Program Progress Performance Report
for University Transportation Centers

Agency: US Department of Transportation
Office of the Assistant Secretary for Research and Technology
University Transportation Center Program

Federal Grant Number: DTRT-13-GUTC-26

Project Title: Technologies for Safe and Efficient Transportation (T-SET)
National University Transportation Center

Program Director: Professor Raj Rajkumar, Director, T-SET UTC
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Submitting Official: Stan Caldwell, T-SET UTC Executive Director
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Submission Date: October 30, 2018
DUNS Number: 05-218-4116
EIN Number: 25-0969449
Recipient Organization: Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213

Recipient ID Number: 31572.x.1080311
Project Grant Period: 9/30/2013 – 9/30/2018
Reporting Period End Date: September 30, 2018
Report Term or Frequency: Semi-Annual

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

What are the major goals of the program?

Research, Development, Deployment - The T-SET UTC focuses on safety. Our research is specifically targeted at improving the safety of automotive drivers and passengers, bicyclists and pedestrians, and the safe usage of trucks and mass transit vehicles. The thrusts of the T-SET UTC are structured along five core areas: In-Vehicle Technologies, Infrastructure Technologies, Human-Vehicle Interactions, Mobility/Data Analytics and Policy. 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 - Education and workforce development are important complements of the T-SET UTC research program. Metrics:

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

Technology Transfer - The UTC will fully use the resources and the experience of these university centers to promote enterprises arising from its research program. Faculty who already created startups in the past, serve as mentors to colleagues interested in this activity. 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 - Collaboration is the heart of the entire T-SET program. CMU and Penn seek to ensure our research and development program leads to deployment of technologies in the transportation systems serving our communities and state, providing pilot applications for global use. The CMU-Penn team will collaborate with related centers on the two campuses, state and local public partners, non-profit community partners and industry partners. Metrics:

- Number and diversity of members of both the T-SET Consortium and Advisory Council, and by the Number and impact of deployments achieved through collaboration

What was accomplished under these goals?

Research, Development, Deployment

Below are examples of specific accomplishments in supporting our research, development and deployment goal in the past six months as researchers completed their projects, and final reports in preparation for the September 30, 2018 close out of the grant:
T-SET staff met with researchers to determine research progress, ensure completion of all T-SET funded projects and submission of final reports.

The T-SET UTC conducted four faculty meetings. A faculty member interactively presents their T-SET funded research at the beginning of each meeting. Meetings are held at Carnegie Mellon University but faculty members from the University of Pennsylvania participate, collaborate and present research through and interactive audio and video format.

T-SET staff and faculty participated in the UTC and Council of University Transportation Centers (CUTC) summer meetings in Minneapolis, which resulted in exchanging best management practices and discussion of UTC priorities. T-SET Executive Director Stan Caldwell serves on the Executive Board of CUTC and served on a panel at the UTC summer meeting on technology transfer.

Some highlights of the research, development, and deployment accomplishments during the past six months:

- The long-term goal of the UTC project Sharing Connected Vehicle Infrastructure for Safety Applications, Smart City and Internet Access research is to provide credible and quantitative results that shed light on the most cost-effective strategies for wireless smart city infrastructure to support connected vehicles. The goal for 2018 is to address major changes in the connected vehicle landscape that have emerged in just the last year or two. During the period ending in September 2018, the major activities performed were twofold. One activity was to make progress on a detailed quantitative analysis of the use of infrastructure and spectrum to support connected vehicles. The second major activity was to write, publish and present our early findings in journal papers and conferences in the areas of transportation and communications.

- As part of the UTC project Bystander Interactions with Failing Vehicle Autonomy project, a master’s degree candidate at the human computer interaction institute conducted an independent study (Spring 2018 semester) with UTC researchers Steinfeld and Forlizzi on communication methods between pedestrians and AVs. A set of designed interactions were prepared and tested in a field study in Pittsburgh. This work revealed numerous areas of possible confusion in bystanders about the vehicle’s intent and what they were supposed to do. For example, do red lights on the windshield indicate the vehicle will stay stopped or that pedestrians should stop? Also tested were words and icons, with similar results. These findings have been discussed with industry and other researchers attempting to run similar studies at a larger scale in more controlled conditions (including MIT, VA Tech, etc).

