



A USDOT NATIONAL
UNIVERSITY TRANSPORTATION CENTER

Carnegie Mellon University



THE OHIO STATE UNIVERSITY



Program Progress Performance Report
for University Transportation Centers

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Office of the Assistant Secretary for Research and Technology
University Transportation Center Program

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Mobility of People and Goods

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1. ACCOMPLISHMENTS: What was done? What was learned?

What are the major goals of the program?

The primary goal of Mobility 21, a National University Transportation Center for Improving Mobility is to develop and deploy technologies, policies, incentives and training programs for improving the mobility of people and goods in the 21st century efficiently and safely. We will accomplish this through a comprehensive program of interdisciplinary research; education and workforce development with a focus on diversity; collaboration with university, deployment, and government partners; and technology transfer and leadership efforts.

Research Metrics

- Faculty scientific leadership as reflected by the number of publications and citations of faculty work in transportation-related areas
- The number of staff, faculty and students involved in leadership positions in academic, industry and government transportation organizations
- New research collaborations in fields related to this work
- Successful technology deployments and their impact
- Patents and start-ups.

Education and Workforce Development Metrics

- Number of transportation-related courses
- Students participating in transportation research projects
- Advanced degree programs funding Mobility21 UTC students
- Mobility21 UTC-funded graduate students
- Mobility21 UTC-funded students who receive degrees
- Institutional educational partnerships
- Participants in workforce and educational programs.

Technology Transfer Metrics

- Simple adoption of the innovation by a transportation operator, company or public, to more formalized outcomes such as licensing, patents, commercialization, and spin-off companies
- Quantify numbers of meetings, attendance, publications, and social media and website activity

Collaboration Metrics

- Number and diversity of members of both the Mobility21 Consortium and Advisory Council
- Number and impact of deployments achieved through collaboration

What was accomplished under these goals?

Research

Fifty-six research projects were active during this report period. In addition to the more traditional research projects, in 2017, there was an intentional call for projects which would allow research to extend to non-urban areas, the Smart Mobility Challenge. Six of the projects are targeted to this non-urban thrust which include: Millvale Mobility: Connecting Millvale to the River and the Region, Integration of Parking Data Across Mixed-density Suburban Communities in the Allegheny County municipalities of Mt. Lebanon and Dormont, Video Analytics for Bike and Pedestrian Counting in Greensburg, Westmoreland County and Bethel Park, Building a Pilot Peer-to-Peer Platform for Ride-sharing in Lawrence County, and Real-time Traffic Monitoring and Prediction for Cranberry Township, Butler County. These projects continued to be active during the report period.

Education and Workforce Development

We view research and education as two sides of the same coin. We cannot educate for future generations without exposing them to research, development and deployment. On the other hand, we cannot do successful research, development and deployment without the input of future generations. Since Traffic21 and the UTCs have emerged on campus it has generated interest among faculty and students, bringing exposure to real-world problems, and engaging faculty and students on multiple projects. As a consequence, courses and class projects are multiplying as well. We have and will focus on education and workforce development in equal and complementary measure to research, development and deployment. Below are some highlights of education and workforce development accomplishments:

- September 21, 2018 - The Smart Mobility Connection Seminar Series continued with a presentation from Lee Branstetter, Professor of Economics and Public Policy at Carnegie Mellon University on his UTC research project “Can Ridesharing help the Disadvantaged Get Moving.”
- September 7, 2018 - The Fall 2018 Smart Mobility Connection Seminar Series began with Stefani Danes, Adjunct Professor of Architecture at Carnegie Mellon University, and her two students presenting their work on connecting Millvale to the River. They discussed the question: is it better to go through, over or under Route 28 – and how to do it.
- June 8, 2018 - Mobility21 Executive Director Stan Caldwell facilitated a roundtable discussion on the workforce implication of autonomous vehicle technology for the CMU Heinz College 2018 Summer Leadership Symposium for mid-career professionals in the Masters of Science in Information Technology and Executive Education Programs.
- May 4, 2018 - CMU Vulnerability Researcher Dan Klinedinst spoke as the Smart Mobility Connection speaker of the semester on addressing cyber-security issues in intelligent transportation systems. Klinedinst discussed how he gets to think like a bad guy to determine whether transportation systems are safe, and how he learned to text his car.
- April 24, 2018 - Bob Koch, who leads the Community College of Allegheny County’s Automotive Technician Training Program, spoke at this month’s UTC faculty meeting about how to prepare technicians for autonomous technologies. Koch noted that with direction from advisory boards, community colleges will be perfectly positioned to educate entry level intelligent transportation technicians in many different career fields.
- April 7, 2018 - On Saturday morning, the UTC’s Chris Hendrickson & Woman in Transportation Fellow, Ngani Ndimbie spoke at the Transit and Equity panel for CMU’s Sustainability Weekend. They were joined by four other panelists to discuss the current state of mobility in Pittsburgh, particularly for those with accessibility or socioeconomic challenges.
- April 4, 2018 - UTC researcher and CMU professor Sean Qian spoke to the CMU Civil Engineering Honor Society Chi Epsilon about data analytics and optimization. The presentation and discussion focused on using tools such as behavioral economics, software development, life cycle assessment, policy, and others to optimize transportation networks.

