Mobility21

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Synthesis of Research Results and Technology Trends to Inform Policies for Smart Mobility of People and Goods

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FINAL RESEARCH REPORT

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DISCLAIMER

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Mobility 21 UTC Project #204
Final Research Report
August 29, 2019

Project Details:

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Chris Hendrickson, Co-PI **https://orcid.org/0000-0002-9812-3580**

Period of Performance July 1, 2018 through July 31, 2019

Federal Funding: $90,000

Research Description
Carnegie Mellon and its University Transportation Center partner institutions (Community College of Allegheny County, The Ohio State University, and the University of Pennsylvania) have a variety of research projects underway or completed on a diverse set of topics. Individual researchers publish research results and transfer technology for their individual projects.
This research project is intended to track disruptive technologies impacting transportation, assess a variety of policy alternatives and to synthesis research results from the full range of CMU and partner research efforts to inform smart mobility policy. It is also intended to identify new research opportunities for smart mobility work.

Personnel
The project involves effort by Stan Caldwell and Chris Hendrickson:

- Stan Caldwell is an Adjunct Associate Professor for Transportation and Policy and serves as Executive Director of Carnegie Mellon's Traffic21 Institute which is housed in the Heinz College and Executive Director of the Technologies for Safe and Efficient Transportation and Mobility21 National University Transportation Centers (UTCs) which are housed in the College of Engineering. Both Traffic21 and the UTCs are co-housed and co-staffed, and Stan manages the day-to-day operations of the three research centers. These centers fund and coordinate faculty from across the University in interdisciplinary transportation research. The research centers maintain a primary focus on deploying transportation research and technology in the community and work with public and private partners to use Pittsburgh, Pennsylvania, and the region as a smart transportation test bed. Through the work of these centers Stan has taken a nationally active role in the emerging intelligent transportation industry and serves on the Leadership Circle of the Intelligent Transportation Society of America and developed the industry recognized Traffic21 Blog. He is also on the Executive Committee of the Council of University Transportation Centers, founding member of the Smart Belt Coalition and member of the Pennsylvania Autonomous Vehicle Policy Tasks Force.
- Chris Hendrickson is the Hamerschlag University Professor Emeritus, Director of the Traffic 21 Institute at Carnegie Mellon University, member of the National Academy of Engineering and Editor-in-Chief of the ASCE Journal of Transportation Engineering. His research, teaching and consulting are in the general area of engineering planning and management, including design for the environment, system performance, construction project management, finance and computer applications.

Expected Impacts
This project is intended to influence transportation decision making and policies with regard to new technology implementation and the improvement in mobility of people and goods both in Pennsylvania and nationally. Progress is assessed from activities such as meetings, presentations and publications as well as policy changes, technology implementations and new research projects.

Matching Funds
The Traffic21 sponsored Smart Mobility Challenge is a direct complement to this research activity and the Hillman Foundation funding for the challenge can be used as matching funds.
Carnegie Mellon University's Traffic21 Institute and its affiliated US DOT National University Transportation Center for Mobility, Mobility21, are sponsoring a challenge to demonstrate how innovative technology can improve mobility using southwestern Pennsylvania as a test bed.
This challenge is inspired by Traffic21's years of successful collaboration with the City of Pittsburgh to become a globally recognized smart city test bed and the desire to demonstrate how suburban and rural communities can also benefit from innovative transportation.

Data Management Plan
This project does not involve extensive data resources. The primary data involves text and presentation. These documents will be managed and updated in accordance with overall Mobility21 center data management plan.

Problem
New disruptive technologies such as vehicle automation, connected vehicles, alternative fuels and data analytics are rapidly developing and impacting society in both positive and negative ways. State and local officials along with community organizations are challenged by a lack of technical capacity and information to assess these disruptive technologies and develop policies to manage these disruptive transportation technologies. Effective public policies have the potential to apply new technology to improve safety and efficiency of transportation systems and these policies can also mitigate unintended consequences of disruptive technology.

Approach
Carnegie Mellon University's Traffic21 Institute and Mobility21 National University Transportation Center have developed a proven model of Research, Development and Deployment through community partnership. Traffic21 and Mobility21 maintain a Deployment Partner Consortium of over 100 public, private and non-profit members who collaborate with researchers to identify real-world transportation needs.

Consortium
- 412 Food Rescue
- Allegheny General Hospital
- American Association of Retired Persons (AARP)
- American Association of State Highway and Transportation Officials (AASHTO)
- Access Transportation Systems
- Airport Corridor Transportation Association
- Alliance for Transportation Working in Communities
- Architecture, Engineering, Consulting, Operations, and Maintenance (AECOM)
- ALCO Parking
- Allegheny Conference on Community Development
- Allegheny County
- Allegheny County Airport Authority
- Allegheny County Office of Children, Youth and Families
- American Public Transportation Association (APTA)
- Aurora Innovation
- Automatic Labs (a SiriusXM company)
- Babst Calland Law Firm
- Bentley Systems
- Bike Pittsburgh

- Bombardier
- Booz Allen Hamilton
- Bosch Research and Technology Center, North America
- The Breathe Project
- Caterpillar
- Children's Hospital of Philadelphia
- Cisco
- City of Philadelphia
- City of Pittsburgh
- Comcast
- Community College of Allegheny County (CCAC)
- Conference of Minority Transportation Officials (COMTO)
- Cranberry Township
- Crown Castle
- Dalian University of Technology
- Delaware River Port Authority (DRPA)
- Delaware Valley Regional Planning Commission (DVRPC)
- Borough of Dormont
- Economic Development South
- Ericsson
- Federal Highway Administration
- GAI Consultants
- General Motors Global Research & Development
- Healthy Ride
- Hulton Arbors
- Hillman Family Foundations
- iNetworks Advisors
- Innovation Works
- Intel
- Intelligent Transportation Society of America
- Jackson/Clark Partners
- Lawrence County
- League of American Bicyclists
- Marshall Township
- Masite
- Meter Feeder
- Mid-Ohio Regional Planning Commission
- Miovision
- Near Earth Autonomy
- North Huntingdon Township
- Oakland Transportation Management Association (OTMA)
- OSHER
- Partner4Work
- Peloton Technologies
- PennDOT
- Pennsylvania Motor Truck Association (PMTA)
- Pennsylvania Turnpike
- Philadelphia Port Authority
- PITT OHIO
- Pittsburgh Community Reinvestment Group
- Pittsburgh Downtown Partnership
- Pittsburgh Parking Authority
- Pittsburgh Technology Council
- Port Authority of Allegheny County
- Port of Pittsburgh Commission
- PPG Industries Inc.
- Propel IT, Inc.
- Quaker Valley Council of Governments
- Rapid Flow Technologies
- Regional Industrial Development Corporation (RIDC)
- Richard King Mellon Foundation
- Roadbotics
- Southeastern Pennsylvania Transportation Authority
- Southwestern Pennsylvania Commission
- Sustainable Pittsburgh
- TJKP Corporation
- The Heinz Endowments
- The Ohio State University
- Tiramisu Transit Inc
- Toyota
- Tsinghua University
- Uber
- University of Pittsburgh
- Uptown Partners
- Wade Trim
- Western Pennsylvania Regional Data Center
- Western Pennsylvania School for Blind Children
- Women's Transportation Seminar (WTS)

Over the past ten years Traffic21 has developed a reputation as an objective third-party advisor to government agencies and community organizations for technology and policy issues related to new development and trends in transportation. Traffic21 also funds and manages cutting edge

research in new transportation technology and interfaces with corporate partners to transfer that technology through pilot deployment and commercialization.

This positioned Traffic21 well to synthesize research results and technology trends to inform policies for smart mobility of people and goods. As Director of Traffic21, Chris Hendrickson, and Executive Director of Traffic21, Stan Caldwell the approach of the researchers in this project was to leverage Traffic21 model and partnerships to advance this synthesis research.

Methodology
The research work for this project was conducted through a variety of activities highlighted below. Under each category are specific outputs by the researchers:

- Meetings with civic and business leaders and government policy makers to discuss transportation challenges and advise on applicable smart mobility policies. These meetings include southwestern Pennsylvania, state, regional, national and international leaders and policy makers.
- Presentations and publications providing policy analyses of smart mobility alternatives, such as connected and automated vehicle policies or multi-modal operational policies.
- Active participation in policy-making groups such as the Pennsylvania Autonomous Vehicle Task Force, Smart Belt Coalition, and the Oakland Transportation Management Association.
- Interaction with researchers at Carnegie Mellon and elsewhere to identify new opportunities for research and transportation policy improvement. Included in this activity is participation in national organization such as Transportation Research Board Executive Committee and the Leadership Circle of the Intelligent Transportation Society of America.
- Research national and international disruptive transportation technology trends and associated policies. Synthesize and disseminate this information through the Traffic21/UTC blog, social media and industry recognized Smart Transportation
- Dispatch weekly email newsletter.

To enable the synthesis of technology trends related to improving mobility, Stan Caldwell curates an industry recognized blog and weekly email newsletter. The Smart Transportation Dispatch is a weekly synopsis of Caldwell's research on mobility technology and research trends. Key articles along with insightful excerpts are posted on a blog and a weekly email newsletter is sent to the over 3,000 subscribers. During this 12 months of this research project, over 250 news articles were researched, synthesized blogged and shared in social media with over 1,300 twitter followers.

Research Outputs
Below are listed specific activities of researchers Chris Hendrickson and Stan Caldwell related to this research project. Activities include research presentation and meetings with government, community and corporate partners where synthesized policy research was transferred.

July 15, 2018
Stan Caldwell, Executive Director of Mobility21, participated in a panel where he presented examples of Mobility21 UTC Technology Transfer. This *Pre-Conference Workshop: University*

Transportation Center (UTC) Technology Transfer was part of the ASCE International Conference on Transportation and Development in Pittsburgh. Also participating on the panel were Kevin Womack and Amy Sterns from the US DOT UTC Program and fellow UTC representatives; Larry Rilett from the University of Nebraska, Lincoln Atorod Azizinamini from Florida International University and David Noyce from the University of Wisconsin – Madison.

July 16, 2018
Pittsburgh hosted the American Society of Civil Engineers' International Conference on Transportation & Development 2018. Prof. Chris Hendrickson, Director of the Traffic21 Institute chaired the local host committee and presented his policy research.

July 31, 2018
Mobility21 faculty members Raj Rajkumar, Chris Hendrickson and Stan Caldwell participated in a visit to Carnegie Mellon University by corporate leadership from Norfolk Southern. The group discussed Mobility21 UTC technology and policy research, issues concerning the railroad industry, and potential opportunities for collaboration.

July 26, 2018
Traffic21/Mobility21 Executive Director Stan Caldwell was an expert panelist for a webinar meeting of the National AARP Autonomous Vehicle Work Group. Other panelists were Karina Rick, Director of Mobility and Infrastructure and Sarah Papperman Program Coordinator for the In Service of Seniors and co-leader of the Age-Friendly Greater Pittsburgh Transportation Working Group. Panelist provided insight and advice on how AARP can educate and activate their members around AV issues.

July 24, 2018
PennDOT Issues Guidance for Increased Safety Oversight of Highly Automated Vehicles. Raj Rajkumar, Director of CMU's Mobility21 National University Transportation Center and Stan Caldwell, Executive Director, Traffic21 Institute and Mobility21 and T-SET National University Transportation Centers serve on the PennDOT Automated Vehicle Policy Task Force and participated in deliberation and provided feedback for the development of this policy. Read the press release about the new guidance here.

July 24, 2018
The Greater Boston Chamber of Commerce visited Pittsburgh for their City to City initiative. They met with Stan Caldwell, Executive Director of Traffic21 and Alex Pazuchanics, Assistant Director of the City of Pittsburgh's Department of Mobility and Infrastructure to learn about Mobility21's transportation deployments in Pittsburgh.

July 23, 2018
Traffic21 Executive Director, Stan Caldwell spoke in front of The Alliance to Save Energy's 50×50 Commission, including several U.S. Representatives, about Traffic21's tech projects to save energy. Stan was joined by Traffic21 researcher, Costa Samaras who discussed "Energy, Sustainability and Climate Impacts of the Transition to Autonomous Vehicles."

July 18, 2018
The ASCE International Conference on Transportation and Development was in Pittsburgh from

July 15 – July 18.
A technical tour was offered to visit (1) an intersection equipped with a Surtrac Adaptive Traffic Signal Controller with Research Professor, Steve Smith and (2) the CMU NavLab to view and hear a short presentation on two autonomous vehicles and a video roadway infrastructure inspection system from Executive Director, Stan Caldwell and Principal Project Scientist, Christoph Mertz.

July 17, 2018
Stan Caldwell, Executive Director of the Traffic21 Institute and the Mobility21 UTC, testified at a hearing of the Pennsylvania Senate Transportation Committee on Act 89, a 2013 transportation bill that generates 2.3 billion per year for infrastructure improvements. This field hearing was held in Monroeville to review the work done in Southwestern PA and Allegheny County because of Act 89, and to consider future needs.