**Education and Workforce Development**

The T-SET 2018 Women in Transportation Fellowship was awarded to Bonnie Fan (Heinz College masters student) and our first Diversity in Transportation Fellowship was awarded to Allante Whitmore (CMU College of Engineering PhD student). These fellows have been working closely with center T-SET staff to support technology transfer, collaboration, education and workforce programs and gain exposure to our national network of partners.

The CMU Transportation Club is supported by T-SET and its Women in Transportation Fellows. The club has met six times, with an average attendance of 20 students during the past reporting period. The Transportation Club exposes CMU students from colleges across the campus to transportation related classes and research opportunities, educates students about employment opportunities in the transportation industry, and provides opportunities to meet industry leaders through programming events, conferences, and networking.
Two of the primary MS students on the Bystander Interactions with Failing Vehicle Autonomy UTC project have joined industry (Google and iRobot), thereby supporting additional knowledge transfer. In fact, the lead author of the project’s published paper is a PhD student who has incorporated aspects of this project into her long-term research agenda.

Also in May 2018, CMU students Sarah Papp and Ross Rybalov spent the spring 2018 semester researching Automotive Transportation Experience for Visually Impaired Individuals. The primary goal of this project was to increase personal agency and autonomy for persons with visual impairments through an improved transportation experience. They developed an in-car conversational interface to provide passengers with critical information and system controls to increase access and practicality for passengers with visual impairments.

On April 30, 2018, undergraduate students in UTC Professor Branstetter’s Methods of Policy Analysis Class shared their “Spatial Mismatch” Research (jobs versus disadvantaged employees/job seekers locations). For this project they received technical assistance from Ngani Ndimbie, T-SET Women in Transportation Fellow and Lisa Kay Schweyer, T-SET Program Manager.

And lastly, on April 19, 2018 – The UTC hosted Chief Strategy Officer of Lyft and Head of Business for Lyft’s self-driving division, Raj Kapoor, for a seminar to CMU students about the “Future of Transportation.” Kapoor discussed Lyft’s expectations and plans for the electric, self-driving, and shared future as well as the impact to cities and the auto industry.

Technology Transfer
Below are highlights of T-SET UTC technology transfer activities during the reporting period:

On July 26, 2018 - UTC 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’s, Pittsburgh 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. Panelists provided insight and advice on how AARP can educate and activate their members around AV issues.

On July 15, 2018, Stan Caldwell, Executive Director of T-SET, participated in a panel where he presented examples of 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.

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 the Department of ECE at CMU.
Collaboration
At the core of our efforts, is collaboration. Below are some examples of how that collaboration takes place:

Researchers at the U.S. Department of Energy’s (DOE) Argonne National Laboratory are deploying advanced modeling and simulation tools. And in a collaborative three-year project, supported by DOE’s SMART (Systems and Modeling for Accelerated Research in Transportation) Mobility Consortium, Argonne researchers are using these tools to predict the impact of CAVs on energy and mobility in metropolitan areas; collaborators include the University of Illinois at Chicago, the University of New South Wales, Texas A&M University, the University of Michigan, Carnegie Mellon University, the University of Washington, George Mason University, as well as multiple cities and planning agencies.

How have the results been disseminated?

T-SET faculty and staff actively present research results at conferences and events.

Stories about T-SET research projects and faculty are distributed in the Breaking in Smart Transportation, a weekly newsletter that highlights T-SET research and efforts in the local, national and international media 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 stories are sent out in the newsletter, they appear as individual updates/articles on the T-SET blog and website, and are also posted on social media through our Facebook and Twitter accounts.