Technology Transfer

Below are some highlights of technology transfer accomplishments:

- September 21, 2018 - Mobility21 Director, Raj Rajkumar, was the keynote speaker at The Flagstaff Festival of Science. The Flagstaff Festival of Science serves to connect and inspire the citizens of Northern Arizona, particularly youth, with the wonders of science and the joy of scientific discovery.
- September 13, 2018 - Mobility21 Director, Raj Rajkumar attended the Value of Data: How Emerging Technologies are Redefining our Future Bloomberg Conference in New York, New York. He was on a panel titled “Driverless Cars Run on Data Not Gasoline.”
- August 31, 2018 - Mobility 21 National UTC Director Raj Rajkumar and other CMU faculty including Martial Hebert 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 autonomous vehicle and drone policy with leading manufacturers, technology companies, and universities.

- 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.
- July 23, 2018 – Mobility21 Executive Director, Stan Caldwell spoke at meeting of The Alliance to Save Energy's 50×50 Commission, including several U.S. Representatives, about Mobility21's tech projects to save energy. Stan was joined by UTC researcher, Costa Samaras who discussed "Energy, Sustainability and Climate Impacts of the Transition to Autonomous Vehicles."
- July 15 – July 18, 2018 - Two UTC projects were presented at the American Society of Civil Engineers' Conference by CMU PhD Students, Xidong Pi and Matthew Battifarano. CMU Undergrad and Vice President of the CMU ASCE Chapter, Sharika Hedge, participated in the Three Minute Pitch competition for younger members where she presented her research on real-time vehicle to vehicle transactions. The winner of the competition was CMU UTC PhD student, Jacob Ward.
- July 16, 2018 - Mobility21 Diversity Fellow Allanté Whitmore presented at the ASCE International Conference on Transportation & Infrastructure. She spoke on robocars, ethics, & infrastructure.
- 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 USDOT 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 10, 2018 - Mobility21 Diversity Fellow Allanté Whitmore attended the Automated Vehicle Symposium in San Francisco. She participated in one of the poster sessions, sharing her recent work on AV ethics.
- June 26, 2018 - UTC Researchers Steve Smith and Aaron Steinfeld were featured speakers at the Accessible Transportation Symposium. Over 80 people attended the event. The event was sponsored by the U.S. Department of Transportation and the U.S. Department of Health and Human Services Administration on Community Living, National Institute on Disability, Independent Living, and Rehabilitation Research.
- June 20, 2018 - Rahul Mangharam, UTC Faculty, Associate Professor, Electrical & Systems Engineering, Univ. of Pennsylvania moderated a panel on Evaluation of Insurance and Liability Issues Across the ADAS Spectrum at the SAE Automated and Connected Vehicle Systems Testing Symposium. Included on the panel was Philip Koopman, Associate Professor in CMU Department of Computer and Electrical Engineering.
- June 14, 2018 - CMU hosted participants of the Community Transportation Association of America Expo for a two-part tour of UTC research at an intersection equipped with Dedicated Short Range Communications followed by a tour of National Robotics Engineering Center Participants expressed their excitement to take the information and technology back to their home cities to help improve traffic and mobility.
- June 5, 2018 - Mobility21, UTC researcher Maxine Eskenazi delivered a keynote speech on Intelligent Agents on June 5th at the Journées d'Etudes sur la Parole 2018 conference in Aix en Provence, France. "The speech and language Laboratory organizes this conference under the aegis and Scientific guaranty of the Francophone Association of spoken Communication."
- May 15, 2018 - Mobility21 Executive Director Stan Caldwell Moderated the ITS America Smart Cities/Smart State Roundtable at the Rayburn House Office Building on Capitol Hill. Stan introduced

USDOT Deputy Assistant Secretary for Transportation Policy Finch Fulton who provided opening remarks and then Stan moderated the a panel discussion on smart cities and smart states deployment activity with:

- Cordell Schachter, Chief Technology Officer, New York City Department of Transportation
- Wes Maurer, Director of Intelligent Transportation Systems, Colorado Department of Transportation
- Steve Ingracia, Deputy Director for Technology and Strategic Planning, Nebraska Department of Transportation
- Rebecca Hunter, External Affairs, Corporate Development & Strategy, Crown Castle
- May 14, 2018 - The USDOT hosted a free webinar to provide an update on the Accessible Transportation Technologies Research Initiative (ATTRI) and the DRRP on Robotics and Automation for Inclusive Transportation, funded by the National Institute on Disability, Independent Living and Rehabilitation Research (NIDILRR) and led by Carnegie Mellon University. The webinar allowed interested stakeholders to learn about some of the progress being made by ATTRI, and more specifically, hear directly from CMU about the successes and challenges of enabling robots and cloud-based autonomy to provide assistance to people in transportation hubs.
- May 7, 2018 - UTC researcher, Scott Matthews, presented twice during the Inspection and Maintenance Solutions conference. First he spoke on the analytics of vehicle trouble codes from emissions inspections as connected to whether the “Check Engine Light” was being illuminated. And secondly he reported results of a survey he had done of last year’s conference attendees in terms of their interest and willingness in the results of data-driven studies of inspection program performance that cross jurisdictional boundaries.
- April 24, 2018 - UTC faculty and researcher Bernardo R. Pires spoke on the Transportation Research Board’s bi-monthly webinar series - Conversations with Colleagues, focused on bicycle and pedestrian monitoring and research. During this webinar, titled “Collecting Bicycle and Pedestrian Data with Video: Methods and Issues,” Pires spoke about data collection efforts underway at CMU to 60-70 webinar attendees.
- April 25, 2018 - The Dean of the Carnegie Mellon University College of Engineering, Jim Garrett, and the Director Mobility21, Raj Rajkumar, were invited by Ray Betler, CEO of WABTEC, to speak at the WABTEC Global Leadership Summit on April 25. Raj gave the keynote presentation on “Challenges and Opportunities in Rail Automation” to the more than 200 WABTEC executives from around the world.
- April 5, 2018 - Researcher Umit Ozguner from Mobility21 partner the Ohio State University spoke as an expert at the Technology Summit in Istanbul, held by Trucell and attended by over 2,500 organizations. Ozguner spoke about current 5G technologies and its role in smart transportation systems.

