planning and modeling for high-growth regions;
Novel (non-traditional or alternative) modes of transport and shared use of infrastructure; and
Regional planning and setting of transportation priorities.</td></tr>
<tr><td colspan="2">2. Reducing congestion:</td></tr>
<tr><td>Optimize the efficiency and reliability of travel for all transportation system users;
Improve operations, controls, and devices;
Urban logistics – last mile for both passengers and freight;
Land use and transportation planning;</td><td>Novel (non-traditional or alternative) forms of freight movement;
Data Modeling and analytical tools to evaluate effects of shifting transit incentive structure; and
Ridesharing and alternative forms of transportation.</td></tr>
<tr><td colspan="2">3. Promoting safety:</td></tr>
<tr><td>Vehicle and system automation across surface modes;
Energy and hazardous material transport;
Safety planning for all users:
Pedestrians and bicyclists;
Vehicular users; and
Integrated systems planning;</td><td>Application of transportation safety data and safety management systems;
Human factors and risk factor analysis;
Transportation worker safety:
Construction zones;
Emergency responders; and
Trespass and vandalism.</td></tr>
<tr><td colspan="2">4. Improving the durability and extending the life of transportation infrastructure:</td></tr>
<tr><td>Application of new materials and technologies;
Cyber and communications security;
Condition monitoring, remote sensing and use of global positioning systems;</td><td>Asset management and performance management:
Data accessibility and security, and
Analytical tools;
Construction methodologies and management; and
Corrosion and aging infrastructure.</td></tr>
<tr><td colspan="2">5. Preserving the environment:</td></tr>
<tr><td>Reduction of transportation system greenhouse gas emissions;
Use of alternative fuels and energy technologies;
Recycling infrastructure assets;
Effects of new materials on the environment;</td><td>Environmentally responsible planning and construction:
Multiple uses of existing infrastructure, and
Noise and vibration reduction; and
Impacts of freight movement.</td></tr>
<tr><td colspan="2">6. Preserving the existing transportation system:</td></tr>
<tr><td>Innovation in aligning transportation decision-making, funding sources, and mechanisms;
Data modeling and analytical tools to evaluate the effects of tolling and investment;
System response to disruptive events/resilience to disasters;</td><td>Infrastructure preservation techniques and cost-effective maintenance practices;
Retrofitting and multiple uses of infrastructure to create efficiencies and reduce barriers to opportunity;
Workforce development and capacity building; and
Modal shifts.</td></tr>
</table>

[12] See Section 6503(c)(1).

TECHNOLOGY TRANSFER

The UTCs are now required to develop Technology Transfer Plans (referred to as T2 Plans). T2 Plans guide the UTCs' technology transfer efforts by making research results available to potential users in a form that can be implemented, utilized, commercialized, or otherwise applied.

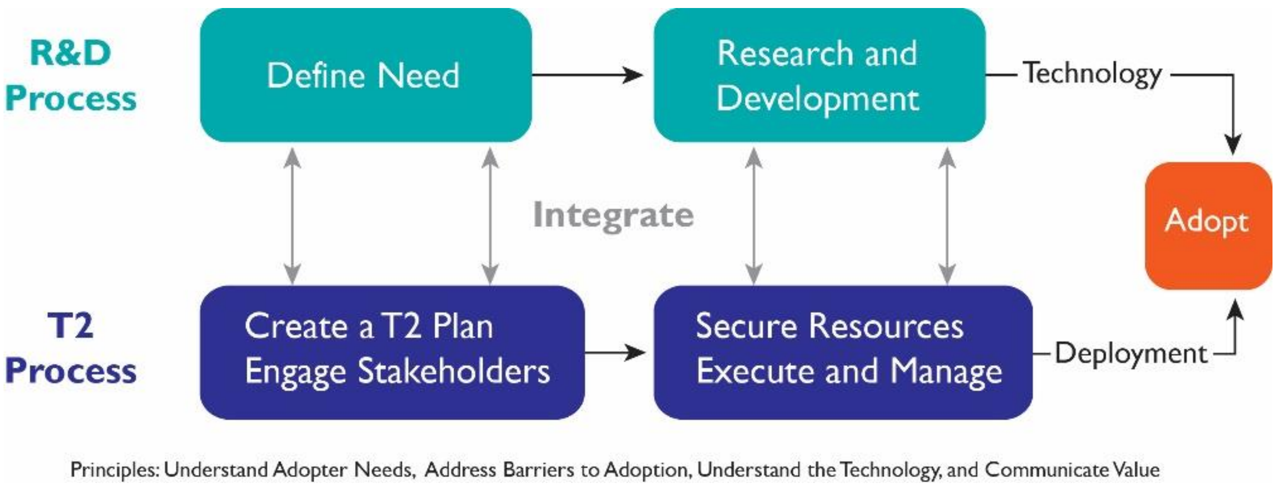
The change from an optional to a mandatory T2 Plan for each UTC was initially announced at the UTC Directors' meeting held during the Transportation Research Board Conference in January 2018, followed by an official memo[13] sent to 32 UTCs in April 2018. The 32 grant agreements that went into effect November 30, 2016, required development of T2 Plans outlining their steps toward improved technology transfer and deployment of research outcomes by July 31, 2018. The three regional grants were to submit their T2 Plans by October 30, 2018. The two newly awarded national UTCs went into effect on July 1, 2019, and they were to submit their T2 Plans by November 30, 2019.

The annual review of UTC performance documents including the T2 Plan will determine if UTCs meet program requirements and the statutory mandate. Where there are instances of insufficient performance, USDOT can withhold additional funding or pursue suspension/termination of the Federal award.

The 37 FAST Act UTCs' T2 Plans now describe the technology transfer activities. As shown in Figure 1 below, the UTCs will undertake the successful transfer of information and technology to those who can use it, especially transportation practitioners. Each plan must outline the people and organizations involved in implementing the T2 process along with identifying their roles, planned activities, and the desired outcomes that will make their transportation technology transfer activity effective

Additionally, the T2 Plans must align with USDOT Strategic Plan FY 2018-2022 to increase USDOT-funded tangible research outputs as a performance measure. The strategic plan requires providing performance measures in terms of number of tangible research outputs, outcomes, and impacts for each UTC's technology transfer plan. Thus, the number of tangible research outputs will now be a required performance measure for each UTC's T2 Plan.

Figure 1: Integrating T2 and Research & Development (R&D)



Source: Building a Foundation for Effective Technology Transfer through Integration with the Research Process

[13] USDOT, Assistant Secretary for Research and Technology, Technology Transfer Plans Memorandum, April 16, 2018.

At a minimum, a UTC's T2 Plan must:

- Identify and describe the involvement of key partners (including funding partners) in the research program;
- Assist involved public and private groups in implementing and deploying research outputs;
- Show the commercialization process of research outputs;
- Allow for the collection and use of licensing revenues to provide further support for research and technology transfer;
- Disseminate research results;
- Discuss how research outputs, outcomes, and impacts will be tracked and reported; and
- Describe how corporate research support will be increased.

UTCs must develop Technology Transfer goals and relevant performance metrics that they will use to measure the effectiveness of their T2 efforts. The "Grant Deliverables and Reporting Requirements for 2016 University Transportation Centers" has been amended to reflect this new requirement.

Table 3. Research Terminology

Term	Definition
Research Output	Any new or improved process, practice, technology, software, training aid, or other tangible product resulting from R&D activities.
Research Outcome	Any changes made to the transportation system, or its regulatory, legislative, or policy framework resulting from R&D outputs. Examples include the full-scale adoption of a new technology technique, or practice, or the passing of a new policy, regulation, rulemaking, or legislation.
Research Impact	The impact of an R&D outcome on the transportation system, or society in general, such as reduced fatalities, decreased capital or operating costs, community impacts, or environmental benefits.

Improving Rush Hour Traffic Flow by Computer Vision-Based Parking Detection and Regulation

Grant Recipient: Carnegie Mellon University

Center Name: Mobility 21, A National UTC for Improving Mobility of People and Goods

Research Priority: Improving Mobility of People and Goods

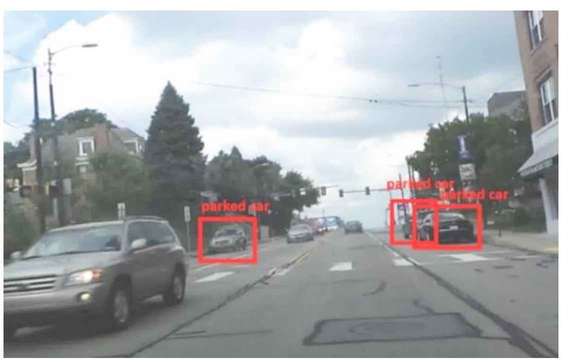
Research Project Funding: $192,000

Project End Date: September 30, 2019

Project Description: The impact of parking management to traffic congestion has long been overlooked, partially due to the lack of highly granular parking data. Real-time monitoring parking occupancy at the block level is oftentimes infeasible, because of costly parking sensors. This project uses computer vision techniques to provide ubiquitous and cheap sensing for detecting parking occupancy in high granularity. Developing the detector is one of the main tasks of this project. By combining the data collected with traffic flow data and other information, the project will allow for analyzing parking restrictions on traffic flow and determining the optimal trade-off between parking availability and traffic flow. The efficient management of parking infrastructure leads to mitigating traffic congestion, enhancing transportation infrastructure resilience, and reducing environmental impacts.

Outputs: The anticipated outputs include: 1) efficient algorithms to process and extract parking occupancy information from images taken from vehicles that travel the road on a regular basis; 2) an integrated parking and roadway information system that collects, archives, and fuses massive parking and traffic data; and 3.) a prototype online map-based information system that can provide user-friendly interfaces to disseminate parking information in different levels of temporal and spatial granularity.

Outcomes/Impacts: This project allows researchers to collect time-varying parking data that could be used, in addition to existing traffic data, to understand travel behavior among various travel modes, such as driving (including solo-driving and carpooling), public transit, and park-and-ride. The travel behavior of all travelers in the network is then simulated to assess system performance and features of passenger/vehicular flow. The results are used to assess policies and operational strategies that target congestion reduction. Those policies and strategies are integrated into the behavioral model and simulation to estimate how passenger/vehicular flow would change compared to the baseline, so that we can deploy the right policies and strategies to efficiently reduce congestion. As one example, we found that when changing the parking prices from $1 to $5 per trip in downtown Pittsburgh, the use of public transportation increases by 11% and the vehicular traffic decreases by 7%.



Computer vision detection of parked cars

Understanding Factors Affecting Arterial Reliability Performance Metrics

Grant Recipient: Portland State University

Center Name: National Institute for Transportation and Communities

Research Priority: Improving Mobility of People and Goods

Research Project Funding: $219,986

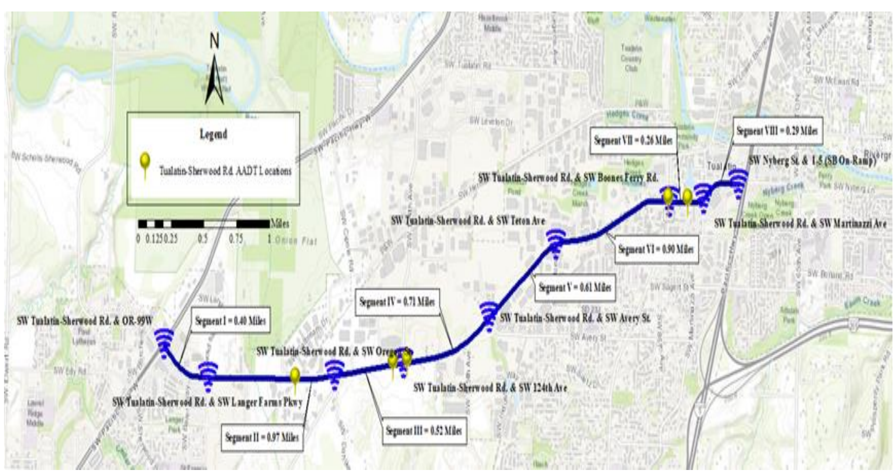
Project End Date: June 30, 2019

Project Description: Portland State University researchers used travel time data from Washington County, Oregon to explore data-driven strategies for prioritizing funding that could improve travel time reliability on their suburban arterials. With a population of nearly 600,000, Washington County is typical of most suburban communities in the U.S. facing worsening congestion issues, which means drivers and freight operators must plan for extra time to arrive at their destinations. Increasingly, travel time reliability is being used as an important measure of congestion, in addition to the commonly used average travel time. But most of existing research has focused on freeways.

This study adopted the Federal Highway Administration's travel time reliability metrics, and used four months of data from three arterials. The data came from County sensors detecting Bluetooth signals at intersections. Algorithms calculated travel time from one intersection to another by matching the signals.

Outputs: Based on the data, researchers developed a modeling framework for determining significant factors on travel time reliability on suburban arterials. For Washington County, significant factors included morning, evening, and weekend peak hours, as well as nighttime hours, and had moderate to considerable effects on average travel time and standard deviation. Considering that each corridor analyzed in the current study has essentially the same traffic volumes, yet effects of time-related factors are shown to be substantially different in some cases, practical and policy lessons can be learned. Washington County was also interested in improving the quality of their data, and the research team provided the County with an automated process to clean up their data by removing outliers.

Outcomes/Impacts: The study addresses gaps in the literature by focusing exclusively on arterials, applying a previously unused parametric method, and quantifying the effects of specific variables on average interval travel time and travel time standard deviation. The research determined that Tualatin-Sherwood Road has the lowest travel time reliability of the three corridors. As a result, the County can focus its efforts in the area surrounding Tualatin-Sherwood Road. Nationally, the research can be replicated to identify corridors with high unreliability and enable transportation system engineers to prioritize project funding.



Location of Bluetooth sensors along Tualatin-Sherwood Road in Washington County, OR

Gentrification Near Rail Transit Areas: A Micro-Data Analysis of Moves into Los Angeles Metro Rail Station Areas

Grant Recipient: University of California, Davis (Lead); University of Southern California

Center Name: National Center for Sustainable Transportation

Research Priority: Preserving the Environment

Research Project Funding: $100,000

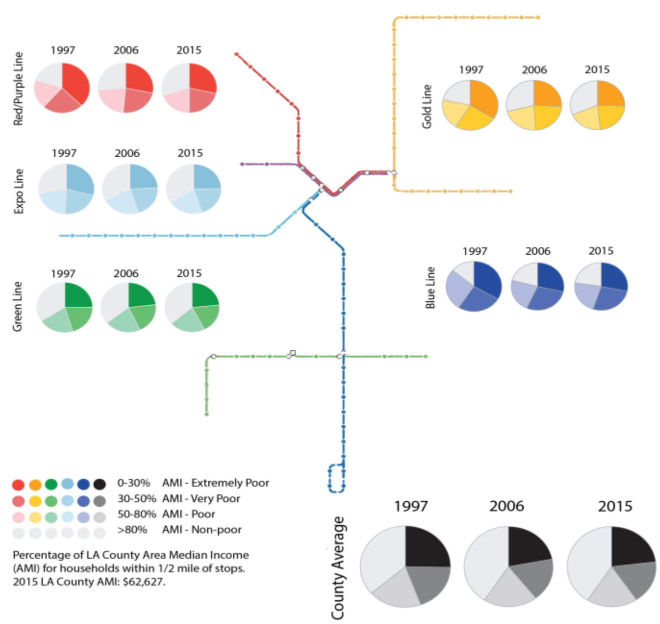
Project End Date: December 31, 2018

Project Description: Nationwide, there is a growing public concern—reinforced by some studies—that expansion of rail transit in large metropolitan areas is linked to neighborhood changes and that rail transit expansion may catalyze or exacerbate gentrification. In Los Angeles, gentrification concerns exist around the Gold, Expo, Red/Purple, and soon-to-open Crenshaw Lines. As part of a four-year sustained research program on displacement near Los Angeles rail transit stations, this research project first briefly reviewed the evidence from prior studies, then introduced a newly available data source to examine the relationship between new station openings and neighborhood income composition. Specifically, the researchers addressed who moves into rail-station neighborhoods and whether higher-income households are growing as a share of station area population relative to the share of lower-income households. The research also examined whether rail stations cause changes in neighborhood income distribution or whether those changes happened regardless of the transit investment. While previous studies focused on housing price changes, this project examined income tax filings to gather household income data, then classified research subjects using the U.S. Department of Housing and Urban Development's Area Median Income (AMI) categories. The researchers also studied move-in and move-out patterns near new transit stations.

Outputs: A comprehensive research report and policy brief summarizing the findings and policy implications has been published. A related report is in development with the California Community Foundation (CCF), a leading affordable housing policy philanthropy, and an NCST webinar was held.

Outcomes/Impacts: The regression analysis showed that opening a new station led to lower move-in rates by the poorest households (those earning less than 30% AMI). This effect is about one-tenth the baseline annual mobility rate (which excludes the effect of station opening). However, those neighborhoods near rail would still have substantial housing insecurity problems with or without rail transit. Counter to many anecdotal accounts, the rail system is not the primary factor affecting changes in income distribution or move rates. Other factors include the housing crisis, in general, and the need for affordable housing near transit. It is a complex problem that requires multi-faceted policy approaches. This finding is consistent with other recent research.

With the assistance of the CCF, the research team has engaged community partners such as the LA Thrives network and has presented results at the CCF's meetings with these partners. The work has helped inform the CCF's advocacy and the results have built awareness that the rail transit system is less of a threat to low-income communities than the severe housing insecurity problem.



Household income distribution near Metro rail stations.

Implementing Safe Systems in the United States: Guiding Principles and Lessons from International Practice

Grant Recipient: University of North Carolina, Chapel Hill (Lead); Florida Atlantic University

Center Name: Collaborative Sciences Center for Road Safety (CSCRS)

Research Priority: Promoting Safety

Research Project Funding: $154,692

Project End Date: September 30, 2019

Project Description: A large number of roadway crashes are misattributed to human error, ignoring important roadway environment features that lead road users to commit often predictable (therefore preventable) errors. Safe Systems is an emerging approach to reducing traffic-related deaths and injuries, centered on the principle that traffic-related crashes should not result in fatalities. The approach emphasizes anticipating and accommodating or mitigating human errors proactively, through roadway designs and coordinated safety programs that eliminate opportunities for crashes to produce energy forces beyond what humans can survive. This project details how Safe Systems concepts can be applied to advance road safety in the United States. The first part of the study synthesizes findings from design engineering, organizational systems safety, and cognitive psychology to improve our understanding of crash causations. The study then details planning and design approaches to prevent the environmental conditions that result in human errors, and thus the incidence of traffic-related deaths. It describes practices in four counties with established Safe Systems programs and details how each has structured its practices around Safe Systems principles, and how these approaches are transferrable to the United States.

Outputs: The research produced a full report, project slide deck, and research brief. In addition, CSCRS partnered with the non-profit organization Vision Zero Network to organize two well-attended webinars: Safe Systems – What Does It Mean for Vision Zero? (August 2018) and Safety & Systems for Vision Zero – Putting Theory Into Practice (December 2018). These highlighted research findings and put them into the context of practitioners' work to develop plans to reduce traffic fatalities. CSCRS also hosted the April 2019 Safe Systems Summit to provide a forum to discuss Safe Systems principles. The event drew nearly 350 people from 32 universities and 29 states.

Outcomes/Impacts: Evidence on the effectiveness of a Safe Systems approach offers new insights and tools for transportation professionals in the U.S. to consider ways to more aggressively reduce traffic-related fatalities. This project has produced significant dialogue in the transportation profession about Safe Systems principles and practices. Leading organizations—including the Traffic Safety Council, Institute of Transportation Engineers, AAA Foundation for Safety, and the Road to Zero Coalition—have since coalesced around Safe Systems principles and incorporated or referenced CSCRS research. Washington State's most recent Strategic Highway Safety Plan adopted a Safe Systems approach, and the CSCRS project team continues to monitor other state and local agencies that are reducing fatalities using this approach.

