

Program Progress Performance Report



Submitted to: U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology

Federal Grant No.: DTRT13-G-UTC58

Project Title: Data-Supported Transportation Operations and Planning (D-STOP) Center

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Submission Date: April 30, 2020

DUNS Number: 170230239

EIN Number: 746000203

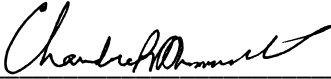
Recipient Organization: The University of Texas at Austin
Office of Sponsored Projects
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Recipient Identifying No: OSP 201300867-001

Grant Period: September 30, 2013 – September 30, 2020

Reporting Period End Date: March 31, 2020

Report Term: October 1, 2019 – March 31, 2020

Signature: 

1. ACCOMPLISHMENTS

What are the major goals of the program?

The Data-Supported Transportation Operations and Planning (D-STOP) Center's vision is to be a national and international multimodal and multidisciplinary center of excellence that promotes the integration of cutting-edge developments in wireless sensor networks and communications technology with transportation systems to improve the United States' economic competitiveness. This vision will be implemented through a research mission, an education and workforce development mission, and a technology transfer mission.

D-STOP's *research mission* is to develop fundamentally new methodologies to better harness traditional and recent data sources, and potentially develop new sources, in seeking to improve models for transportation planning and traffic operations. D-STOP research will occur in three areas: operations, planning, and technology, with significant priority placed on work that cuts across these areas.

The *education and workforce development (EWD) mission* is to build a transportation workforce that is able to use multi-disciplinary approaches to address multi-dimensional complex problems, through an emphasis on real-time data analysis and processing, the study of the dynamics underlying human activity-travel decision-making, and training on the effective use of information technology innovations.

D-STOP's *technology transfer (TT) mission* is to disseminate information on research activities and findings, and actively promote the utilization and implementation of research products/findings through demonstrations on small-scale networks (in collaboration with industry and public agency partners).

What was accomplished under these goals?

Research Program Accomplishments

D-STOP's research activities focus on harnessing innovative technologies and data sources to develop architectures and systems for data collection and analysis. The research will foster economic competitiveness through its focus on gathering and analyzing data to support effective and efficient decision-making. The major research accomplishment during this reporting period was the continued development of the research agenda in coordination with D-STOP faculty and researchers. A total of 10 projects are being pursued with partial or full funding support from D-STOP.

Ongoing Projects

- 1. Video Data Analytics for Safer and More Efficient Mobility**
(PI: Natalia Ruiz Juri); Anticipated end date: September 30, 2020
- 2. Data-Driven, Real-Time Traffic Signal Optimization: A Distributed Approach**
(PI: Stephen Boyles); Anticipated end date: September 30, 2020
- 3. Real-time, Targeted Incentives for Strategic Travelers**
(PI: Stephen Boyles); Anticipated end date: September 30, 2020
- 4. Tight-coupling of Vision, Radar, and Carrier-phase Differential GNSS for Robust All-weather Positioning**
(PI: Todd Humphreys); Anticipated end date: September 30, 2020
- 5. Modeling Willingness-to-Share Trips in an Autonomous Vehicle Future: A stochastic psychological latent construct approach**
(PI: Chandra Bhat); Anticipated end date: September 30, 2020
- 6. Emerging Transportation Mobility Options and Technologies: A comprehensive analysis of consumer preferences using survey and supplementary data**
(PI: Chandra Bhat); Anticipated end date: September 30, 2020
- 7. Sensing and Communications in V2V and V2I Settings**
(PI: Sanjay Shakkottai); Anticipated end date: September 30, 2020

8. Online Matching, Black-box Optimization and Hyper-parameter Tuning

(PI: Sanjay Shakkottai); Anticipated end date: September 30, 2020

9. Solving Perception Challenges for Autonomous Vehicles Using SGD

(PI: Constantine Caramanis); Anticipated end date: September 30, 2020

10. Large Scale Optimization with Small Scale Data

(PI: Constantine Caramanis); Anticipated end date: September 30, 2020

Research Results Disseminated: 7 papers were published and 6 papers are forthcoming in refereed journals based on the research projects associated with D-STOP. Several other papers are in the review process. 32 presentations were made at conferences and meetings.

Plans for Next Reporting Period to Accomplish Research Goal: Provide support, guidance, and assistance to project Principal Investigators so individual research project objectives can be achieved. Renew funding for supporting research through the North Central Texas Council of Governments (NCTCOG). Undertake supporting research funded through the Texas Department of Transportation and Cintra. Participate in the analysis and data processing of a multi-city survey undertaken in collaboration with TOMNET (Center for Teaching Old Models New Tricks) Tier 1 University Transportation Center.

Education and Workforce Development Accomplishments

The research projects outlined above have several students working on them. Please note that students work in groups. Some are on fellowships, or obtain funding from other sources too. Below, we indicate all students who undertake research associated with D-STOP, regardless of whether they obtain no funding support or only partial funding support from D-STOP. The students are:

Undergrad

Emily Niemeyer, Rubina Singh (supervised by Chandra Bhat).