T-SET researchers and their accomplishments and impacts are frequently mentioned in the news. Below are some media highlights in addition to what was been highlighted already in this report:

- In September 2018, Plan Philly, a WYYY project published an article called “A Philly-Pittsburgh Hyperloop? State House resolution calls for feasibility study” written by Jim Saska. In the article he quotes Megan Ryerson, UTC researcher sharing her experience on this topic. “…The critical question about the wisdom of investing billions into developing Hyperloop lines is one of demand, said Dr. Megan Ryerson, who studies intercity transportation at the University of Pennsylvania. She points to the fact that there is only one daily passenger train between Philadelphia and Pittsburgh and just four non-stop flights. “The airlines are private companies — they are looking for city pairs where they will make money,” she said. If more people needed to get cross state quickly, there’d be more flights — especially considering that Philadelphia International Airport is a hub for American Airlines… According to Ryerson, the buzz around the Hyperloop echoes an earlier era in American history, when cities rushed to build and expand airports in the 1920s. The run on runways had long-lasting consequences to municipal budgets in smaller cities where there simply weren’t enough air travelers. The critical question about the wisdom of investing billions into developing Hyperloop lines is one of demand, said Dr. Megan Ryerson, who studies intercity transportation at the University of Pennsylvania. She points to the fact that there is only one daily passenger train between Philadelphia and Pittsburgh and just four non-stop flights. “The airlines are private companies — they are looking for city pairs where they will make money,” she said. If more people needed to get cross state quickly, there’d be more flights — especially considering that Philadelphia International Airport is a hub for American Airlines… According to Ryerson, the buzz around the Hyperloop echoes an earlier era in American history, when cities rushed to build and expand airports in the 1920s. The run on runways had long-lasting consequences to municipal budgets in smaller cities where there simply weren’t enough air travelers.
• September 21, 2018 – T-SET Director, Raj Rajkumar is interviewed in Axios article on “A Car that’s better without a driver,” as saying “Driving is the most complex activity that most adults engage in on a regular basis…Just because we do it doesn't mean we can teach computers to easily do it. It will be many more years for full automation."

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

UTC research will continue at Carnegie Mellon University, under the efforts of the National UTC, Mobility21, a US DOT University Transportation Center for the Mobility of People and Goods.

2. PRODUCTS: What has the program produced?

Publications, conference papers, and presentations

Journal publications

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<thead>
<tr>
<th>Title</th>
<th>Citation</th>
<th>Type</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>IEEE Access: The Multidisciplinary Open Access Journal</td>
<td>IEEE, ieeaccess.ieee.org</td>
<td>Other</td>
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Books or other non-periodical, one-time publications:

Nothing to report.

Other publications, conference papers and presentations (listed by date, title, where presented, number of attendees):

<table>
<thead>
<tr>
<th>Title</th>
<th>Event</th>
<th>Type</th>
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<td>smart cities and the funding needs</td>
<td>Automobili-D</td>
<td>Other-</td>
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<td>2018-01-18</td>
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<tr>
<td>and sources for these ventures</td>
<td>Professional</td>
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<tr>
<td><strong>Autonomous vehicle technology: impacts, benefits, and applicability for developing countries</strong></td>
<td>Asian Development Bank transport symposium</td>
<td>Symposium-Professional</td>
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<td>2018-09-12</td>
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<td><strong>Human Reactions to In/Appropriate Robot Behavior</strong></td>
<td>Pittsburgh Humanities Festival</td>
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<td>20</td>
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<tr>
<td><strong>Sharing Connected Vehicle Infrastructure Between Governments and Internet Service Providers</strong></td>
<td>ASCE International Conference on Transportation &amp; Development (ICTD)</td>
<td>Conference-Academic</td>
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<td><strong>Smart City Technologies for Local Governments</strong></td>
<td>Allegheny County &amp; Western PA Association of Township Commissioners, Fall Conference</td>
<td>Conference-Professional</td>
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**Website(s) or other Internet site(s)**