The Safe Systems Summit engaged researchers, state and local agencies, industry stakeholders, and students.

Driver Training Research and Guidelines for Automated Vehicle Technology

Grant Recipient: Virginia Polytechnic Institute and State University (Lead); Texas A&M University

Center Name: Safety Through Disruption National University Transportation Center

Research Priority: Promoting Safety

Research Project Funding: $435,386

Project End Date: July 31, 2019

Project Description: Advanced driver-assistance systems present the opportunity to improve transportation safety significantly. Complex sensor-based systems within vehicles can take responsibility for tasks typically performed by drivers, thus reducing driver-related error as a source of crashes. While there may be a reduction in driver errors, these systems fundamentally change the driving task from manual control to supervisory control. This fundamental change in the driving task means that there are no established methods to train drivers on the use of these systems, which may be counterproductive to safety improvements. The aim of the project was to develop training protocol guidelines that could be used by advanced driver-assistance system trainers to optimize driving safety. The project developed guidelines based on the results of three activities: the development of a taxonomy of the knowledge and skills necessary to operate advanced driver-assistance systems, a driving simulator study that examined the effectiveness of traditional training protocols, and a test track study that examined the efficacy of a vehicle-based training protocol.

Outputs: Driver Training Guidelines for Advanced Driver-Assistance Systems were developed from the results of identifying necessary knowledge and skills for advanced driver assistance systems, the simulation and instrumented vehicle studies, and from discussion with key entities. In addition, the study objectives, methods, data collection procedure, and analysis efforts were used to develop a teaching module on driver training and behavior modeling. This preliminary module was taught at San Diego State University and presented at several national conferences. Additionally, a publication of this study's findings received the "*Best Student Paper Award*" from the Human Factors and Ergonomics Society, a non-profit group promoting and advancing the interchange of knowledge and methodology in the behavioral, biological and physical sciences.

Outcomes/Impacts: This work has the potential to affect transportation policy and safety. The Driver Training Guidelines for Advanced Driver-Assistance Systems could be used by advanced driver assistance system trainers and training protocol developers to optimize driving safety. These guidelines were disseminated to the primary driver training organizations in the United States including American Automobile Association, American Driver and Traffic Safety Education Association, the Driving School Association of the Americas, and to major automotive manufacturers.

It is recommended that operators of vehicles with driving automation systems receive training.

Proactive Congestion Management

Grant Recipient: University of South Florida

Center Name: National Institute for Congestion Reduction

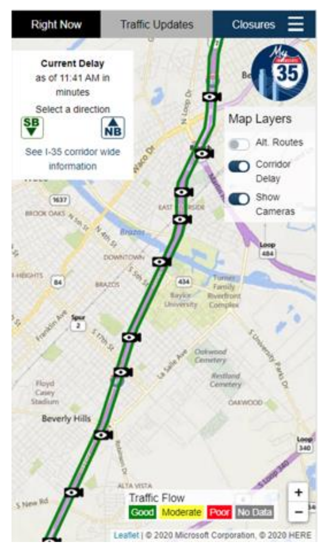
Research Priority: Reducing Congestion

Research Project Funding: $259,764

Project End Date: June 30, 2021

Project Description: Investigating the occurrence of both recurrent and non-recurrent congestion for corridors both with and without tolled/managed lanes, this project will collect data using conventional sources such as loop detectors and traditional probe-based data with newer sources, such as Bluetooth and connected vehicle (CV) data to identify conditions that signal impending congestion. The joint research team, consisting of research faculty and students from both the University of South Florida (USF) Center for Urban Transportation Research and the Texas A&M Transportation Institute (TTI), is developing and implementing machine-learning techniques to produce data-driven models to forecast the likely occurrence of both recurrent and non-recurrent congestion. The USF/TTI team is integrating near-real-time and high-resolution CV Basic Safety Messages generated on the Tampa-Hillsborough Expressway Authority (THEA) tolled Reversible Express Lane system using CV technology with Bluetooth data that are also being collected in real-time. The THEA CV project is part of the USDOT CV Pilot program. The team is also assembling data from Houston TranStar® and Interstate 35, including sensor and probe-based travel time data and freeway operational data including incidents, crashes, and lane closures. The final output will be the identification of congestion mitigation strategies to proactively mitigate congestion and improve travel time reliability.

Outputs: The team will produce an integrated data set and a literature review on the state of practice of congestion measurement for a congestion definition and measurement. The team will also produce a menu of operational strategies to delay or mitigate congestion effects that will be tested using a simulation platform. Simulation results will be used as input to an interactive tool that will serve as a decision matrix for proactive congestion management. The tool will be publicly shared so that other researchers/agencies can apply it in their environment. The decision matrix will be disseminated via a webinar targeted at infrastructure owner-operators to gather feedback. Results will be disseminated via a final report, policy brief, and final project webinar. The team will also produce articles and presentations for dissemination via conferences and peer-reviewed journals.



I-35 Congestion Map

Outcomes/Impacts: By developing a methodology to forecast the likely occurrence of both recurrent and non-recurrent congestion, operating agencies will be able to identify operational strategies to mitigate or delay the onset of congestion. The dissemination of the matrix information will allow agencies to forecast possible congestion issues and plan accordingly. Agencies could use the project outputs to improve their operations and as decision support in setting pricing levels, which would then lead to benefits such as reduced travel time, emissions, and fuel consumption as well as improved travel time reliability.

Performance of ABC Columns and Cost Effective Retrofit Strategies Subjected to Synergistic Distress Resulting from Corrosion and Seismic Loading

Grant Recipient: Washington State University

Center Name: National Center for Transportation Infrastructure Durability and Life Extension

Research Priority: Improving Durability and Extending the Life of Transportation Infrastructure

Research Project Funding: $140,000

Project End Date: June 30, 2021

Project Description: The seismic performance and durability of field-assembled columns with accelerated bridge construction (ABC) are typically investigated when they are subjected to synergistic distress resulting from corrosion and earthquakes. Although ABC is an emerging trend in the United States due to advantages of minimal disruption to traffic and quality control, there is a lack of knowledge on the performance of corroded ABC columns in earthquake-prone regions. No design provisions are currently available in published specifications. Technical investigations are conducted through large-scale laboratory testing in conjunction with advanced analytical modeling to address this need. Research interests of the project are the mechanisms of corrosion initiation and progression in ABC columns, hysteretic response, ductility, structural vulnerability, and failure probability. Upon elucidating the behavior of the columns, cost-effective retrofit strategies will be established using non-corrosive carbon fiber reinforced polymer composites to extend the longevity of deteriorated columns. Engineers from state departments of transportation (DOT) are participating in the research to generate practical outcomes; industry partners are also involved which immediately benefits the infrastructure community. Conforming to TriDurLe thrust areas, the project brings to light the state of the art of ABC technologies and provides opportunities to students from underrepresented groups. The goal of this research is to enhance the durability performance of ABC columns. Experimental programs and advanced modeling techniques will be conducted to: 1) study the deterioration mechanisms of ABC columns exposed to synergistic distress comprising corrosion and seismic loading, 2) characterize structural behavior and reliability, and 3) develop cost-effective retrofit approaches using advanced composite materials.


Corrosion-damaged reinforced concrete column

Outputs: Upon completion of the proposed research, technical findings will be integrated to develop practice guidelines. In so doing, bridge designers and DOT engineers will adopt ABC technologies with confidence. All findings will be integrated to develop in the implementation guidelines. Significant synergies are expected by the collaboration of the University of Utah and the University of Colorado Denver in terms of a scientific understanding, educational activities, and technology transfer.

Outcomes/Impacts: The technology of accelerated bridge construction is emerging to save construction time with controlled quality. However, there are no design provisions regarding the corrosion damage and seismic distress of ABC columns at this time. By developing implementation guidelines, the safety of ABC structures will be ensured. The proposed research fills such an identified gap and provides necessary information to the bridge engineering community.

Field Live Load Testing and Advanced Analysis of Concrete T-Beam Bridges to Extend Service Life

Grant Recipient: The University of Maine

Center Name: Transportation Infrastructure Durability Center

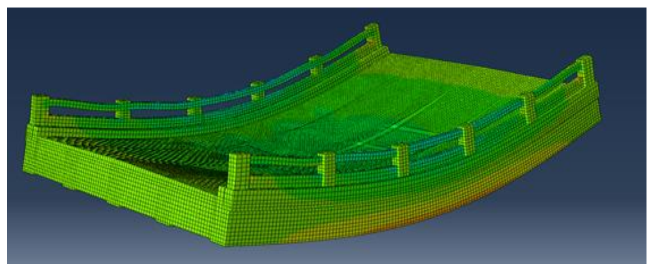
Research Priority: Improving the Durability and Extending the Life of Transportation Infrastructure

Funding: $95,992

Project End Date: December 31, 2019

Project Description: Over 35,000 concrete T-beam bridges exist in the U.S. These bridges have multiple concrete girders, an integral concrete deck, and are an important class of structures. Maine Department of Transportation (MaineDOT) inspection records often indicate that these are in good condition despite many years of service, but they possess very low rating factors based on conventional analysis per the American Association of State Highway Transportation Officials *Manual for Bridge Evaluation*. With support from the MaineDOT, the University of Maine engineers load-tested five similar T-beam bridges to assess their capacity. These five T-beam bridges tested in the summer of 2018 were instrumented with specialized equipment to assess how the bridges respond to heavy truck loads.

In the initial project phase, three-dimensional mathematical models of all bridges were constructed and validated by comparing model predictions with data from the field tests. More significantly, new, more complex, yet efficient mathematical models were developed and used to provide a more realistic assessment of T-beam bridge strength and to advance our understanding of these bridges.



Typical Finite-Element Model

Outputs: A novel application of the widely used finite-element analysis technique, Proxy Finite-Element Analysis (PFEA), was developed for the purpose of load-rating older concrete girder bridges. PFEA does not rely on the simplifying assumptions inherent to standard engineering analysis, and therefore gives a less conservative and a more realistic assessment of bridge strength. Perhaps most significantly, PFEA allows more realistic response to be captured in a very computationally efficient manner and PFEA model inputs are well-defined and readily available for older bridges. These attributes make PFEA more accessible and useful to practicing engineers than other complex analysis methods for concrete structures. A journal paper detailing the development and use of PFEA recently appeared in the peer-reviewed journal *Structures*.

Outcomes/Impacts: PFEA was used to update the flexural load ratings of ten T-beam bridges. These analyses showed that 9 of these 10 bridges originally deemed under-capacity using conventional engineering analysis are structurally sufficient. With continued development, this technique has the potential to improve the rating factors of additional older bridges. Many of these structures routinely carry modern loading without distress despite having low rating factors based on conventional engineering analysis, and PFEA's predictions are more consistent with the observed behavior of these bridges. Our work to-date indicates that PFEA is extensible to other common concrete girder bridge types.

Augmented Reality in Life-Cycle Management of Transportation Infrastructure Projects

Grant Recipient: Rutgers, The State University of New Jersey

Center Name: Rutgers Center for Advanced Infrastructure and Transportation

Research Priority: Improving the Durability and Extending the Life of Transportation Infrastructure

Funding: $80,000

Project End Date: September 30, 2019

Project Description: Virtual Reality (VR) and Augmented Reality (AR) technologies have seen rapid growth recently, but the question remains of how these technologies can support the needs of transportation infrastructure managers. This project addresses that question. The research develops VR/AR environments that give transportation on-the-job training to the transportation workforce that is safer, cost-efficient, and more effective than traditional methods. In addition, the project also introduces these training products to key regional entities. Two fully-interactive VR environments have been designed that can train roadside crews in activities ranging from bridge inspection to work zone setup**,** safely and efficiently. The first module is designed after a recently constructed large cable-stayed bridge. Workers can use this environment to set up cones for work zones, experience how traffic flow reacts to them, and simulate bridge inspection tasks, among other variables. The second module is a full-scale critical facility modeled after an in-service pump station. It serves as a practice and training area for when a job site enters a critical state. The two virtual environments will help reduce training costs for the transportation workforce by allowing onsite training through the modules. It will also help improve field effectiveness and safety as workers are exposed to a variety of simulated conditions.

Outputs: Two programmable systems allow different users to experience different environments within the systems. In the bridge module, everything from weather to traffic type can be simulated depending on what training needs the workers have. The critical facility is designed to be three stories deep and represent a naturally confined space so that users can test how long it takes them to get out of an unsafe environment, and react to warning signals and other variables. Gas leaks and fires can also be simulated in this environment. The users can also experience the outdoor environment of this facility to simulate utility mark out (a precise way of identifying and marking the location of underground installations before a digging operation) processes, such as locating underground gas lines and putting down correct utility markers.

Outcomes/Impacts: (1) The Federal Highway Administration Work Zone Management Program reported that there were 799 work zone fatalities in 2017. These training modules will help foster a safer working environment, and potentially help reduce transportation and work-zone related fatalities. (2) Every year, there are hundreds of utility strikes caused by excavations in New Jersey; and high-quality utility mark out is a critical element in preventing these accidents. (3) Through demonstrations with key partners such as the Port Authority of New York and New Jersey, New Jersey Board of Public Utilities, highway construction unions, and others, the capabilities of this technology could help agencies save time and money on training, workshops, work zone setups, and infrastructure inspections while improving overall safety.

Workers can simulate reacting to fires in the critical facility module

Evaluation, Beneficiation, and Implementation of Alternative Concrete Pozzolans for Transportation Infrastructure

Grant Recipient: The Pennsylvania State University

Center Name: The Center for Integrated Asset Management for Multi-Modal Transportation Infrastructure Systems

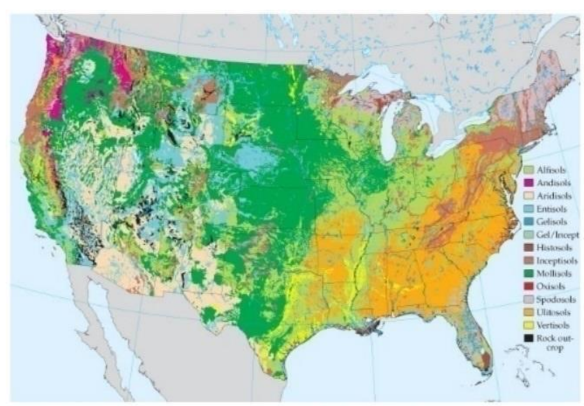
Research Priority: Improving the Durability and Extending the Life of Transportation Infrastructure

Funding: $100,059

Project End Date: March 11, 2020

Project Description: Pozzolans or supplementary cementitious materials (SCMs) such as fly ash and blast furnace slag, are a key ingredient of concrete that forms the backbone of transportation infrastructure. SCMs are used to improve the quality and durability of concrete and reduce its life-cycle cost. Recently, the supply of high-quality SCMs has fallen short of the industry demand and this trend is forecasted to worsen in the coming years. To address this problem, this study will evaluate, improve, and facilitate the use and field implementation of two new, low-cost, and locally available SCM sources that can be used for producing high-performance concrete. The first source is the fluidized bed combustion (FBC) fly ash that is widely produced (3+ million tons/year) in Pennsylvania and West Virginia as a result of environmental cleanup of waste coal piles in the region by electric power utilities. The second is the low-purity kaolinite clay that is intermixed with glacial deposits of sand and gravel within the region (Pennsylvania, Maryland, Virginia). Aggregate producers need to wash off this clay, which can be retrieved, heat treated, reduced to a powder, and used as a quality SCM for concrete. While promising, these SCM resources do not have a track record of use in concrete and their properties and performance are largely unknown. As such, they are not included in the state Departments of Transportation specifications in the region. This study will address these gaps by providing reliable data on the performance of these materials, developing guidelines and draft specifications, and educating and connecting practitioners and key entities on proper testing and use of these valuable materials. The project benefits from strong involvement and cost-sharing by these key parties, including FBC power plants (fly ash producers), a major regional aggregate producer (clay and limestone source), the Pennsylvania Aggregates and Concrete Association, and the Pennsylvania Department of Transportation.

Outputs: Two sources of FBC fly ash and one source of clay have been evaluated to date and proven to meet relevant specifications and exhibit good performance in concrete. Several beneficiation techniques have been devised and evaluated to improve the performance of these pozzolans. These include methods for purification of clays and removal of the unburned carbon in FBC fly ashes. The project results have been published in a journal paper for the *American Concrete Institute* and two other journal papers have been submitted to the *Transportation Research Record* and *Construction and Building Materials*. The results have also been disseminated at several national and regional conferences and industry meetings.



Geographical availability of clay sources (orange-ultisols) that can be processed and used as a new quality pozzolan for concrete infrastructure

Outcomes/Impacts: This project brings together all interested parties and helps ensure that research products are commercialized and implemented in practice. The research outputs will lead to agency cost savings in the form of material cost and improved durability, leading to reduced life-cycle cost of concrete infrastructure.

Transit in the Era of Shared Mobility

Grant Recipient: University of Florida (Lead); Georgia Institute of Technology

Center Name: Southeastern Transportation Research, Innovation, Development and Education Center

Research Priority: Reducing Congestion

Funding: $269,562

Project End Date: May 13, 2019

Project Description: This study analyzed changes in transit ridership in the United States with the introduction of on-demand ridesourcing options, also known as Transportation Network Companies (TNCs). This project assessed the structure of partnerships between shared mobility providers and the public sector to provide access to those with limited mobility. A transit ridership analysis was conducted, including an assessment of partnerships between TNCs and transit agencies. The research team compared trends within similar groups of transit agencies and metropolitan areas to create clusters in ridership. The cluster analysis suggested that changes in ridership are not uniform across modes and clusters. By conducting disaggregate level research in three cities (Portland, Minneapolis, and Miami), the study team found that the most productive routes are experiencing a reduction in ridership. Models also indicated that the economic displacement of transit-dependent patrons may be causing ridership to decline in the three systems studied. The research team also worked with multiple service providers in Atlanta, including transit agencies such as Metropolitan Area Rapid Transit Authority, by helping them re-examine their changing markets due to research results. Additional work on TNC and transit focused on how technology is enabling new demand-response services, e.g., paratransit or dial-a-ride, particularly around access to healthcare. Traditional demand services are costly for operators to provide and users face costs above standard transit fares, lengthy travel times, and difficulties with real-time scheduling.

Outputs: The research produced a full report that analyzed the major factors underlying transit ridership decreases and increases in four different metropolitan areas including Portland, Minneapolis, Atlanta, and Miami. This research also produced a taxonomy of TNC/transit agency interactions for use by transit agencies to understand how more effective partnerships of shared mobility providers and public-sector entities can be formed over time.

Outcomes/Impacts: New partnerships and companies continue to emerge as a consequence of this study. Additionally, this project has provided useful information for both healthcare providers and transportation providers to help them evaluate ridership programs to ensure they meet the mobility needs of the most vulnerable populations. This includes but is not limited to the elderly, low-income, and disabled. Rapidly evolving mobility services will affect transit ridership and user experiences. The products of our research will help transit agencies understand these critical new ridership trends.

New technologies have emerged which allow mobility to provide people with on-demand travel alternatives.