James Lentz, Rishabh Thakkar, Karthik Velayutham (supervised by Stephen Boyles).

Omar Jamil (supervised by Christian Claudel).

Grad

Supervised by Chandra Bhat: Katie Asmussen (MS), Felipe Dias (PhD), Shuqing Kang (MS), Aupal Mondal (PhD), Gopindra Nair (PhD).

Supervised by Stephen Boyles: William Alexander (PhD), Carlin Liao (PhD), Venkatesh Pandey (PhD), Priyadarshan Patil (PhD), Cesar Yahia (PhD), Tengkuo Zhu (PhD).

Supervised by Constantine Caramanis: Tianyang Li (PhD).

Supervised by Chris Claudel: Hassan Iqbal (MS).

Supervised by Todd Humphreys: Lakshay Narula (PhD).

Supervised by Sanjay Shakkottai: Soumya Basu (PhD), Kartik Patel (PhD), Isfar Tariq (PhD), Yi Zhang (PhD).

Supervised by C. Michael Walton: Michael Moore (PhD).

The D-STOP Center selected PhD student Michael Moore, supervised currently by Dr. C. Michael Walton, as its 2019 Outstanding Student of the Year. Former MS student Manoj Gedela (supervised by Dr. Stephen Boyles) was awarded the Council of University Transportation Centers (CUTC) 2019 Neville A. Parker Science and Technology Award for his non-thesis master's project report entitled "Deep Learning Framework for Crash Detection using Twitter Data". Michael and Manoj were recognized at an annual awards banquet in January 2020 in Washington DC before the Transportation Research Board Annual Meeting.



Michael Moore



Manoj Gedela

PhD student Venkatesh Pandey (supervised by Dr. Stephen Boyles) was a recipient of the 2020 Graduates Linked with Undergraduates in Engineering (GLUE) Mentor Award from the Women in Engineering Program (WEP) at UT Austin.

Dr. Robert Heath was recognized as a Highly Cited Researcher for 2019. The Highly Cited Researchers from the Institute for Scientific Information is a list released annually to identify global research scientists and social scientists who have demonstrated exceptional influence – reflected through their publication of multiple papers frequently cited by their peers during the last decade.

Dr. Todd Humphreys received the Institute of Navigation's (ION) "highest honor." Humphreys was elected to the membership rank of Fellow at ION's International Technical Meeting in January 2020. He is one of only three recipients of the honor for 2020. Humphreys' election cited his "significant and fundamental contributions to PNT security and precise GNSS positioning for the mass market, and for dedication to GNSS education and outreach." He was commended for his "pioneering" research and publications, which have advanced the study of Global Navigation Satellite Systems worldwide over the past ten years. In particular, his 2008 paper "Assessing the Spoofing Threat" is one of the most-cited GNSS-related articles ever published. His research group was the first to demonstrate cm-accurate RTK positioning through a smartphone antenna, and in 2012 his group demonstrated the first successful spoofing of UAVs. Dr. Humphreys directs the Radionavigation Laboratory and is the associate director of UT SAVES.



Education and Workforce Development Results Disseminated:

Invited Guest Speaker

D-STOP was pleased to invite Dr. Ondrej Pribyl from Czech Technical University in Prague to travel to Austin, TX on October 29-31 to meet with our graduate students and faculty, and to give a guest lecture entitled "Automated Vehicles in an Urban Environment." Dr. Pribyl heads the Department of Applied Mathematics in the Faculty of Transportation Sciences at the Czech Technical University in Prague (CTU). He has experience in cybernetics and artificial intelligence, which he is applying to the traffic control and management of automated vehicles. His presentation focused on the integration of connected and automated vehicles (CAVs) into the urban environment and how user surveys, field tests, and microscopic traffic simulations demonstrate impacts on CO2 emissions, for example. His talk stressed the importance of integrating CAVS via a cooperative framework to ease potential impacts in the transition phase.

Girl Day

Girl Day at UT Austin, presented by Halliburton, BAE Systems, BASF, and Kiewit Corporation was held on The University of Texas at Austin campus February 22, 2020. Girl Day at UT Austin, including Introduce a Girl to Engineering Day and the Girl Day STEM Festival, is a free event for K-8 students who get the chance to explore engineering, science, math, and technology at their own pace throughout the event. Over 8,000 elementary and middle school students registered with over 1,700 volunteers and 185 student organizations, community organizations and companies leading hands-on activities, demos, shows and STEM adventures. Founded in 2001, Introduce a Girl to Engineering Day (Girl Day) is an international event celebrated during Engineers Week each year. The Women in Engineering Program at UT Austin hosted its first Girl Day in 2002. The Girl Day STEM Festival was added to Girl Day at UT Austin in 2016 to broaden participation across STEM disciplines, increase the number of computer science activities in the programming, and eliminate the cap on participant registrations to allow all interested students the opportunity to participate. In honor of this event, Saturday, February 22, 2020 was proclaimed Girl Day by Mayor Steve Adler and the City of Austin. D-STOP graduate student members of the UT Austin Transportation Student Council gave an interactive demonstration to learn how to manage traffic signals and keep traffic flowing safely (Transportation: Getting You Where You Want to Go). Participants tried to get all the traffic through an intersection accident-free before time ran out.