Professor Caldwell spoke about the current benefits from Act 89 including how the funding allowed collaboration between researchers, industry, the City of Pittsburgh and the Port Authority of Allegheny County on new technologies and impacts on mobility. Stan highlighted the fact that due to Act 89 funding stabilizing budgets, state and local agencies have been able to begin planning for the opportunities and impacts of disruptive new technologies on transportation safety, mobility and workforce. The Traffic21 and UTC researchers were able to work with the City of Pittsburgh on deploying the world's smartest traffic signals, help

PennDOT plan for autonomous vehicles, and partner with the Port Authority of Allegheny County on connected vehicle research and data analytics to improve service.
Furthermore, these technologies have created spinoff companies that are creating good paying jobs here in southwestern Pennsylvania.

After testifying, Stan was asked by the committee about broadband infrastructure outside of the city and if that hinders the ability for autonomous vehicles to expand. Stan explained that past infrastructure investments were made for both transportation and economic development interests. These include port, canals, railroads, streets, highways and airports. The next critical transportation infrastructure investment will on need to focus on information and communication technology and that the investments and technology rollouts should be equitably distributed.

Here is a link the video testimony, a link to the written testimony and below are the recommendation provided.

Recommendations:
- Maintain a high quality of existing roadways and provide real-time information on road closures.
- Support the development of information and communications technology infrastructure to enable safety and mobility applications as well as economic development.
- Invest in research and test beds to develop next generation technology, evaluate emerging disruptive technology and recommend policy.

- Assist local government in technology investment and policy development.
- Encourage and promote the emerging transportation technology industry in Pennsylvania.
- Develop policy to mitigate the risks and unintended societal consequence.

August 31, 2018
Mobility 21 National UTC Director Raj Rajkumar and other CMU faculty including Martial Hebert, Stan Caldwell and Phil Koopman participated in a roundtable discussion in Pittsburgh with US Congressman Keith Rothfus (PA-12) and US Under-Secretary of Transportation for Policy Derek Kan. Pittsburgh Law Firm Babst Calland hosted the roundtable for the Congressman and Under Secretary to discuss policy of autonomous vehicles and drones with leading manufacturers, technology companies, and universities.

August 28, 2018
The City of Pittsburgh's Department of Mobility and Infrastructure has been working with the North Side, North Shore, Downtown Pittsburgh, and Oakland communities to develop a pedestrian wayfinding system. Today a public meeting was held to display the final design. Mobility21 Program Manager, Lisa Kay Schweyer stopped by and got a picture with the proposed signage. Mobility21 researcher Don Carter and Executive Director, Stan Caldwell have been involved in the design process which led to this final design.

August 15, 2018
The AASHTO Committee on Construction Meeting was held in Pittsburgh this year and attendees were able to tour CMU's NavLab. The tour included presentations from Christoph Mertz of CMU's Robotic's Institute and Mobility21 Director, Raj Rajkumar. Attendees were from different DOT's from around the country, who were eager to talk AV, policy and have a seat in the autonomous vehicles in the NavLab.

August 8, 2018
Claire Bornzer, legislative assistant for Congressman Mike Doyle visited CMU's Pittsburgh campus today, which included an overview of the Traffic21 Institute and the Mobility21 University Transportation Center, and a tour of the NavLab by Stan Caldwell who discussed policy research.

August 6, 2018
Chris Hendrickson, Director of Traffic21 Institute, gave a keynote presentation at the University Transportation Center for Advance Multimodal Mobility Solutions and Education Research Symposium today in Charlotte, NC. His talk was titled 'Transition to Connected and Automated Vehicles.' He also served as a judge for the student poster competition.

September 10, 2018
Congressman Bill Shuster, Chairman of the House Transportation and Infrastructure Committee and State Senator Guy Reschenthaler visited Carnegie Mellon University's National Robotics Engineering Center for a tour and round table discussion with representatives from local autonomous and connected vehicle companies. Mobility21 UTC faculty member Chris Hendrickson moderated the discussion and Mobility21 UTC faculty member Steve Smith represented his spin off company Rapid Flow Technologies and Stan Caldwell participated in the discussion. Also participating was Roadbotics, another UTC spin off company.

September 17, 2018
Mobility21 Executive Director Stan Caldwell served as a delegate the 2018 Intelligent Transport Systems World Congress in Copenhagen Denmark where he engaged ITS experts from academia, government and industry from around the world.

September 2018
The Mobility21 Center, in partnership with the PRECISE Center, at the Engineering School of the University of Pennsylvania hosted a two-day event entitled "Moving America Forward: Next Generation of Truck Freight Transport Summit." The keynote speakers for the summit was Raymond P. Martinez, administrator of the Federal Motor Carrier Safety Administration, and Leslie Richards, Secretary of the Pennsylvania Department of Transportation. Stan Caldwell participated in the summit and served on the organizing committee. The event was held on October 24-25, 2018 at the Singh Center for Nanotechnology, University of Pennsylvania. More details about the event can be found on PRECISE's **website**

October 12, 2018
Stan Caldwell, Executive Director of the Traffic21 Institute and Mobility21 University Transportation Center, spoke about disruptive transportation technologies at the Pittsburgh Region Clean Cities 2018 Odyssey Day at the Community College of Allegheny County – West Hills Center. Over thirty alternative fueled vehicles on display as well as vendors in the alternative fuels arena. Almost one hundred fifty attendees that were able to see all the different vehicles from cars, trucks, vans, buses, tractor trailers and other utility vehicles.

October 4 – 6, 2018
International Symposium on Emerging Trends in Transportation in Waikiki Beach, Hawaii with the Chinese Overseas Transportation Association (COTA) and the University of Hawaii. With a theme on Emerging Technologies for Future Mobility Systems, this inaugural symposium aims to stimulate the exchange of ideas among transportation professionals in academia, industry, and government on emerging policy, technology, and innovation trends. CMU's Chris Hendrickson presented UTC research.

September 27, 2018
Eight Mobility21 National UTC faculty including Stan Caldwell and two students presented research at the 2018 Research Symposium Sponsored by the Pennsylvania Department of Transportation and the Pennsylvania Divisional Office of the Federal Highway Administration. The event was held in Harrisburg Pennsylvania.

October 22, 2018
Rail-Volution, a national transit-orientated conference, hosted in Pittsburgh, included a "Walkshop" organized and hosted by Stan Caldwell that featured several of Mobility21's pilot deployment projects and researchers including Steve Smith with Surtrac. The walkshop included a visit to Smart Traffic Signals and presentations by Stan Caldwell.

November 27, 2018
Stan Caldwell, CMU Executive Director of Traffic21 and Mobility21 participated with Justine Kasznica of law firm Babst Calland's Mobility, Transport and Safety practice on the

panel *Paving the Way for Autonomous Vehicles* hosted by Babst Calland. The presentation included a discussion about autonomous vehicles in the broader context of infrastructure design and development, and issues related to urban infrastructure and research and advancements in mobility technologies.

November 15, 2018
Mobility21 Executive Director Stan Caldwell provided a guest lecture at the Urban Planning Choices course of the Carnegie Mellon University Osher Lifelong Learning Institute. He presented Mobility21 research and highlighted the policy implications of new technologies disrupting transportation and urban planning.

November 9, 2018
Over 100 attendees participated in the annual Symposium of
the Traffic21 /Mobility21 Deployment Partner Consortium. Participants included consortium members from the public and private sectors along with faculty and students. The symposium is sponsored by the Carnegie Mellon University Traffic21 Institute and Mobility21 National University Transportation Center and held on CMU's campus.

The group was welcomed by Ramayya Krishnan, Dean, Heinz College of Information Systems and Public Policy. He thanked everyone for their involvement and critical role in providing the "real life" connection to the research. Then Chris Hendrickson, Director, Traffic21 Institute and Raj Rajkumar, Director, Mobility21 National University Transportation Center provided an overview of both Traffic21 and Mobility21 activity and plans.

The day included three panels focused on industry, government, and community along with lots of audience participation. Each panel featured thought leaders who shared their perspective on how new transportation technology is impacting industry and communities and and how research or education might address these real-world needs.

Raymond Betler, President and CEO of Wabtec Corporation

The first panel focused on industry, with panelists discussing "Emerging Technology Trends."

- Rebecca Brewster, President and Chief Operating Officer of the American Transportation Research Institute
- Raymond Betler, President and CEO of Wabtec Corporation
- Robert Grant, Head of Government Relations, Aurora
- Jim Misener, Senior Director of Technical Standards at Qualcomm


Johanna Jochum, Attorney, Mobility, Transport & Safety Practice Group of Babst Calland

The second panel of the day was the Government Panel which focused on "New Technology Policy Challenges."

- Roger Cohen, Senior Advisor to the Secretary, Pennsylvania Department of Transportation
- Johanna Jochum, Attorney, Mobility, Transport & Safety Practice Group of Babst Calland
- Karina Ricks, Director, City of Pittsburgh's Department of Mobility and Infrastructure
- Paul Skoutelas, President and Chief Executive Officer of The American Public Transportation Association

JaLissa D. Coffee, Director of Operations, Conference of Minority Transportation Officials

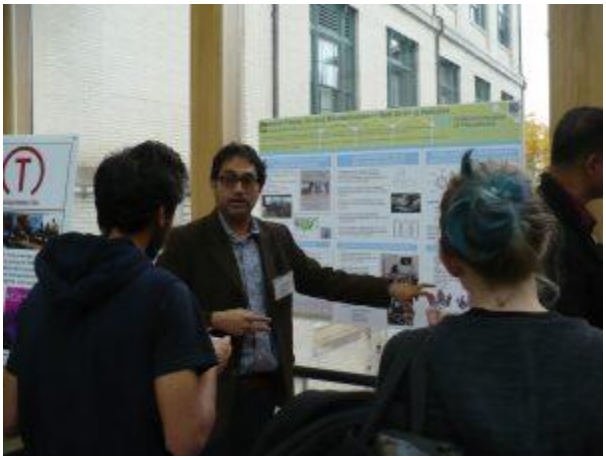
The last panel highlighted community issues and the "Societal Impacts of Disruptive Technology."

- JaLissa D. Coffee, Director of Operations, Conference of Minority Transportation Officials
- Ashley Hand, Co-founder, CityFi
- Ken McLeod, Policy Director, The League of American Bicyclists
- Chris Sandvig, Policy Director, Pittsburgh Community Reinvestment Group

Leslie Richards, Secretary of the Pennsylvania Department of Transportation

The keynote speaker for the event was Leslie Richards, Secretary of the Pennsylvania Department of Transportation. Secretary Richards shared her thoughts on the future of transportation in the commonwealth, the new autonomous vehicle testing policy, and the challenges of keeping up with all the changes. She also spent time answering questions from the symposium attendees.

The day concluded with a research poster session and networking reception. Over 16 research projects were featured during the event. Researchers were able to share information about their projects, exchange ideas with attendees, and even forge some new partnerships.


Poster Session

Putting our research, development and deployment approach into action – the symposium provided an opportunity for interaction and discussion among researchers, students and deployment partners. Conversations were held not only during the formal program, panels and poster sessions, but during breaks and over lunch.

The Mobility21 team is a tight collaboration among Carnegie Mellon University (Lead), the University of Pennsylvania, the Ohio State University and the Community College of Allegheny County, and brings to bear the reach and scale of all four institutions.

Tackling the multi-faceted nature of Mobility21 objectives requires coordinated research, education, workforce development and technology transfer. This work is supported by researchers spanning multiple disciplines such as engineering, computer science and robotics, public policy, urban design, information systems and data analytics.

Deployment Partner Consortium members represent public agencies, non-profit organizations, private sector companies, and other research institutions who actively support Traffic21 and Mobility21 research.

Learn more about the Deployment Partner Consortium by clicking here.

November 8, 2018
A talented group of national leaders attended the Carnegie Mellon University Traffic21 Institute and Mobility21 National University Transportation Center (UTC) Advisory Council meeting, held on CMU's campus.

CMU Interim Provost, Laurie R. Weingart welcoming the Advisory Council to CMU.

The group was welcomed by CMU Interim Provost, Laurie R. Weingart. She shared her thoughts on the role of education, research, innovation and technology transfer happening at university. She also talked about the importance of the advisory council and thanked the council for their role in the work being done through Traffic21 and the Mobility21 UTC.

Mobility21 UTC Director, Raj Rajkumar and Traffic21 Director, Chris Hendrickson then provided an overview of update of activities and plans at the centers. The day continued with Traffic21 and Mobility21 Executive Director, Stan Caldwell leading a discussion on technology transfer and plans for the upcoming National UTC Mobility Summit scheduled to be held in Washington, DC on April 11, 2019. Advisory Council members shared their expertise and ideas on workforce demand, technology trends, research needs, and new funding opportunities to advance the missions of Traffic21 and Mobility21.

One of the members reflected on the experience and reported the meeting was a “Great opportunity to meet with CMU leaders and Advisory Council members with whom I don’t normally interact with in the transportation industry.”