<table>
<thead>
<tr>
<th>URL for Internet site(s) that disseminates the results of the research and/or program activities</th>
<th>Short description of the site</th>
<th>Metrics</th>
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</thead>
<tbody>
<tr>
<td>- <em>During this report period work began the process to “archive” this website. The site and its contents will remain available online, but visitors will be directed to the Traffic21 Institute and the Mobility21 UTC website for current research and UTC activities.</em></td>
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<tr>
<td><a href="https://www.facebook.com/traffic21.tset">https://www.facebook.com/traffic21.tset</a></td>
<td>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</td>
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<td>URL</td>
<td>Description</td>
<td>Stats</td>
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<td>The Carnegie Mellon University’s YouTube 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</td>
<td>Videos: 12 Views: 2,165</td>
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<tr>
<td><a href="https://twitter.com/Traffic21_CMU">https://twitter.com/Traffic21_CMU</a></td>
<td>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</td>
<td>Followers: 893 Following: 1,626 Tweets: 6,166</td>
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</tbody>
</table>

**Technologies or techniques**

*Inventions, patent applications, and/or licenses*

Nothing new to report.

**Other products**

Nothing new to report.
### 3. PARTICIPANTS & COLLABORATING ORGANIZATIONS: Who has been involved?

What organizations have been involved as partners?

<table>
<thead>
<tr>
<th>Partner Organization Name</th>
<th>Location</th>
<th>Financial support</th>
<th>In-kind support</th>
<th>Facilities</th>
<th>Collaborative research</th>
<th>Personnel exchanges</th>
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<td>Honda</td>
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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, and class and capstone projects. Our consortium members include:

- AASHTO
- Access Transportation Systems
- Accessible Transportation & Workforce Interagency Cooperative
- ALCO Parking
- Allegheny Conference on Community Development
- Allegheny County
- APTA
- Beth’s Barricades
- Bike Pittsburgh
- Bombardier
- Booz Allen Hamilton
- Bosch Research & Technology Center
- City of Philadelphia
- City of Pittsburgh
- Community College of Allegheny County
- Conference of Minority Transportation Officials
- Delaware River Port Authority
- Delaware Valley Regional Planning Commission
- General Motors Global Research & Development
- IBM
- Innovation Works
- ITS America
- Open Roads
- PennDOT
- Pennsylvania Motor Truck Association
- PITT OHIO Express
- Philadelphia Port Authority
- Pittsburgh Technology Council
- Port Authority of Allegheny County
- Port of Pittsburgh Commission
- Southeastern Pennsylvania Transportation Authority
- Southwestern Pennsylvania Commission
- Takata
- Three Rivers Workforce Investment Board
- Uber
- University of Pittsburgh
- Women’s Transportation Seminar
And lastly, the UTC also has a distinguished Advisory Council of national leaders that provides strategic guidance and counsel. Members include:

- Allen Biehler, Recently retired from CMU as Distinguished Service Professor and Executive Director of the University Transportation Center, formerly Secretary of Pennsylvania Department of Transportation.
- Raymond T. Betler, President and CEO of the American Transportation Research Institute
- Rebecca M. Brewster, President and Chief Operating Officer of the American Transportation Research Institute
- Deborah Butler, Former Executive Vice President and Chief Information Officer, Norfolk Southern Corp.
- Joseph M. Casey, Former General Manager, Southeastern Pennsylvania Transportation Authority
- Douglas I. Foy, President of Serrafix; former Secretary Office of Governor Romney
- Charles L. Hammel III, President and owner, PITT OHIO Express
- Ashley Hand, Co-founder CityFi; formerly Transportation Technology Strategist Fellow for Los Angeles
- John M. Inglish, Former Chief Executive Officer of the Utah Transit Authority
- Jane Lappin, Director, Public Policy & Government Affairs, Toyota Research Institute
- Dr. Michael D. Meyer, Senior Advisor to Parsons Brinckerhoff, Inc and former Director of the Georgia Transportation Institute
- William W. Millar, Past President of American Public Transportation Association
- James A. Misener, Director of Technical Standards at Qualcomm and former Director of UC Berkeley PATH
- Leslie Richards, Secretary of the Pennsylvania Department of Transportation
- Robert E. Skinner Jr., Former Executive Director of Transportation Research Board
- Kirk T. Steudle, Director of the Michigan Department of Transportation and past president of AASHTO and ITS America

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?