Collaboration

At the core of our efforts, is collaboration. During this report period, Lisa Kay Schweyer, Program Manager for the UTC made the first of what will continue as regular on-site visits with the UTC’s academic partner institutions. On September 18, she visited the University of Pennsylvania’s PI’s and the center’s administrative manager to review the current research projects, processes to help streamline project start-up/reporting, student involvement, and was even able to sit in one of the classes on F1/10 miniature autonomous racing vehicles. The goal of these meetings is to provide opportunities for face-to-face meetings to discuss projects, upcoming events, student work, and other opportunities for collaboration.

Other examples of collaboration with campus, local officials and partner organizations include:

- September 14, 2018 - Mobility21 Director, Raj Rajkumar, moderated a panel on the Intersection of Tech & Business: Smart Home, Smart Car and Smart City at Intersect@CMU during the Tepper Quad Grand Opening, featuring Secretary Anthony Foxx, Homaira Akbari, Brian Olsavsky & Jay Apt.

- August 23, 2018 - UTC Researchers Christoph Mertz and Sean Qian presented their research to the City of Pittsburgh today, including Mayor Bill Peduto and Director of Mobility and Infrastructure, Karina Ricks. The meeting was to discuss potential collaboration for improving paving and asphalt efforts in the city.
- August 6, 2018 – Mobility21 researcher Chris Hendrickson, 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.
- 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 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 UTC 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 Mobility21 Executive Director, Stan Caldwell and Principal Project Scientist, Christoph Mertz.
- July 16, 2018 - Pittsburgh hosted the American Society of Civil Engineers’ International Conference on Transportation & Development 2018. Mobility21 faculty member Chris Hendrickson, was a plenary speaker.
- June 5, 2018 - Metro21: Smart Cities Institute Executive Director, Karen Lightman, presented for the 2018 TMA Summit: Oakland Mobile Workshop at CMU organized by the Oakland Transportation Management Association (OTMA). The OTMA works to improve mobility, access and safety for commuters. Karen presented Metro21/Mobility21 projects that focus on making our cities smarter for people in the Oakland area.
- June 5, 2018 - Stan Caldwell, the Executive Director for Mobility21, was a featured keynote panelist at this morning’s Council of University Transportation Center Summer Meeting. His presentation highlighted ways Traffic21 conducts “Community and Publicly Engaged Research.”
- May 21, 2018 - The University of Pittsburgh celebrated their first year of the School of Computing and Information with a conference that focused on Modeling the World’s Systems. The goal of the conference was rational analysis and management of complicated system and an unusually diverse network of stakeholders. Prof. Raj Rajkumar, Director of CMU’s Mobility21 National University Transportation Center joined D. Tyler Gourley, Vice President, Hillman Family Foundations, Steve Smith, Director, CMU Intelligent Coordination and Logistics Laboratory and Christina Mair, University of Pittsburgh on the Modeling Urban Systems Panel Presentation.

How have the results been disseminated?

Updates on the projects and results are distributed in Breaking in Smart Transportation, a weekly newsletter that highlights UTC research and efforts in the news as well as industry news. With over 2,400 subscribers (an increase of over 300 people since the last report), and the readership represents a wide range of interests.

Before the updates are sent out in the newsletter, they appear as individual updates/articles on the website, and are also posted through our Facebook and Twitter accounts.

We also held the First Annual National Mobility Summit of UTCs, held April 12 in Washington, DC. The National Mobility Summit brought together industry, community, workforce, and academic thought leaders around our country to explore ‘*New Frontiers and Opportunities for 21st Century Mobility.*’ Over **95** attendees came together for The First Annual National Mobility Summit. This included **9** university transportation centers representing **48** Colleges and Universities across the US. After the Summit, a new webpage was added to the

Mobility21 website to document the event and provide copies of all the presentations (<http://mobility21.cmu.edu/events/the-national-mobility-summit/national-mobility-summit-2018/>).

What do you plan to do during the next reporting period to accomplish the goals?

- We will be continuing the planning for the 2nd Annual Mobility Summit in 2019. The date has already been set for April 11, 2019 and invitations have already started going out.