Prospective Grad Student Lunch: Dr. Stephen Boyles and current transportation graduate students involved in D-STOP research met with visiting prospective graduate students during a lunch meeting organized by the transportation graduate program on March 6, 2020. This session was designed to provide information to prospective graduate students of research currently being undertaken at UT-Austin, including under the D-STOP Center. The presentation also discussed ways to make the transition to graduate school easy, and the expectations of graduate school.

Explore UT (Cancelled)

Scheduled for March 7, 2020, this event was unfortunately cancelled at the last minute due to COVID-19 concerns. D-STOP Graduate students from the Center for Transportation Research were scheduled to give demonstrations on intelligent transportation systems, their use in the future, and to learn what and how a connected and autonomous vehicle “sees” (Creating a “Vision” for Connected and Autonomous Vehicles), and the Transportation Student Council were to give an interactive session for participants to learn how to manage traffic signals and keep traffic flowing safely (Transportation: Getting You Where You Want to Go). Held annually at UT Austin, Explore UT aims to inform students, parents, teachers and community members from across the state about the importance of the public research institution and higher education in Texas. The day-long event held each Spring invites Texans of all ages to experience robust research experiences, hands-on demonstrations and experiments, and participate in the richness of the university's scholarship and knowledge.

Dr. Bhat is a member of the Engineering Advisory Board of Westwood High School and continues to advise the school on engineering curriculum issues.

Plans for Next Reporting Period to Accomplish Education and Workforce Development Goal:

Recruit and introduce a fresh batch of graduate students to D-STOP. Continue discussion with the ASCE Transportation and Development Institute (T&DI) to explore avenues for graduate student, young faculty members, and young practitioners to improve teaching/communication skills. Re-schedule invited guest speaker Dr. Kumares Sinha from Purdue University for the Fall 2020 semester (he was originally scheduled to give a lecture on April 9, 2020 but had to cancel due to COVID-19).

Technology Transfer Accomplishments

Technology transfer activities will be pursued to deliver timely information on research activities and findings. These activities include: maintaining a D-STOP website, producing high quality peer-reviewed journal papers, and supporting researcher travel to participate in conferences that disseminate research results.

D-STOP website: The D-STOP website provides information about the Center and includes a listing of current research projects being conducted, as well as educational information, technology transfer, news and events, publications, and resources applicable to the to the overall D-STOP effort. The website address is dstop.utexas.edu

2019 Texas Wireless Summit

The Texas Wireless Summit (TWS), hosted by the Wireless Networking and Communications Group (WNCG), was held November 12, 2019 at UT Austin. TWS brings together leading figures in industry, academia, and government to discuss the latest developments in information systems technology. The 17th summit focused on “Connectivity and Sensing at the Human-Machine Frontier”, highlighted advances and opportunities at the intersection of human-centered computing, sensing and connectivity. Sessions and panels focused on wearables, virtual and mixed reality, bio-interfaces, and perception. We explored the challenges and demands of the communication infrastructure required to support and enhance devices and experiences, examined in large trends as well as specific solutions. Speakers included industry and academe leaders from Qualcomm, Microsoft Research, Samsung, Caltech, and more. Prof. Joseph A. Paradiso, director of MIT Media Lab's Responsive Environments group, delivered a keynote titled "How We Will Connect To Our Networked Future in a Post-IoT World." The event also included poster sessions, a UT Research Showcase, and demos given by augmented reality startup Magic Leap. D-STOP's Dr. Todd Humphreys participated in an afternoon panel discussion on AR/VR/MR, which supported D-STOP's technology transfer mission of disseminating information on research activities and findings, and actively promoting the utilization and implementation of research products/findings (in collaboration with industry and public agency partners).



Hack for Resilient Communities

The Center for Transportation Research's Network Modeling Center (NMC) hosted a project hackathon on February 29, 2020 that explored community resiliency through health, transportation, weather, and pollution data. Hackers had access to real Austin data on pollution, weather, transportation, and health, as well as access to prototype custom and commercial data sensors. No previous hacking or programming experience was required, and participants from any discipline and all career stages were encouraged to participate. This event stemmed from NMC's participation in a project on transportation-related air pollution (TRAP), a Planet Texas 2050 effort (an initiative created

through the UT Bridging Barriers Grand Challenge). NMC Director (and D-STOP researcher) Natalia Ruiz Juri and Strategic Planning Manager Heidi Ross co-organized the hackathon.

Publications: Papers whose research is fully or partially supported by D-STOP:

Published:

Pandey, V., and S.D. Boyles (2019). Comparing Route Choice Models for Managed Lane Networks with Multiple Entrances and Exits. *Transportation Research Record*, 2673(10), 381-393.