Reliable V2V Communication Networks: Application in Fuel-Efficient Platooning

Grant Recipient: University of Michigan

Center Name: Center for Connected and Automated Transportation

Research Priority: Promoting Safety

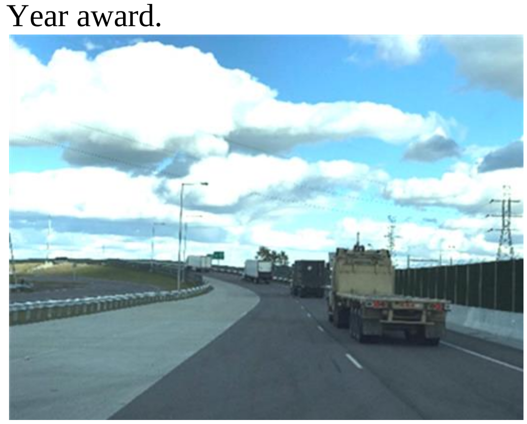
Research Project Funding: $266,682

Project End Date: December 31, 2019

Project Description: This project develops a multi-truck platooning application where the lead truck is manually driven and the following ones are connected and automated vehicles (CAVs). It is crucial to maintain a closer-than-normal gap distance, for drafting purposes, resulting in increased fuel efficiency. Drafting refers to the strategy of a vehicle avoiding head wind by closely following behind another vehicle. Vehicle-to-vehicle (V2V) communications between the vehicles enable autonomy. V2V failure impacts autonomy. Based on data collected from recent tests, researchers have identified specific cases where V2V fails when using dedicated short-range communication (DSRC). This project addresses two follow-on research problems: the cause of the DSRC failure in the identified edge cases, and the ability of cellular vehicle-to-everything (CV2X) to overcome such failures. Further testing is being done, along with modeling and simulation, to understand the failure modes. Long-standing industry partner, Ford Motor Company, actively participates in the project planning and testing. Additionally, the project leverages already funded research from the Department of Defense and the Department of Energy, which is focused on the demonstration of realizable fuel efficiency in long-haul trucks.

Outputs: A new graphical method for simulating key performance indicators of V2V communication networks, such as real-time radio-frequency field strength, is being pursued. The researchers will file invention disclosures with the University of Michigan, Office of Technology Transfer. The researchers' related invention disclosure, which has resulted in a patent filing is UM OTT File # 7489: Line-of-Sight Power Optical Communication System for Vehicle-to-Vehicle-Infrastructure Mobile Communication Networks. In addition, the researchers will make available the data collected to the University of Michigan Transportation Research Institute central database – data is being collected in both test track and public road scenarios. Finally, a student supported by the project, who is pursuing pioneering work in the simulation of V2V communication networks, will be recommended for the University Transportation Center Student of the Year award.

Outcomes/Impacts: The project output will inform regulatory, legislative, or policy organizations regarding the impact of V2V communications on truck platooning and supporting data regarding its performance in a variety of high-speed environments. The data will also allow these organizations to assess the current performance of directly competing V2V communication technologies, namely, DSRC and CV2X. A commercially viable truck platooning application will improve the operation and safety of trucking transportation. Also, it may address the shortage of truck drivers by potentially reducing the driving task-related mental workload on long-haul truck drivers, and thereby enabling them to drive longer.



Platoon of 4 semi-trucks: lead truck is manually driven, the rest are CAVs

Application of Engineered Cementitious Composites for Jointless Ultrathin Whitetopping Overlay

Grant Recipient: Louisiana State University (Lead); University of New Mexico

Center Name: Transportation Consortium of Southcentral States

Research Priority: Improving the Durability and Extending the Life of Transportation Infrastructure

Research Project Funding: $610,480

Project End Date: September 15, 2020

Project Description: Whitetoppings are concrete overlays on top of asphalt pavement structures and are classified as either: thin whitetoppings (TWT) (4- to 8-in. thick) or ultrathin whitetoppings (UTW) (2- to 4-in. thick). UTW are used to rehabilitate hot mix asphalt pavements, which may have failed from rutting, local surface distresses, fatigue cracking, or low-temperature cracking. While using smaller joint spacing allows for the utilization of UTW (4- by 4-ft and 6- by 6-ft.), it is usually more economical to utilize TWT (a thicker overlay) with larger joint spacing, since the cost of concrete is relatively low compared to saw cutting and the performance of the overlay is not compromised due to the coincidence of joints with the wheel path (as in 4- by 4-ft UTW). Therefore, enhancements to concrete materials could allow for the utilization of UTW with larger joint spacing that would mitigate joint-related distresses, increase construction speed, and be more cost-effective.

This study proposes Engineered Cementitious Composites (ECC), also known as bendable concrete, as a novel alternative for UTW application, since its outstanding mechanical properties (extreme ductility and superior strength) have the potential to allow for jointless UTW systems at a reduced thickness. Specifically, this study: (1) develops a cost-effective ECC material specific for UTW overlays application, (2) develops a model to predict performance of a jointless UTW-ECC overlay, (3) validates the model via a full-scale field test, (4) conducts a cost analysis (between UTW-ECC and a traditional UTW overlay), and (5) develops a preliminary specification for UTW-ECC overlays.

Construction of the Full-Scale, Jointless UTW-ECC Overlay

Output: This study will produce a durable, cost-effective jointless whitetopping overlay material and system. Specifically, the study will produce: (1) a jointless UTW-ECC overlay material/system, (2) a performance prediction model of the overlay, and (3) preliminary specification of the overlay for the State of Louisiana.

Outcomes/Impacts: By providing a more durable and reliable alternative for pavement repair, the jointless UTW-ECC overlay has the potential to significantly improve the durability, resiliency, and structural safety of transportation infrastructure. Likewise, the overlay may lead to a new generation of UTW that could be faster to build, more cost-effective, and more sustainable.

Investigation and Development of a MASH Test Level 6, Cost-Effective, Barrier System for Containing Heavy Tractor Tank-Trailer Vehicles and Mitigating Catastrophic Crash Event

Grant Recipient: University of Nebraska, Lincoln

Center Name: Mid-America Transportation Center

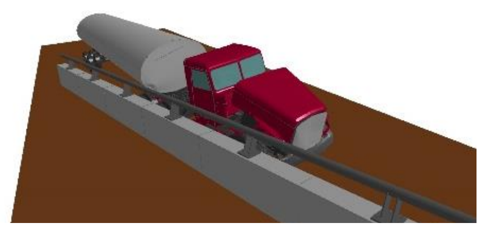
Research Priority: Promoting Safety

Research Project Funding: $210,886

Project End Date: September 30, 2018

Project Description: Large tanker trucks often transport hazardous and/or flammable chemicals through heavily-populated communities. Current barrier designs do not provide adequate protection in the event of a crash, leaving our communities and critical facilities, e.g., schools, hospitals, military bases, etc., vulnerable to the devastating and destructive effects of hazardous materials release. Although tractor-tank trailer crashes occur rarely, the effects of a crash can be catastrophic. To date, only one Test Level 6 vehicle containment system was successfully tested and evaluated according to National Cooperative Highway Research Report 230 that identifies safety performance criteria using a tractor-tank trailer vehicle. Unfortunately, the cost, height, and appearance of this Test Level 6 containment barrier have prevented its widespread implementation. Due to its current configuration, few Test Level 6 barriers have been utilized in the real-world thus far to prevent and mitigate situations such as: (1) cross median, opposing-traffic, vehicle crashes involving hazardous heavy tanker trucks along urban freeways and interstates and (2) tanker vehicle penetration or override of existing lower capacity, Test Level 4 or 5 barriers located on bridges, elevated road structures, or high volume roadways, which create potential catastrophic events near schools, malls, sports venues, concert arenas, military bases, international airports, critical government buildings, or other high-risk facilities.

A new, cost-effective, Test Level 6 vehicle containment system has been developed to prevent and/or mitigate the consequences of errant heavy tanker-truck vehicles striking opposing traffic on heavily-congested urban freeways and interstates as well as crashes into high-risk facilities or highly-populated areas. The new optimized barrier system provides adequate structural strength, investigate reduced heights, consider visual appeal for communities, implement height transitions for barrier ends, incorporate options for expansion/contraction joints, and remain safe for errant motorists operating light to heavy passenger vehicles.



Computer simulation of a tractor tank-trailer vehicle impacting a new prototype barrier

Outputs: A new *Manual for Assessing Safety Hardware* (MASH) Test Level 6 containment barrier will be developed to contain errant tractor-tank trailer vehicles. The barrier will be evaluated using finite element analysis computer simulation, small-scale component and material testing, and full-scale crash testing. The final barrier safely contains and redirect vehicles ranging from 2,420-lb small passenger cars to 79,300-lb tractor tank trailers while also limiting vehicle climb, roll, and peak-impact forces in smaller cars and trucks. The barrier will be aesthetically pleasing while being economically competitive to existing Test Level 5 containment barriers.

Outcomes/Impacts: The newly developed, cost-effective MASH Test Level 6 containment barrier will improve the safety of our traveling public, protect those living and working in highly-populated areas or high-risk facilities, and mitigate the negative impacts of hazardous material spills on our nation's infrastructure and economy.

Enhancement of Mechanistic-Empirical Pavement Design Guide for Roadway Design and Construction in the State of Wyoming

Grant Recipient: North Dakota State University (Lead); University of Wyoming

Center Name: Mountain-Plains Consortium (MPC)

Research Priority: Preserving the Existing Transportation System

Funding: $105,927

Project End Date: September 30, 2019

Project Description: The Mechanistic-Empirical Pavement Design Guide (MEPDG) was developed through the National Cooperative Highway Research Program to account for different variables related to traffic, climate, and materials, and their interactions that affect pavement performance. This guide is being adopted by the Wyoming Department of Transportation (WYDOT) for roadway designs. However, the default input variables recommended in the MEPDG were estimated for national conditions that do not reflect local Wyoming conditions. In a recently completed project, MPC researchers developed procedures and methods to calibrate the guide for local use. This effort focused on calibrating local material properties for the unbound subgrade layer (without any chemical stabilization) and serves as a supplementary study to better implement the MEPDG in Wyoming, including using it in pavement rehabilitation projects. In this study, the subgrade parameters required for designing asphalt pavements were calibrated to reflect the local materials and environmental conditions in Wyoming.

Outputs: The project resulted in a set calibrated subgrade design parameters that have been adopted for use by WYDOT to design longer-lasting more cost-effective pavements. The materials property factors were calibrated to reflect local conditions. The study provided WYDOT with typical calibrated values for most materials used in paving projects around the state.

Outcomes/Impacts: This work allows the Wyoming Department of Transportation to design longer-lasting and more cost-effective pavements. On average, the overall material cost of a new asphalt pavement designed using the new design approach developed in this study using locally calibrated material properties based on Wyoming conditions was found to be 21% less than the material cost using WYDOT's 2012 design guide. The improved designs will reduce the life-cycle costs of pavements by 20% to 25% and result in longer-lasting pavements that provide better service for highway travelers.

Wyoming highways to determine how a design approach specifically calibrated for local materials performed to national design standards

Innovation on Job Accessibility with General Transit Feed Specification (GTFS) Data

Grant Recipient: University of Southern California

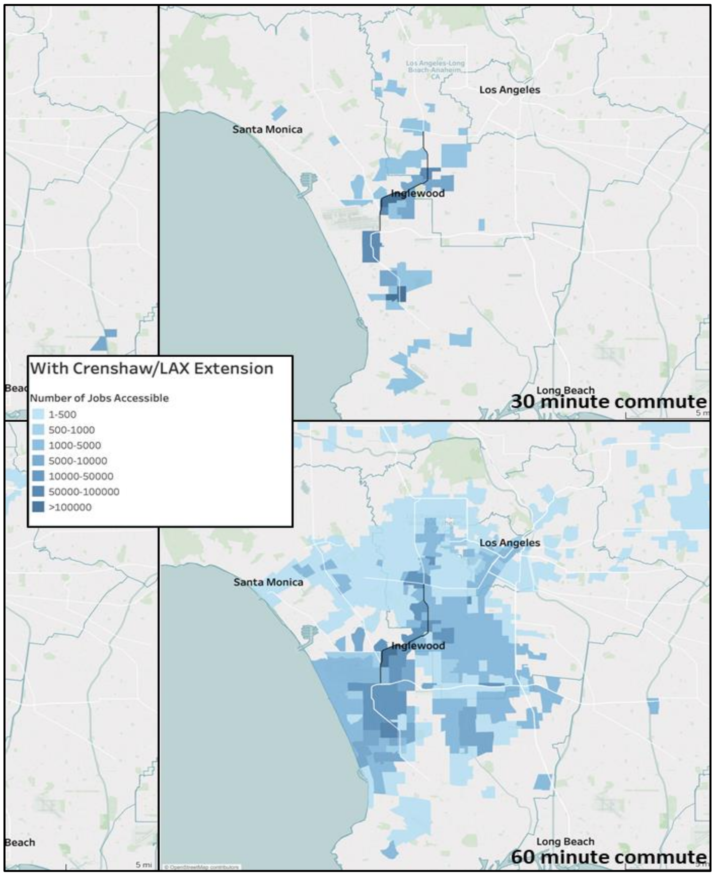
Center Name: Pacific Southwest Region University Transportation Center

Research Priority: Improving Mobility of People and Goods

Research Project Funding: $99,983

Project End Date: December 31, 2019

Project Description: This project investigates job access via public transportation in Los Angeles County, California. Researchers relied on the automated Remix access tool (aRat) to measure accessibility based on travel time, via public transit to jobs, across different transit network scenarios. Remix is an online transit planning program, used by transit agencies and related groups to forecast changes in transit network access travel times with changes in service levels. Relying on open-source General Transit Feed Specification (GTFS) data, researchers modeled the transit network in Remix. After modeling the network, researchers augmented the existing transit system with planned improvements to the network and relied on aRat to measure the number of jobs accessible from the center of each of the county's 2,345 census tracts within a 30- and 60-minute commute time in each of the transit network scenarios. The result is a method that uses GTFS data and aRat to estimate how tract-level job access might change with improvements to transit infrastructure. Researchers measured transit job access change across three different transit improvements: Expo Line Phase II, Los Angeles International Airport (LAX)/Green Line Extension, and the Vermont Bus Rapid Transit Corridor. Researchers illustrated that job access measures can go beyond the common "static" measures of access over existing networks and be used to evaluate the benefits of a variety of different transit investment scenarios.



LAX/Crenshaw green line extension job access improvements

Outputs: The first part of this research built a tool to plan for future scenarios. The tool uses open source data to quickly calculate how different transit system changes will change job access. Public transit is vital in providing job access, particularly for households with no access to a car. Until this research, there were few ways to quickly calculate job access measures.

Outcomes/Impacts: The scenario planning tool will be used to calculate how job access, from public transit and the automobile, is related to employment outcomes. Because researchers used a license to the commercial Remix software tool as part of their process, they are communicating with the private sector throughout the research. Researchers are already using the access tool to simulate transportation network changes in Los Angeles. An example of possible light rail and bus rapid transit alignments is shown in the figure.

A Novel Multisource Traffic Sensor: Mobile Unit for Sensing Traffic

Grant Recipient: University of Washington

Center Name: Pacific Northwest Transportation Consortium

Research Priority: Improving Mobility of People and Goods

Research Project Funding: $60,000

Project End Date: September 15, 2020

Project Description: Over the past several years, researchers in the University of Washington's Smart Transportation Application and Research (STAR) Lab, have been developing a multisource traffic sensor called the Mobile Unit for Sensing Traffic (MUST) sensor. This specific project partially funded the development of the second iteration of this technology (version 2), as well as some educational materials to better inform the industry about this sensor's capabilities. The MUST sensor version 1 was developed to capture the hardware Media Access Control (MAC) address of Wi-Fi and Bluetooth devices in the surrounding area. This MAC address can be used as a unique identifier for each traveler to determine spatial-temporal movement characteristics so that traffic parameters can be extracted including travel time, traffic speed, traffic volume, etc. This sensor can also detect the traffic information of non-motorized traffic by monitoring mobile devices carried by pedestrians and bicyclists. The MUST sensor version 2 integrated multiple additional sensing modules, e.g. global positioning system (GPS), video camera, thermal camera, and environmental sensors. By having the multisource sensing capacity, the MUST sensor version 2 has the capability to address more challenging data collection scenarios. One such example is the addition of the GPS module, which allows the MUST sensor version 2 the capability of being installed on mobile objects to collect data, such as a transit vehicle (i.e., bus) or a probe vehicle (a vehicle acting as a roving traffic detector).

Outputs: The major output of this work is the device itself, as described above. Further, this technology has been presented in an academic setting at the 2018 American Society of Civil Engineering International Conference on Transportation & Development. Demonstration presentations were also made and to potential interested parties and partners, such as to representatives of the Norwegian Public Roads Administration (NPRA). NPRA was looking to deploy sensors along a vital supply chain route that connects fisheries in the arctic circle with Helsinki, Finland. They identified this sensor because researchers in the STAR Lab offered to make specific modifications for extreme cold weather climates. Finally, researchers produced an educational video to help potential partners better understand the capabilities of the sensor.

Outcomes/Impacts: This technology has been, and will soon be, implemented in several projects around the world including: 1) on the campus of Tongji University, Shanghai, China to map pedestrian movements through campus; 2) at the Sound Transit Angle Lake Light Rail Station parking structure in SeaTac, WA, to better understand facility use; 3) along the E-8 corridor in Northern Norway as part of a project with NPRA to better identify issues along this vital corridor; and 4) at two freight truck parking facilities along Interstate 5 in a project with the Washington State Department of Transportation. This project aims to better understand how these facilities are being used and to provide drivers more accurate parking availability information. These projects demonstrate the powerful capability and versatility of this sensor to collect better data. This data then allows researchers to better understand a variety of transportation situations and conditions, and then finally to make the most informed decisions. In each of these projects those decisions help to manage and improve the mobility and safety of all users.

Two implementations of the MUST sensor

Tier 1 Centers

Enlarging the Set of "Common Variables": How Much Can Targeted Marketing and Travel Behavior Data Improve the Prediction of Attitudes?

Grant Recipient: Arizona State University (Lead); Georgia Institute of Technology

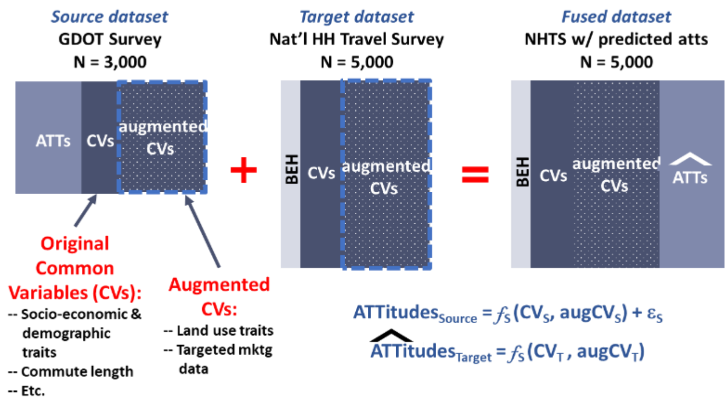
Center Name: Center for Teaching Old Models New Tricks (TOMNET)

Research Priority: Improving Mobility of People and Goods

Research Project Funding: $234,445

Project End Date: September 30, 2022

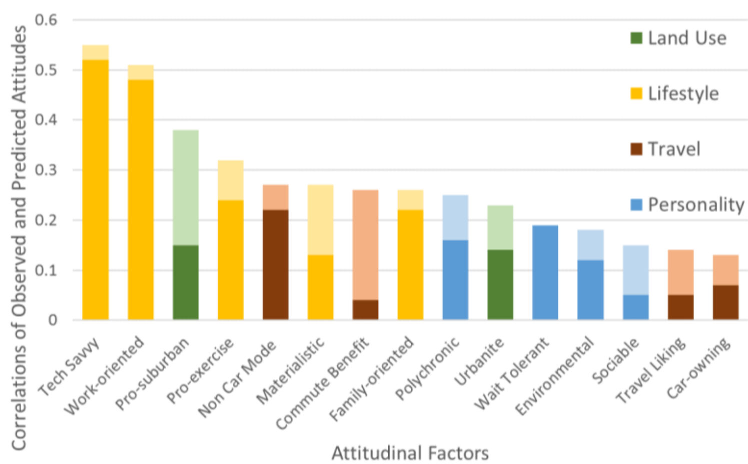
Project Description: Emerging technologies, major demographic shifts, and evolving policy and planning instruments are creating unprecedented changes in the transportation field. We do not know how all these changes will alter our travel and land use patterns, and how we should design our transportation system to improve mobility, accessibility, and environmental sustainability. To answer these questions, we need to understand the attitudes that motivate people's decisions about lifestyle and travel. But under the constraints of real-world travel forecasting, transportation planners view attitudes as being too difficult and burdensome to measure. This project continues a multi-year effort to address this barrier. Specifically, researchers are developing, demonstrating, and testing the effectiveness of using machine learning methods for incorporating attitudinal information obtained from separately-collected data into national/regional travel survey datasets.