2. PRODUCTS: What has the program produced?

Publications, conference papers, and presentations

Journal publications:

Title	Citation	Type	Date
Understanding and predicting highway travel time with spatio-temporal features of network traffic flow, weather and incidents	Shuguan Yang, Sean Qian. (2018) Understanding and predicting highway travel time with spatio-temporal features of network traffic flow, weather and incidents, submitted to IEEE Intelligent Transportation Systems Magazine	Peer-reviewed Journal	
User-centric interdependent urban systems: using time-of-day electricity usage data to predict morning roadway congestion	Pinchao Zhang, Sean Qian. (2018) User-centric interdependent urban systems: using time-of-day electricity usage data to predict morning roadway congestion, submitted to Transportation Research Part C, under 2nd round review	Peer-reviewed Journal	
Localization and Perception for Control and Decision Making of a Low Speed Autonomous Shuttle in a Campus Pilot Deployment	A2. Bowen, W., Gelbal, S.Y., Aksun-Güvenç, L., Güvenç, L., 2018, "Localization and Perception for Control and Decision Making of a Low Speed Autonomous Shuttle in a Campus Pilot Deployment," SAE International Journal of Connected and Automated Vehicles, accepted.	Peer-reviewed Journal	
"Crowd motion detection and prediction for transportation efficiency in shared spaces"	D. Yang, J. M. Maroli, L. Li, M. El-Shaer, B. A. Jabr, K. Redmill, F. Ozguner, and Umit Ozguner "Crowd motion detection and prediction for transportation efficiency in shared spaces," Proceeding SCOPE '18 Proceedings of the 2nd International Workshop on Science of Smart City Operations and Platforms, Porto, Portugal.	Trade/Professional	
Smooth Behavioral Estimation For Ramp Merging Control In Autonomous Driving	Dong, C., Dolan, J.M., and Litkouhi, B., Smooth Behavioral Estimation For Ramp Merging Control In Autonomous Driving, Proceedings of the 2018 IEEE Intelligent Vehicles Symposium, Changshu, China (June 2018).	Peer-reviewed Journal	2018-06-27
Cost-Effectiveness of Sharing Roadside Infrastructure for Internet of Vehicles	Alexandre K. Ligo, Jon M. Peha, "Cost-Effectiveness of Sharing Roadside Infrastructure for Internet of Vehicles," IEEE Transactions on Intelligent Transportation Systems, Vol. 19, Issue 7, July 2018	Peer-reviewed Journal	2018-07-01

Strategic Timing and Pricing in On-demand Platforms	V. Abhishek, M. Dogan and A. Jacquillat (2018), Strategic Timing and Pricing in On-Demand Platforms, under review. Available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3186931	Peer-reviewed Journal	2018-07-01
Point Completion Network.	Yuan, W., Khot, T., Held, D., Mertz, C., & Hebert, M. (2018). PCN: Point Completion Network. International conference on 3D vision, Sept. 2018	Trade/Professional	2018-09-05
Spectrum for Intelligent Transportation Systems: Allocation and Sharing	Alexandre K. Ligo, Jon M. Peha, "Spectrum for Intelligent Transportation Systems: Allocation and Sharing," to appear in Proceedings of the IEEE International Symposium on Dynamic Spectrum Access Networks, 2018.	Peer-reviewed Journal	2018-10-01
"Using GANs for Generation of Realistic City-Scale Ride Sharing/Hailing Data Sets"	Submitted to the Seventh International Conference on Learning Representations (ICLR), May 6-9, 2019	Peer-reviewed Journal	2019-05-06
"Using GANs for Generation of Realistic City-Scale Ride Sharing/Hailing Data Sets"	Submitted to the Seventh International Conference on Learning Representations (ICLR), May 6-9, 2019	Peer-reviewed Journal	2019-05-06

- The June 2018 edition of the *Civil Engineering* magazine of the American Society of Civil Engineers includes an article featuring UTC researcher Sean Qian discussing CMU's traffic engineering and intelligent transportation systems interdisciplinary course. He shares details course objectives and how students are engaged in learning.

Books or other non-periodical, one-time publications:

- August 14, 2018 - UTC Researcher Maxine Eskenazi, along with Laurence Devillers and Joseph Mariani recently published a new book called "*Advanced Social Interaction with Agents.*" She also published a paper called "*Zero-Shot Dialog Generation with Cross-Domain Latent Actions*" with Tiancheng Zhao that won best paper award from SigDIAL.

Identify for each one-time publication:

Nothing to report.

Other publications, conference papers and presentations:

Title	Event	Type	Attended	Date
Camera and GPS Fusion for Automated Lane Keeping Application	SAE World Congress 2018	Conference-Professional	100	2018-04-10
Use of Robust DOB/CDOB Compensation to Improve Autonomous Vehicle Path Following Performance in the Presence of Model Uncertainty, CAN Bus Delays and External	SAE World Congress 2018	Conference-Professional	100	2018-04-10