# # #

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The distinguished Advisory Council of national leaders provides strategic guidance and counsel. Advisory Council members include:

- Raymond T. Betler, President and CEO of Wabtec Corporation
- Rebecca M. Brewster, President and Chief Operating Officer of the American Transportation Research Institute
- Robin Chase, Co-founder Zipcar, Veniam, NUMo
- Ty Gourley, Vice President of the Hillman Family Foundations
- Charles L. Hammel III, President and owner, PITT OHIO Express
- Ashley Hand, Co-founder CityFi; formerly Transportation Technology Strategist Fellow for Los Angeles
- Katharine Kelleman, Chief Executive Officer at Port Authority of Allegheny County
- Jane Lappin, Director, Public Policy & Government Affairs, Toyota Research Institute
- Ken McLeod, Policy Director at The League of American Bicyclist
- James A. Misener, Senior Director, Technical Standards at Qualcomm
- Leslie Richards, Secretary of the Pennsylvania Department of Transportation
- David Roger, President of the Hillman Family Foundations
- Paul Skoutelas, President and Chief Executive Officer of The American Public Transportation Association
- Kirk Steudle, Director of Michigan Department of Transportation

Learn more about the Advisory Council members here.
The next in person meeting of the Advisory Council will be in November 2019.

November 8, 2018
Traffic21 Director, Chris Hendrickson and Rick Grahn from the Mobility Data Analytics Center Rick Grahn presented a talk for discussion titled "Travel Behavioral Trends in the United States: Evidence from the 2017 National Household Travel Survey."

November 5, 2018
Chris Hendrickson presented Traffic21 research to NAIOP, Commercial Real Estate Development Association Nashville Chapter during their visit to Carnegie Mellon University.

January 25, 2019
Traffic21 Director, Chris Hendrickson was invited to the University of Central Florida for their Future City Seminar Series. Hendrickson presented "*Past and Future of the US Interstate Highway System*" where he looked back at the impacts and innovations of the Interstate Highway System, including engineering, financing and planning challenges.

January 16, 2019
Chris Hendrickson, the Director of the Carnegie Mellon University Traffic21 Institute was called upon last minute to fill in for a speaker at the TRB session *"Future of the Interstate Highway*

System: A TRB Consensus Study." As a contributing author of the study, he stepped in to provide the session attendees with an overview of the study.

January 15, 2019
Mobility21 Executive Director, Stan Caldwell served as a speaker for the TRB annual meeting session, *Integrating Research and Technology Transfer*. His presentation included an overview of how technology transfer happens through the CMU Traffic21 Institute and the Mobility21 UTC, and highlighted some of the companies that have spun out of the UTC funded research efforts.

December 11, 2018
The Governors Highway Safety Association visited Carnegie Mellon University to learn more about Mobility21's policy, technology, and people in autonomous vehicles. They spent time learning more about the AV's here on campus and visiting the Navigation Lab. Stan Caldwell organized and hosted the event.

February 7, 2019
Stan Caldwell, Executive Director of the Mobility21 University Transportation Center was appointed to the advisory group for the Cooperative Automation Research Mobility Applications (CARMA) platform which supports the testing and evaluation of connected and automated vehicle research. This opportunity has Caldwell directly involved in how research can support advancing the use and implementation of Transportation Systems Management and Operations strategies and more.

February 5, 2019
Traffic21 Director, Chris Hendrickson was unanimously approved by the **National Research Council (NRC)** Governing Board to be the new Transportation Research Board (TRB) Division Committee Chair. The **TRB Division Committee** is charged to ensure that NRC procedures and policies are faithfully employed with respect to study and project committee appointments and report review.

March 12, 2019
Twelve months ago, Franklin Area High School had four lonely VEX robots that students traveled around Pennsylvania and West Virginia with, searching for teams to compete against. Fast-forward to the end of this February and those four robots have 180 new companions right next door. Together they make up the Pennsylvania Rural Robotics Initiative, a consortium of 11 school districts, one technology center, and an intermediate unit that all share a common robotics platform and curriculum. Twenty-five schools, covering five counties, have found like-minded friends in higher education, business and industry, state and local government, non-profits, and regional economic and workforce development that not only support their initiative but help it to thrive.

The Traffic21 and Mobility21 Institute's leadership team, including Caldwell and Hendrickson, have been trusted advisors since the conception of PA Rural Robotics and continues to look for ways to support their mission. Both faculty and graduate students from the Robotics Institute are working to bring CMU and these young STEM students together. PA Rural Robotics was also excited to find themselves partnered with a team of CMU undergraduate students as part of the

Information Systems Spring Project. The Office of Outreach and Engagement have provided a menu of options that can further the CMU connections as the initiative grows. The most recent Carnegie Mellon connection was with the CMU CS Academy. PA Rural Robotics plans to introduce their member schools to the CS1 course and discuss the potential it could have in expanding computer science offerings within all of the member districts.

March 12, 2019
Some members of the Marathon Petroleum Corporation (MPC) Board of Directors met with Carnegie Mellon University representatives, including Stan Caldwell of Mobility21 and Chris Hendrickson of Traffic21 to explore collaborative opportunities with Carnegie Mellon University.

March 1, 2019
Bosch hosted a "Curbside Management Ideation Event" at Carnegie Mellon University. Over 25 students signed up to participate. Stan Caldwell participated and helped organize the event. The event kicked off at 8:30 am with "Welcome's and Introductions" by Sylvia Vogt from Carnegie Bosch Institute and Oliver Steinig, VP Business Development and Corporate Strategy Americas at Robert Bosc. Karina Ricks, Director of Mobility and Infrastructure from the City of Pittsburgh then shared with the participants the importance of curbside management and Pittsburgh's specific challenges:

- Geographically challenged roadway network with congested, narrow avenues
- Congestion compounded by transit stops, parallel parking, and commuter traffic
- Competition amongst various modes and users for curb space
- Lack of universal value for curb access and allocation
- Lack of real time curbside utilization rates

The students were assigned to one of four teams. And after the teams received their instructions on how to conceptualize solutions to Pittsburgh mobility challenges by leveraging Bosch strengths in Video as Sensor, the students quickly got started. An observation from the VP Business Development and Corporate Strategy Americas at Bosch, Oliver Steinig was how diligently the students worked, even choosing to eat lunch with their teams to continue working on their curbside management ideas.

At the end of the day, the students' hard work paid off. Each team presented solutions that combined Bosch sensors, sensible technology and pragmatic policy changes.
Mobility21 and Metro21 helped promote the event and engage students and were on hand for the day's activities.

The Curbside Ideation event is an example of how industry, government, and academia can come together to create real solutions to real world problems.

February 25, 2019
The Traffic21/Mobility21 Team, Chris Hendrickson, Stan Caldwell, and Lisa Kay Schweyer took a 'road trip' to RoadBotics to tour their facilities. The team met with Christoph Mertz, UTC Faculty who lead the spin-off of RoadBotics from CMU and Mark DeSantis, CEO of RoadBotics to discuss further research opportunities.

February 23, 2019
Mobility21 Executive Director, Stan Caldwell, was a guest lecturer in Heinz College course on Food Insecurity and discussed the mobility challenges getting people to food or getting food to people in poor rural communities. The course is jointly led by both Carnegie Mellon University and Waynesburg University.

February 22, 2019
Today's Smart Mobility Connection featured Chris Hendrickson, Director of Traffic21. Based upon the National Academy of Science, Engineering and Medicine's study *'Renewing the National Commitment to the Interstate Highway System: A Foundation for the Future'* Hendrickson led us through a look back at the impacts and innovations of the Interstate Highway System, including engineering, financing and planning challenges. Read the study here. Watch the seminar here.

March 27, 2019
Stan Caldwell, Executive Director of Mobility21, met with the Consul General, the Honorary Consul and the Head of Trade and Business Promotion from the Consulate General of Sweden in New York City. The Consulate General was interested in meeting with Mobility21 to learn more about sustainability transportation systems and potential university-to-university collaboration.

March 13, 2019
Mobility21 UTC Executive Director Stan Caldwell was appointed to the Pennsylvania State Transportation Innovation Council (STIC) and participated in the quarterly meeting in Harrisburg which was co-chaired by FHWA Division Administrator Alicia Nolan. Caldwell is honored to represent the UTC at STIC.

April 5, 2019
A delegation from Italy traveled to Pennsylvania to learn more about policy, mobility technology and the modernization of train/rail travel. The organization that came to CMU was "Ditecfer" District for Rail Technologies, High Speed, Safety and Security based in Pistoia, Italy. Tuscany is the leading cluster for innovative rail technologies in Italy. This organization considers the U.S. as their top priority for international collaboration and because both countries have significant railway supply chains based on SMEs and important integrations that can be built in the railway sector, they have identified Pittsburgh as a prime opportunity. Executive Director, Stan Caldwell, presented research from Mobility21.

April 11, 2019
Today, Mobility21 hosted the Second Annual National Mobility Summit in Washington D.C. The summit provided a unique opportunity for **125** people, made up of faculty members, researchers, government, community, and industry representatives from across the country to discuss improving mobility for people and goods. The day also highlighted work from **10** of the mobility-themed UTC's around the country (representing 50+ educational institutions) and a research showcase to share their ideas and create new collaborative efforts to transfer research to deployment. Stan Caldwell and Chris Hendrickson organized and participated in the event.

The Second Annual National Mobility Summit
of
USDOT University Transportation Centers
EXPLORING THE RESEARCH FRONTIER
FOR 21ST CENTURY MOBILITY
April 11, 2019 – Washington, D.C.

More than 125 attendees came together for the Second Annual National Mobility Summit to discuss real-world problems, opportunities and innovations in the mobility of people and goods. This included 10 university transportation centers representing more than 50 colleges and universities across the US.

From left to right: Kevin C. Womack, Ph.D., F.ASCE Director, Office of Research, Development and Technology; Allante Whitmore, Ph.D. Candidate for Civil and Environmental Engineering, CMU; Diana Furchtgott-Roth, Deputy Assistant Secretary for Research and Technology, U.S. Department of Transportation; Raj Rajkumar, Director, Mobility21 National UTC, Carnegie Mellon University

It was great to seeing people from many different disciplines, each that touches transportation, were present. I'm thinking specifically about the fact that there was someone there from a hospital, Easter Seals and a community college. The diversity of participants is top notch.
– ATTENDEE FEEDBACK

AGENDA

Welcome, Introductions, & Overview of the Day

Raj Rajkumar, Director, Mobility21 National UTC, Carnegie Mellon University

Remarks from the UTC Program

Dr. Kevin Womack, Director, USDOT Office of Research, Development & Technology, & the Transportation Safety Institute

Mobility-Themed UTC Lightning Round 1: *Brief Updates on Research, Education & Technology Transfer Efforts from Participating UTCs*

Moderator, **Chris Hendrickson**, Director, Traffic21 Institute, Carnegie Mellon University

Wei Fan, Director, Center for Advanced Multimodal Mobility Solutions and Education, University of North Carolina at Charlotte

Hau Hagedorn, Associate Director, Transportation Research and Education Center, Portland State University

David Kack, Mobility Director, Small Urban, Rural and Tribal Center on Mobility, Montana State University

Cole Kopca, Assistant Director, PacTrans, University of Washington

Hilary Nixon, Deputy Executive Director, Mineta Transportation Institute, San Jose State University

Expert Panel 1: *Opportunities and Challenges to Improve the Mobility of People Moderator,* **Stan Caldwell**, Executive Director, Mobility21 National UTC, Carnegie Mellon University

Robin Chase, Co-founder Zipcar, Veniam, and NUMO

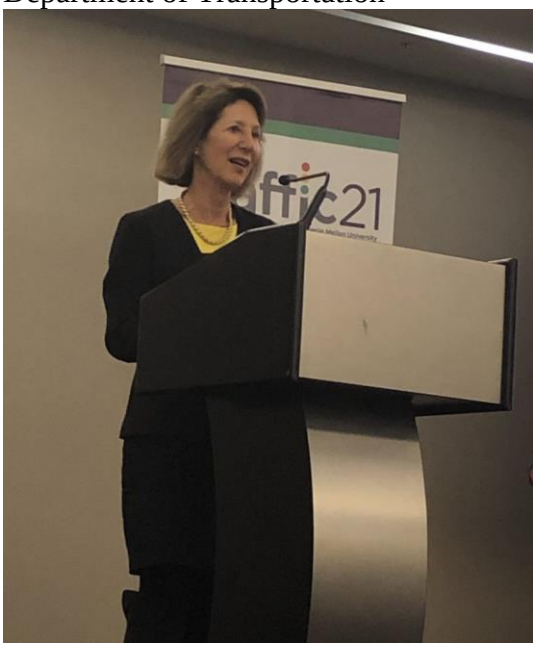
Brian Cronin, Director, FHWA Office of Operations Research & Development

Jane Lappin, Director, Public Policy & Government Affairs, Toyota Research Institute

Paul Skoutelas, President and CEO, American Public Transportation Association

Lunch and Keynote Speaker

Diana Furchtgott-Roth, Deputy Assistant Secretary for Research and Technology, U.S. Department of Transportation



Mobility-Themed UTC Lightning Round 2: *Brief Updates on Research, Education & Technology Transfer Efforts from Participating UTCs*
Moderator, **Lisa Kay Schweyer,** Program Manager, Mobility21 National UTC, Carnegie Mellon University
Raj Rajkumar, Director, Mobility21, Carnegie Mellon University
Andrew Farkas, Director, Urban Mobility & Equity Center, Morgan State University
Jill Hough, Program Director & Associate Professor of Transportation, North Dakota State University
Evangelos Kaisar, Professor, Freight Mobility research Institute (FMRI), Florida Atlantic University
Kaan Ozbay, Director, C2 Smart, New York University
Expert Panel 2: *Opportunities and Challenges to Improve the Mobility of Goods Moderator,* **Loren A. Smith, Jr.,** Senior Advisor for Policy and Program Operations in the Office of Transportation Policy, U.S. Department of Transportation
Bob Bourg, Vice President, Strategy & Growth, Wabtec
Steve Boyd, Co-Founder, VP of External Affairs & Market Development, Peloton Technology
Rebecca Brewster, President and Chief Operating Officer, the American Transportation Research Institute
Caitlin Hughes, Director, FHWA Office of Freight Management and Operations
Networking Reception and UTC Poster/Demo Session
10 UTCs Representing 50+ Colleges and Universities across the US

DOWNLOAD ALL PRESENTATIONS BY CLICKING HERE (APPROX 35 MB)
DOWNLOAD NATIONAL MOBILITY SUMMIT '19 RECAP BY CLICKING HERE

May 7, 2019
Mobility21 Executive Director, Stan Caldwell, advised the The Heinz College Capstone project with Amtrak entitled *"Improving Intercity Rail Data Analytics".* Today, the capstone project team presented their project results, which included their examination of a variety of data sources to develop a data-driven model for identifying and marketing to new customers.