Combining Datasets for Better Prediction

Outputs: A key output of the project will be the 2017 National Household Travel Survey dataset (Georgia subsample), enriched with attitudes predicted using the newly-developed methods of the TOMNET center. This dataset can then be used to create a variety of travel behavior models that incorporate the imputed attitudes as explanatory variables, so the improved models will be another important output. In addition, the project will produce a wealth of information on how others can replicate the methods we are pioneering, to apply them in several possible domains.

Outcomes/Impacts: A high degree of uncertainty and planning challenges affect our transportation landscape, and our current models are ineffective in forecasting changes in travel demand in the wake of new disruptive technologies and mobility options. The methods developed in this project will greatly increase the realism and flexibility of those models. Accordingly, this research will directly contribute to improved forecasting of travel demand and better-informed transportation plans and designs.



Predicting Attitudinal Factors

Infrastructure and Policy Needs for Personal Electric Mobility Devices in a Connected Vehicle World

Grant Recipient: Clemson University (Lead); South Carolina State University

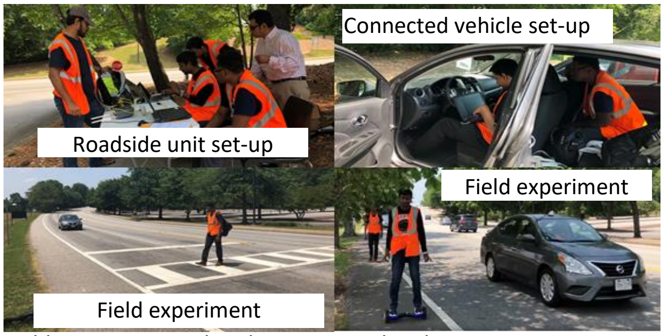
Center Name: Center for Connected Multimodal Mobility

Research Priority: Improving Mobility of People and Goods

Funding: $41,665

Project End Date: June 30, 2019

Project Description: Personal electric mobility devices (PEMDs) were initially created for people with popular accessible transportation mode among people who used to walk, bike, and drive cars, but currently are mobility challenged. Due to advances in technology, PEMDs can be used to bridge the first and last-mile gap (thus, increase accessibility to public transportation), improve people's mobility, and reduce congestion and vehicle emissions by replacing automobile travel. As these devices are too fast for a footpath and too slow for highways, they may need particular infrastructure and new policies for their safety and operation. The research team conducted a comprehensive review of the literature of current PEMDs in the global market and analyzed the safety incidences of PEMDs in the past 12 years by utilizing the National Electronic Injury Surveillance System database. These analyses are crucial in revealing the potential safety hazards and operational benefits associated with PEMDs use and effective measures for safe inclusion of PEMDs into the existing infrastructure. Further, the research team has conducted two field experiments, first, under a traditional traffic operating condition (non-connected environment) at South Carolina State University and second, under a connected environment at the Clemson University Connected Vehicle Testbed (CU-CVT).



Field experiments related to PEMD and pedestrian at CU-CVT

Outputs: A published project report, "Infrastructure and Policy Needs for Personal Electric Mobility Devices in a Connected Vehicle World," summarizes of the key outputs from the research effort related to infrastructure and policy needs for PEMDs. We recommend that transportation planners and professionals should consider the impact of PEMDs operation on the width of the walkway. Since these non-traditional modes increase vehicle travel time on the roadway and reduce pedestrian walking speed, an alternative lane could be created to divert the PEMDs from walkways while restricting the use of the PEMDs on walkways. Widening of walkways could also help reduce PEMD travel time.

Outcomes/Impacts: This research will significantly increase the safety and operational efficiency of PEMDs. The research findings will help transportation planners to decide how to manage non-motorized facilities (walkways, sidewalks, paths and trails) to maximize the benefits of PEMDs while minimizing any adverse impacts. Further, the research results also will inform our infrastructure needs as we evolve into a connected transportation environment. As research on vehicle automation and connectivity continues to advance, our research results will aid the design of infrastructure that aims at seamless multimodal interactions between vehicles, PEMDs, pedestrians, and other road users.

Reliability-Based Design Optimization of Sequential Excavation Method of Tunneling

Grant Recipient: Colorado School of Mines

Center Name: University Transportation Center for Underground Transportation Infrastructure

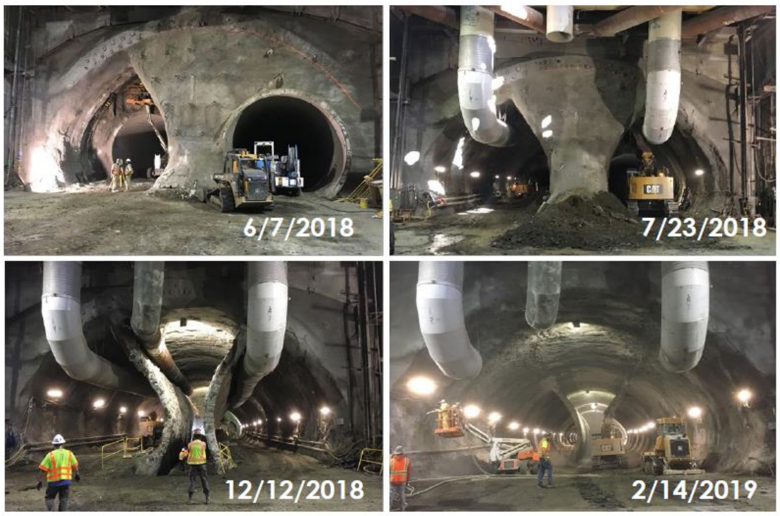
Research Priority: Improving the Durability and Extending the Life of Transportation Infrastructure

Research Project Funding: $330,000

Project End Date: September 30, 2020

Project Description: Rapid urbanization is placing huge demands on transportation systems to improve mobility and life quality. To meet these demands, tunnels are being widely used, particularly those built using mechanized tunneling methods with the help of tunnel boring machines. Tunnel construction methods like the Sequential Excavation Method are also rapidly expanding in urban areas. The goal of this project is to improve the design and construction of urban tunnels by developing a reliability-based design optimization in combination with an observational method that relies on real-time field monitoring of tunnel response during construction.

Outputs: The research team has developed a framework for the reliability-based design and construction of tunnels constructed using the Sequential Excavation Method that accounts for uncertainties in ground parameters and construction variables. To support the reliability-based design framework, a 3D computational technique was established to predict the displacement characteristics of sequentially excavated tunnels. The computational technique accounts for the sensitivity of predicted tunnel response to model input parameters and updates the parameter values using a back-analysis procedure that learns from field monitoring data during tunneling by comparing predicted response with field measurements. The reliability-based design and construction procedure is a significant improvement of tunnel analysis and design. The methodology is being tested in collaboration with industry vendors in the on-going construction of the Los Angeles Regional Connector Transit Corridor Crossover Cavern.



Sequential excavation method applied to the Regional Connector Crossover Cavern

Outcomes/Impacts: The expected research outcome is an improved design approach and construction of sequentially excavated tunnels with reduced cost, and enhanced safety and reliability. The impacts of better designed and more economically and safely built tunnels include: 1) Reduced urban traffic congestion and travel times, 2) Reduction in fossil fuel use and emissions, 3) Improved land use and development by reducing urban sprawl and traffic noise, and preserving landscape and biodiversity, and 4) Increased resilience of communities by providing reliable transport service safe from natural and anthropogenic hazards.

Potential Impacts of Electric Vehicles on Air Quality and Health in Houston

Grant Recipient: Cornell University

Center Name: Center for Transportation, Environment, and Community Health

Research Priority: Preserving the Environment

Research Project Funding: $57,607

Project End Date: February 28, 2020

Project Description: Project Description: The Center for Transportation, Environment, and Community Health is conducting research that might potentially improve the future of Houston's breathable air. By replacing at least 35% of Houston's cars and trucks with electric vehicles by 2040, Houstonians could reduce ozone and particle pollution. These citizens could live longer and enjoy a better environment. In this study, researchers analyzed multiple scenarios to understand how future transportation electrification and fleet turnover affect air quality and health in the Houston area.

Outputs: To capture urban features in significant detail, researchers model each scenario using the high-resolution (1x1km) integrated weather-emissions-air quality and health modeling framework to gain an understanding of the concentrations of ozone (O_3), to find particulate matter ($PM_{2.5}$), and to evaluate the processes over Houston. This analysis captures intra-urban variation in air pollution and health impacts from the transportation sector. The study outputs help answer the following questions: (1) How will transportation activity change in the Houston area by 2040? What are the possible scenarios corresponding to different emission control or fleet electrification/turnover? (2) What are the magnitudes and distributions of resulting changes in regional O_3 and $PM_{2.5}$ pollution? (3) What are the health and economic impacts/benefits?

Outcomes/Impacts: Although Houston's population is expected to significantly increase by 2040, we can apply new technologies such as transportation electrification to reduce emissions, improve air quality, and think about health. If left unchecked, ozone and particulate-matter levels would result in 122 more premature deaths annually throughout greater Houston by 2040. With moderate or aggressive electrification for cars and trucks, the numbers reflect air-quality improvement, with prevented premature deaths at 114 and 188, respectively. In the case of a complete turnover, the number of prevented premature deaths per year around Houston shoots to 246. The knowledge from the study supports decision makers, mayors, and city planners to be creative and innovative to design policies that would help the electrification of the transportation sector.

Next Generation of Freight Planning and Operation Models to Incorporate Emerging Innovative Technologies

Grant Recipient: Florida Atlantic University (Lead); University of Memphis

Center Name: Freight Mobility Research Institute

Research Priority: Improving Mobility of People and Goods

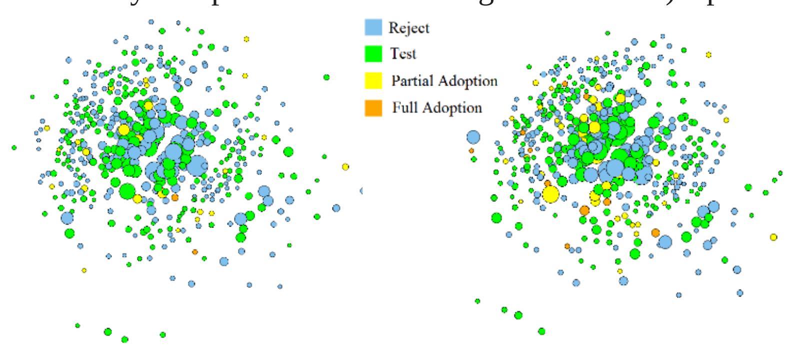
Research Project Funding: $209,984

Project End Date: June 30, 2020

Project Description: New technologies have created opportunities to address critical freight transportation challenges across all modes in urban, suburban and rural areas. Some examples of new technologies include expansion of e-commerce, last mile deliveries by unmanned aerial vehicles or delivery robots, and potential applications of automated and connected vehicles in freight transportation (e.g. truck platooning). These new technologies are also influencing consumer behavior and thereby reshaping freight supply chains at the urban, regional, and international level. First, this research project will develop empirical models to predict how freight organizations will adopt autonomous trucks over the next twenty-five years. Second, we will address how transportation planning models will incorporate truck platooning. We will examine such criteria as how many trucks will be allowed in a platoon, platoon speed, platooning hours, freeway platooning zones, etc. Third, we will model the potential emissions impacts of last mile delivery robots. Fourth, we will assess the role and feasibility of technological innovations such as automated and connected vehicles and operations research methods in freight transportation.

Outputs: The outputs of the research will include reports depicting: 1.) adoption behavior of highly automated trucks by freight organizations, 2.) truck platooning analysis in transportation planning and operation models, 3.) the impacts of last mile deliveries by delivery robots, and 4.) how the mode choice and the cost variation is formed in intermodal transportation, when using more cost-efficient vehicles.

Outcomes/Impacts: This multi-university research study will produce the following outcomes: 1.) a prediction of the impact of highly automated truck technology in the trucking industry in the next 25 years, 2.) the establishment of a process in which state departments of transportation and local agencies may promote truck platooning by assessing their performance in planning and operational models, 3.) a method of modeling emissions and other performance impacts of delivery robots for last mile deliveries, and 4.) a measurement of the impact of new operations research methods and emission regulations in intermodal freight transportation operations.



Trucking firms without (left) and with (right) peer effects on automated technology adoption

Extending Maximum Length of the Folded Steel Plate Girder Bridge System, exceeding 100 ft. with Capability to Incorporate Camber

Grant Recipient: Florida International University

Center Name: Accelerated Bridge Construction (ABC) University Transportation Center

Research Priority: Improving the Durability and Extending the Life of Transportation Infrastructure

Research Project Funding: $110,000

Project End Date: March 29, 2019

Project Description: Imagine upgrading existing substandard bridges at 10 percent of the cost of replacing them and building new ones. Envision these bridges lasting more than 100 years, maintenance-free. At ABC-UTC, researchers are developing technologies that can retrofit existing bridges at a fraction of the cost of replacing them and better yet, can result in bridges that are even stronger and more resilient than when they were built. ABC-UTC researchers are using a new material called Ultra-High Performance Concrete (UHPC). The cost of UHPC is about 15 times more than regular concrete, mainly because the available mixtures are proprietary in addition to the lack of experience in using it by contractors. Researchers are addressing this challenge, by a) developing a generic version of UHPC that has the same properties, but costs only 4 times that of regular concrete and b) organizing workshops and training stakeholders in using these new materials and technologies.

This project is addressing both retrofitting existing substandard bridges using UHPC and producing cost-efficient and long-lasting new bridges, in order to significantly reduce onsite construction and to improve mobility during the construction period. The upgrading of existing substandard bridges is achieved through wrapping existing substandard bridge elements with thin layers of UHPC. For new bridges, a concept was developed to eliminate the time-consuming and expensive form building process associated with conventional construction. This concept is achieved by building, what researchers call the UHPC shell, which is in the shape of the outer surface of various bridge elements. These lightweight UHPC shells are then transported to the final bridge site, attached using special connections. A reinforcement cage is placed inside the shell and then the shell cavity is filled with regular or lightweight concrete. Moisture or saltwater does not penetrate through UHPC shells. As a result, what is inside is protected for more than 100 years, without any maintenance. Our next step is to automate both the repair and construction of UHPC shell using robotics, which is an ongoing effort.

UHPC Shell

Outputs: This project has resulted in the development of retrofitting procedures and associated design provisions for existing substandard bridges. Further, this project has introduced the novel idea of using UHPC shells in bridge construction. This project has resulted in two U.S. Patents entitled “High performing protective shell for concrete structures-US Patent 9,708,821” and “Composite construct and methods and devices for manufacturing the same-US Patent 16/202,318”.

Damage in bridges (left) complete wrapping (right)

Outcomes/Impacts: The results of this ongoing project will provide an ABC solution that is similar to conventional types of construction. The outcomes are expected to revolutionize the bridge industry and place the U.S. as a leader in these technologies worldwide.

Unmanned Aerial Vehicle Enabled Smart Rock Positioning for Bridge Scour Monitoring

Grant Recipient: Missouri University of Science and Technology (Lead); University of Nevada, Reno

Center Name: Inspecting and Preserving Infrastructure through Robotic Exploration

Research Priority: Preserving the Existing Transportation System

Research Project Funding: $292,940

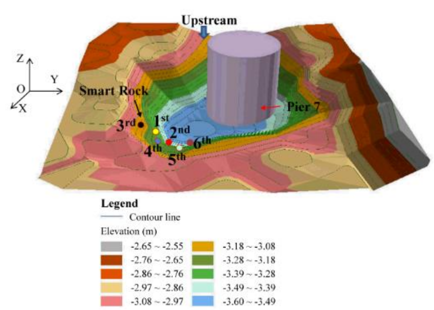
Project End Date: December 31, 2020

Project Description: In current practices, divers are dispatched to visually inspect and assess underwater bridge foundations for stability and thus safety due to potential flow-induced riverbed erosions, called bridge scour. This project aims to develop and validate an alternative technology, smart rock positioning for bridge scour monitoring. Engineered smart rocks with embedded magnets, based on the critical velocity of water flow, can automatically roll down the bottom of their surrounding scour hole under strong water current. They are positioned through remote sensing with a magnetometer and a localization algorithm. The rock position is then translated into the maximum scour depth over time, which is needed in the evaluation of foundation stability. One smart rock has been deployed near Pier 7 of the Roubidoux Creek Bridge since November 2015, and located during six field tests. During the February 25, 2019 visit, it was estimated to settle by 0.4 m between the 6^{th} and 7^{th} field tests after the February 2019 flood.

Outputs: The ‘Smart Rock’ system consists of a 135-pound spherical fiber-reinforced concrete encasement with one or two permanent magnets in stack embedded in an aligned gravity-controlled polarization direction, which is deployed at the river bed as a field agent, and a 3-axis magnetometer and a ground-referenced global positioning system, which are installed on an unmanned aerial vehicle (UAV) as a mobile measurement station. This hardware system allows for a rapid collection of dense magnetic field intensity and coordinates data at a bridge site. Its corresponding software is the localization algorithm of a smart rock from a spatial distribution of its surrounding magnetic field measurements.

Deployment of a smart rock

Magnetic measurement with a UAV-based sensor



Smart rock movement during six field tests

Outcomes/Impacts: Smart rock positioning technology uniquely meets the needs in bridge scour monitoring for an efficient and cost-effective instrumentation that can be deployed and operated in near real time during a flood event. On one hand, existing portable instrumentations such as radio-controlled boats and sounding rods, which can move from one bridge to another for cost-effective scour monitoring, cannot provide a real-time detection of the scour condition at bridge foundations. On the other hand, existing fixed instrumentations such as float-out devices and magnetic sliding collars, which are installed at pre-determined locations for real-time monitoring, can neither give the most critical scour condition around the perimeter of foundations nor survive the harsh environment during a flood event. The smart rock positioning technology combines the advantages of both portable and fixed instrumentations.

Inference of Transit Passenger Counts and Waiting Time Using Wi-Fi Signals

Grant Recipient: Montana State University

Center Name: Small Urban, Rural and Tribal Center on Mobility

Research Priority: Improving Mobility of People and Goods

Research Project Funding: $58,723

Project End Date: June 30, 2019

Project Description: Passenger data such as real-time origin-destination (OD) flows and waiting times are central to planning public transportation services and improving the user's experience. This project explored the use of Internet of Things Technology to infer transit ridership and waiting time at bus stops. Specifically, this study explored the use of Raspberry Pi computers, which are small and inexpensive sets of hardware, to scan the Wi-Fi networks of passengers' smartphones. The process was used to infer passenger counts and obtain information on passenger trajectories based on Global Positioning System (GPS) data. The research was conducted as a case study of the Streamline Bus System in Bozeman, Montana. To evaluate the reliability of the data collected with the Raspberry Pi computers, the study conducted technology-based estimation of ridership, OD flows, wait time, and travel time for a comparison with ground truth data (passenger surveys, manual data counts, and bus travel times).

Outputs: Researchers developed a device called the Smart Station, which is a wireless Wi-Fi scanning device for transit data collection. It combines an innovative set of hardware and software to create a non-intrusive and passive data collection mechanism. Through the field testing and comparison evaluation with ground truth data, the Smart Station produced accurate estimates of ridership, origin-destination characteristics, wait times, and travel times.