Disturbances				
Localization and Perception for Control and Decision Making of a Low Speed Autonomous Shuttle in a Campus Pilot Deployment	SAE World Congress 2018	Conference-Professional	100	2018-04-10
What can we learn from the first automated-vehicle-involved traffic fatality?	Philadelphia's Vision Zero Research Partnership Workshop	Workshop-Professional	80	2018-05-02
Human-Robot Interaction	Retail Industry Leaders Association (RILA) webinar	Other-Professional	80	2018-06-27
Incentivizing Participation in Peer-to-Peer Ride-Sharing Platform	Discussion with Hulton Arbors community	Other-Professional	10	2018-06-28
Sharing Connected Vehicle Infrastructure Between Governments and Internet Service Providers	ASCE International Conference on Transportation & Development (ICTD)	Conference-Academic	40	2018-07-01
Strategic Timing and Pricing in On-demand Platforms	Manufacturing, Service and Operations Management Conference	Conference-Academic	30	2018-07-03
ML and Robotics to Enable People With Disabilities to Go Where They Want	Guest lecture, AI4ALL Summer School	Other-Academic	60	2018-07-03
Car-truck modeling for McKees Rocks	Meeting with McKees Rocks Borough	Seminar-Professional	5	2018-08-07
Car-truck simulation for Pittsburgh region	Meeting with Pittsburgh Mayor's office	Seminar-Professional	10	2018-08-23
Millvale Mobility	Smart Mobility Connections	Seminar-Academic	40	2018-09-07
"Generating Urban Mobility Data Sets Using Scalable GANs"	MASITE/ITSPA Annual Meeting	Conference-Professional	500	2018-09-10
"Generating Urban Mobility Data Sets Using Scalable GANs"	MASITE/ITSPA Annual Meeting	Conference-Professional	500	2018-09-10
Smart Traffic Infrastructure for Urban Mobility	2018 MASITE & ITSPA Annual Meeting	Conference-Professional	200	2018-09-10
Rethink O-D estimation	FHWA workshop on data fusion	Workshop-Professional	25	2018-09-19
Can Ridesharing Help the Disadvantaged Get Moving?	SMC Talk	Seminar-Academic	40	2018-09-21
Car-truck simulation for Pittsburgh region	Meeting with PennDOT	Seminar-Professional	30	2018-09-27
Can Ridesharing Help the Disadvantaged Get Moving	PennDOT research symposium	Symposium-Professional	20	2018-09-27
Smart City Technologies for Local Governments	Allegheny County & Western PA Association of Township	Conference-Professional	60	2018-09-28

	Commissioners, Fall Conference			
Mobility Data Analytics	Cranberry Township	Seminar-Professional	5	2018-10-05
Spectrum for Intelligent Transportation Systems: Allocation and Sharing	IEEE International Symposium on Dynamic Spectrum Access Networks	Conference-Academic	50	2018-10-25
Parameter Space and Model Regulation based Robust, Scalable and Replicable Lateral Control Design for Autonomous Vehicles	IEEE Conference on Decision and Control	Conference-Academic	100	2018-12-19

Website(s) or other Internet site(s)

URL for Internet site(s) that disseminates the results of the research and/or program activities	Short description of the site	Metrics
http://mobility21.cmu.edu/ <i>Based on feedback from our Women in Transportation Fellows, a new section was added to the Mobility21 website during this report period called "For Students." This new section of the website is tailored to student interest in the UTC. The information includes how students can get involved in transportation club, other involvement opportunities, updates on previous fellows, etc. We have been working with our academic partners to add tabs for their schools and student information. At the end of this report period, CMU and the University of Pennsylvania both had tabs in this section. Work has also begun to also collect information from OSU for inclusion.</i>	The Carnegie Mellon University's Mobility21 National University Transportation Center website	New Posts: 642
https://www.facebook.com/traffic21.tset	The Carnegie Mellon University's Facebook Page for the Technologies for Safe and Efficient Transportation National University Transportation Center and Mobility21, A National University Transportation Center for Improving Mobility of People and Goods	Likes: 120
https://www.youtube.com/user/Traffic21TSET	The Carnegie Mellon University's YouTube Page	Videos: 12 Views: 2,165

	for the Technologies for Safe and Efficient Transportation National University Transportation Center and Mobility21, A National University Transportation Center for Improving Mobility of People and Goods	
https://twitter.com/Traffic21_CMU	The Carnegie Mellon University's Twitter Page for the Technologies for Safe and Efficient Transportation National University Transportation Center and Mobility21, A National University Transportation Center for Improving Mobility of People and Goods	Followers: 893 Following: 1,626 Tweets: 6,166

Technologies or techniques

Inventions, patent applications, and/or licenses

A core focus from the beginning of Traffic21 has been to apply university research and technology to real-world mobility problems. This process began by first talking with transportation professionals, identifying real-world problems, and then sharing those problems with researchers. As technologies prove successful, Mobility21 staff work with researchers and government and industry partners to advance the application of that technology. This may result in agencies, such as the City of Pittsburgh, adopting a technology such as Surtrac adaptive traffic signals, commercialization with an industry partner, such as Delphi, or spinning off a company, such as RoadBotics. Following are some examples of developing technologies:

- A computerized Graphical User Interface has been developed to run on a PC that facilitates the manual extraction of vehicle data from video footage images in order to estimate traffic flows as part of the UTC project, Using municipal vehicles as sensor platforms to monitor health and performance of the traffic control systems.
- As part of the UTC project Incorporation uncertainty for reinforcement learning of agent policies, new Bayesian approach to Reinforcement Learning using off-policy TD methods and Assumed Density Filtering has been developed to allow for updates on action-values (Q) through an online Bayesian inference method that explicitly takes into account uncertainty. The empirical results show these proposed algorithms outperform comparable algorithms in several task domains, and has been submitted for publication at the AAAI conference.

Other products

Nothing to report.