May 3, 2019
Today's National Public Radio *On Point* show *"There's Talk Of $2 Trillion For Infrastructure. How Should The U.S. Spend It?"* features an interview with Mobility21 UTC Executive Director Stan Caldwell. Listen to the broadcast here: https://www.wbur.org/onpoint/2019/05/02/infratstructure-trump-congress-democrats.

May 1, 2019
Mobility21 Executive Director, Stan Caldwell, attended the Philadelphia & Pittsburgh Chamber of Commerce Legislative Briefing in Harrisburg to promote Mobility21 research efforts. The briefing included stakeholders and regional policymakers to help strengthen relationships between the region's business community and elected officials.

May 29, 2019
Mobility21 Executive Director Stan Caldwell and UTC Researcher, Christoph Mertz led Comcast's Heartland Regional Team on a tour of CMU's NavLab. The Comcast leadership was

interested in learning more about the research, development and deployment of Mobility21-led research in the region.

May 21, 2019
Stan Caldwell, Mobility21's Executive Director, sat down with Ken Dunlap, Managing Partner of Catalyst-Go, a company that specializes in the autonomous technologies industries, to discuss urban mobility in their latest podcast.

The podcast entitled "*"Key Lessons in Urban Mobility"* explores a wide variety of topics, including how Pittsburgh has transitioned from an industrial city to one that competes with Silicon Valley for companies and talent.

Ken and Stan discuss the role of Traffic21 and Mobility21 in the transformation of Pittsburgh including the model of using seed funding from partners to develop, research and deploy technology in the city. Stan discusses how the formula has led to successful university-government partnerships and how these partnerships are helping the mobility of the greater Pittsburgh region and subsequently nation-wide.

The podcast then shifts gears to discuss the whole picture of Mobility21 and how the transportation center and the future of transportation is not simply about automation but rather using new urban mobility technologies to ensure that all, not just some, communities benefit. Stan describes the difference between Pennsylvania's approach to automation and policy compared to states like California – and how Pennsylvania's might be a better recipe for success.

Listen to the podcast to hear Stan share the lessons he and his Mobility21 colleagues have learned and are learning while research, developing and deploying technology in mobility: https://www.catalyst-go.com/thinkingthroughautonomy/2019/5/24/stan-caldwell-lessons-in-urban-mobility.

May 17, 2019
Former U.S. Secretary of Transportation Anthony Foxx, a Distinguished Executive in Residence at Carnegie Mellon University, joined Mobility21 students, staff and faculty including Stan Caldwell for a lunch and learn today to discuss the variety of transportation related research being done at Carnegie Mellon University.

May 16, 2019
Mobility21's Executive Director, Stan Caldwell, participated in the second workshop of the Pennsylvania Safety Transportation and Research Track (PennStart). This proposed test track is a collaboration with the PA Turnpike, FHWA and PennState. Stan attended to provide expertise on connected and automated technology testing applications.

May 14, 2019
Stan Caldwell, Exec. Director of Mobility21 presented research at the Council of University Transportation Center spotlight conference held at the Rayburn Office in Washington DC. Stan was also able to participate in visits to legislative offices to highlight Mobility21's education initiatives, including a visit with Claire Borzner, Legislative Assistant to Congressman Mike Doyle.

May 8, 2019
Mobility21 Executive Director, Stan Caldwell, presented an overview of Mobility21 activities and research to the Young Presidents Forum (YPO). The YPO is a global organization where members meet with innovative and influential business leaders with the goal of inspiring business, personal and community impact.

June 20, 2019
Stan Caldwell participated in a public meeting where the Pittsburgh Department of Mobility and Infrastructure and the Pittsburgh Water and Sewer Authority presented plans for innovative transportation plans connecting the neighborhoods of Hazelwood, Greenfield, the Run and Oakland.

June 17, 2019
Mobility21's Executive Director, Stan Caldwell, instructed a workshop session entitled "*Pittsburgh's Evolution as a Smart Transportation Testbed*" at the Pennsylvania Society of Professional Engineers Bootcamp West. The bootcamps are designed for licensed engineers to gain a broad range of knowledge and make connections with experienced professionals.

June 4-7, 2019
ITS America held their annual meeting in Washington D.C. entitled "*Intelligent Mobility: Safer. Greener. Smarter*." Mobility21 Executive Director, Stan Caldwell, was there representing Mobility21 UTC research efforts. UTC spin-off, Rapid Flow Technologies, was an exhibitor, to showcase their Surtrac technology.

June 27, 2019
Today, 15 students from the Franklin Area High School went to Carnegie Mellon University for the day. The students, all part of the PA Rural Robotics Initiative, traveled almost 2 hours each way to get a glimpse into some of CMU's programs and resources.
Organized and supported by CMU's Mobility21 University Transportation Center and the Robotics Institute, the visit included:

- A discussion of transportation & technology
- An introduction to making traffic "smarter"
- A tour of the NavLab where the students saw and learned about autonomous vehicles
- A tour of the Field Robotics Center where the students learned more about aerial robotics
- A networking lunch where the students met and talked with members of the 2019 CMU Robotics Institute Summer Scholars cohort

When asked what she thought of the experience, Grace said "I really enjoyed learning about the autonomous vehicles and our discussions with the summer scholars. Thank you, CMU!"

Tim Heffernan, the Executive Director of the PA Rural Robotics Initiative said "Although geographically Carnegie Mellon isn't too far from home, sometimes these types of opportunities and institutions seem worlds away to these students. Having the chance to meet the summer scholars and interact with the world's best in their professions will change how these kids view themselves and their futures. We couldn't be more excited about, and grateful for, the opportunity that our friends at CMU have provided for these young people. Events like today have a positive impact on our kids and our region."

In addition to the students and Mr. Heffernan, five chaperones accompanied the group:

- Mrs. Jill Foys, Northwest Commission, Director
- Mr. Trenton Moulin, Bridge Builders Community Foundation, Executive Director
- Mr. William Vonada, Cranberry Area School District, Superintendent
- Dr. Jody Strausser, Clarion University of Pennsylvania, Associate Professor Computer Information Science, PA Rural Robotics 2019 Volunteer of the Year
- Mr. Albert Abramovic, Venango County Commissioner. He said he was impressed with the day's program and was grateful for the opportunity to join the students for the day.
-

One of the Mobility21 UTC's focus areas is Education & Workforce Development. Research and technology is only one half of the new mobility equations. The transportation industry is being deluged with disruptive technologies just as its current, aging workforce faces mass retirement. Educating, training and inspiring the currently and next generation of transportation professionals is critical to the success of new technology. Helping coordinate and participate in the visit from the PA Rural Robotics Initiative is one way the Mobility21 UTC is engaging the next generation of transportation professionals.

Learn more:

- PA Rural Robotics Initiative – https://www.paruralroboticsinitiative.com/
- Mobility21 UTC – https://mobility21.cmu.edu

- CMU Robotics Institute Summer Scholars – https://riss.ri.cmu.edu/

# # #

In 2018, Franklin Area High School had four lonely VEX robots that students traveled around Pennsylvania and West Virginia with, searching for teams to compete against. Fast-forward to the end of this June and those four robots have 180 new companions right next door. Together they make up the Pennsylvania Rural Robotics Initiative, a consortium of 11 school districts, one technology center, and an intermediate unit that all share a common robotics platform and curriculum. Twenty-five schools, covering five counties, have found like-minded friends in higher education, business and industry, state and local government, non-profits, and regional economic and workforce development that not only support their initiative but help it to thrive.

The Traffic21 and Mobility21 Institute's leadership team have been trusted advisor since the conception of PA Rural Robotics and continues to look for ways to support their mission. Both faculty and graduate students from the Robotics Institute are working to bring CMU and these young STEM students together. PA Rural Robotics was also excited to find themselves partnered with a team of CMU undergraduate students as part of the 2019 Information Systems Spring Project. The Office of Outreach and Engagement have provided a menu of options that can further the CMU connections as the initiative grows. The most recent Carnegie Mellon connection was with the CMU CS Academy. PA Rural Robotics plans to introduce their member schools to the CS1 course and discuss the potential it could have in expanding computer science offerings within all of the member districts.

June 28, 2019
Stan Caldwell, Mobility21 UTC Executive Director, participated today in the Transportation Research Board's "Ahead of the Curve" Subcommittee meeting at the National Academies of Science Keck Center in Washington DC. During the meeting, members made final edits to the 'Instructor's Manual' for this course, which was designed for transportation research managers including those at the state departments of transportation and University Transportation Centers.

June 25, 2019
During the Annual Council of University Transportation Center's summer meeting in Norman, Oklahoma, Stan Caldwell, Executive Director, Mobility21 presented the UTC's technology transfer plan, and how impacts and accomplishments are tracked. The meeting brings together the nation's leading transportation professionals from academia and industry along with U.S. DOT and other transportation agency officials.

June 18, 2019
Stan Caldwell, Mobility21 UTC Executive Director served as a member of the Southwest Partnership for Mobility Advisory Council. This month as a result of the council's work, a report was released describing the challenges facing the region's transportation system. Read the report and learn more about the council's work
here: https://www.paturnpike.com/yourTurnpike/partnership_for_Mobility.aspx.

June 3, 2019
Mobility21 UTC researcher, Steve Smith participated in a panel at the Traffic Safety and the 5.9 GHz Band Conference in Washington D.C. along with the U.S. Deputy Assistant Secretary for Research and Technology, Diana Furchtgott-Roth. The purpose of the panel was to provide

examples of Vehicle-to-Everything (V2X) Communications deployment. Professor Smith highlighted research deployed in Pittsburgh connecting blind pedestrians to smart traffic signals. Stan Caldwell also participated in this forum.

Findings

Chris Hendrickson Publications:

Net-societal and net-private benefits of some existing vehicle crash avoidance technologies 2019
A Khan, CD Harper, CT Hendrickson, C Samaras
Accident Analysis & Prevention 125, 207-216

Socioeconomic and Usage Characteristics of Public Transit Riders in the United States 2019
R Grahn, C Hendrickson, ZS Qian, HS Matthews
Transportation Research Board 98th Annual Meeting Transportation Research Board

Socioeconomic and usage characteristics of transportation network company (TNC) riders 1 2019
R Grahn, CD Harper, C Hendrickson, Z Qian, HS Matthews
Transportation, 1-21

The implications of scope and boundary choice on the establishment and success of metropolitan greenhouse gas reduction targets in the United States 2018
SA Markolf, HS Matthews, IML Azevedo, C Hendrickson
Environmental Research Letters 13 (12), 124015

Corrigendum to "GHG emissions in daily travel and long-distance travel in Germany–Social and spatial correlates"[Transp. Res. D 49 (2016) 25–43] 2018
A Reichert, C Holz-Rau, J Scheiner
Transportation Research Part D: Transport and Environment 65, 854-857

Low-level automated light-duty vehicle technologies provide opportunities to reduce fuel consumption 3 2018
S Vasebi, YM Hayeri, C Samaras, C Hendrickson
Transportation Research Record 2672 (24), 60-74

Corrigendum to "Life cycle ownership cost and environmental externality of alternative fuel options for transit buses"[Transport. Res. Part D 57 (2017) 287–302] 2018
F Tong, C Hendrickson, A Biehler, P Jaramillo, S Seki
Transportation Research Part D: Transport and Environment 65, 858

Exploring the Economic, Environmental, and Travel Implications of Changes in Parking Choices due to Driverless Vehicles: An Agent-Based Simulation Approach
CD Harper, CT Hendrickson, C Samaras
Journal of Urban Planning and Development 144 (4), 04018043

Conclusions and Recommendations

This synthesis of research trends impacting the mobility of people and goods has informed policy on the local, state and federal level. Activities associated with this research have brought together academics, government officials, industry leaders and community organizations to better understand and engage in discourse on policies related to disruptive transportation technology.