The efforts conducted as part of this center have resulted in significant impacts, including where our center leadership and researchers are sought to comment in the media on current events. Some examples:

- September 21, 2018 - Raj Rajkumar, Director of T-SET is quoted in Axios: “Driving is the most complex activity that most adults engage in on a regular basis, just because we do it doesn’t mean we can teach computers to easily do it. It will be many more years for full automation.”

- September 15, 2018 - Mobility21 Director, Raj Rajkumar attended the International Workshop on Next-Generation Cyber-Physical Systems at the University of Virginia. He participated on a Panel Discussion: Future of Cyber-Physical Systems with – Chenyang Lu (moderator), Tarek Abdelzaher, Chris Gill and Al Mok.
• September 4, 2018 *The Incline* (Pittsburgh online newspaper) published their list “Who’s Next: Transit; Meet 17 Pittsburghers helping you get around” and the T-SET 2018 Women in Transportation Fellow, Ngani Ndimbie was featured on the list for her impacts on local transportation.

• September 13, 2018 - UTC Researcher Erick Guerra has published several articles and been featured in the press, including:

  o [https://whyv.org/episodes/making-philly-safer-for-cyclists/](https://whyv.org/episodes/making-philly-safer-for-cyclists/)
  o [https://islandpress.org/blog/podcast-beyond-mobility](https://islandpress.org/blog/podcast-beyond-mobility)
  o [https://whyv.org/episodes/hands-off-self-driving-future/](https://whyv.org/episodes/hands-off-self-driving-future/)

• In September 2018 T-SET UTC spin off company Roadbotics impacts were highlighted, according to WTOC, “In any city, there’s wear and tear, but knowing where it is and how to fix it is really the key. The city of Savannah has assessed half of the city’s roadways - using an iPhone…The technology is able to spot cracked surfaces, damaged roads, and potholes, which the city says is a large concern for residents right now. ‘It’s a great tool to allow us to do ultimately what we want to do, which is be efficient with the taxpayer dollars but also repair the infrastructure that needs to be prepared,’ Lloyd claimed.”

• In August 2018, the UTC Spin-off company, Roadbotics, has partnered with Montgomery, Alabama to analyze 200 miles of roads and improve upon their binary system of road rating. City officials are eager to use the new technology to decide what roads need to be repaired. Director of Public Works in Montgomery said that Roadbotics was cheaper than sending out workers and that it would take subjectivity out of deciding paving needs.

• In June, The Future of Work Systems Synthesis graduate capstone class team, composed of five Carnegie Mellon University students, partnered with the Aspen Institute Future of Work Initiative to explore potential impacts to long-haul truckers and policy responses to automation in the trucking industry. The team set out to answer two primary questions:

  1. How might highly automated commercial vehicles disrupt the trucking workforce and long-haul trucking industry?
  2. How are states and state trucking advocacy groups responding to this potential disruption?

The next steps, concluded in the thesis, was that policy makers need to systematically manage the future of work for long-haul truckers through data collection. The data might include the
exit and entry of drivers in the workforce, rate of displacement from automation and tracking new jobs created by automation. Data could also be collected on the drivers themselves, such as who leaves the industry and where they go.

The team concluded that regulators and policymakers need to focus in the short-term on understanding how autonomous technology will be used in the long-haul trucking industry. This will aid policymakers in being empowered and informed when developing policy on how autonomous technology will be used in the long-haul trucking industry, including performance, safety and workforce issues.

- Also in June 2018, Mayor Bill Peduto and John Kwant, Vice President of Ford City Solutions, announced Tuesday that Pittsburgh will be the first city to work with Ford’s City of Tomorrow Challenge. The new program calls on the public to identify and then offer solutions for mobility problems with the help of a team of private experts, with one or two ideas receiving a total of $100,000 to move ahead to a demonstration project…Mr. Kwant said Ford’s decision to kick off the program here evolved after Ford’s announcement in February 2017 that it would invest $1 billion over five years in Pittsburgh-based Argo AI to develop technology for a self-driving vehicle. He called Pittsburgh “the ideal partner” because of its leadership in areas such as smart traffic signals through Carnegie Mellon University.