3. PARTICIPANTS & COLLABORATING ORGANIZATIONS: Who has been involved?*What organizations have been involved as partners? * Indicates new partners this reporting period.*

Partner Organization Name	Location	<i>Contribution to the Project</i>				
		Financial support	In-kind support	Facilities	Collaborative research	Personnel exchanges
Rapid Flow Technologies *	Pittsburgh, PA		X			
Roadbotics *	Pittsburgh, PA	X			X	
Allegheny County Department of Human Services *	Pittsburgh, PA				X	
Innova EV *	Burr Ridge, IL		X		X	
Ericsson *	Stockholm, Sweden	X				
Nagoya University *	Japan	X		X	X	X
Bloomfield Development Corporation	Bloomfield, PA				X	
Borough of McKees Rocks	McKees Rocks, PA			X	X	
City of Philadelphia	Philadelphia, PA				X	
City of Pittsburgh Department of Mobility and Infrastructure	Pittsburgh, PA			X	X	
City of Pittsburgh Mayor's Office	Pittsburgh, PA				X	
Clemson University	Clemson, South Carolina				X	
Cranberry Township	Cranberry, PA			X	X	
Delaware Valley Regional Planning Commission	Philadelphia, PA				X	
Florida Atlantic University	Florida				X	
Mathworks	Natick, MA				X	
Michelle Kondo, Scientist					X	
USDA Forest Service	Philadelphia, PA				X	
Nvidia Autonomous Driving	Santa Clara, CA				X	

Philadelphia Streets Department	Philadelphia, PA				X	
Pittsburgh Parking Authority	Pittsburgh, PA			X	X	
Port Authority of Allegheny County	Pittsburgh, PA			X	X	
Transportation and Traffic Management at The Ohio State University	Columbus, OH				X	
University of Modena, Italy	Modena, Italy				X	
University of Pennsylvania Center for Clinical Epidemiology and Biostatistics	Philadelphia, PA				X	
University of Pennsylvania Injury Science Center	Philadelphia, PA				X	
University of Porto, Portugal	Porto, Portugal				X	

Have other collaborators or contacts been involved?

Our Deployment Partner Consortium is utilized for identifying real-world transportation needs, research project development and deployment, technology licensing and commercialization, student recruitment for jobs and internships, class and capstone projects. The list of partners is continually updated based on the research projects being conducted. The latest update resulted in a partner list of over 80 organizations.

During this report period, planning also began for the 2018 Advisory Council meeting and Deployment Partner Consortium Symposium (which will be held November 8 and November 9, 2018 respectively). These are both opportunities for identifying real-world transportation needs, research project development and deployment, technology licensing and commercialization, student recruitment for jobs and internships and class and capstone projects.

Our current consortium members include:

- 412 Food Rescue
- American Association of Retired Persons (AARP)
- American Association of State Highway and Transportation Officials (AASHTO)
- Access Transportation Systems
- Alliance for Transportation Working in Communities
- Architecture, Engineering, Consulting, Operations, and Maintenance (AECOM)
- Airport Corridor Transportation Association
- 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
- 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
- Community College of Allegheny County (CCAC)
- Conference of Minority Transportation Officials (COMTO)
- Cranberry Township
- Crown Castle
- Delaware River Port Authority (DRPA)
- Delaware Valley Regional Planning Commission (DVRPC)
- Borough of Dormont
- Economic Development South
- Federal Highway Administration
- General Motors Global Research & Development
- Healthy Ride
- Hulton Arbors
- Hillman Family Foundations
- iNetworks Advisors
- Innovation Works
- Intelligent Transportation Society of America
- Jackson/Clark Partners
- Lawrence County
- League of American Bicyclists
- Marshall Township
- Meter Feeder
- Miovision
- Near Earth Autonomy
- North Huntingdon Township
- Oakland Transportation Management Association (OTMA)
- 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.
- 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
- Tiramisu Transit Inc.
- Toyota
- Uber
- University of Pittsburgh
- Uptown Partners
- Wade Trim
- Western Pennsylvania Regional Data Center
- Western Pennsylvania School for Blind Children
- Women’s Transportation Seminar (WTS)

And lastly, the UTC also has a distinguished Advisory Council of national leaders that provides strategic guidance and counsel. We sought to achieve modal and demographic diversity. The individual members provide significant collaboration opportunities with their extensive professional affiliations. During this reporting period, some new Advisory Council Members were recruited. The following prominent transportation professionals serve on the Council:

- 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 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 Bicyclists
- James A. Misener, Senior Director, Technical Standards at Qualcomm and former Director of UC Berkley PATH
- Leslie Richards, Secretary of the Pennsylvania Department of Transportation
- David Roger, President of Hillman Family Foundations
- Paul Skoutelas, President and Chief Executive Officer of the American Public Transportation Association
- Kirk Steudle, Director of Michigan Department of Transportation

4. IMPACT: What is the impact of the program? How has it contributed to transportation education, research and technology transfer?

What is the impact on the development of the principal discipline(s) of the program?

- September 2018 - To continue to improve energy efficiency and increase mobility intelligence, Sean Qian and Costa Samaras were awarded over \$2.5 million in combined funding from the Department of Energy. This funding will be used to advance Sean Qian's project in understanding and improving energy efficiency of regional mobility systems leveraging system-level data and Costa Samaras' project on drones, delivery robots, driverless cars, and intelligent curbs for increasing energy productivity of first/last mile goods movement.
- 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 neighborhoods to develop a pedestrian wayfinding system. Mobility21 researcher Don Carter and Executive Director, Stan Caldwell have been involved in the design process which led to this final design.
- May 28, 2018 - Mobility21 researchers Costa Samaras and Raj Rajkumar were quoted in national media for reactions of the NTSB Uber Crash Initial Report. References to their expert analyses can be found in The Wall Street Journal, The Washington Post, WIRED, San Francisco Chronicle, Pittsburgh Tribune Review, Stuff, Independent Recorder, KJZZ News and Transport Topics.
- April 10, 2018 - The CMU Heinz College weekend course taught by various Mobility21 researcher's and partners, Societal Consequences of Technological Change: Autonomous Vehicles in the Central Business District, presented a summary of students' findings to Pittsburgh, PennDOT and Port Authority of Allegheny County policy makers. Recommendations included curb mapping, a use tax on transportation network companies, and deploying an autonomous electric shuttle, among others.