With structures, activities and networks in place from the CMU Traffic21 Institute and the Mobility21 National University Transportation Center continued synthesis research on this topic are enabled. As the proliferation and adoption of new transportation and communications technologies continue to grow rapidly, the need for government, industry and community partners to access this synthesis research also grows. The researchers recommend building on the activities and networks from this project and begin a similar Phase 2 project to continue research in this area and further impact policy.

Below is a policy brief that Hendrickson and Caldwell developed with CMU PhD. Student Rick Grahn from this research.

Recommended Policies for the 21st Centu

By Rick Grahn, Stan Caldwell and Chris Hendrickson
Mobility21 National University Transportation Center/Traffic21 Institute
Carnegie Mellon University

Executive Summary

Major shifts in the transportation sector have been observed through the beginning of the 21st century due to emerging technologies and changing travel behaviors. Concurrent technology revolutions affecting travel include vehicle automation, general connectivity, information systems, and alternative fuel technologies. For the first time the 2017 National Household Travel Survey (NHTS) included questions to capture impacts of emerging technologies on the transportation system and to learn about the users of such technologies and the underlying trends and shifting travel behaviors resulting from technology adoption.

For this policy analysis the researchers selected four major transportation user groups to explore and analyze travel behavior and underlying trends that might be affected by emerging technologies. In addition, the selected groups directly impact 21st century management challenges in the transportation field, like, safety, congestion and emissions mitigation, urbanization, and environmental sustainability. The four sections highlighted in this report are listed below with research questions:

- **Ride-hailing** – Who is using ride-hailing services? When and why are they using them? Which modes are being substituted? What policies can mitigate negative outcomes?
- **Public Transit** – What is the current state of public transit in the United States? What travel behavior shifts surround public transit? What is the relationship between ride-hailing services and transit?
- **Alternative fuel vehicles** – What is the popularity of various modes of alternative fuel vehicles? What are travel behaviors and annual miles traveled among various fuels? What are the socioeconomic and demographic characteristics of alternative fuel vehicle owners?
- **Active Transit (e.g. bicycling and walking)** – What are trends in active transit? What are the socioeconomic and demographic characteristics of active commuters? How to facilitate/incentivize increased active commuter mode share?

Overall in the survey, the following observations stood out to the researchers. The general trend observed was that younger populations with higher incomes and educational attainment seemed to be early adopters of emerging mobility technologies, such as ride-hailing and alternative fuel vehicles. There seems to be an interesting relationship between transit and ride-hailing, in that ride-hailing users use transit at increased rates. Public transportation continues to decline in the United States, while ride-hailing services have observed a large increase in annual trips during the previous eight years. Active transit commuter mode share has increased since 2009 for short trips. Low income commuters largely rely on walking while bike commuters are dominated by white males.

	Summary of Policy Recommendations
Ridehailing: [Add picture] [Uber/Lyft]	• Open, collaborative partnerships between local governments, transit providers, taxi companies, and ride-hailing companies • Facilitate a complementary relationship between transit and ride-hailing services through first- and last- mile services and late-night programs when transit services become less reliable
Public Transit: [Add picture]	• Select appropriate incentives/fees to promote most efficient modes of travel during peak congestion hours • Explore partnerships with ride-hailing providers to improve urban mobility among vulnerable populations.
Alternative Fuel Vehicles: [Add picture]	• Explore alternative financial incentives to the federal tax credit, such as upfront cost savings, which might help improve AFV adoption rates among low-income households. • Outreach and infrastructure investment for alternative fuel vehicles in non-urban areas
Active Transit: [Add picture]	• Include emerging micro-mobility trends in latest surveys to adequately study and plan for changing travel behaviors. • Invest in active transportation infrastructure (bike lanes, separated lanes for micro-mobility, improved sidewalks) to improve safety, especially in low-income areas. • Partnerships between micro-mobility providers and local governments to ensure equal access and smooth rollout

National Household Travel Survey

The National Household Travel Survey (NHTS) is conducted by the United States Department of Transportation (USDOT) and gathers travel related information about the United States population through survey-based methods. The survey data is released periodically to track travel behaviors through time and inform transportation planners and policymakers about the latest developing trends in transportation. The 2017 NHTS is the most recent version and documents socioeconomic attributes for all members (≥5 years of age) among 129,969 households. Survey data is documented at four levels: household, person, vehicle, and trip level which can be linked with unique identifiers

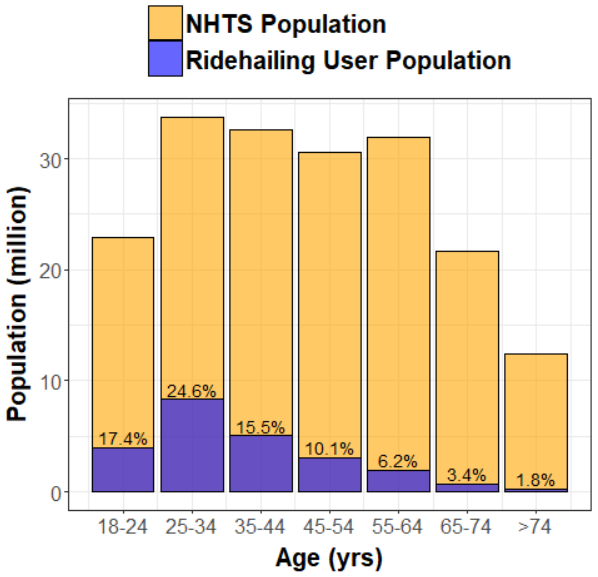
at each level. New questions were added to the 2017 NHTS to capture that latest trends in transportation.

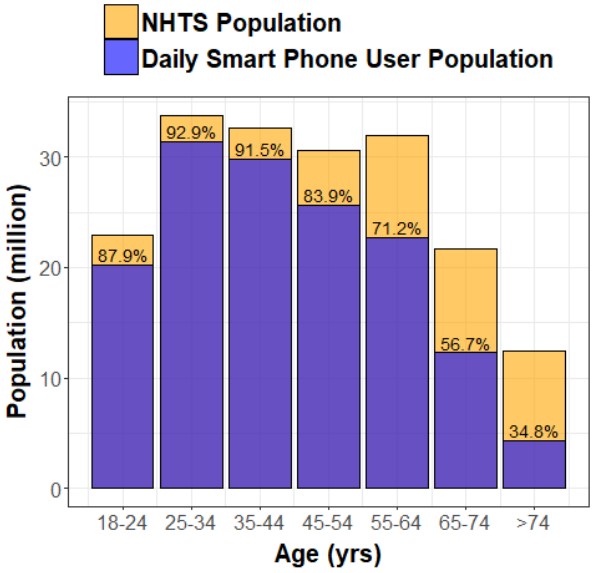
The widespread adoption of smart phones has enabled the emergence of ride-hailing companies, such as Uber and Lyft. Ride-hailing companies provide a service that matches passengers to drivers with personal vehicles using an online mobile application. Ride hail providers are also called transportation network companies (TNC) and ride share companies. The use of information and communications technologies, algorithms, and data analytics allows ride-hailing companies to provide convenient and reliable transportation alternatives throughout many urban areas. To capture changing travel behaviors surrounding the introduction of new mobility services, the 2017 NHTS asks participants about their frequency of ride-hailing use in the previous month.

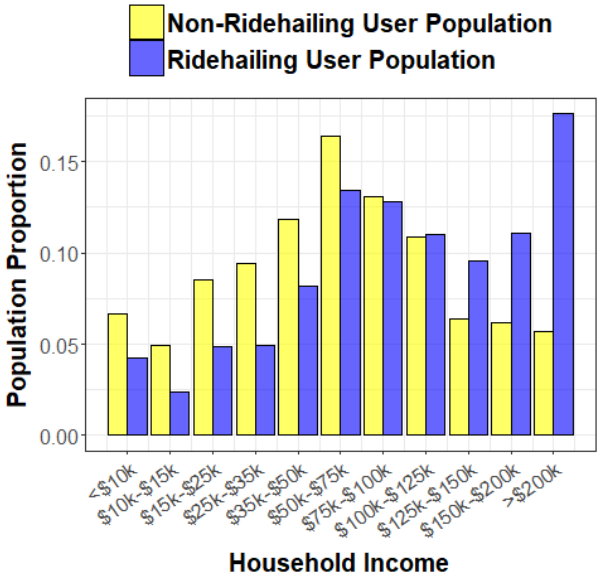
Vehicle fuel technologies continue to evolve and improve motivated by the desire to mitigate negative climate change and public health outcomes from vehicle emissions. The 2017 NHTS captures more detail regarding the fuel types of private vehicle purchases in the United States using additional questions. Alternative fuel vehicles (AFV) were added as a response to the fuel type question in addition to gasoline and diesel. Additionally, a follow-up question was asked to all AFV owners regarding the specific type of fuel (electric, hybrid, or plug-in hybrid).
The NHTS is a survey that focuses on personal ground travel within the United States. For this reason, air transportation and freight movement were not included in the analysis.

Results and Findings
Analyzing the NHTS data resulted in some significant policy findings related to changing travel behaviors in the United States due to the disruptive technologies noted above. The following results highlight characteristics and policy recommendations identified within and among the travel behaviors of four highlighted traveler groups; ride-hailing users, transit users, alternative fuel vehicle owners, and active travelers.

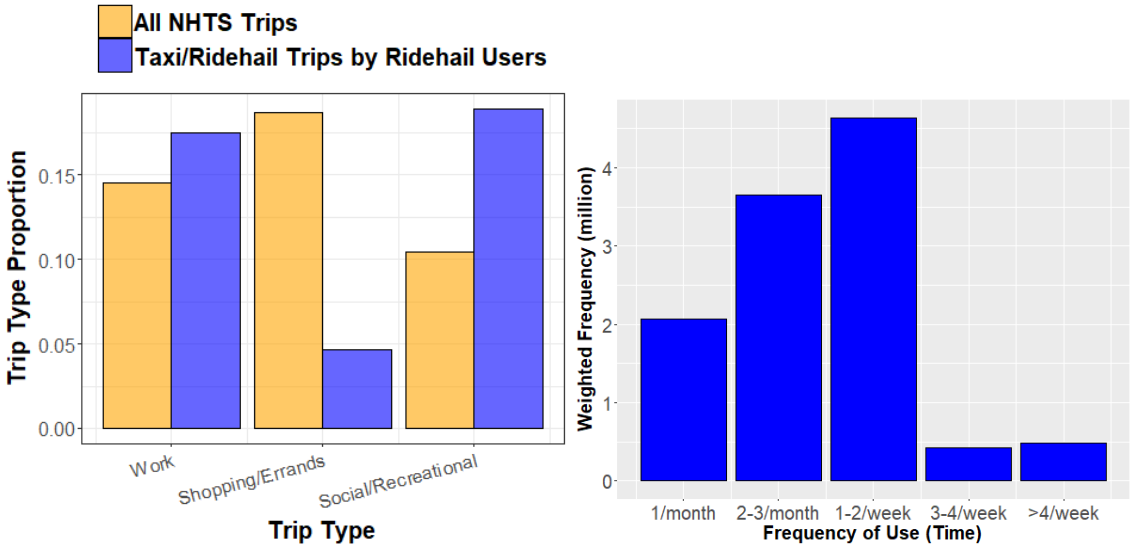
1. Findings and Characteristics of Ride-hail Users
a) Results from the NHTS
Considering respondents over the age of 18 (the minimum passenger age for Uber/Lyft without an accompanying adult), the proportion of the United States population who have used a ride-hailing service at least once in the previous month was 10%. Ride-hailing users tend to be younger, earn higher incomes, and are more likely to reside in urban areas with high population densities. Compared to the general population, white and Asian populations represented a larger proportion of the ride-hailing user population while African Americans represented a smaller proportion. As might be expected, smart phone users outnumber ride hail users by a large margin. The ride hailing population tends to have higher incomes than transit users.