Outcomes/Impacts: Ridership data has traditionally been collected through a combination of manual surveys and Automatic Passenger Counter systems, which can be time-consuming and expensive, with limited capabilities to produce real-time data. The Smart Station shows promise as an accurate and cost-effective alternative. The advantages of using Smart Station over traditional data collection methods include the following: (1) Wireless, automated data collection and retrieval, (2) Real-time observation of passenger behavior, (3) Negligible maintenance after programming and installing the hardware, (4) Low costs of hardware, software, and installation, and (5) Simple and short programming and installation time. The Smart Station was used to collect raw Wi-Fi and GPS data on the buses and at bus stops. Once the datasets were created, the research team developed algorithms to calculate ridership, OD matrices, travel times and wait times. If further validated through additional research and development, the device could help transit systems facilitate and improve data collection for route optimization, trip planning tools, and traveler information systems to result in timely information dissemination to the public.

Streamline bus containing Smart Station device (left) and components of the Smart Station data collection system (right)

Sustainable Design of Concrete Bus Pads to Improve Mobility in Baltimore City

Grant Recipient: Morgan State University

Center Name: Urban Mobility and Equity Center

Research Priority: Improving Mobility of People and Goods

Research Project Funding: $50,000

Project End Date: March 2, 2019

Project Description: Bus pads, the part of the road in front of a bus stop, need a durable surface. Concrete is preferable to asphalt, which ripples under the weight of a bus, but if concrete pads are not properly designed and constructed, they will crack, requiring expensive, inconvenient repairs. Researchers conducted a field study in Baltimore, Maryland, that involved extracting two concrete strips in longitudinal and transverse axes from a bus pad. Researchers tested the concrete strips under a four-point bending produced by two concentrated monotonic loads. The load and deflection were measured to investigate the strips' performances under the applied load until failure. All load cases and combinations were identified based on possible loading scenarios. Researchers developed a numerical model and studied soil-structure interaction using the Winkler method. The maximum design shear and bending forces were extracted from the finite element (FE) model, which considers the effect of moving loads and temperature on a two-way slab. This research evaluated the load-bearing capacity of the current design of Baltimore bus pads and compared it to the tested strips as well as the required bending capacity of FE models. Results show the design and construction of bus pads in Baltimore need to be modified.

Outputs: This research conducted an experimental study and developed a numerical model to study moment forces and soil structure interaction, and then developed best practices for the design and construction of concrete bus pads in Baltimore City. The subgrade settlement can cause much larger moment in the longitudinal and transverse directions of bus pads than design moment. The subgrade modulus significantly affects the moving load distribution and soil pressure, changing moment by up to 8 times. This means poor compaction of the subgrade increases moment, which is underestimated in the design, resulting in surface cracks. Considering more realistic models for moving load and boundary conditions, the moment envelope of the numerical model was extracted and shows that the bus pad experiences 49% larger moment in longitudinal direction than the current design moment capacity. Concrete slab failure due to positive moment is harder to see because cracks initiate from the bottom face of the slab. More attention needs to be paid to designing bus pad slabs for positive moment.

Outcomes/Impacts: Reducing repairs reduces the inconvenience for bus riders, especially at high-volume stops. Bus pad conditions affect bus operating costs because surface cracks increase wear and tear on buses; cracks are more severe in bus pads than pavement due to braking forces. Most of the bus pads studied required more than routine maintenance due to cracking. Removal and replacing a bus pad can cost upwards of $42,600. Better design and construction will not only reduce maintenance costs and significantly delay the need for replacing bus pads, but also reduce bus operating costs.

Testing specimen under four-point bending (left) and the sudden failure of a transverse at breakpoint (right)

Development of A Mobile Navigation Smartphone Application for Seniors in Urban Areas

Grant Recipient: New York University (Lead); Rutgers University and The University of Texas at El Paso

Center Name: Connected Cities for Smart Mobility towards Accessible and Resilient Transportation (C2SMART)

Research Priority: Improving Mobility of People and Goods

Research Project Funding: $210,000

Project End Date: May 31, 2019

Project Description: Over the past two years, C2SMART researchers have collaborated on the development of a smartphone application, Urban Connector, which is designed to cater to the urban mobility needs and preferences of seniors. The research team conducted surveys with 458 participants at senior centers in El Paso, TX to identify seniors' unique mobility needs and preferences, then developed a prototype of the application. A pilot survey was conducted with 65 senior participants to gather feedback on the application's interface and functions, and the results of the survey were used to improve the application. Then, 38 seniors were recruited to field-test the application for a month and surveyed about their experience. More than half the participants strongly agreed or agreed that the application was easy to use or benefits their travel related concerns. Sixty-eight percent (68%) of the participants said that they would recommend the Urban Connector application to their friends. The application is being piloted, and a further expansion of the outreach efforts to seniors in New York City is currently taking place.

Outputs: The research team conducted surveys to learn about the specific mobility needs and concerns of seniors in urban areas to develop a smartphone application to cater to those needs. This project delivered a smartphone application prototype in Android platform, which will be available for free download. Surveyed participants gave the Urban Connector application an average rating of 3.47 out of 5.00. This project also collected data, documented the preference of smartphone application features, and documented user experience by the seniors. To keep their target users informed about the project and the application, the researchers created posters and videos showcasing their results and a video user guide for the application.

Outcomes/Impacts: Seniors who use this application are expected to experience improved mobility, connections with society, and increased activity options. The data collected from the application program will lead to new ideas for other smart mobility services. The experience gained in developing this smartphone application will benefit future projects that will use smartphones for data collection, especially from seniors.

Urban Connector Mobile App

Automated Last Mile Connectivity for Vulnerable Road Users

Grant Recipient: North Carolina Agricultural & Technical University (Lead); Virginia Polytechnic Institute and State University

Center Name: Center for Advanced Transportation Mobility

Research Priority: Improving Mobility of People and Goods

Research Project Funding: $819,267

Project End Date: September 30, 2020

Project Description: Low speed automated vehicles, or autonomous shuttles can provide people with disabilities, the elderly, and other vulnerable road users with efficient, convenient, and timely on-demand access to existing fixed-route transit systems to address first/last mile mobility challenges. To better understand the potential obstacles to their usage, researchers have deployed an autonomous shuttle on a public road in a first/last mile role that includes a local bus transit stop in vehicle lanes, through a roundabout, and within a busy parking lot.

Outputs: This research will help transportation providers and technology developers to better understand the issues related to real-world use of autonomous shuttles by vulnerable road users. This research will study preconceived attitudes about autonomous shuttles, detailed analysis of actual physical and cognitive system usage, and evaluation of how education and technology exposure change user attitudes. The research team will use multiple survey methods, focus group participation, and naturalistic study. Study participants will be exposed to a high level of service that may include aid from an onboard attendant. A secondary but highly salient output of this work will stem from the experience of implementing an autonomous shuttle system in a real and complex transportation environment and coordinating its operation with local fixed-route bus transit operations.

The project's autonomous vehicle deployed in Blacksburg, VA

Outcomes/Impacts: This research knowledge will inform future implementations concerning the special needs and attitudes of vulnerable road users and how autonomous technologies should be applied and regulated considering human factors and real-life usage characteristics. These factors and characteristics may include the need for onboard attendants, real-time rider communication with remote operators, physical access for those with special needs, and route considerations such as the presence of vehicles parked along routes. Federal, state, regional, and local transit planners considering the use of autonomous shuttles will understand better the deployment aspects and issues related to serving the needs of vulnerable road users. Federal regulatory and funding efforts related to disability issues, public transit (including paratransit), and vehicle safety certification programs will benefit from informed and careful research.

Analysis of Disengagements in Semi-Autonomous Vehicles Drivers' Takeover Performance and Operational Implications

Grant Recipient: San Jose State University

Center Name: Mineta Consortium for Transportation Mobility

Research Priority: Improving Mobility of People and Goods

Research Project Funding: $74,577

Project End Date: June 30, 2019

Project Description: This study analyzed the performance of human drivers in taking back control of semi-automated vehicles following failures of the autonomous technology. The study was executed in a human-in-the-loop setting, within a high-fidelity integrated car simulator capable of handling both manual and autonomous driving. A population of 40 individuals was tested, equally split among males and females, ranging in age from 18 to 65. The following dependent variables for control takeover were examined: i) response times (considering inputs of steering, throttle, and braking); ii) vehicle drift from the lane centerline after takeover as well as overall (integral) drift over an S-turn curve compared to a baseline obtained in manual driving; and iii) accuracy metrics to quantify human factors associated with the simulation experiment. Independent variables included driver age, speed at the time of disengagement, and the time at which the disengagement occurred (i.e., how long automation was engaged for). The tests were executed in a simulated 7.6 mile closed-loop track that resembled a highway environment.

Outputs: Findings from the study show that:

- Of the two speed settings (high speed of 65 mph and low speed of 55 mph), the low speed category fared better performance for all test subjects.
- In 69% of the cases, unintentional lane departure was recorded. However, all participants but one still described their control takeover as "successful".
- Duration of engagement of automation was not found to be statistically significant in affecting the investigated metrics.
- Of the three age groups tested (18-35; 35-55; 55+), the age group of 55+ performed best in terms of both maximum drift and comparison between conventional driving and driving after AT failure.

The human-in-the-loop simulator owned by Silicon Valley

Outcomes/Impacts: The results point to the importance of setting up thresholds for maximum operational speed of vehicles driven in autonomous mode when the human driver serves as back-up, perhaps warranting a lower speed limit than conventional vehicles. In particular, the average maximum drift after takeover increased (and worsened) by 116% (from 3 ft. to 6.5 ft.) when the operational speed went from 55 mph to 65 mph. Unintentional lane departures indicate the need for possible dedicated lane usage for autonomous vehicles separated from conventional traffic, as well as the possibility of increasing lane width in dedicated lanes for semi-autonomous vehicles (lane width tested was 12 ft.). With regards to the age variable, neither the response time analysis nor the drift analysis provide support for any claim to limit the age of drivers of semi-autonomous vehicles.

Traffic-Related Air Pollution and Childhood Asthma in the United States: A Burden of Disease Assessment

Grant Recipient: Texas A&M University (Texas A&M Transportation Institute)

Center Name: Center for Advancing Research in Transportation Emissions, Energy and Health

Research Priority: Preserving the Environment

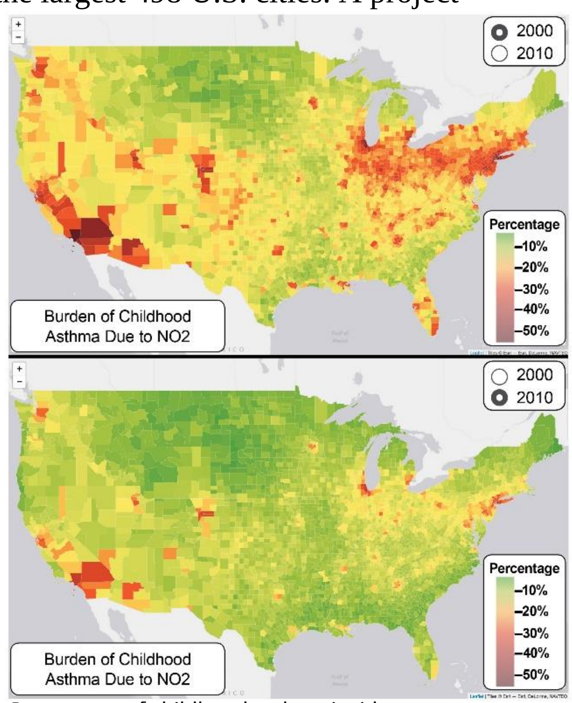
Research Project Funding: $126,940

Project End Date: December 31, 2019

Project Description: The economic burden of asthma in the U.S., including costs incurred by absenteeism and mortality, was $81.9 billion in 2013. In 2016, over 6 million children had ongoing asthma. Emerging evidence shows that Traffic-Related Air Pollution (TRAP), commonly marked by urban nitrogen dioxide (NO_2) concentrations, leads to the onset of childhood asthma. This study estimated the number of new asthma cases among children that may be attributable to nitrogen dioxide and particulate matter ($PM_{2.5}$ and PM_{10}) as surrogates of TRAP exposures in the contiguous U.S., for the years 2000 and 2010. Researchers used burden of disease assessment methods that combined multiple data sources, namely: 1) population counts of children, 2) annual levels of exposures as estimated by validated land-use regression models at all populated U.S. census blocks, 3) asthma incidence rates as calculated from surveys administered by the Centers for Disease Control and Prevention and 4) meta-analysis estimates of the associations between incident childhood asthma and NO_2, $PM_{2.5}$ and PM_{10}. Researchers found that average concentrations in 2000 and 2010, respectively, were 20.6 and 13.2 $\mu g/m^3$ for NO_2, 12.1 and 9 $\mu g/m^3$ for $PM_{2.5}$ and 21.5 and 17.9 $\mu g/m^3$ for PM_{10}, marking significant improvements in air quality over the 10-year study period. Asthma incident cases attributable to TRAP represented 27%–42% of all cases in 2000 and dropped to 18%–36% of all cases in 2010.

Outputs: Researchers produced online open-access interactive maps summarizing research findings at the county level and a look-up table summarizing research findings for the largest 498 U.S. cities. A project repository was created with all necessary datasets to replicate the analysis and specific visual guidance on how to download and analyze the data. Finally, the research team published an open-access peer-reviewed scientific paper, with another under peer-review, and has received high-profile press coverage.

Outcomes/Impacts: This project provided a well-described open-access methodology to study the impacts of Traffic-Related Air Pollution on human health. It also provided open-access interactive maps and a look-up table that can highlight areas of concern across the U.S. that would benefit the most from interventions in the transportation system to improve air quality and protect public health. Texas A&M Transportation Institute's communications team reports widespread media coverage of these findings, both nationally and internationally, in the first month of publication. This coverage creates awareness of the impact of air pollution on children's health. It also provides mapping of the U.S. counties where air pollution affects children the most. This increased awareness creates an opportunity for planners, policy makers, and vehicle manufacturers to improve technologies and support decisions to reduce vehicle emissions across the nation.



Percentage of childhood asthma incident cases attributable to NO_2 among all causes in year 2000 (top) and 2010 (bottom)

Enabling Data-Driven Transportation Safety Improvements in Rural Alaska

Grant Recipient: University of Alaska

Center Name: Center for Safety Equity in Transportation

Research Priority: Promoting Safety

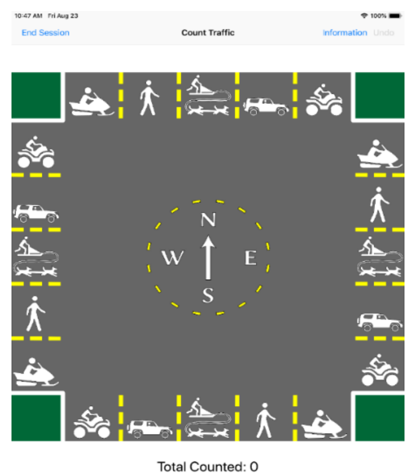
Research Project Funding: $60,000

Project End Date: December 31, 2019

Project Description: Agencies that allocate funding to transportation safety depend on roadway safety data to identify community problems and to formulate a solution. Data needed to support funding requests for transportation safety improvements including crash data and traffic volumes are often not available for small, isolated communities. The Department of Motor Vehicles (DMV)/Public Safety system, where most states store crash data, works well for roadways in developed areas. That system becomes less robust, and therefore less useful, for remote regions with low population densities and a variety of alternate transportation modes besides standard vehicles on roadways. For Alaskan communities that are not connected to the larger state road system, the DMV system may contain very limited relevant safety data. Traffic data required for many Bureau of Indian Affairs and Federal Highway Administration grants is generally not available. The goal of this project is to develop recommendations for data collection methods that will support safety-related transportation improvement in rural Alaska and implement proof-of-concept trials as appropriate. Vital to this goal is a summary of the data and data analysis needed by a funding agency to support project approval.

Outputs: One product is the University of Alaska, Fairbanks (UAF) Traffic collection app that can be installed on an Apple iPad, enabling anyone to collect traffic data. The application is an iOS application and a prototype for a data management service that processes and uploads data to a database. Alternatively, researchers rely on the Comma Separated Values format allowing the user to process the data in a spreadsheet. The user can choose up to five modes from pedestrians to all-terrain vehicles or even dog sleds. They can also enter additional information like street names or geographical position. The application handles two-, three-, and four-way intersections. The software was designed and developed in collaboration with faculty and students from the UAF Department of Computer Science and the Center for Safety Equity in Transportation in less than one year.

Outcomes/Impacts: Counting traffic at intersections is a valuable tool for communities to enable data-driven improvements. The UAF traffic app provides an easy-to-use interface tailored for the variety of vehicles present in rural Alaska. The potential for this includes offering the software for use in rural schools as part of a potential science, technology, engineering and mathematics project. The app allows rural communities to collect data required to identify problems, develop transportation plans, apply for funding requiring traffic data, and document the success of efforts as required by funding agencies.



UAF Traffic Application with icons enabled to count snowmobiles, pedestrians, dog sleds, cars, and all-terrain vehicles

Developing and Applying a Methodology to Identify Flow Generation Influences between Vessel and Truck Shipments

Grant Recipient: University of Arkansas (Lead); Texas A&M Transportation Institute

Center Name: Maritime Transportation Research and Education Center

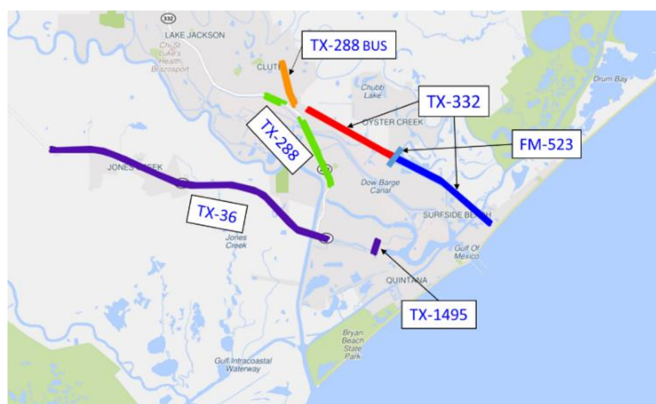
Research Priority: Preserving the Existing Transportation System

Research Project Funding: $125,420

Project End Date: March 30, 2019

Project Description: Truck activity is connected to vessel activity at a port and, in turn, vessel activity is influenced by truck shipments. Although one might expect a direct and straightforward relationship between these two types of shipments, that is rarely the case. For example, many maritime containers carry consolidated cargos that have multiple and varied final destinations. This increases container dwell times at the terminal yards and delays the impact on subsequent transportation flows. Also, different truck capacities, customs clearance, and regulations play a critical role in determining the actual relationship between these two types of shipments. This study provides a comprehensive and quantitative understanding of the relationship between maritime and truck shipments and offers system support tools for truck management that maximizes efficiency for industry.

Outputs: The study explored terminal capacity and operations, which shows high utilization of yards in terms of container inventory and their incoming and outgoing truck flow behavior. This intra-terminal truck flow is congruent with the statistical findings on truck flow changes in surrounding road segments. Therefore, the terminal capacity analysis provided additional insights into the possible causes of the "out-of-the-terminal" traffic behavior identified by the aforementioned statistical analysis. A terminal capacity analysis provided insights into the possible causes of the traffic behavior identified by the statistical analysis. The research output is in the form of coefficients representing the increments of traffic for the corresponding roadway and direction by a unit of change in import or export weights. Specifically, this analysis provides estimates of traffic changes in specific roads, with specific directions of traffic flows and the time when those changes could be expected. In addition, the terminal capacity analysis and operations provided possible causes for the traffic behavior that was observed.



Major roadway segments at Port Freeport, a deep-water port located 60 miles south of Houston, Texas

Outcomes/Impacts: This research helps to determine planning and operational measures to better manage traffic flows from and to seaports. The insights from the statistical analysis and terminal capacity analysis from the Port Freeport case study will benefit the public sector and private sector decision-makers in investment planning, resource allocation, and operations management in general.