Patel, R., P. Venkatraman, and S.D. Boyles (2019). Optimal Placement of Reservation-based Intersections in Urban Networks. *Transportation Research Record*, 2673, 10, 781-792.

Ali, A., N. González-Prelcic and R.W. Heath (2019). Spatial Covariance Estimation for Millimeter Wave Hybrid Systems using Out-of-Band Information. *IEEE Transactions on Wireless Communications*, 18(12), 5471-5485.

Kumari, P., S.A. Vorobyov, and R.W. Heath (2020). Adaptive Virtual Waveform Design for Millimeter-Wave Joint Communication-Radar. *IEEE Transactions on Signal Processing*, 68, 715-730.

Moore, M.A., P.S. Lavieri, F.F. Dias, and C.R. Bhat (2020). On Investigating the Potential Effects of Private Autonomous Vehicle Use on Home/Work Relocations and Commute Times. *Transportation Research Part C*, 110, 166-185.

Chen, T., N.N. Sze, S. Saxena, A.R. Pinjari, C.R. Bhat, and L. Bai (2020). Evaluation of Penalty and Enforcement Strategies to Combat Speeding Offences among Professional Drivers: A Hong Kong Stated Preference Experiment. *Accident Analysis and Prevention*, 135, 105366.

Mannering, F., C.R. Bhat, V. Shankar, and M. Abdel-Aty (2020). Big Data, Traditional Data and the Tradeoffs between Prediction and Causality in Highway-Safety Analysis. *Analytic Methods in Accident Research*, 25, 100113.

Forthcoming:

Anand, A., G. de Veciana and S. Shakkottai. Joint Scheduling of URLLC and eMBB Traffic in 5G Wireless Networks. *IEEE/ACM Transactions on Networking*, forthcoming, April 2020.

Dias, F.F., P.S. Lavieri, S. Sharda, S. Khoeini, C.R. Bhat, R.M. Pendyala, A.R. Pinjari, G. Ramadurai, and K.K. Srinivasan. A Comparison of Online and In-Person Activity Engagement: The Case of Shopping and Eating Meals. *Transportation Research Part C*, forthcoming, May 2020.

Nair, G.S., C.R. Bhat, I. Batur, R.M. Pendyala, and W.H.K. Lam. A Model of Deadheading Trips and Pick-Up Locations for Ride-Hailing Service Vehicles. *Transportation Research Part A*, forthcoming, May 2020.

Devaraj, A., G.A. Ramakrishnan, G.S. Nair, K.K. Srinivasan, C.R. Bhat, A.R. Pinjari, G. Ramadurai, and R.M. Pendyala. Joint Model of App-Based Ride Hailing Adoption, Intensity of Use and Intermediate Public Transport (IPT) Consideration among Workers in Chennai City. *Transportation Research Record*, forthcoming.

Dias, F.F., G.S. Nair, N. Ruiz Juri, C.R. Bhat, and A. Mirzaei, "Incorporating Autonomous Vehicles in the Traditional Four Step Model," *Transportation Research Record*, forthcoming.

Mondal, A., C.R. Bhat, M.C. Costey, A.C. Bhat, T. Webb, T.B. Magassy, R.M. Pendyala, and W.H.K. Lam. How Do People Feel While Walking? A Multivariate Analysis of Emotional Well-Being for Utilitarian and Recreational Walking Episodes. *International Journal of Sustainable Transportation*, forthcoming.

Presentations whose research is fully or partially supported by D-STOP:

Presented:

Xu, W., N. Ruiz Juri, R. Huang, J. Duthie, J. Meyer, and J. Clary, "Deep Learning Methods to Leverage Traffic Monitoring Cameras for Pedestrian Data Applications." Presented at the 26th ITS World Congress, Singapore, 21-25 October 2019.

Bhat, C.R., "A New Technology-Transformed Transportation Landscape: The Excitement and the Challenges," *Energy@UT Research Expo*, Austin, TX, October 2019.

Bhat, C.R., "*Implications of the Shift to the Connected and Autonomous Vehicle Economy*," *Connected and Autonomous Vehicles (CAV) 101 Seminar: Education for Texas Small Towns, Counties and Satellite Cities*, Austin, TX, October 2019.

Bhat, C.R., "Transportation Research – Part B: EIC Talk," Editor-in-Chief Conference at the 7th *International Conference on Transportation and Space-time Economics (TSTE 2019)*, Beijing, China, October 2019.

Kumari, P., N.J. Myers, S.A. Vorobyov and R.W. Heath, "A Combined Waveform-Beamforming Design for Millimeter-Wave Joint Communication-Radar." Presented at the *2019 53rd Asilomar Conference on Signals, Systems, and Computers*, Pacific Grove, CA, November 2019.

Moore, M.A., P.S. Lavieri, F.F. Dias, and C.R. Bhat, "Autonomous Vehicles and Potential Changes in Commute," *Invited seminar*, Kent Distinguished Lecture, Illinois Center for Transportation, University of Illinois at Urbana-Champaign, Urbana, IL, November 2019.