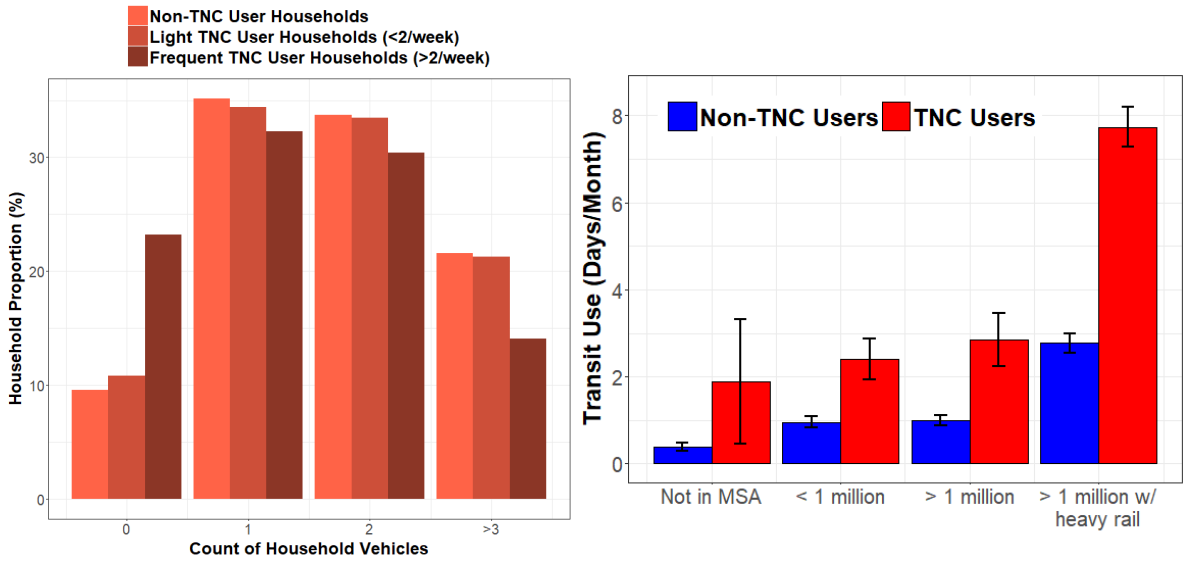
Of the ride-hailing users, 60% hailed a ride three times or less in the previous month, indicating that ride-hailing services are primarily used for special occasions. This is based on analysis of trip types among ride-hailing users from the NHTS trip level file. It is important to note that ride-hailing (Uber/Lyft) and taxis are combined and represent one mode of transportation in the NHTS data set. This fact makes it difficult to separate the two modes and make any strong conclusions regarding ride-hailing trip purpose. However, among ride-hailing users, approximately 19% of ride-hailing/taxi trips were social/recreational trips. The total proportion of social/recreational trips among all trips for the aggregate NHTS population was only 10%. Shopping and errands accounted for over 18% of total annual trips compared to less than 5% for ride-hailing/taxi trips among ridehail users. Overall, 17.5% of ride-hailing/taxi trips were work related among ride-hailing users. In many cases, work-related transportation can be reimbursed, which might alter some of the travel behavior conclusions mentioned in this analysis.



Ride-hailing users utilize transit at higher rates and own fewer vehicles compared to the aggregate United States population. In fact, the ride-hailing user population reported similar frequencies of use for both ride-hailing services and public transit during the previous month. Reported use of public transit for ride-hailing users living in large cities (>1 million) with access to heavy rail was almost three times greater when compared to similar sized cities without heavy rail. The average monthly frequency of ride-hailing use was also elevated when heavy rail was present.

	NHTS	Ridehailing Frequency of Use			
	Population	1/month	2-3/month	1-2/week	>2/week
Percentage of Ridehail Users (%)		24	34	28	13
Average Age (yrs)	46	39	37	35	34
Percent White (%)	70.1	72.5	70.4	72.8	68.5
Median Income ($US)	$50k-$75k	$75k-$100k	$75k-$100k	$100k-$125k	$100k-$125k
Median Education Level	Associate's	Bachelor's	Bachelor's	Bachelor's	Bachelor's
Average Monthly Public Transit Trips	1.9	3.1	4.4	6.9	9.6
Average Commute Time (min)	18.5	19.1	19.3	17.6	18.7
Average Household Cars	1.9	2.1	2	1.9	1.5

Table XX: Summary statistics with varying frequency of ridehailing use



b) Potential Issues

The interaction between ride-hailing and transit is complicated and varies from city to city. Additionally, concrete conclusions are hard to make because ride-hailing trip data is closely guarded by privately-held firms. However, the results indicate clear differences among ride-hail users and non-users in terms of transit use. Possible scenarios might be (i) respondents are pairing ride-hailing services with transit as a first-mile and/or last-mile solution (ii) transit riders are replacing transit trips with ride-hailing trips, or (iii) transit use doesn't change and other modes of transportation are being replaced by ride-hailing services. The inability to understand the role ride-hailing services play in urban mobility creates challenges in the transportation decision making process (i.e. investment, design, equity implications, etc.) for local governments and transportation planners.

Commuter rail provides a potentially convenient pairing with ride-hailing services due to fast travel speeds and limited stops. Ride-hailing services can provide first- and last-mile solutions for rail travelers because the total travel time is likely similar to that of the personal vehicle due to high commute speeds of heavy rail mostly due to their own right of way. This pairing will also reduce parking costs incurred at transit stations. However, this observation might be better explained by the user's socioeconomic status, as it was found that both commuter rail and ride-hail users tend to be from higher income households.

Extra travel by ride hailing services to re-position vehicles or pick up passengers can also lead to roadway and curbside congestion.

c) Policy recommendations

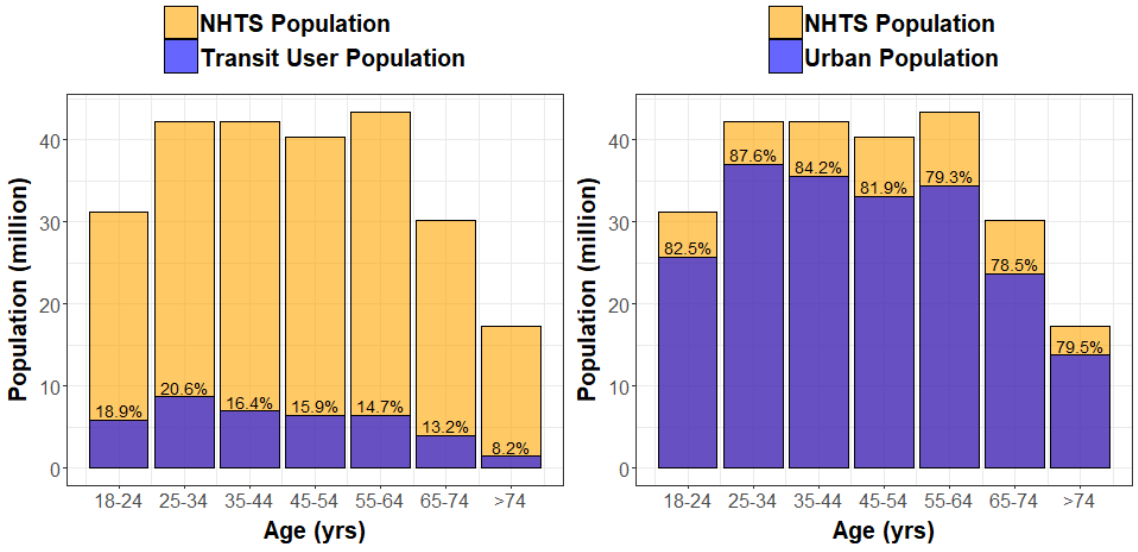
Ride-hailing services provide an alternative, flexible, and convenient mode of transportation in many urban areas. The first step to ensure equity and efficiency in urban transportation networks is to appropriately understand the roles ride-hailing services play within the urban system. An effective and open partnership between local governments, transit providers, taxi companies, and ride-hailing companies is extremely important to provide the highest level of service. This partnership would include data sharing and program design to provide first- and last-mile services to transit stations (bus, heavy rail, subway, etc.) and late-night services when transit services become less reliable. Service coverage can be increased to regions of low density through ride-

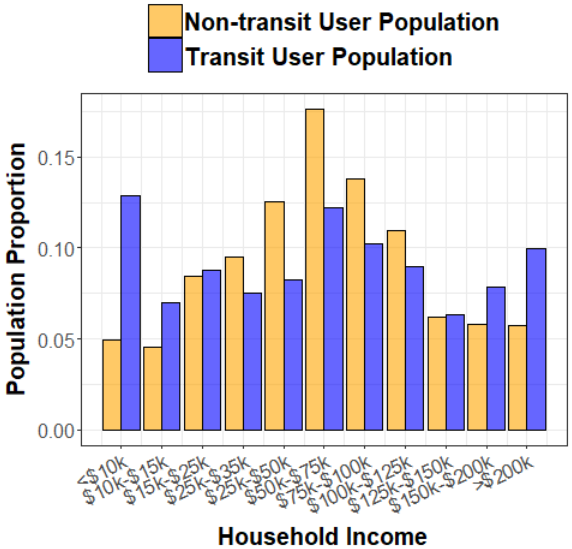
hailing services. Equity considerations may be considered through voucher programs to ensure equal access to mobility services.

2. Findings and Characteristics of Transit Users

a) Results from the NHTS

The proportion of the United States population that reported transit use in the previous month was 16.1%. Transit riders are predominately young and reside in urban regions. Low- and high-income households represent large proportions of the transit user population. Low income users tend to use bus services while high income households often use rail. Minority groups rely on public transit more heavily than the white population. High frequency transit riders use ride-hailing services at increased rates and own fewer household vehicles. High frequency ride-hailing users earn higher incomes compared to transit users indicating that vehicle ownership is likely by choice. The overall proportion of people using transit for commuting has declined between 2009 and 2017. During this same period, the proportion of taxi/ride-hailing users (taxis and ride-hailing were considered one category in the NHTS) has increased dramatically, likely due to the emergence of ride-hailing companies, such as Uber and Lyft.





More than 60% of transit riders use transit services at least once per week and over 27% use public transit as a daily commute mode. Frequent transit commuters tend to be younger and less white than the general NHTS population. Average monthly ride-hailing trips increase with increased transit use while household vehicle ownership rates decrease. These observations are likely because existing transit network and built environment characteristics that facilitate frequent transit use are the same features that facilitate increased use of ride-hailing services (short travel distances, limited parking availability and high parking costs). However, in certain situations, these results might indicate either a complementary (ride-hailing as first- and last-mile solutions) or a substitutional (frequent transit users are shifting to ride-hailing services) relationship. These attributes also disincentivize vehicle ownership by providing reliable alternative travel options while reducing individual costs from vehicle ownership. Frequent transit users have only 1 household vehicle compared to the NHTS average of 2.2 household vehicles. A further breakdown of transit users by mode yields that African Americans most often use bus services, while white and Asian populations use more subway and light rail services. Almost 80% of low-income households use buses compared to 22.4% for the highest earning households. The proportion of commuter rail, subway, and light rail all increase as household income increases.

	NHTS	Transit Frequency of Use			
	Population	1-3/month	1-2/week	3-4/week	>4/week
Percentage of Transit Users (%)		37	22	14	27
Average Age (yrs)	47.2	45	44	44	42
Percent White (%)	73.1	66.1	60.2	56.1	53.4
Median Income ($US)	$50k-$75k	$50k-$75k	$50k-$75k	$50k-$75k	$50k-$75k
Median Education Level	Associate's	Bachelor's	Bachelor's	Associate's	Bachelor's
Average Monthly Rideshare Trips	0.4	0.9	1.6	1.9	2.2
Average Commute Time (min)	19.2	19.4	19.4	20.9	26.1
Average Household Cars	2.2	1.8	1.4	1.1	1
Zero Car Households (%)	7	14.9	27	34.8	42.2

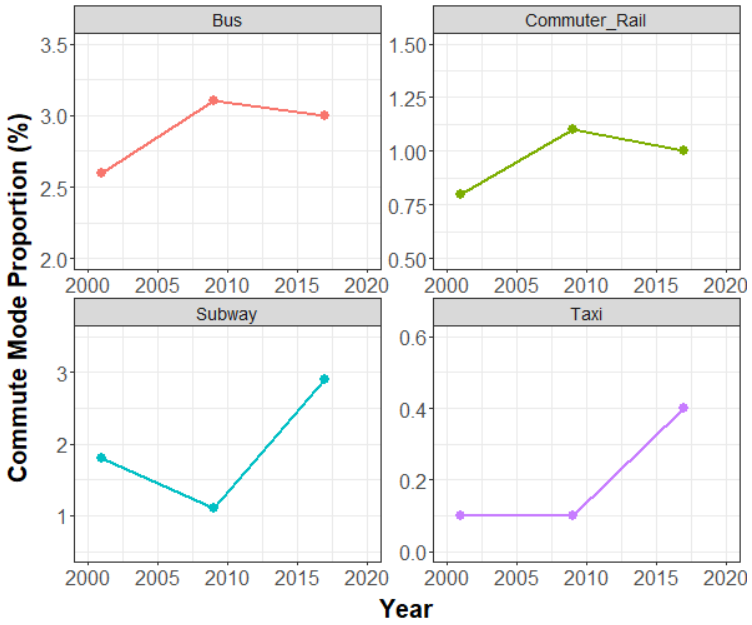
Table XX: Summary statistics with varying frequency of transit use

	Status	Bus[1] (%)	Commuter Rail[2] (%)	Subway[3] (%)	Transit (%)	NHTS (%)	Difference (%)
Race	White	34.1 (±3.7)	19.0 (±3.2)	46.9 (±3.3)	58.2	73.6	-15.4
	Black	62.9 (±6.2)	7.2 (±4.1)	29.9 (±8.0)	20.5	12.5	+8.0
	Asian	34.9 (±7.6)	12.3 (±6.3)	48.3 (±5.5)	11.2	5.4	+5.8