What is the impact on other disciplines?

- Mobility21 continues to take a leadership role in the Smart Belt Coalition, which is comprised of CMU, the Ohio State University, the University of Michigan, Penn State University, Kettering State, PennDOT, ODOT, MDOT, and Pennsylvania and Ohio Turnpike officials. The coalition was initiated by the Mobility21 UTC faculty and has created the first multi-state connected and automated vehicle test bed for research, deployment of technologies, and policy development.
- Raj Rajkumar, Mobility21 Director, and Stan Caldwell, Mobility21 Executive Director continue to serve on Pennsylvania's Autonomous Vehicle Policy Task Force and provide both the Pennsylvania Department of Transportation and the State Legislature's Transportation Committees counsel on automated vehicle policy.
- UTC Executive Director, Stan Caldwell served on the planning committee for the FHWA and Pennsylvania Department of Transportation Research Symposium which resulted in a new process for university engagement with the PennDOT research program.
- Due to its interdisciplinary nature, the UTC project: the Connected Vehicle Infrastructure for a Smart City, has had impact in the body of knowledge not only in the transportation field, but also in the areas of wireless communications and Internet policy:
 - In the area of transportation, the research has produced knowledge that can inform decisions about alternative uses of DSRC technology. More specifically, an approach to infrastructure sharing between government transportation agencies and commercial ISPs that could benefit both, as well as Internet users and tax-payers. In addition, exploration of the pricing policies that government agencies might adopt in such arrangements, quantified the trade-offs implicit in pricing, and shown how optimal pricing varies from urban areas to rural areas. Finally, the results have shown that if DSRC technology becomes widespread, as it would under federal policies promulgated by the U.S. Department of Transportation in 2016, then the sharing strategies we propose could cover roughly 20% of the cost of safety infrastructure, making the adoption of this potentially life-saving technology far more affordable, which may expand deployment and reduce the burden on tax-payers. Such results inform policy, and are important when developing local, state and federal budgets.
 - In the federal level, the research has impact on the current debate about the use of spectrum for

Intelligent Transportation Systems. While it has been recently proposed that spectrum is shared between vehicular and unlicensed devices, transportation authorities have concerns that such sharing may cause harmful interference to vehicular communications. The project's ongoing research suggests that as long as safety messages are transmitted on exclusive spectrum, policymakers in the federal level could allow vehicles and unlicensed devices to share spectrum for non-safety communications in a highly efficient way. When these results become public, we expect them to have impact on this important debate for the future of connected vehicles.

- This project's contributions also advance knowledge in the areas of wireless communications and Internet policy. Expanding Internet infrastructure to keep up with the growth in the demand for mobile Internet is costly. ISPs have been using alternative technologies such as Wi-Fi to offload some of the mobile Internet data, but Wi-Fi hotspots are not suitable to offload data of fast-moving users such as those in vehicles. Our research has demonstrated that DSRC technology is a promising and largely ignored alternative that Internet operators could consider. The results have shown that the approach can be more cost-effective than other technologies in urban areas, although not in rural areas. A reduction in costs for network operators is likely to lead to more affordable Internet services for consumers.

What is the impact on the development of transportation workforce development?

This grant has expanded workforce development efforts through a partnership with Community College of Allegheny County's Automotive Technician Training Program. This program provides students with the education to maintain vehicles. Their coursework involves integrating safety system alignments, and computer assisted diagnostics. The new components being added as a result of research, will need to be maintained and these students are learning how to do that. CCAC taught three advanced electronics courses for automotive technicians the spring of 2018, which 33 student technicians participated. The operation, diagnosis and calibration/validation processes are all taught in the following systems, they include:

- Advance Adaptive Cruise Control Systems
- Forward Collision Warning and Collision Avoidance Systems
- Stability-Traction Control Systems
- Lane Keeping Systems
- Advanced Sensor Technology and Sensor Disturbances Due To Environmental or Driving Conditions
- Sensor Plausibility Failures
- Many other advanced vehicle technologies

CCAC also trained 225 automotive credit students through fall 2018. 26 students graduated in May with an associate degree, and 52 new students started their careers in August of 2018. With Pennsylvania's State & Emission re-certification programs going to an on-line format with a private vendor, CCAC's workforce training numbers will decline. Students seeking licensing are still required to attend a formal classroom/lab format to obtain their license.

CCAC has and will continue to hold events for students and the public to learn and have an opportunity to see advanced vehicle technologies. The events CCAC hosts are:

- Odyssey Day 2018 – This outreach event is sponsored by the Pittsburgh Regional Clean Cities and is all about informing students and the public about alternative fuels for transportation use. This event is on October 12, 2018. Last year CCAC had over 300 interested attendees.
- CCAC Trade Fair – This event is open to all students interested in trade careers. In the Transportation sector we explain the opportunities for an automotive technician working on advanced vehicles, and

other opportunities related to the transportation industry and the skills required for them. Last year CCAC had almost 600 students attend.