Bhat, C.R., "Driverless Cars and Work/Home Relocations: Potential Impacts and Policy Implications," *Invited seminar*, Transportation Engineering Program, The Pennsylvania State University, University Park, PA, November 2019.

Bhat, C.R., "Predictive Analytics for Transportation in an Emerging World of Ubiquitous Sensing," *Invited seminar*, Department of Civil and Environmental Engineering, The Pennsylvania State University, University Park, PA, November 2019.

Bhat, C.R., "Brainstorming for Young Faculty Workshop," *ASCE Transportation & Development Institute (T&DI) Board of Governors Meeting*, University of Arkansas, Fayetteville, AR, November 2019.

Dias, F.F., G.S., Nair, N. Ruiz-Juri, and C.R. Bhat, "Travel Modeling in an Era of Connected and Automated Transportation Systems: An Investigation in the Dallas-Fort Worth Area, Phase III," *Project Peer-Review*, North Central Texas Council of Governments (NCTCOG), Arlington, TX, November 2019.

Humphreys, T.E., "Precise Positioning for Urban Air Mobility." Presented to Joby Aviation, Santa Cruz, CA, December 2019.

Buckley, R.F. and R.W. Heath, "Selective OFDM Transmission for Simultaneous Wireless Information and Power Transfer." Presented at the *2019 IEEE Global Communications Conference (GLOBECOM)*, Waikoloa, HI, December 2019.

Petrov, V., D. Moltchanov, S. Andreev, and R.W. Heath, "Analysis of Intelligent Vehicular Relaying in Urban 5G+ Millimeter-Wave Cellular Deployments." Presented at the *2019 IEEE Global Communications Conference (GLOBECOM)*, Waikoloa, HI, December 2019.

- Saab, S., A. Mezghani, and R.W. Heath, "Capacity Based Analysis of a Wideband SIMO System in the Presence of Mutual Coupling." Presented at the *2019 IEEE Global Communications Conference (GLOBECOM)*, Waikoloa, HI, December 2019.
- Batur, I., S. Sharda, T. Kim, S. Khoeini, R.M. Pendyala, and C.R. Bhat, "Mobility, Time Poverty, and Well-Being: How Are They Connected and How Much Does Mobility Matter?," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Capasso da Silva, D., S. Astroza, I. Batur, S. Khoeini, T.B. Magassy, R.M. Pendyala, and C.R. Bhat, "Are Millennials Really All That Different Than Generation X? An Analysis of Factors Contributing to Differences in Vehicle Miles of Travel," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Chauhan, D. R., A. Unnikrishnan, M. Figliozzi, and S.D. Boyles, "Robust Maximum Coverage Facility Problem with Drones Considering Uncertainties in Battery Availability and Consumption," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Chen, T., N.N. Sze, S. Saxena, A.R. Pinjari, C.R. Bhat, and L. Bai (2020), "Evaluation of Penalty and Enforcement Strategies to Combat Speeding Offences among Professional Drivers: A Hong Kong Stated Preference Experiment," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Devaraj, A., G.A. Ramakrishnan, G.S. Nair, K.K. Srinivasan, C.R. Bhat, A.R. Pinjari, G. Ramadurai, and R.M. Pendyala, "Joint Model of App-Based Ridehailing Adoption, Intensity of Use and Intermediate Public Transport (IPT) Consideration among Workers in Chennai City," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Dias, F.F., T. Kim, C.R. Bhat, R.M. Pendyala, W.H.K. Lam, A.R. Pinjari, K.K. Srinivasan, and G. Ramadurai, "Modeling the Evolution of Ride-Hailing Adoption and Usage: A Case Study of the Puget Sound Region," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Dias, F.F., P.S. Lavieri, S. Sharda, S. Khoeini, C.R. Bhat, R.M. Pendyala, A.R. Pinjari, G. Ramadurai, and K.K. Srinivasan, "A Comparison of Online and In-Person Activity Engagement: The Case of Shopping and Eating Meals," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Dias, F.F., G.S. Nair, N. Ruiz Juri, C.R. Bhat, and A. Mirzaei, "Incorporating Autonomous Vehicles in the Traditional Four Step Model: A Case Study in Dallas-Fort Worth," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Li, T., N. Ruiz Juri, H.W. Ross, R. Machemehl, J. Nevaes, and A. Kaliszewski, "Using DTA Models to Evaluate User Delay Costs Due to Incidents: A Case Study in Austin, Texas," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Mondal, A., C.R. Bhat, M.C. Costey, A.C. Bhat, T. Webb, T.B. Magassy, R.M. Pendyala, and W.H.K. Lam, "How Do People Feel While Walking? A Multivariate Analysis of Emotional Well-Being for Utilitarian and Recreational Walking Episodes," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Moore, M.A., P.S. Lavieri, F.F. Dias, and C.R. Bhat, "On Investigating the Potential Effects of Autonomous Vehicle Use on Home/Work Relocations and Commute Times," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.