	Other	57.0 (±13.9)	7.3 (±3.7)	35.6 (±11.7)	10.2	8.5	+1.7
Household Income	<$25k	79.0 (±7.8)	4.9 (±3.7)	16.1 (±6.9)	17.9	19.6	-1.7
	$25k-$50k	56.7 (±7.2)	4.8 (±2.8)	38.5 (±7.0)	14.9	21.1	-6.2
	$50k-$75k	46.0 (±8.0)	10.6 (±4.9)	43.4 (±7.0)	14.3	16.8	-2.5
	$75k-$100k	36.9 (±10.9)	10.8 (±6.3)	52.3 (±11.5)	12.5	13.2	-0.7
	$100k-$150k	22.8 (±6.5)	23.6 (±5.9)	53.5 (±5.3)	19.1	16.8	+2.3
	>$150k	22.4 (±8.0)	26.8 (±5.1)	50.8 (±10.4)	21.3	12.5	+8.8
Residence	Second City	68.2 (±7.9)	18.6 (±7.4)	13.2 (±4.7)	13.3	19.8	-6.5
	Rural	52.5 (±18.7)	16.9 (±10.6)	30.6 (±25.2)	0.5	18.2	-17.7
	Suburban	46.1 (±9.3)	35.7 (±9.8)	18.2 (±4.8)	17.1	22.8	-5.7
	Small Town	52.9 (±17.3)	32.8 (±18.5)	14.3 (±9.6)	4.2	19.3	-15.1
	Urban	36.1 (±4.1)	7.2 (±1.8)	56.7 (±4.2)	64.8	20	+44.8

Note: The proportions are calculated for each characteristic of interest (race, household income, and living location). For example, the first row calculates the proportion of transit commuters for each transit mode for the white transit commuter population. "Transit" and "NHTS" correspond to the total transit and general NHTS population proportions for each race, household income, and living location. Values in parentheses represent the 95% confidence interval.
[1]Represents the proportion of transit commuters that most often use bus services
[2]Represents the proportion of transit commuters that most often use commuter rail
[3]Represents the proportion of transit commuters that most often use subway, light rail, or street cars

The proportion of work commutes for both buses and commuter/heavy rail observed a slight decrease since 2009. Subway/light rail observed a large increase since 2009. However, subway services are dominated by New York City, and the ridership was down in 2009 due to the financial crisis, thus making the longer-term increase much less pronounced. The 2017 NHTS grouped taxis with ride-hailing companies (Uber/Lyft) for the first time which resulted in a large increase in the proportion of commuters who reported taxis/ride-hailing as their most common commute mode. Since 1980, taxi commute mode share has been relatively constant between 0.1% and 0.2%. The large increase observed in 2017 to 0.4% is likely due to the rapid growth of ride-hailing services.



b) Potential Issues

Transit commuter mode share has declined while ride-hailing/taxi services observed a large increase since 2009. While uncertainty about the transit/ride-hailing interaction exists due to data limitations, general observations from the 2017 NHTS indicate that a substitutional relationship might exist due to contrasting trends. These observations are concerning because of the impact they might have on congestion. Transit modes (buses, commuter rail, etc.) are extremely space efficient compared to personal vehicles, including taxi and ride hailing vehicles. A substitutional effect between these two modes, especially during peak hours, can increase congestion significantly.

Low income households predominately rely on bus services compared to various forms of rail (heavy, elevated, street car, commuter, subway, light) that are most utilized by higher income households. Additionally, transit level of service metrics (walk time to/from transit station and wait time) improved for high income households since 2009 while the same metrics were worse for low income households. Transit agencies often face two competing objectives; 1) access and 2) ridership. As transit agencies invest and improve the transit network to boost ridership, it is important that access to transit for vulnerable populations is preserved.

c) Policy recommendations

While ride-hailing services improve urban mobility options for many residents, it is important to ensure that the sub-set of ride-hailing users are not affecting the greater network in a harmful manner. A combination of incentives and/or fees that nudge ride-hailing/taxi users to choose more efficient modes of travel, especially during times of congestion, is important to preserve network sustainability and equity.

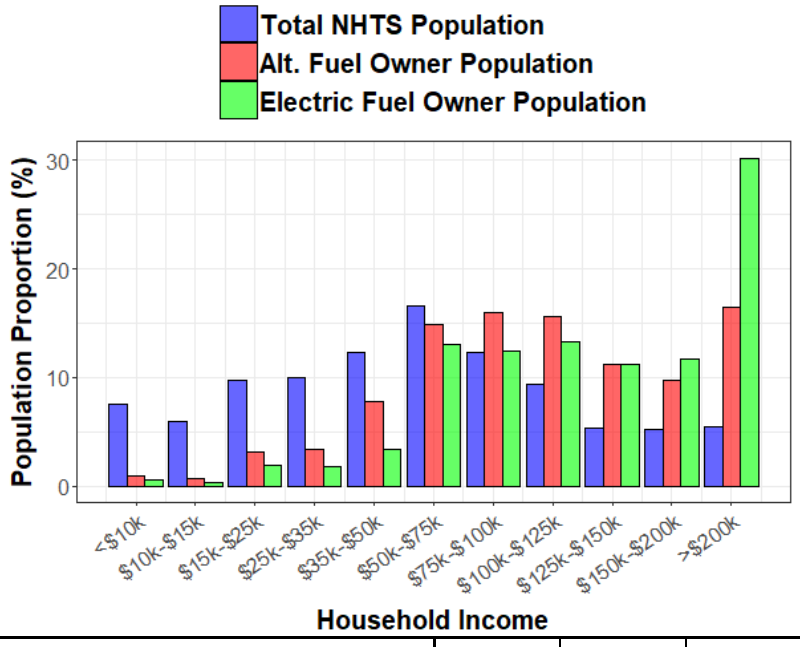
Emerging forms of mobility, such as ride-hailing companies, also have the potential to greatly improve access to jobs, health care and education for vulnerable populations. Pairing ride-hailing services with existing transit or providing mobility in an area without transit can drastically improve the economic and health status among vulnerable populations. Partnerships between

transit agencies and ride-hailing companies can improve mobility access, however, a voucher type policy might be required to ensure that ride-hailing services are affordable to low income populations. Additionally, a seamless payment system where individuals can pay for a multi-modal trip with one payment method that is accessible will also be important for the success of the program.

3. Findings and Characteristics of Alternative Fuel Vehicle Owners

a) Results from the NHTS

The proportion of the United States households that own at least one alternative fuel vehicle was 3.7%. AFVs are defined as all non-gasoline, non-diesel vehicles. Hybrid electric vehicles are considered alternative fuel vehicles in the 2017 NHTS, even though their primary fuel is gasoline. At a vehicle level, only 2.2% of the private vehicle fleet in the United States consist of AFVs. Of the AFVs, 80% were hybrid-electric vehicles that still rely on gasoline. Alternative fuel vehicle owners earn higher incomes and have higher levels of education compared to the general population. A large proportion of AFV households live in urban areas. More than 75% of AFV households own at least one conventional fuel vehicle (diesel or gasoline) in addition to their AFV. Further splitting alternative fuel vehicle fuel types by household, results indicate that more than 30% of electric vehicle (EV) households make more than $200k per year compared to just 16% and 5% of the AFV and overall NHTS households respectively. The initial costs of EV ownership remain high compared to similar-performing conventional fuel vehicles. Household EVs are often present in multi-car households to be used for specific trip types. Home ownership and the presence of a garage both influence the choice to purchase an EV because of charging outlet availability. These characteristics are all representative of higher income populations.

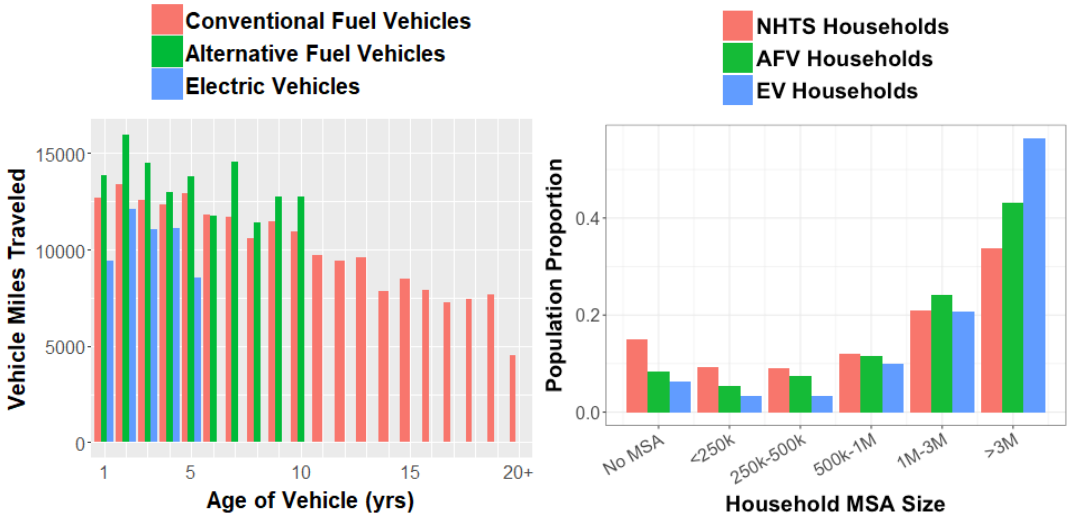


Number of Cars in Household	Zero	One	Two	Three+	Total
Number of Households (millions)	10.5	39.6	39.1	28.8	118.2
Total NHTS Population	8.9%	33.5%	33.1%	24.4%	99.9%
Conventional Fuel Only Vehicle Owners	NA	97.8%	95.1%	94.3%	87.3%
Alternative Fuel Only Vehicle Owners	NA	2.2%	0.04%	0.04%	0.9%

Both Alternative and Conventional Fuel Vehicles	NA	NA	4.5%	5.6%	2.9%

Table XX: Breakdown of vehicle count characteristics

The highest annual miles traveled for AFV were observed for hybrid and/or plug-in hybrid vehicles. Electric vehicles traveled the least number of annual miles. These observations are likely due to improved efficiency for hybrid-electric vehicles and range limitations for fully electric vehicles. Sine alternative fueled vehicles are newer than the entire fleet, their mileage would be expected to be somewhat higher since vehicle miles traveled per vehicle drops as vehicles age. More than 60% of EV households and 52% of AFV households have a graduate degree compared to only 28% for the general United States population. Large proportions of AFV and EV households resided in large metropolitan areas. More than 40% of AFV owners live in MSAs with populations greater than 3 million. EV households average one additional vehicle per household compared to the NHTS population.



	All Households	Biodiesel	Plug-in Hybrid	Electric	Hybrid	Other
AFV Households (%)	NA	0.4	7.5	8.9	78.5	2.9
Average Age (yrs)	49.0	50.0	52.0	54.0	54.0	48.0
Percent White (%)	76.0	74.1	83.3	79.2	79.9	93.3
Median Income ($US)	$50k-$75k	$75k-$100k	$75k-$100k	$75k-$100k	$75k-$100k	$50k-$75k
Median Education Level	Associate's	Bachelor's	Bachelor's	Bachelor's	Bachelor's	Associate's
Urban/Rural Ratio (%)	82.0	88.0	90.0	90.0	88.0	52.0
Average Household Cars	2.0	3.0	2.6	2.9	2.4	3.1

Table XX: Summary statistics by vehicle fuel type

b) Potential Issues

Results from the NHTS indicate that a large proportion of AFV households are wealthy and own multiple vehicles. The current incentive structure is to provide tax breaks to AFV owners. This policy framework doesn't seem to be improving AFV ownership among low income households. The push to increase AFV ownership is not only important from an emissions standpoint, but many other perks exist for AFV owners in selected states (e.g. preferred parking, permission to enter HOV lanes, etc.) that might further widen the gap between high- and low-income households.

The proportion of AFVs in the private vehicle fleet in the United States is currently 2.2%. The same private vehicle fleet is used to provide ride-hailing services, as all drivers must utilize their private vehicles. Ride-hailing popularity is increasing rapidly, and vehicle miles traveled is expected to increase due to dead-head miles between ride-hail trips and mode shift to ride-hailing. In the absence of policy intervention, it is likely that many metropolitan regions will observe large increases in congestion and emissions which can negatively affect public health and increase the likelihood of climate change related events.

c) Policy recommendations

To mitigate potentially harmful outcomes related to a slow transition away from conventional fuel vehicles towards cleaner alternatives might require policy interventions in addition to the existing tax break for households that purchase an alternative fuel vehicle. First, to deal with the high upfront costs associated with AFVs, a policy where cost savings are provided at the time of vehicle purchase for low income families might provide the needed financial assistance for such families to realistically consider AFVs. A second policy intervention pertains to the rapid adoption of ride-hailing services and their use of the private vehicle fleet. This issue is likely worked out in a partnership with local governments where a minimum proportion of the ride-hailing vehicle fleet must be an alternative fuel vehicle is agreed upon.