The Impact of Driver's Mental Models of Advanced Vehicle Technologies on Safety and Performance

Grant Recipient: University of Iowa (Lead); University of Massachusetts Amherst

Center Name: Safety Research Using Simulation

Research Priority: Promoting Safety

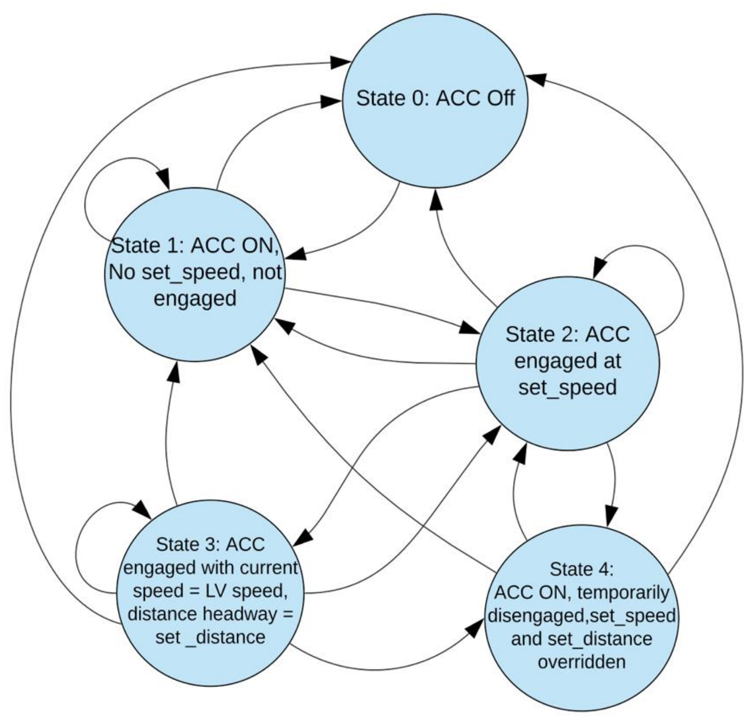
Research Project Funding: $300,000

Project End Date: December 31, 2019

Project Description: This project examined the impact of Advanced Vehicle Technologies on drivers' safety and performance by studying their mental models of such technologies. Advanced vehicle technologies offer new safety and convenience features to drivers, but in consequence, these technologies change the fundamental nature of driving. Driver knowledge and understanding of these technologies – i.e., a driver's mental model of these technologies —are critical considerations in the safe and appropriate use of these systems. To the extent that a mental model is inaccurate or insufficient, drivers might believe that their system can perform actions it cannot, or that it operates properly in conditions that, in actuality, it was not designed for. This project created a two-step process to examine this impact. First, the project developed a taxonomy of types and categories of potential user errors concerning advanced technologies and then researchers conceived of scenarios to empirically measure driver performance using these metrics. Second, researchers constructed a survey to assess drivers' mental models and used a driving simulator to assess performance. This research was further supported by a cooperative research agreement with the American Automobile Association Foundation for Traffic Safety.

Outputs: This research produced a taxonomy of error types and error categories in terms of mental models of advanced vehicle technologies/systems. Additionally, a variety of 'edge case' scenarios (i.e., scenarios that are outside of the technologies capabilities) were conceptualized for measuring drivers' performance. Mental models of drivers were evaluated using a survey developed for this project aimed at assessing the quality of a mental model, and driver performance was assessed using driving simulation approaches.

Outcomes/Impacts: This research lays the groundwork for improving transportation safety in the context of new technologies. The outcomes of this work provide for tools and knowledge that can be used to better understand the human factors aspect of introducing advanced vehicle technologies, including issues with behavioral adaptation, over-reliance, and trust and acceptance of the systems. These elements have important considerations for the design and deployment of these technologies; legislative and policy decisions; enforcement, compliance and insurance issues; and, driver training, education, and licensing.



Representative State Diagram for an Adaptive Cruise Control (ACC) System

Determination of Top of Rail Lubricity, Using Stationary and Moving Contacting and Non-Contacting Devices

Grant Recipient: University of Nevada, Las Vegas (Lead); Virginia Polytechnic Institute and State University

Center Name: University Transportation Center on Improving Rail Transportation Infrastructure Sustainability and Durability

Research Priority: Improving the Durability and Extending the Life of Transportation Infrastructure

Research Project Funding: $442,500

Project End Date: September 30, 2020

Project Description: Lubricants are dispensed from wayside applicators deployed across the rail networks operated by Class I railroads (railroads with operating revenues of $433.2 million or more). The lubricant is applied to the wheels of passing trains and carried down the track by the rolling wheels. The goal of this research is to develop an instrument capable of identifying the presence of lubricants. The research provides the railroads with a tool to determine the effectiveness of their wayside applicator placement and overall successfulness of their track lubricity programs. The U.S. railroads implement rail lubricants on their rail systems to reduce contact forces, particularly in curves. There are two different varieties of rail lubricants: Top-of-Rail (TOR) Friction Modifiers and Flange Grease. Flange grease is applied to the side or "gage corner" of the rail and is designed to lower the wear forces from wheel flange contact as much as possible. TOR is an engineered lubricant designed to modify the coefficient of friction at the top of the rail surface to an ideal value for traction and braking forces while reducing contact forces. Track Lubricity programs benefit the railroads by extending the asset life of the track and wheels as well as increasing train efficiency. The increase to train efficiency allows for lowered fuel consumption from diesel-electric locomotives and increased train tonnage. This is especially valuable today as U.S. railroads use increasingly longer trains as part of Precision Scheduled Railroading, a business model designed to optimize operating efficiency. Further development of the sensor will allow it to make qualitative assessments of "how much" lubricant is present beyond initial presence / absence evaluations.

Outputs: This project involves research of optical scattering signatures of clean and lubricated rail in both a laboratory and field setting. To do this, custom optical instruments have been developed to take lubricity measurements. Measurements of component scattered and reflected light intensities are evaluated to provide lubricity assessments. This research will produce an instrument capable of detecting the presence of track lubricants to within a micron through optical, non-contact methods on a moving platform.

Outcomes/Impacts: The resulting Rail Lubricity Instrument will provide an objective measurement of track conditions for the railroad maintenance-of-way departments. This will allow railway engineers to determine if they are failing to adequately lubricate a section of the track—hence, causing unnecessary asset wear and fuel consumption—or if they are dispensing excessive amounts of lubricant with no added benefit in reducing wheel and track wear/damage. Direct benefits will include improving safety and fuel efficiency and reducing operational costs.

Prototype Rail Lubricity Instrument during a field test on revenue service track

Forecasting Ridership for Commuter Rail in Austin

Grant Recipient: University of North Carolina, Charlotte (Lead), The University of Texas at Austin

Center Name: Center for Advanced Multimodal Mobility Solutions and Education

Research Priority: Improving Mobility of People and Goods

Research Project Funding: $140,000

Project End Date: September 30, 2018

Project Description: Austin Texas is one of the most rapidly growing cities in the United States. Current estimates indicate over 150 people per day are moving to Austin. To deal with the growing transportation needs, Capital Metro, Austin's regional public transportation provider, is proposing the addition of commuter rail services in several corridors where the rail right of way is already dedicated for public use. Forecasting ridership for such services is problematic due to a lack of knowledge on how people typically access public transit (walk, bike, drive, drop-off) and how the transport systems work (travel times, reliability) in a rapidly growing city. The research team has developed a dynamic traffic assignment algorithm for such problems; however, it currently estimates time and cost of access in very rudimentary ways. The goal of this study was to examine the influence of access modes from a commuter's decision-making process while understanding the characterization at each boarding station. An onboard survey was deployed on Capital Metro's MetroRail Red Line, revealing access mode patterns and trip purposes for each train station. Then, a binomial logit model was developed to estimate whether a rider may choose to access the Red Line by walking or driving to the station. The binomial logit was used because this model only considers two possible outcomes walking or driving (i.e. not walking). This study illustrates a case involving a 32-mile stretch of rail and nine stations where we model the commuters' decision-making process and future trips relating preferences in travel. Whether train passengers decided to walk, bike, ride a bus, or drive to a park-and-ride facility, data collected based on distances and choice of access mode lead to generalizations of individual trip preferences.

The Capital Metro Red Line, a 32-mile long rail line, Austin, TX

Outputs: This work has developed robust predictive tools for assessing modes used for accessing the proposed commuter rail systems and a database containing 1,203 survey responses collected over three consecutive days. The results of the revealed preference survey data were collected from commuter rail riders and were used to build a binomial logit model predicting walk versus drive access modes. The binomial logit model predicts commuter rail riders' access mode to their boarding station in Austin, TX. The model uses access distance, boarding station, trip purpose, and household vehicle ownership as access mode predictors.

Outcomes/Impacts: This research has contributed to the development of better travel demand models and better travel estimation tools so that the feasibility of commuter rail services in this growing area can be more accurately measured. The model specified in this research could be expanded to include other access modes, such as biking or riding the bus, in addition to walking and driving to the station. The same modeling approach used for access mode in this research could be applied to riders' egress trip mode choice as well.

Union Rides: Harnessing the Shared Value of Commute Travel

Grant Recipient: University of Texas, Arlington (Lead); University of Wisconsin - Madison

Center Name: Center for Transportation Equity, Decisions and Dollar

Research Priority: Preserving the Existing Transportation System

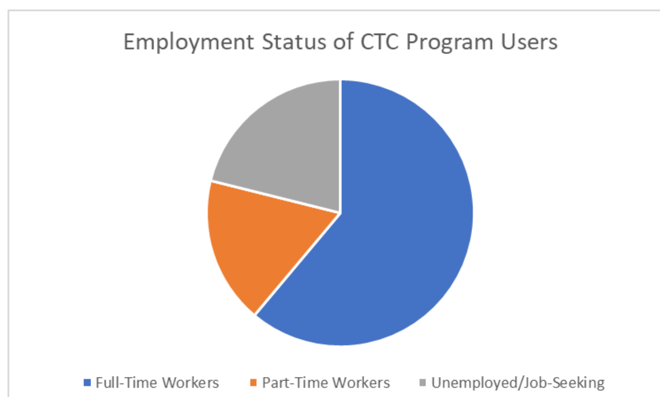
Funding: $106,368

Project End Date: October 31, 2019

Project Description: This project seeks to improve job access and economic policy outcomes for a public-private partnership in Dane County, Wisconsin. The State of Wisconsin has partnered with Union Cab – the largest taxi operator in Madison – to provide an affordable shared-ride taxi service linking unemployed and low-wage workers with area jobs. The partners are now engaged in a pilot project called "Commute to Careers," (CTC) aimed at ultimately linking up to 200 area workers with approximately 25-30 area employers, representing roughly 2,000 work-related trips each month. A researcher at the University of Wisconsin-Madison is leading the analysis and evaluating the program's operations, community outreach, costs, and productivity as a means of advancing economic opportunity in Dane County, Wisconsin. This project has yielded rich data on how these partnerships can help vulnerable workers overcome mobility gaps and secure long-term employment. Their results, when shared with community partners and a national audience of practitioners, will greatly help communities to understand what they can do to efficiently and inclusively link quality job opportunities with the nearby pool of workers.

Outputs: This project generated a series of practitioner-oriented products designed to improve the performance of these programs. The team has developed an evaluation report for their local partners, documenting the successes of the program. Researchers have also generated a final report based on these findings. In addition, researchers developed a service delivery manual for service providers and local governments, detailing the various costs, benefits, and recommended plans of action for community members seeking to launch or improve a workforce transportation program.

Outcomes/Impacts: As of the summer of 2019, the pilot project was serving 81 unique riders and providing just over 2,000 rides per month. Nearly 60% of riders were female, and just over half of riders reported an income of $10,000 or less. Also, 68% of riders use this program as their sole means of work transportation, and would otherwise be unable to reach their place of employment. Nineteen percent of CTC riders were unemployed, and used the program to reach job interviews that otherwise would have been impossible but for the Program. The CTC Program remains in operation, and its continued strength in linking vulnerable workers to permanent employment is generating useful techniques for peer agencies nationwide.



Creating a Framework to Determine Purpose and Need for Increased Travel Options in the Megaregion for Vulnerable Non-Urban Communities

Grant Recipient: University of Texas, Austin (Lead), Texas Southern University

Center Name: Cooperative Mobility for Competitive Megaregions

Research Priority: Improving Mobility of People and Goods

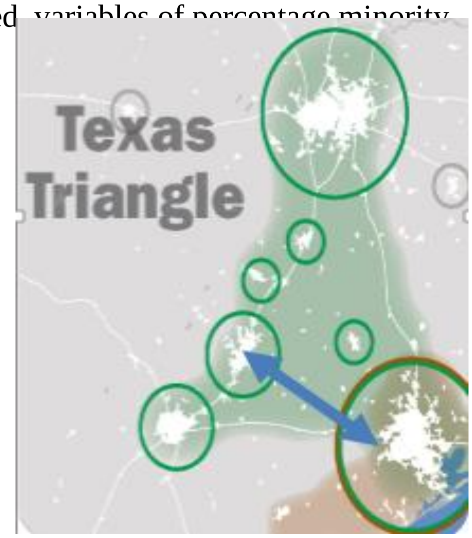
Funding: $100,581

Project End Date: February 28, 2019

Project Description: This case study examines a corridor that links Houston and Austin in the Texas Triangle Megaregion of Houston, Dallas, and Austin/San Antonio. The focus is the areas in between the boundaries – the interstices. Low income residents of rural and low-density counties find it challenging to travel to anchor cities' metropolitan areas where opportunities are greater for work, physicians and hospitals, shopping, recreation or other needs. For instance, over the last decade, the unemployment rate has been higher in the interstice counties proximate to megaregion anchor counties; in some years the rate was as little as 5% higher, but other years as much as 20% higher. Projections do not reflect a change in these trends. As the megaregions' anchors strengthen, the already vulnerable interstice community residents are at risk of being further disadvantaged. Environmental Justice considerations use characteristics such as poverty, ethnicity, English speaking and female headed households to indicate vulnerability and identify those at risk for being disenfranchised. The *Framework to Determine Purpose and Need for Increased Travel Options* designs an equity rubric to be used by transportation planners in decision making. The rubric is a method that begins with traditional environmental justice characteristics. To these characteristics, the rubric calculation adds the percentage of income spent on transportation by the vulnerable population compared to their county's mean.

Outputs: The study determines whether there is a need for public transit in the six counties along the US 290 corridor connecting Houston and Austin. Currently, public transit service is available for three contiguous counties that are near Austin. Public transportation service does not exist for the three counties in the middle or close to Houston. Data show 34 block groups with poverty levels higher than the Texas mean (15.9%). Residents in these areas spend a higher percentage of their income on transportation than their county or state counterparts. The research team developSed a Composite Vulnerability Index (CVI) that provides a rank value for vulnerable populations. After the county's vulnerability is determined, variables of percentage minority, female head of household, senior residents and auto ownership are collected by block group and compared to the individual county mean for each variable. Next, researchers calculated the percent of income spent on transportation for each block group. Each variable is individually indexed; thereafter, a mean index value is calculated, the CVI. The CVI is designed to supplement project evaluation criteria that transportation planners use to establish the priority among potential projects.

Outcomes/Impacts: The CVI documents the vulnerability of low income rural and low-density populations and shows their need for public transportation. Planners and transportation professionals can use the index when competing for public transit projects for these communities. Specifically, the CVI will facilitate implementation of projects that will improve linkages for US 290 corridor interstice residents to the employment, educational, health and other opportunities available in the anchor counties.



Texas Triangle and US 290 Corridor – Clockwise, Dallas, Houston, Austin/San Antonio

2013–2018 PROGRAM-WIDE PERFORMANCE INDICATORS

Section 5505(b)(4)(B)(viii) of 49 U.S.C. as amended by FAST Act specifies performance metrics should be used in assessing the performance of the recipient in meeting the stated research, technology transfer, education and outreach goals. UTC Program-wide performance indicators are used to measure productivity at individual UTCs and for the UTC Program as a whole. They are not intended to be used to compare UTCs, as each center has a unique combination of attributes that make exact comparisons impossible.

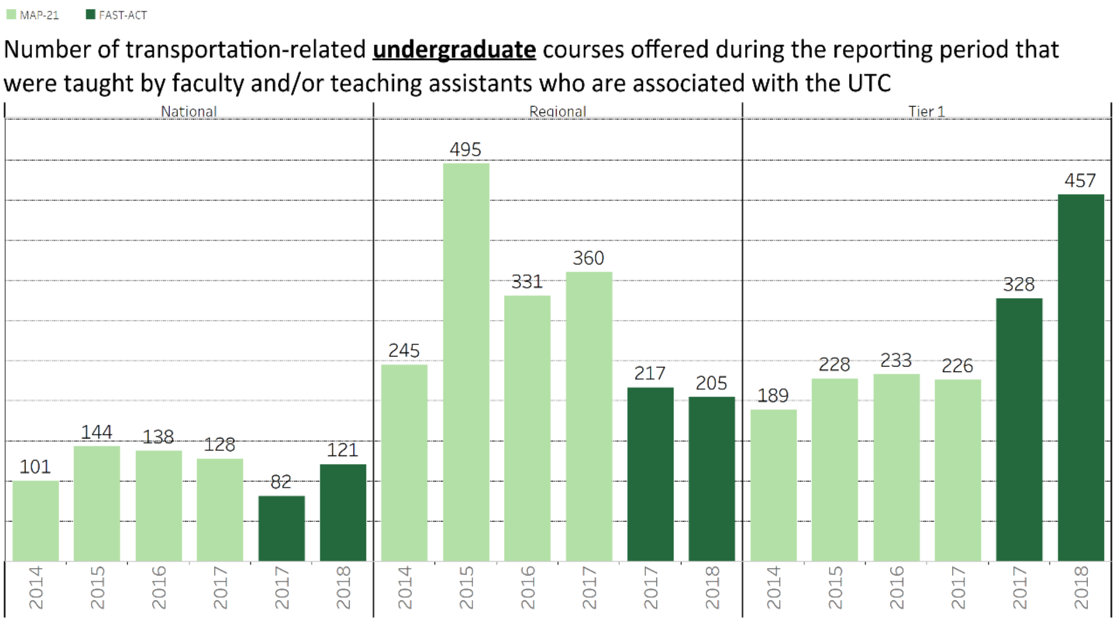
This section provides a high-level summary of six program-wide indicators (course, students, degree programs, students supported, degrees awarded, and research) developed by USDOT in conjunction with the universities for four years of Moving Ahead for Progress in the 21st Century (MAP-21) and the first two years of the FAST Act grants covering a total of five years with UTC Program MAP-21 grants overlapping with the first-year FAST Act grants. Performance indicators 1 through 5 present data on education and workforce development measures while performance indicator 6 measures research and technology.

Grant recipients must submit program-wide indicators for the prior reporting year and include the indicators for each consortium member. Due to performance indicator deliverable due dates, the 2020 UTC Report to Congress will include the third-year performance indicator data. USDOT re-competed Regions 1, 2, and 3, due to a lack of meritorious candidates in the initial FAST Act grant competition. The final three UTCs were awarded in June 2018. The 2020 UTC Report to Congress will contain performance indicators for the three regional FAST Act grant recipients covering their first reporting period of June 5, 2018 to September 30, 2019. Additionally, performance indicators for two new National UTCs funded through the Consolidated Appropriations Act of 2018 will get reported in the 2020 UTC Report to Congress. These two new National UTCs were not awarded funding until July 1, 2019.