Nair, G.S., C.R. Bhat, I. Batur, R.M. Pendyala, and W.H.K. Lam, "A Model of Deadheading Trips and Pick-Up Locations for Ride-Hailing Service Vehicles," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.

Pandey, V., E. Wang, and S.D. Boyles, "Deep Reinforcement Learning Algorithm for Dynamic Pricing of Express Lanes with Multiple Access Locations," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.

Patil, P., K. Ross, and S.D. Boyles, "Convergence Behavior for Traffic Assignment Characterization Metrics," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.

Zhu, T., S.D. Boyles, and A. Unnikrishnan, "Electric Vehicle Traveling Salesman Problem with Drone," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.

Bhat, C.R., "Predictive Analytics for Planning and Public Policy in a New Data Landscape," *Invited seminar*, JSW School of Public Policy, Indian Institute of Management (IIM) Ahmedabad, Ahmedabad, India, January 2020.

Bhat, C.R., "Might Driverless Cars Lead to Urban Sprawl? Increase Vehicle Miles of Travel? The Need for Proactive Policies in the Emerging Transportation Landscape," *Invited seminar*, Indian Institute of Management (IIM) Ahmedabad, Ahmedabad, India, January 2020.

Bhat, C.R., "Will Driverless Cars Lead to More Travel? To More Urban Sprawl?," *Invited seminar*, Department of Civil Engineering, Indian Institute of Technology (IIT) Roorkee, Roorkee, India, February 2020.

Plans for Next Reporting Period to Accomplish Technology Transfer Goal: Continue to support researchers as they present their research results through peer-reviewed publications and professional presentations. Organize a Center for Transportation Research (CTR) Symposium to be held April 10, 2019. Work with a new set of summer interns and expose them to the many challenging aspects of data analysis and implications.

2. PRODUCTS

Publications, conference papers, and presentations:

Journal Publications - Published

Pandey, V., and S.D. Boyles (2019). Comparing Route Choice Models for Managed Lane Networks with Multiple Entrances and Exits. *Transportation Research Record*, 2673(10), 381-393.

Patel, R., P. Venkatraman, and S.D. Boyles (2019). Optimal Placement of Reservation-based Intersections in Urban Networks. *Transportation Research Record*, 2673, 10, 781-792.

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Chen, T., N.N. Sze, S. Saxena, A.R. Pinjari, C.R. Bhat, and L. Bai (2020). Evaluation of Penalty and Enforcement Strategies to Combat Speeding Offences among Professional Drivers: A Hong Kong Stated Preference Experiment. *Accident Analysis and Prevention*, 135, 105366.

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Bhat, C.R., "A New Technology-Transformed Transportation Landscape: The Excitement and the Challenges," *Energy@UT Research Expo*, Austin, TX, October 2019.

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Bhat, C.R., "Driverless Cars and Work/Home Relocations: Potential Impacts and Policy Implications," *Invited seminar*, Transportation Engineering Program, The Pennsylvania State University, University Park, PA, November 2019.

Bhat, C.R., "Predictive Analytics for Transportation in an Emerging World of Ubiquitous Sensing," *Invited seminar*, Department of Civil and Environmental Engineering, The Pennsylvania State University, University Park, PA, November 2019.

Bhat, C.R., "Brainstorming for Young Faculty Workshop," *ASCE Transportation & Development Institute (T&DI) Board of Governors Meeting*, University of Arkansas, Fayetteville, AR, November 2019.

Dias, F.F., G.S., Nair, N. Ruiz-Juri, and C.R. Bhat, "Travel Modeling in an Era of Connected and Automated Transportation Systems: An Investigation in the Dallas-Fort Worth Area, Phase III," *Project Peer-Review*, North Central Texas Council of Governments (NCTCOG), Arlington, TX, November 2019.