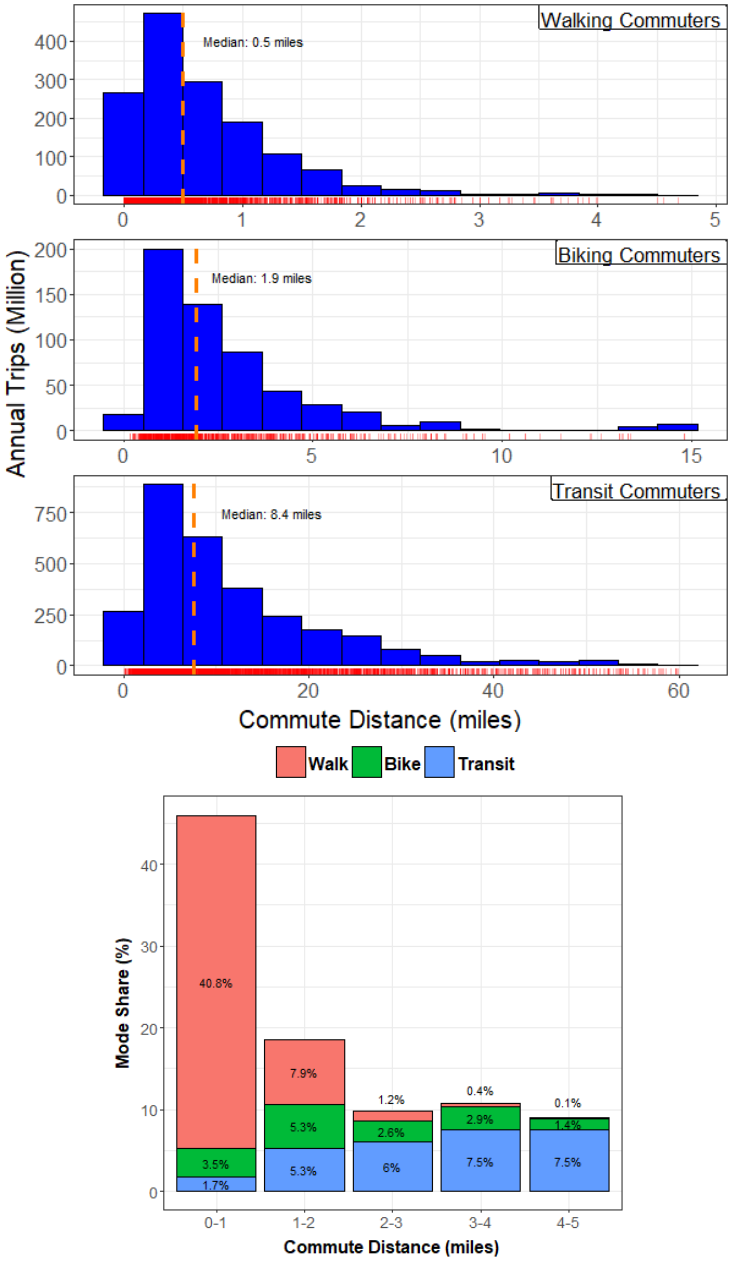
An alternative solution might be an incentive-based structure where local governments and ride-hailing companies provide financial incentives to drivers who utilize alternative fuel vehicles. This type of solution can both help improve AFV ownership among low-income individuals in addition to reducing emissions from ride-hailing vehicles.

In addition to the above recommendations, an outreach effort to educate households in more rural locations about technology improvements to EV range will be important in the transition away from the internal combustion engine. Proper investment into charging infrastructure in less population dense regions, and advertising those locations, will ensure equitable access and allow for a more sustainable transition, both from an environmental and equity point of view.

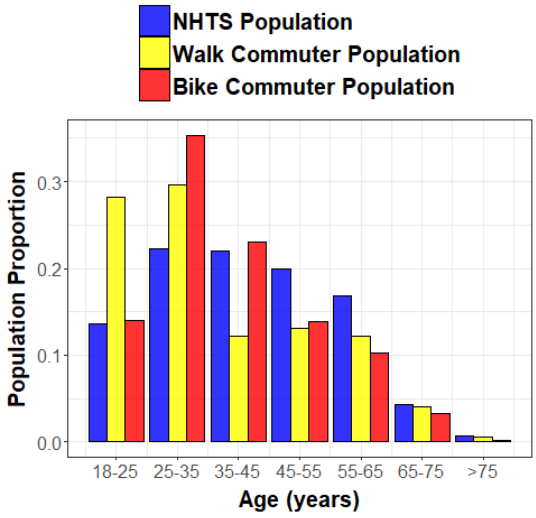
4. Findings and Characteristics of Active Travelers

a) Results from the NHTS

Currently, 82.3% of the United States population resides in urban areas. Of the urban population, approximately 54% commute to work regularly. The urban commuter population is used in this analysis to understand behaviors and characteristics of active commuters in the United States. Of the commuting population, 3.2% of people reported walking and 1.3% reported biking as their most frequent commute mode. From a trip level perspective, commute trips account for 15% of the total annual trips taken and 16.5% of the annual person miles traveled. The median travel length for walking commutes was 0.5 miles compared to 1.9 miles for bike commutes.



Walking commuters are the youngest with approximately 60% of walking commuters being under the age of 35. Bike commuters are also young compared to the NHTS population, however, approximately 60% of the bike population is represented by commuters between 25 and 45 years of age. A large proportion of walking commuters live in households making less than $25k annually which is likely due to the high costs of car ownership. Male bike commuters outnumber females by almost 3-to-1. The black population makes up approximately 13% of the NHTS general population, however, only 3.8% of the bike commuter population is black. Both the lowest and highest income households represent larger proportions of the bike commuter population compared to the general NHTS population. Over 40% of bike commuters have graduate degrees.



	Status	NHTS[1] (%)	Walking Commuter[2] (%)	Bike Commuter[2] (%)
Gender	Male	53.3	53.2 (-0.1)	72.7 (+19.4)
	Female	46.7	46.8 (+0.1)	27.3 (-19.4)
Race	White	71.3	72.2 (+0.9)	78.9 (+7.6)
	Black	12.8	11.5 (-1.3)	3.8 (-9.0)
	Asian	6.4	8.6 (+2.2)	7.8 (+1.4)
	American Indian	0.7	1.0 (+0.3)	0.2 (-0.5)
	Pacific Islander	0.3	0.1 (-0.2)	0.6 (+0.3)
	Multiple	3.4	2.9 (-0.5)	3.5 (+0.1)
	Other	5.1	3.6 (-1.5)	5.2 (+0.1)
Household Income	<$25k	12.6	27.2 (+14.6)	17.0 (+4.4)
	$25k-$50k	20.0	22.6 (+2.6)	18.4 (-1.6)
	$50k-$75k	17.2	12.4 (-4.8)	17.9 (+0.7)
	$75k-$100k	14.7	10.3 (-4.4)	10.7 (-4.0)
	$100k-$125k	12.5	9.9 (-2.6)	10.8 (-1.7)
	$125k-$150k	7.8	4.0 (-3.8)	5.6 (-2.2)
	>$150k	15.2	13.6 (-1.6)	19.5 (+4.3)
Education	< high school	3.2	6.6 (+3.4)	1.3 (-1.9)
	GED	18.0	18.8 (+0.8)	7.3 (-10.7)
	Some College/Associates	30.0	25.8 (-4.2)	26.3 (-3.7)
	Bachelor's	26.8	24.1 (-2.7)	24.6 (-2.2)
	Graduate Degree	22.0	24.7 (+2.7)	40.5 (+18.5)

[1]NHTS refers to the National Household Travel Survey urban commuter population
[2]Values in parentheses indicate deviation from the NHTS commuter population

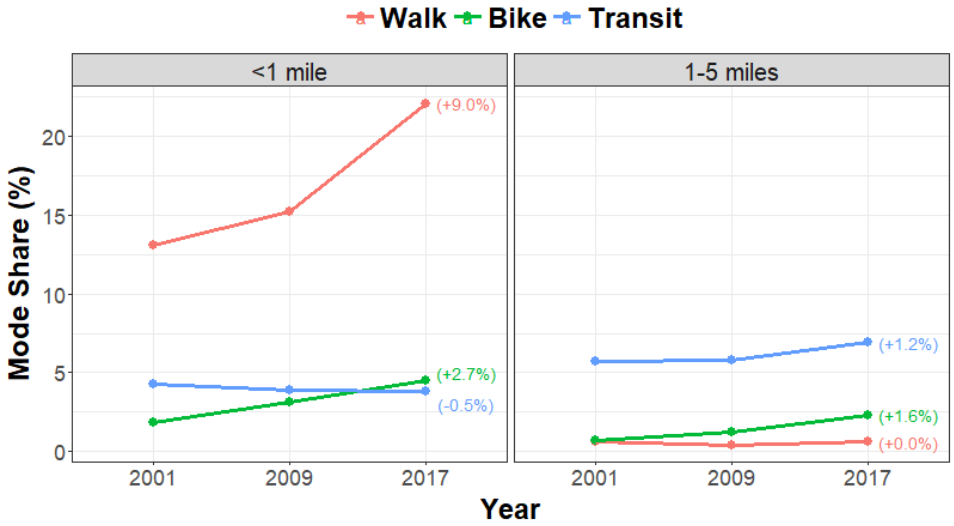
Both forms of active commuters (walking and biking) are most common in no children households. Additionally, almost 70% of active transportation commuters live in zero or one car households, which only represent 30% of the NHTS population.

	Status	NHTS[1] (%)	Walking Commuter[2] (%)	Bike Commuter[2] (%)
Occupation	Sales/Service	26.0	37.8 (+11.8)	24.9 (-1.1)
	Clerical/Administrative	10.4	7 (-3.4)	4.9 (-5.5)
	Labor[3]	13.0	7.2 (-5.8)	6.0 (-7.0)
	Professional/Managerial	50.5	48 (-2.5)	64.3 (+13.8)
Life Status	No Children	50.0	64.8 (+14.8)	68.0 (+18.0)
	Single Parent[4]	4.8	6 (+1.2)	1.9 (-2.9)
	2+ Parents[4]	45.2	29.2 (-16.0)	30.1 (-15.1)
Household Vehicles	0 Household Cars	4.7	28.2 (+23.5)	22.3 (+17.6)
	1 Household Car	24.5	38.0 (+13.5)	43.7 (+19.2)
	2+ Household Cars	70.8	33.7 (-37.1)	34.0 (-36.8)

[1]NHTS refers to the 2017 National Household Travel Survey urban commuter population
[2]Values in parentheses indicate deviation from the NHTS commuter population
[3]Laber refers to Manufacturing, Construction, Maintenance and Farming Occupations
[4]Youngest child is less than 21 years of age

Table XX: Active Commuter Characteristics

High income households are responsible for the steepest increases in active transportation commuter mode share. Walking times to and from transit stations and wait times have become worse for low income populations while high income populations have experienced improved transit travel and wait times.



b) Potential Issues

Active transportation modes (walking and biking) can provide numerous benefits to the individual traveler and the greater transportation network. From a traveler perspective, it is common to observe improved public health and well-being among active commuters. From an engineering point of view, the reduction in private vehicles on the roadway resulting from commuters opting to travel via foot or bicycle can help reduce congestion and emissions that negatively impact all nearby residents. As the global population continues to grow and move to urban areas, sustainable commute modes are more important than ever.

Results from the NHTS indicate that travel times to and from bus stations have become longer for low income households since 2009. Travel times from high income households decreased during the same time period. Equal access to reliable transit for all socioeconomic and demographic backgrounds is a fundamental building block to ensure economic stability within the community. Lastly, new forms of urban mobility continue to be deployed across many United States metropolitan areas. Electric scooters, e-bikes, sit scooters, bike shares, and many more are being piloted without policies to ensure equal access. Additionally, new micro-mobility users and their greater interaction with the existing transportation network are poorly understood. How cities and governments prepare for the rapid deployment of new mobility options will dramatically influence the potential success or failure regarding their integration into the existing transportation system.

c) Policy Recommendations

As new forms of mobility take shape, from bikeshares to electric scooters, policies to ensure access for low income and minority communities is extremely important in preserving reliable mobility access for all. Partnerships between private mobility providers and local governments can help ensure that equity considerations are met by strategic placement of new mobility systems. A policy and regulatory framework should also be sketched out before new mobility options are deployed to avoid potential negative outcomes that might stem from the absence of regulation. Education, safe infrastructure, and access to community bikeshares, scooters, etc. that can reduce travel time to and from transit stations can help improve commute travel time among vulnerable populations.

New infrastructure investment that improves safety for active commuters and micro-mobility users is extremely important due to current vehicle-centric infrastructure designs in many American cities. Bike lanes, active commute corridors, sidewalks, dedicated lanes for micro-mobility are all infrastructure designs that separate vehicular traffic from more vulnerable modes (walk, bike, micro-mobility) to help reduce collisions. Investment should also be distributed across all neighborhoods and socioeconomic classes to ensure transportation system equity.
As emerging technologies and new micro-mobility alternatives continue to be deployed and gain popularity, it is recommended that transportation planners and researchers continue to study user populations and behavioral changes for informed network design and investment. To do this, it is recommended that travel surveys (local, regional, or national) include new forms of mobility questions to analyze behavioral shifts and underlying trends to better inform future transportation planning and investment.

5) Appendix: Details of NHTS (e.g. weighting, excluded groups)

The 2017 NHTS collects data from a stratified random sample of households based on the household address and requires responses from all household members over the age of 5.

Appropriate weighting factors are assigned at each level (vehicle, person, household, and trip) to produce unbiased population-level estimates. The total weighted survey population was 301,599,169, or approximately 93% of the United States population in 2017. Individuals under the age of 5 and people living in institutionalized facilities (e.g. prisons, medical institutions, military bases, etc.) were not considered in the survey, thus accounting for the difference in the survey weighted population and true population. The summary statistics and mean calculations in this report consider the full sample weights outlined by NHTS. All additional information regarding survey techniques, weighting procedures, and datasets in general can be found in the 2017 NHTS User's guide (NHTS 2018).

6) References

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