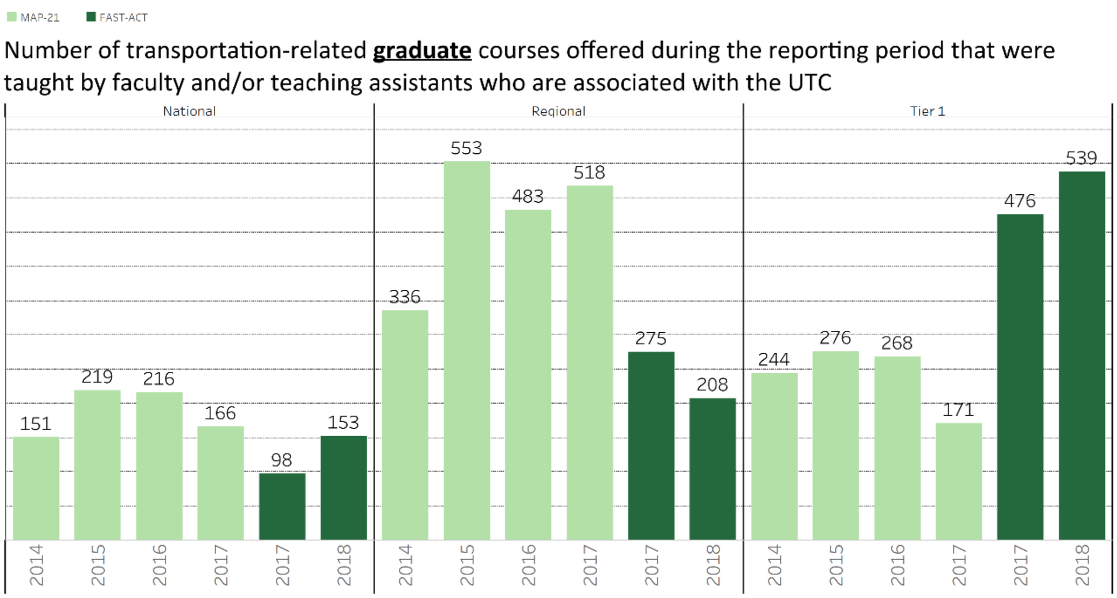
Courses

Transportation-related courses offered: Undergraduate and Graduate Levels
The first indicator measures transportation-related courses offered during the 2013-2018 reporting period and taught by faculty and/or teaching assistants who were associated with the UTC. There are two sub-categories: undergraduate and graduate. As shown on the charts below, the UTCs are offering a significant number of undergraduate and graduate-level courses relevant to transportation to students seeking advanced degrees. Undergraduate and graduate transportation-related courses cover topics including, but not limited to, traffic impact assessment, transit design, freight transportation systems, advanced materials testing, highway bridge design, transportation engineering, and computer science and information science courses related to transportation.

Undergraduate Courses



Graduate Courses

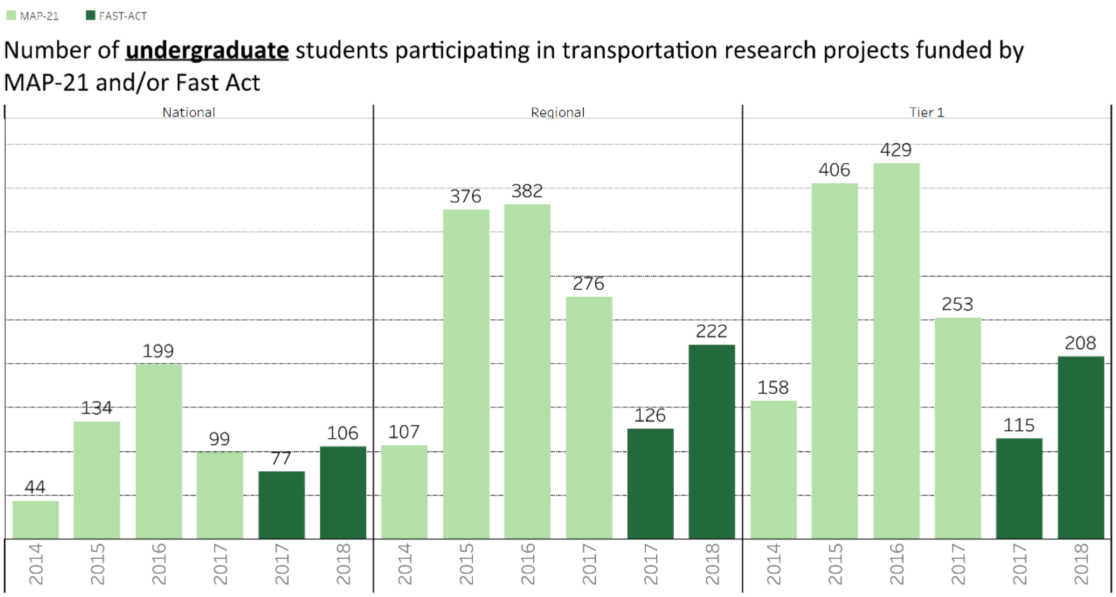


Students

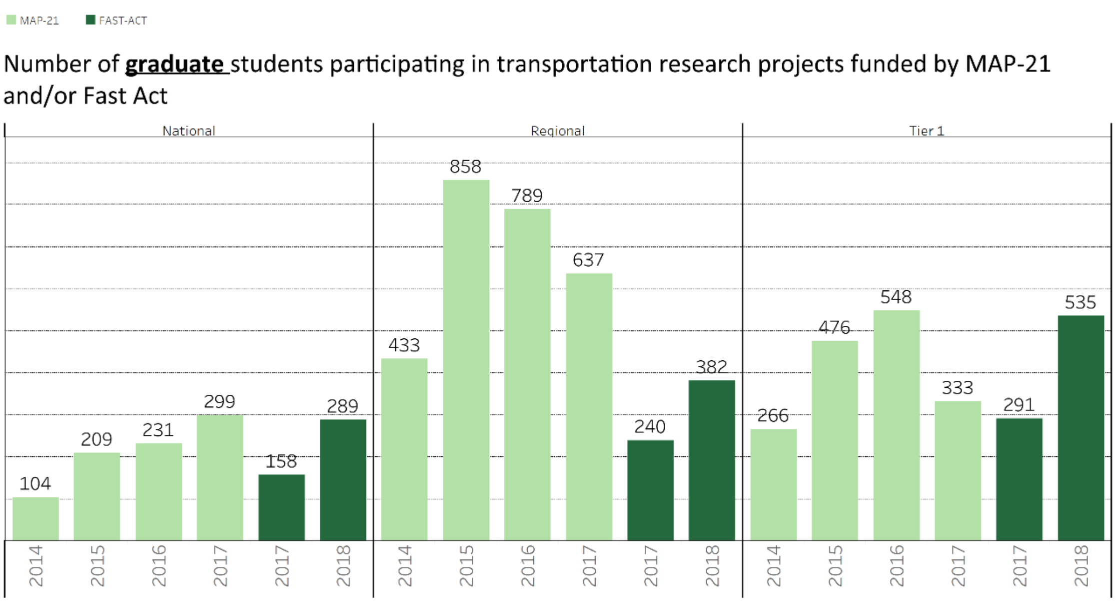
Students doing transportation research projects

The second indicator measures the involvement or participation of undergraduate and graduate students in transportation research projects funded by the grant during the 2013 -2018 reporting periods. All levels of UTCs supported both undergraduate and graduate students. During years two and three, MAP-21 regional and Tier 1 UTCs have more universities participating in the program and they supported more than 375 undergraduate and graduate students. MAP-21 regional UTCs supported a significant number, more than 750 graduate students involved or participating in transportation research projects during years two and three.

Undergraduate



Graduate

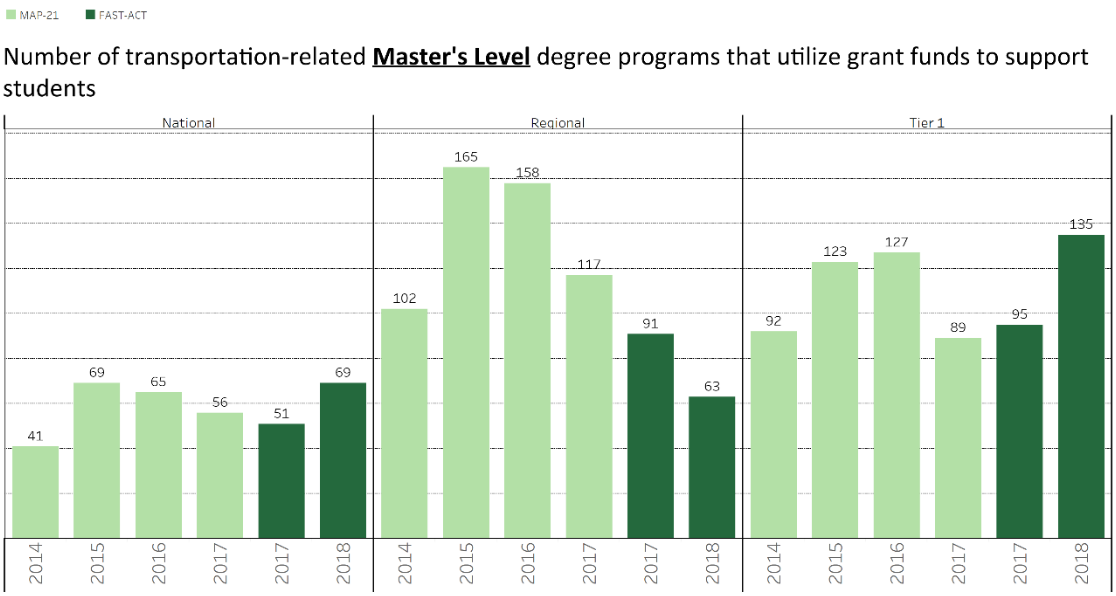


Degree Programs

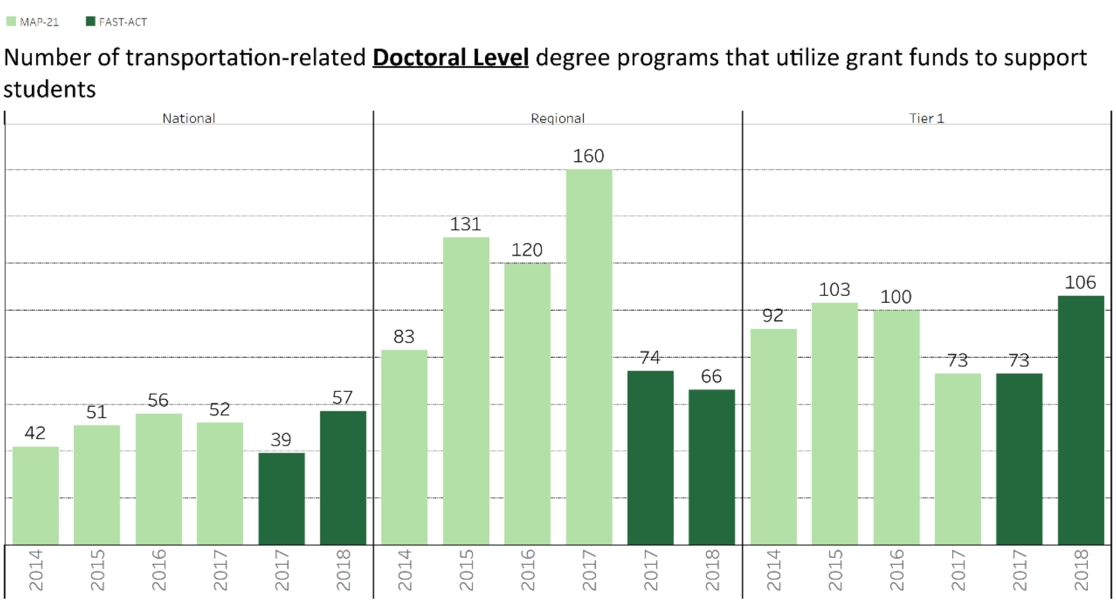
Transportation-related advanced degree programs

The third indicator measures the number of transportation-related advanced degree programs that used grant funds (UTC Federal funds and/or match) during the 2013–2018 reporting period to support graduate students. All UTCs supported graduate students pursuing transportation advanced degrees. Similar to last year's report, the number of master's degree students supported by grant funding is slightly higher than doctoral students.

Master's



Doctoral

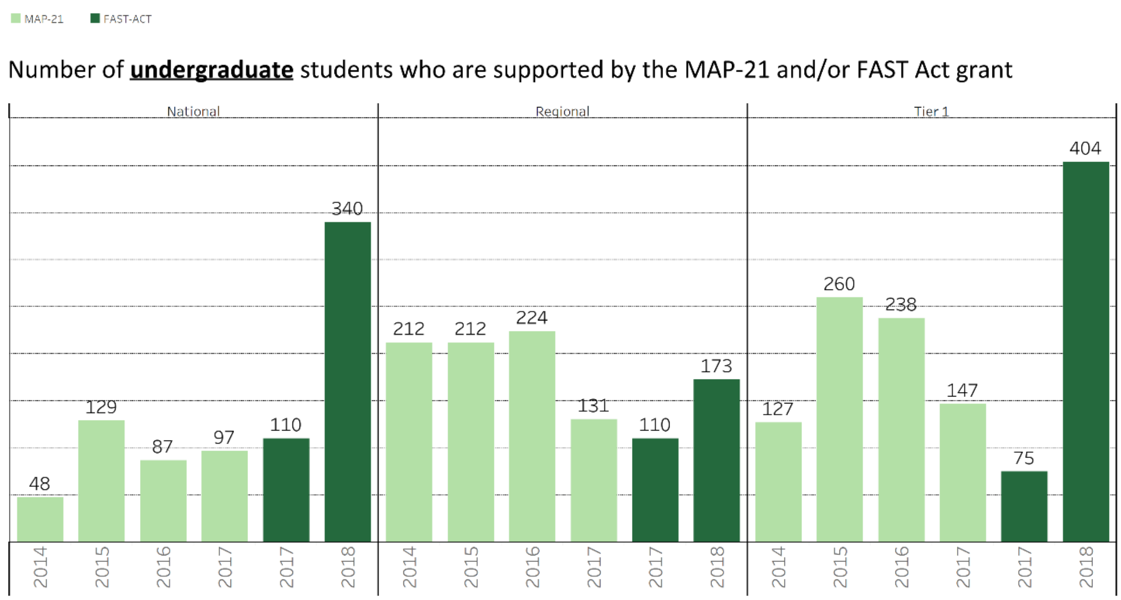


Students Supported

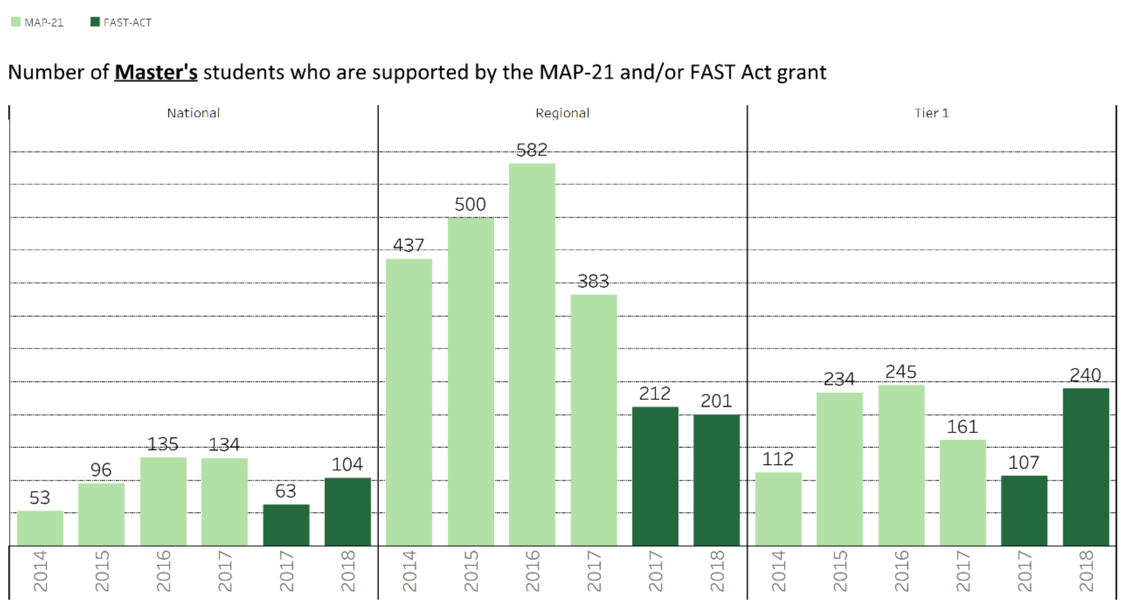
Total students supported

The fourth indicator measures the total number of students supported by grant funding including undergraduate, master's and doctoral students during the 2013 – 2018 reporting period. Here, the UTCs are reporting the number of students who received financial support from Federal funds and/or match in the form of tuition relief, wages or stipend. Overall, undergraduate and graduate students were supported by both MAP-21 and FAST Act grants. UTCs grant funds supported more students pursuing master's degrees followed by doctorate students. FAST Act National and Tier 1 UTCs numbers for undergraduate students show a significant increase in 2018 compared to previous years.

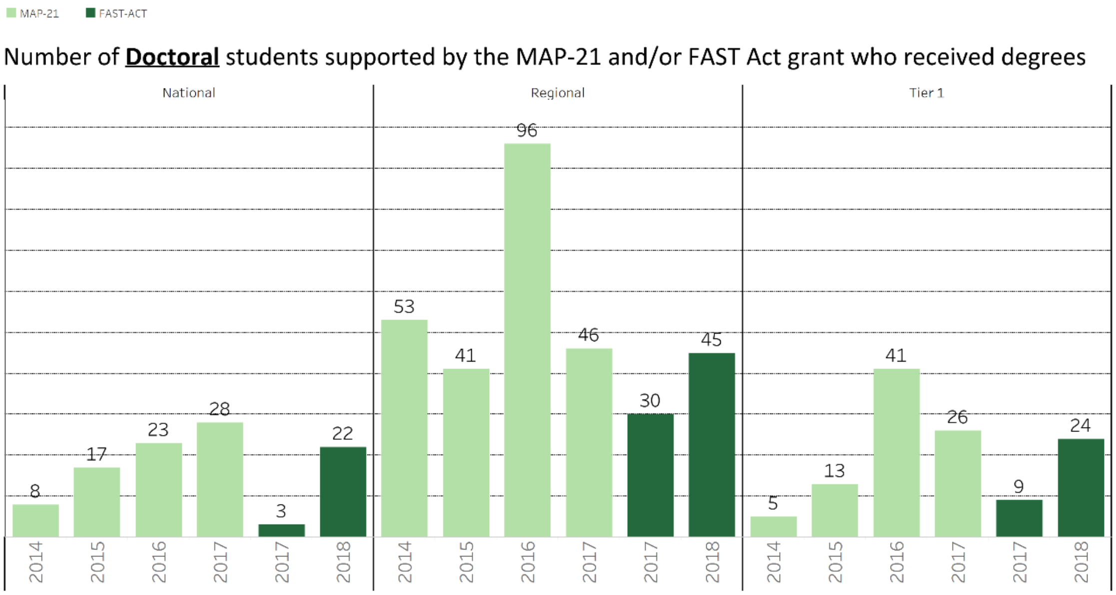
Undergraduate



Master's



Doctoral

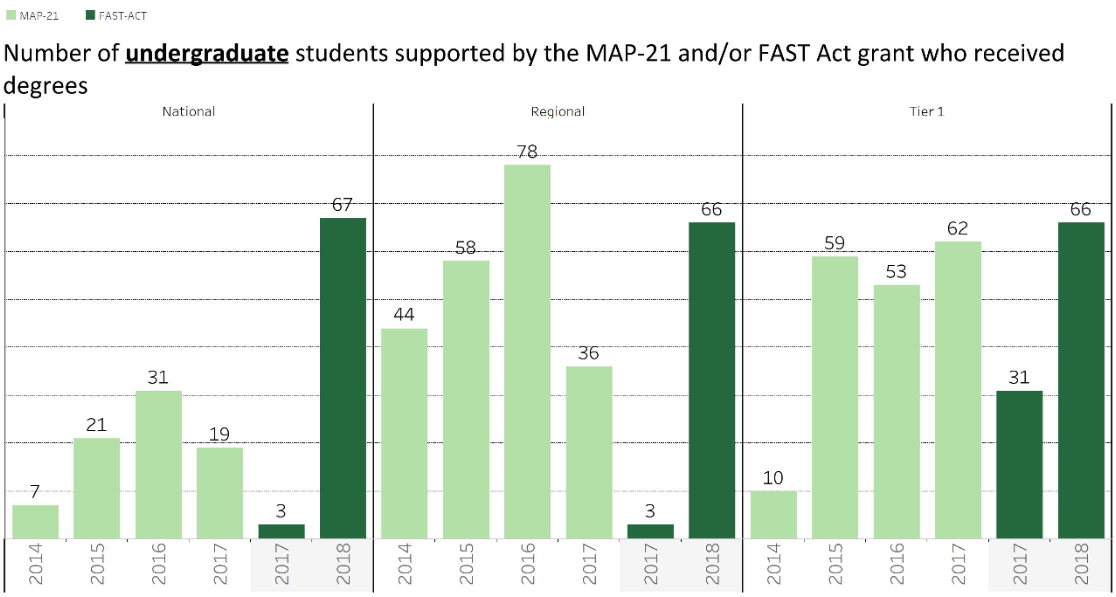

MAP-21
FAST-ACT
Number of Doctoral students supported by the MAP-21 and/or FAST Act grant who received degrees
National
Regional
Tier 1
8
17
23
28
3
22
53
41
96
46
30
45
5
13
41
26
9
24
2014
2015
2016
2017
2017
2018
2014
2015
2016
2017
2017
2018
2014
2015
2016
2017
2017
2018