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- Buckley, R.F. and R.W. Heath, "Selective OFDM Transmission for Simultaneous Wireless Information and Power Transfer." Presented at the *2019 IEEE Global Communications Conference (GLOBECOM)*, Waikoloa, HI, December 2019.
- Petrov, V., D. Moltchanov, S. Andreev, and R.W. Heath, "Analysis of Intelligent Vehicular Relaying in Urban 5G+ Millimeter-Wave Cellular Deployments." Presented at the *2019 IEEE Global Communications Conference (GLOBECOM)*, Waikoloa, HI, December 2019.
- Saab, S., A. Mezghani, and R.W. Heath, "Capacity Based Analysis of a Wideband SIMO System in the Presence of Mutual Coupling." Presented at the *2019 IEEE Global Communications Conference (GLOBECOM)*, Waikoloa, HI, December 2019.
- Batur, I., S. Sharda, T. Kim, S. Khoeini, R.M. Pendyala, and C.R. Bhat, "Mobility, Time Poverty, and Well-Being: How Are They Connected and How Much Does Mobility Matter?," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Capasso da Silva, D., S. Astroza, I. Batur, S. Khoeini, T.B. Magassy, R.M. Pendyala, and C.R. Bhat, "Are Millennials Really All That Different Than Generation X? An Analysis of Factors Contributing to Differences in Vehicle Miles of Travel," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Chauhan, D. R., A. Unnikrishnan, M. Figliozzi, and S.D. Boyles, "Robust Maximum Coverage Facility Problem with Drones Considering Uncertainties in Battery Availability and Consumption," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Chen, T., N.N. Sze, S. Saxena, A.R. Pinjari, C.R. Bhat, and L. Bai (2020), "Evaluation of Penalty and Enforcement Strategies to Combat Speeding Offences among Professional Drivers: A Hong Kong Stated Preference Experiment," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Devaraj, A., G.A. Ramakrishnan, G.S. Nair, K.K. Srinivasan, C.R. Bhat, A.R. Pinjari, G. Ramadurai, and R.M. Pendyala, "Joint Model of App-Based Ridehailing Adoption, Intensity of Use and Intermediate Public Transport (IPT) Consideration among Workers in Chennai City," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Dias, F.F., T. Kim, C.R. Bhat, R.M. Pendyala, W.H.K. Lam, A.R. Pinjari, K.K. Srinivasan, and G. Ramadurai, "Modeling the Evolution of Ride-Hailing Adoption and Usage: A Case Study of the Puget Sound Region," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Dias, F.F., P.S. Lavieri, S. Sharda, S. Khoeini, C.R. Bhat, R.M. Pendyala, A.R. Pinjari, G. Ramadurai, and K.K. Srinivasan, "A Comparison of Online and In-Person Activity Engagement: The Case of Shopping and Eating Meals," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Dias, F.F., G.S. Nair, N. Ruiz Juri, C.R. Bhat, and A. Mirzaei, "Incorporating Autonomous Vehicles in the Traditional Four Step Model: A Case Study in Dallas-Fort Worth," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.
- Li, T., N. Ruiz Juri, H.W. Ross, R. Machemehl, J. Nevaes, and A. Kaliszewski, "Using DTA Models to Evaluate User Delay Costs Due to Incidents: A Case Study in Austin, Texas," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.

Mondal, A., C.R. Bhat, M.C. Costey, A.C. Bhat, T. Webb, T.B. Magassy, R.M. Pendyala, and W.H.K. Lam, "How Do People Feel While Walking? A Multivariate Analysis of Emotional Well-Being for Utilitarian and Recreational Walking Episodes," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.

Moore, M.A., P.S. Lavieri, F.F. Dias, and C.R. Bhat, "On Investigating the Potential Effects of Autonomous Vehicle Use on Home/Work Relocations and Commute Times," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.

Nair, G.S., C.R. Bhat, I. Batur, R.M. Pendyala, and W.H.K. Lam, "A Model of Deadheading Trips and Pick-Up Locations for Ride-Hailing Service Vehicles," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.

Pandey, V., E. Wang, and S.D. Boyles, "Deep Reinforcement Learning Algorithm for Dynamic Pricing of Express Lanes with Multiple Access Locations," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.

Patil, P., K. Ross, and S.D. Boyles, "Convergence Behavior for Traffic Assignment Characterization Metrics," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.

Zhu, T., S.D. Boyles, and A. Unnikrishnan, "Electric Vehicle Traveling Salesman Problem with Drone," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2020.

Bhat, C.R., "Predictive Analytics for Planning and Public Policy in a New Data Landscape," *Invited seminar*, JSW School of Public Policy, Indian Institute of Management (IIM) Ahmedabad, Ahmedabad, India, January 2020.

Bhat, C.R., "Might Driverless Cars Lead to Urban Sprawl? Increase Vehicle Miles of Travel? The Need for Proactive Policies in the Emerging Transportation Landscape," *Invited seminar*, Indian Institute of Management (IIM) Ahmedabad, Ahmedabad, India, January 2020.

Bhat, C.R., "Will Driverless Cars Lead to More Travel? To More Urban Sprawl?," *Invited seminar*, Department of Civil Engineering, Indian Institute of Technology (IIT) Roorkee, Roorkee, India, February 2020.

Websites:

<http://dstop.utexas.edu>, D-STOP website

<http://ctr.utexas.edu/>, Center for Transportation Research (CTR)

<http://ctr.utexas.edu/nmc/>, Network Modeling Center at CTR

<http://www.datarodeo.org/>, Data Rodeo, A Data Analytics Environment for the Central Texas Region

<http://wncg.org/>, Wireless Networking & Communications Group (WNCG)

http://www.caee.utexas.edu/prof/bhat/fULL_PAPERS.htm, Dr. Bhat's personal webpage

<http://tinyurl.com/steveboyles/>, Dr. Boyles' personal webpage

<http://www.profheath.org/>, Dr. Heath's personal webpage

Technologies or techniques: Nothing to report for this period.

Inventions, patent applications, and licenses: Nothing to report for this period.