- Day at the Auto Show – This event is for automotive students interested in automotive technician careers. CCAC put on a presentation every February in conjunction with the Greater Pittsburgh Automotive Dealers Association at the Greater Pittsburgh Auto Show at the David L. Lawrence Convention Center in Pittsburgh. This past February CCAC hosted almost 500 automotive students. We discussed and answered questions regarding jobs, advancements in vehicle technology, connected vehicles and autonomous vehicles.

In addition to hosting these events CCAC automotive instructors visit local Career and Technology Centers to talk to students in automotive classes. CCAC carried out over a dozen visits this past year talking to over 300 students. Our outreach events have educated well over 1000 individuals that may be interested in automotive technology or their related careers.

CCAC continues to explore how to integrate Mechatronics and Data Analytics courses into a certificate for transportation related careers, and we continue to modify our automotive curriculum to enhance the students and technician's knowledge about technology.

At CMU, Dan Klinedinst of Carnegie Mellon University was a panelist at the ITS America Forum on Cyber Security Risk and the Future of Mobility in Denver, Colorado on August 1, 2018. Dan was on 'The Cyber Industry' panel where the panelists discussed resources available to address cybersecurity challenges, how do you attract, cybersecurity talent, and building a cybersecurity workforce.

What is the impact on physical, institutional, and information resources at the university or other partner institutions?

Nothing new to report.

What is the impact on technology transfer?

- 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. Also participating was Roadbotics, another UTC spin off company.
- August 31, 2018 Mobility 21 National UTC Director Raj Rajkumar and other CMU faculty including Martial Hebert 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 autonomous vehicles and drones with leading manufacturers, technology companies, and universities.
- July 24, 2018 - PennDOT Issued 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, Mobility21 serve on the PennDOT Automated Vehicle Policy Task Force and participated in deliberation and provided feedback for the development of this new policy.
- July 17, 2018 - Stan Caldwell, Executive Director of 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. Caldwell testified at this hearing about impacts of current smart infrastructure investments and future infrastructure needs for connected and automated vehicles.
- June 26 & 27, 2018 - Mobility21 Executive Director Stan Caldwell participated in the Federal Highway

Administration's National Dialogue on Highway Automation to provide input from the University Transportation Center perspective and share both technology and policy research on vehicle automation. This two day workshop in Philadelphia, which focused on planning and policy, was the first of five national events.

- June 15, 2018 - Mobility21 National UTC Director, Raj Rajkumar and Traffic21/Mobility21 Executive Director, Stan Caldwell participated in the Pennsylvania Autonomous Vehicle Policy Task Force meeting to provide policy guidance as automated vehicle researchers and tester on public roadways.
- June 12, 2018 - The Southwestern Pennsylvania Commission is the Metropolitan Planning Organization serving the 10-county southwestern Pennsylvania region. Mobility21 Executive Director Stan Caldwell participated in their Forces of Change Expert Resource Panel Discussion to provide feedback on disruptive transportation technologies evolving in the region.

What is the impact on society beyond science and technology?

Through research, development, and deployment, the end goal is increasing mobility for all users of the transportation system. One way in which we expand the impact of our efforts is to sponsor Smart Mobility Connections seminars, every other week during the fall and spring semesters. The seminars are advertised on the UTC website, and recordings of each sessions are added to the site's What's Happening section. The sessions draw students, fellow researchers/faculty, staff and members of the general public.

In addition the UTC is often asked to provide tours to community groups, conference attendees and industry groups. These tours allow us to share the research being done, and discuss how the ideas can be replicated in their hometowns. Some examples of these tours include:

- September 9 – 11, 2018 – The 2018 Annual Conference of Intelligent Transportation Society of Pennsylvania and the Mid Atlantic Section of the Institute of Transportation Engineers was held in Pittsburgh, PA. Over 230 ITS professionals attended the 3 day event. Several UTC researchers, staff and students were featured during the conference:
 - Dr. Steve Smith spoke on smart infrastructure for future urban mobility and innovative real-time traffic controls.
 - Dr. John Paul Shen and Abhinav Jauhri spoke on synthetic data generation for modeling human mobility in urban areas.
 - UTC Program Manager Lisa Kay Schweyer and Women in Transportation Fellow, Joohyun (Sarah) Cho provided the Carnegie Mellon University's Traffic21 Institute rapid-fire research overview.
 - In addition, the University Transportation Center sponsored 7 students so they could attend the conference and learn from the conference presentations.
 - Mobility21 sponsored an informational table on UTC activity.
- 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.
- July 24, 2018 - The Greater Boston Chamber of Commerce visited Pittsburgh for their City to City initiative. Stan Caldwell, Executive Director of Mobility21 and Alex Pazuchanics, Assistant Director of the City of Pittsburgh's Department of Mobility and Infrastructure presented examples of UTC/City research projects to the group of business, government and civic leaders from Boston.

5. CHANGES/PROBLEMS

Changes in approach and reasons for change
Nothing to report.

Actual or anticipated problems or delays and actions or plans to resolve them
Nothing to report.

Changes that have a significant impact on expenditures
Nothing to report.

Significant changes in use or care of human subjects, vertebrate animals, and/or biohazards
Nothing to report.

Change of primary performance site location from that originally proposed
Nothing to report.

Additional information regarding Products and Impacts

Nothing to report.

6. SPECIAL REPORTING REQUIREMENTS

Nothing to report.