- May 17, 2018 - The CMU Robotics Institute spinoff, “RoadBotics” received the Overall Greatest Impact Award from the American Society of Civil Engineers (ASCE) annual Innovation Contest. RoadBotics also received awards in subcategories including Most Feasible in the Sustainable Engineering category and Most Feasible, Most Innovative and Best Value in the Internet of Things category. RoadBotics uses smartphone and artificial intelligence technology to monitor the condition of concrete and asphalt surfaces.

- May 7, 2018 - How the UTC research, and early spin off company Ottomatika continue to impact transportation is highlighted in the *Car & Driver* article, “Lyft and Aptiv Launch Self-Driving Fleet in Las Vegas” written by Pete Bigelow. The article states, “…software developed by Ottomatika, a Carnegie Mellon University spinoff purchased by Aptiv in 2015, controlled perception and vehicle movement. In the intervening months, engineers have integrated software from NuTonomy, the self-driving software startup Aptiv acquired in 2017 for $450 million. Further, Aptiv has enhanced its mapping of the city. During the CES demos, vehicle systems controlled their own movements along public roads, but human safety drivers retook control in parking lots of the casinos and other destinations. An Aptiv spokesperson told C/D that the newly launched program will offer autonomous service all the way to pickup and drop-off spots in parking lots, which suggests the company has now mapped the applicable parking lots.”

- During March and April, T-SET UTC Fellow Ngani Ndimbie has been interning with the Pittsburgh Department of Mobility and Infrastructure to help complete Pittsburgh’s Bike Plan— a document for the public and other key stakeholders that explains the City’s goals for building out its bike network. This is the City’s first update since the 1999 bike plan.

*What is the impact on other disciplines?*

In the September 13, 2018*th* Construction Dive’s article “How infrastructure can improve mass evacuations” UTC researcher Sean Qian said the country’s state transportation departments have been able to amass considerable information about driving patterns and the use of highways and main arterials during the last decade. That data could be useful in creating models that can inform officials’ plans for
high-capacity events like a mass evacuation. Closing lanes, reprogramming traffic signals and emergency traffic routing are some of the measures on the table when trying to get people from point A to point B safely and efficiently in such a situation, he said.

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

The startup RoadBotics was founded in 2016 with the technology of earlier work of this project. The company has direct and significant impact on employment, attracting private investment, and improving infrastructure maintenance:

- Within 21 months of founding, RoadBotics has:
  - Raised $2 M in capital, including from multiple out of state institutional investors.
  - Acquired 75 paying customers in 15 US states and 2 countries (i.e., US and Australia) with total annual contract value of ~$560K
  - Employed 30 people (full-time and part-time professionals as well as full and part-time interns)
  - The project web page is http://www.cs.cmu.edu/~road/ and a related web site is http://www.cs.cmu.edu/~reconstruction/

Rapid Flow Technologies LLC, also spun out of Carnegie Mellon University with the goal of introducing new Intelligent Transportation Systems (ITS) technologies into the marketplace. The original deployment of 9 intersections in 2012 has expanded to a current 50 intersections and is now funded by US DOT ATCMTD and PennDOT grants for an additional 150 intersections in Pittsburgh. With two patents from the UTC research Dr. Smith spun off the Pittsburgh-based company Rapid Flow Technologies which has created 8 jobs and currently has commercial deployments in Atlanta, Portland Maine, and Needham and Quincy Massachusetts. It also has been mentioned in the news, featured in national webinars, and won awards:

- March 26, 2018 - Examples of How AI Can Make Cities Smarter article in Government CIO, featured “Surtrac, using technology patented by the Robotics Institute at Carnegie Mellon University, claims its technology can produce 25 percent reductions in travel time and 40 percent reductions in time spent waiting at intersections.” https://www.governmentciomedia.com/4-examples-how-ai-can-make-cities-smarter.
- February 8, 2018 - The U.S. Department of Transportation hosted a webinar to provide an update on Mobility21 researcher Steve Smith’s project that is part of the Accessible Transportation Technologies Research Initiative (ATTRI): the Safe Intersection Crossing project.
- 2017 Le Monde Smart-Cities International Innovation Award
- 2017 Innovation Award winner: Rapid Flow Technologies