Degrees Awarded

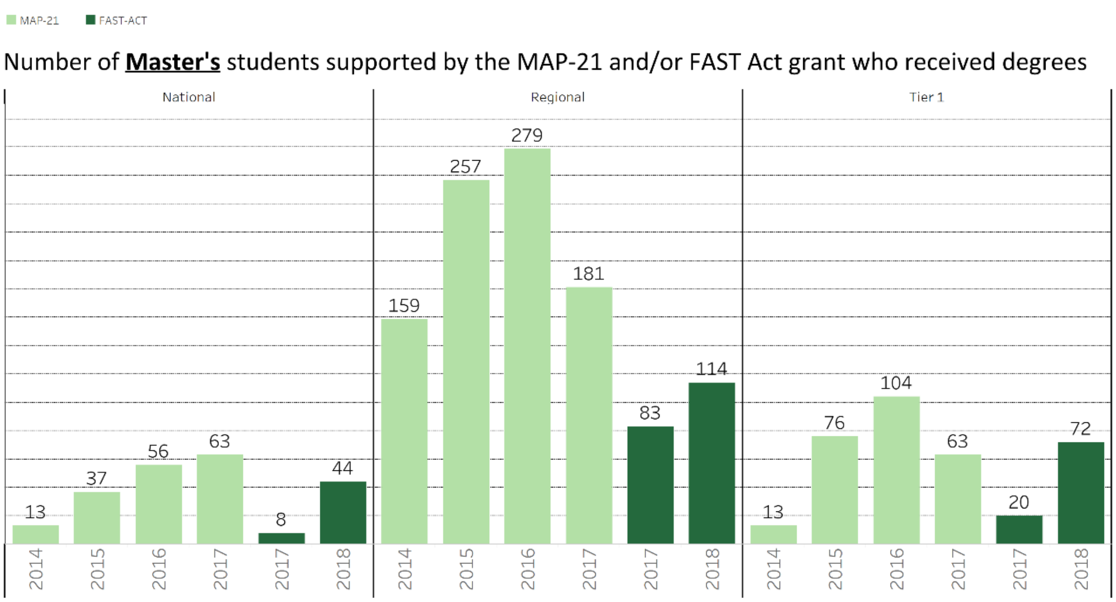
Student receiving degrees

The fifth indicator measures the number of undergraduate, master's, and doctoral students who received financial support from UTC Federal funds and/or match during all or any part of their studies AND received their degrees during the 2013 - 2018 reporting period. The number of undergraduate, graduate and doctoral students supported by the grant is slightly lower than normal. Regional UTCs supported a significant number of master's degree students in years 2015 totaling 257 and 279 in 2016. All students supported by the FAST Act grant showed an increase the last two years.

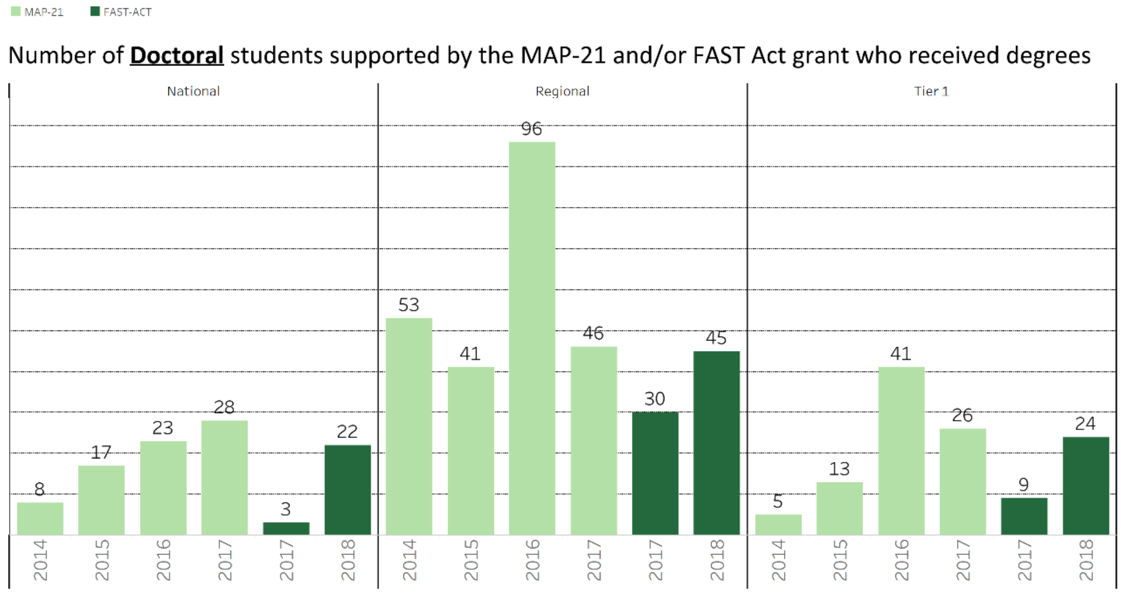
Undergraduate



Master's



Doctoral



MAP-21
FAST-ACT
Number of Doctoral students supported by the MAP-21 and/or FAST Act grant who received degrees
National
Regional
Tier 1
8
17
23
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3
22
53
41
96
46
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45
5
13
41
26
9
24
2014
2015
2016
2017
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2015
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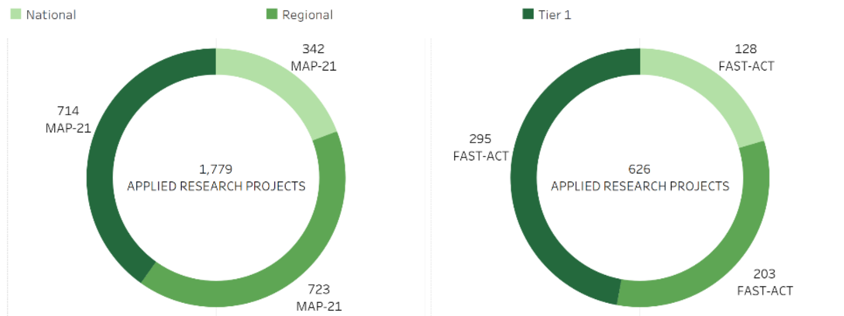
2017
2017
2018

Research

Applied and advanced research projects

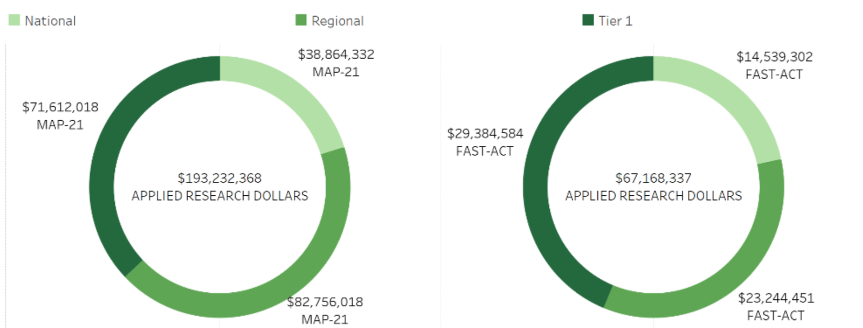
The sixth and final performance indicator measures the number of applied and advanced research projects selected for funding using grant funds during the 2013-2018 reporting period. This indicator has two parts: 1) applied research projects and budget, and 2) advanced research projects and budget. MAP-21 and FAST Act UTCs funded a total of 2,405 applied research projects over the course of five years (October 2013 to October 2018). The amount of funding spent over the course of five years for applied research projects totals approximately $260 million.

Applied (#)



Number of **Applied research** projects selected for funding using UTC grant funds (Federal and/or Recipient share) that you consider to be applied research

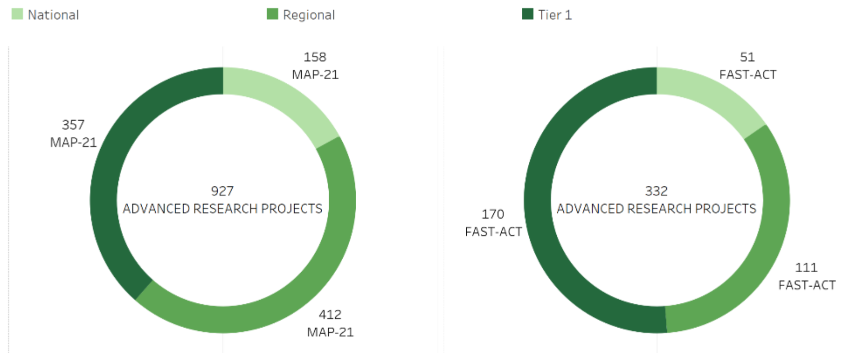
Applied ($)



Total dollar value of **Applied research** projects selected for funding using UTC grant funds (Federal and/or Recipient share) that you consider to be applied research

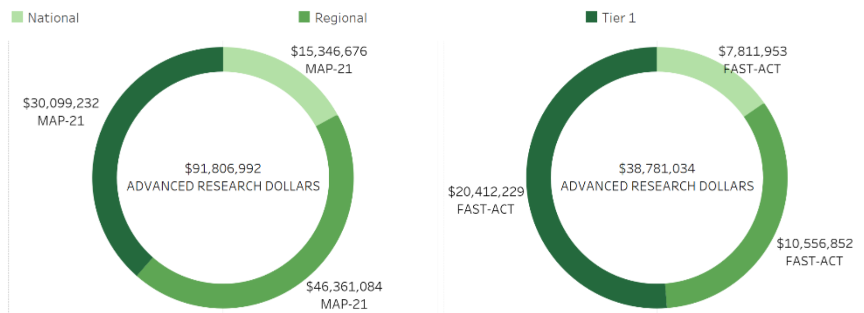
UTCs funded a total of 1,259 advanced research projects over the course of five years. The dollar value for 1,259 advanced research projects selected for funding over the past five years totaled approximately $131 million (actual total $130,588,026).

Advanced (#)



Number **Advanced research** projects selected for funding using UTC grant funds (Federal and/or Recipient share) that you consider to be advanced research

Advanced ($)



Total dollar value of **Advanced research** projects selected for funding using UTC grant funds (Federal and/or Recipient share) that you consider to be advanced research

NOTE: This report is a second in a series of annual reports as required by Section 5505(d)(2) of 49 United States Code as amended by the FAST Act.

UTC SUBMISSIONS IN TRANSPORTATION RESEARCH BOARD DATABASES

A legislative requirement in Section 6016 the FAST Act requires the UTC Program to "*disseminate the results of that research through the establishment and operation of a publicly accessible online information clearinghouse.*" OST-R, which administers the UTC program, has contracted with the National Academy of Sciences, Transportation Research Board (TRB) since 2006 to launch and operate a clearinghouse of UTC final research reports and research that is in progress. The UTC clearinghouse was established using TRB's Transportation Research Information Services (TRIS) database (now called TRID) and RiP database to meet the legislative mandate to establish and operate a clearinghouse for UTC transportation research. The clearinghouse also assists in addressing OST-R's responsibility to coordinate all research across USDOT.

Both TRID and RiP, which contain more than one million records of published and ongoing research, are publicly searchable databases currently used by national and international transportation researchers and stakeholders, state and local DOTs, USDOT, and other Federal agencies, the general public, and others. TRID is an integrated database that combines the records from TRB's TRIS database and the Organization for Economic Cooperation and Development Joint Transport Research Centre's International TRID database. TRID provides access to more than 1.2 million records of transportation research worldwide. The RiP database contains information on more than 12,000 current or recently completed transportation research projects.

Table 2 on the following page provides data on the number of UTC submissions to RiP and TRID databases listed by the National, Regional and Tier 1 UTCs and categorized by FAST Act and MAP-21 grant recipient.

Table 4. UTC Submissions to RiP and TRID Databases

MAP-21 (2013) and FAST ACT (2016) GRANT RECIPIENTS ONLY	
UTC submissions into RiP and TRID beginning 1/1/13 and ending 9/29/19	
MAP-21 Grant recipients Total 3,446 • National UTCS 857 • Regional UTCS 1,450 • Tier 1 UTCS 1,139	*FAST Act Grant recipients 2,759* • National UTCS 599 • Regional UTCS 1,238 • Tier 1 UTCS 922
UTC submissions into RIP only beginning 1/1/13 and ending 9/29/19	
MAP-21 Grant recipients Total 1,573 • National UTCS 351 • Regional UTCS 716 • Tier 1 UTCS 506	*FAST Act Grant recipients 1,571* • National UTCS 335 • Regional UTCS 651 • Tier 1 UTCS 585
UTC submissions into TRID only beginning 1/1/13 and ending 9/29/19	
MAP-21 Grant recipients Total 1,873 • National UTCS 506 • Regional UTCS 734 • Tier 1 UTCS 633	*FAST Act Grant recipients 1,188* • National UTCS 264 • Regional UTCS 587 • Tier 1 UTCS 337
Number of submissions for the year only into RiP and TRID (9/30/18 – 9/29/19)	
MAP-21 Grant recipients Total 752 • National UTCS 225 • Regional UTCS 278 • Tier 1 UTCS 249	*FAST Act Grant recipients 1.052* • National UTCS 225 • Regional UTCS 366 • Tier 1 UTCS 461
Number of submissions for the year only into RiP (9/30/18 – 9/29/19)	
MAP-21 Grant recipients Total 305 • National UTCS 128 • Regional UTCS 89 • Tier 1 UTCS 88	*FAST Act Grant recipients 662* • National UTCS 148 • Regional UTCS 218 • Tier 1 UTCS 296
Number of submissions for the year only into TRID (9/30/18 – 9/29/19)	
MAP-21 Grant recipients Total 444 • National UTCS 97 • Regional UTCS 186 • Tier 1 UTCS 161	*FAST Act Grant recipients 390* • National UTCS 77 • Regional UTCS 148 • Tier 1 UTCS 165

APPENDIX A - REPORTING REQUIREMENTS

Annual Reviews

The Fixing America's Surface Transportation Act, which authorized funding for the current UTC program, requires a periodic review and evaluation of the UTC grant program. Section 5505(d)(2) of 49 U.S.C. as amended by the FAST Act specifies:

> "*Annual review and evaluation. Not less frequently than annually, and consistent with the plan developed under section 6503, the Secretary shall –*
>
> *(A) review and evaluate the programs carried out under this section by grant recipients; and*
>
> *(B) submit to the Committees on Transportation and Infrastructure and Science, Space, and Technology of the House of Representatives and the Committees on Environment and Public Works and Commerce, Science and Transportation of the Senate, a report describing that review and evaluation*."

APPENDIX B - LEGISLATIVE BACKGROUND

The Moving Ahead for Progress in the 21st Century Act (MAP-21) authorized funding for up to 35 centers, and OST-R established a detailed, transparent process for the competitive proposal solicitation, evaluation, and grant recipient selection. Applicants for grant funding were required to demonstrate a commitment to broadening participation and attracting new entrants to the transportation field to enhance diversity. They were also asked to describe planned outreach or activities designed to increase interest in science, technology, engineering, and mathematics disciplines, and raise awareness of transportation careers among underrepresented groups including women and minorities. Minority institutions whose enrollment of a single minority or a combination of minorities exceeds 50 percent of the total enrollment were encouraged to apply as the lead institution for a center or to be part of a consortium as an institution of higher education.

The FAST Act's authorization of the UTC Program not only sustains existing research. It also establishes vital new initiatives in research, education and workforce development and technology transfer that have benefited the U.S. transportation system over the years. The FAST Act authorized funding for up to 35 Centers and emphasized accelerating and better-coordinating research and innovation across multimodal systems. The FAST Act required establishing six research priorities supporting departmental goals and fostered broad cross-modal research. One of the ten regional awards must be given to a center focusing on the fields of comprehensive transportation safety, congestion, CVs, connected infrastructure, and AVs.

Additional funding for two new Centers was provided through the Consolidated Appropriations Act of 2018 (P.L. 115-141), in the areas of congestion relief research, and improving the durability and extending the life of transportation infrastructure research. The UTC Program now has a total of 37 Centers.

APPENDIX C - LIST OF ACRONYMS

aRat	Automated Remix access tool
ABC	Accelerated Bridge Construction
ACC	Adaptive Cruise Control
AMI	Area Median Income
AV	Autonomous Vehicles
C2SMART	Connected Cities for Smart Mobility towards Accessible and Resilient Transportation
CAV	Connected and Autonomous Vehicles
CCAT	Center for Connected and Automated Transportation
CCF	California Community Foundation
CSCRS	Collaborative Sciences Center for Road Safety
CTC	Commute to Careers
CU-CVT	Clemson University Connected Vehicle Testbed
CV	Connected Vehicles
CV2X	Cellular Vehicle-to-Everything
CVI	Composite Vulnerability Index
DSRC	Dedicated Short-Range Communication
DMV	Department of Motor Vehicles
ECC	Engineered Cementitious Composites
FAST	Fixing America's Surface Transportation Act
FBC	Fluidized Bed Combustion
FE	Finite Element
GPS	Global Positioning System
GTFS	General Transit Feed Specification
LAX	Los Angeles International Airport
MAC	Media Access Control
MaineDOT	Maine Department of Transportation
MAP-21	Moving Ahead for Progress in the 21st Century
MEPDG	Mechanistic-Empirical Pavement Design Guide
MPC	Mountain-Plains Consortium
MUST	Mobile Unit for Sensing Traffic
NPRA	Norwegian Public Roads Administration
O-D	Origin - Destination

OST-R	Office of the Assistant Secretary for Research and Technology
PEMDs	Personal Electric Mobility Devices
PFEA	Proxy Finite-Element Analysis
R&D	Research and Development
RiP	Research in Progress
SCM	Supplementary Cementitious Materials
STAR	Smart Transportation Application and Research
T2	Technology Transfer
THEA	Tampa-Hillsborough Expressway Authority
TOMNET	Center for Teaching Old Models New Tricks
TOR	Top-of-Rail
TRAP	Traffic-Related Air Pollution
TRB	Transportation Research Board
TRID	Transportation Research International Documentation
TRIS	Transportation Research Information Services
TTI	Texas A&M Transportation Institute
TWT	Thin Whitetoppings
UAF	University of Alaska, Fairbanks
UAV	Unmanned Aerial Vehicle
UHPC	Ultra-High Performance Concrete
USDOT	United States Department of Transportation
USF	University of South Florida
UTC	University Transportation Centers
UTW	Ultrathin Whitetoppings
V2V	Vehicle-to-Vehicle
VR	Virtual Reality
WYDOT	Wyoming Department of Transportation