Other products:

Todd E. Humphreys, *MIT Technology Review*, Nov 15, 2019, "Ghost Ships, Crop Circles, and Soft Gold: A GPS Mystery in Shanghai"

Todd E. Humphreys, *Scientific American*, Dec 1, 2019, "GPS Is Easy to Hack, and the U.S. Has No Backup"

Todd E. Humphreys, *Inside GNSS*, Jan 2020, "Characterizing GNSS Interference from Low Earth Orbit"

3. PARTICIPANTS & COLLABORATING ORGANIZATIONS

What organizations have been involved as partners?

City of Austin, Austin, TX: In-kind support, technical consultancy
Texas Department of Transportation, Austin, TX: In-kind support, financial support
North Central Texas Council of Governments (NCTCOG): financial support
Huawei Technologies, USA: In-kind support, technical consultancy
Cintra, In-kind support, financial support
Nuria G. Prelcic, Universidade de Vigo, Department of Signal Theory and Communications, Vigo, Spain: Technical consultancy.
Sergiy A. Vorobyov, Dept of Signal Processing and Acoustics, Aalto University, Espoo, Finland: Technical consultancy
Amine Mezghani, Dept of Electrical and Computer Engineering University of Texas at Austin: Technical consultancy
Texas Advanced Computing Center (TACC), University of Texas at Austin, technical consultancy
Honda R&D Americas, technical consultancy
Samsung Research America: technical consultancy
Toyota, technical consultancy
Qualcomm, technical consultancy

Have other collaborators or contacts been involved?

D D-STOP has allowed us to build new relationships, including a contract with TxDOT San Antonio District to assist with DTA modeling, and also a new task with TxDOT Austin District to help with planning to use advanced modeling.

We have made DSTOP known to industrial affiliates of the Wireless Networking & Communications Group (WNCG): Crown Castle; Cisco; Huawei; Qualcomm; DOCOMO; Department of Defense; AT&T; CoomScope; National Instruments; Samsung; Yokagawa; Universidade de Vigo, Spain; Toyota; Iteris; Microsoft Research; 3M Traffic Safety Systems; RideScout.

We have also discussed DSTOP with several public agencies who have come on board as members of the D-STOP Business Advisory Council (BAC). These include North Central Texas Council of Governments (NCTCOG), Capital Metro, Austin Chamber of Commerce, the City of Austin, Texas, FHWA Texas Division, and the Texas Dept of Transportation.

4. IMPACT

Impact on the development of the principal disciplines of the program:

D-STOP projects have contributed to ways in which traffic mobility and reliability may be improved through a heterogeneous system of wireless sensors. They have also demonstrated how smart technologies can promote ride-hailing and traffic road safety. A recent matching fund TxDOT project is developing sensor-based mechanisms to improve traffic safety during extreme weather conditions.

Impact on other disciplines:

The D-STOP research projects involve collaborations with faculty in other disciplines, including Electrical Engineering, Computer Science, Digital Humanities, Information Technology and English. Several demonstrations and presentations contribute in substantive ways to incorporate the human element in the fast developing technology landscape.

Impact on the transportation workforce development:

Continuing to prepare the leaders of tomorrow through undergraduate and graduate student research and education. Our students obtain experiential training in real-world problems through our research interactions with practice-oriented agencies such as Capital Area Metropolitan Planning Organization (CAMPO), North Central Texas Council of Governments (NCTCOG), Cintra, and TxDOT. As part of D-STOP activities, we have reached out to high school students in the Austin region, providing a glimpse of the exciting transportation research landscape.

Impact on physical, institutional, and information resources at the university or other partner institutions:

Contributed to the establishment of the Good Systems Bridging Barriers theme at UT Austin. The Good Systems theme focuses on how best to choreograph the evolution of technology to meet the needs of society. Dr. Bhat is one of eight leaders in this effort, which officially kicked off in September 2019.

Impact on technology transfer:

Developed a travel model system that incorporates ride-hailing and autonomous vehicle technologies in collaboration with the North Central Texas Council of Governments (NCTCOG) and Cintra.

Impact on society beyond science and technology:

The models developed under DSTOP-supported research can lead to more efficient and safe use of transportation infrastructure, decreasing congestion, improving roadway safety, and supporting the economic competitiveness of the nation. It also contributes to assessing the impact of autonomous vehicles on activity travel patterns, as a means of design proactive policies and regulations in the emerging driverless vehicle era.

5. CHANGES/PROBLEMS

COVID-19 Impacts

Due to COVID-19, we cancelled the seventh University Transportation Center-Undergraduate Internship (UTC-UI) program to be held the summer of 2020 out of an abundance of caution. The Center for Transportation Research also cancelled its Annual Symposium originally scheduled for April 8, 2020. The UT Austin campus is currently closed to students, with online learning and limited on-campus operations for the remainder of the Spring 2020 semester, and for the Summer 2020 semester. There is also a suspension of all university sponsored international and domestic travel through May 31 with the possibility that this date could be extended.