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

T-SET research has been the core component to the designation of the Traffic21 Institute at Carnegie Mellon University. Traffic21 now serves CMU as significant institutional resource that leverages significant corporate and foundation funding for research development and deployment of intelligent transportation systems technology. Furthermore CMU has expanded the Traffic21/T-SET model of research, development and deployment to its new Metro21: Smart Cities Institute which combines transportation with broader smart city applications. And finally this model has been taken national with
the Metro Lab Network which is a collaboration of over 50 university/city applying university research in pilot deployment within their hometown test beds.

**What is the impact on technology transfer?**

Through the efforts of the UTC project Bystander Interactions with Failing Vehicle Autonomy researchers, the study’s findings has been aggressively disseminated to industry and policy makers through small meetings, presentations at conferences, and a high quality conference publication. Insights on these outcomes can help inform research, development, and policy regarding how AVs and associated systems convey failure and status.

On September 6, a team of Carnegie Mellon University researchers led by Venkat Viswanathan, the lead PI for the T-SET project, Analyzing and Defending Cyberattacks on Electric, Hybrid, and AV Battery Systems, in collaboration with Ather Energy, was a finalist in the MOVE: Global Mobility Summit’s Hackathon.  
The hackathon provides a platform for participants to generate innovative ideas and solutions on issues concerning topics such as commuter mobility, freight, charging infrastructure design and alternative energy.

The CMU team, which was one of 30 teams from around the world, presented its solution for efficient charging infrastructure design in New Delhi, India. The team’s approach, Infrastructure Networks for Charging EVs through Physics-based Transient Systems (INCEPTS), addressed key challenges limiting the wide-spread penetration of electrifying urban modality. The team developed a model to map out charging points and battery swapping stations for electric vehicles (EVs) depending on factors such as traffic, most used routes, time taken, route-wise peak times and range anxiety, vehicle charging patterns, malls, parking areas and conventional fuel stations.

By combining the same smart routing as most robotic navigation systems with the team’s vehicle dynamics model and traffic flow data, the researchers were able to accurately simulate the depletion of a vehicle’s battery during operation and determine which of the possible charger locations it should visit.

The result of the team’s hard work was a high-resolution map of where the optimal charging locations are, how much demand they are expected to see and how that demand changes with seasons.

Although the INCEPTS team did not win the grand prize, Viswanathan says, “We received an exceptional amount of positive feedback about our approach and numerous new collaboration opportunities have emerged. We hope to take this analysis forward and apply it to other cities and other vehicle types like trucks.”

**What is the impact on society beyond science and technology?**

Through the research, development, and deployment happening through the research, the end goal of increasing safety in transportation impacts all users of the transportation system:

The PI for the UTC project, the Sharing Connected Vehicle Infrastructure for Safety Applications, Smart City and Internet Access has been invited to serve as an (unpaid) advisor to the City of Pittsburgh on deployment of wireless technology for smart city applications such as transportation. Through these efforts the PI is putting research results and concepts to work for the benefit of Pittsburgh and its citizens.
In August 2018, the UTC Spin-off company, Roadbotics, has partnered with Montgomery, Alabama to analyze 200 miles of roads and improve upon their binary system of road rating. City officials are eager to use the new technology to decide what roads need to be repaired. Director of Public Works in Montgomery said that Roadbotics was cheaper than sending out workers and that it would take subjectivity out of deciding paving needs, which can help pave more roads and save costs for the taxpayers.

Also in August, UTC researcher Sean Qian was featured in the GCN Magazine in an article called “Can electricity use predict a bad morning commute?” The article explains that new research shows that nighttime and early-morning energy use can be a good predictor of morning traffic congestion. The researchers created a model that mined data on electricity consumption from 322 homes in Austin, Texas, and used artificial intelligence to predict what traffic would look like the next morning.

### 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 additional to report.

### 6. SPECIAL REPORTING REQUIREMENTS

Nothing to report.