

Program Progress Performance Report



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Office of the Assistant Secretary for Research and Technology

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

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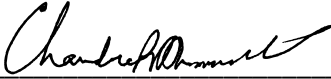
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Grant Period: September 30, 2013 – September 30, 2020

Reporting Period End Date: March 31, 2019

Report Term: October 1, 2018 – March 31, 2019

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 17 projects were pursued with partial or full funding support from D-STOP. Of these, 2 projects were completed during this reporting period. Currently, 15 projects are underway.

Completed Projects

- 1. Explorations to Inform V2I Managed Lanes Design and Development**
(title updated from *V2I Managed Lanes Test Bed*)
(PI: Natalia Ruiz Juri); End date: February 28, 2019
- 2. Internet of Moving Things using Full Duplex Mesh Networks**
(PI: Sriram Vishwanath); End date: December 31, 2018

Ongoing Projects

- 1. Real-Time Signal Control and Traffic Stability**
(PI: Stephen Boyles); Anticipated end date: August 31, 2019
- 2. Spatial Correlation Estimation of Millimeter Vehicular Communication Channels Using Out-of-Band Information**
(PI: Robert Heath); End date: May 31, 2019 (extended)
- 3. Joint Millimeter-Wave Communication and Radar for Automotive Applications**
(PI: Robert Heath); End date: May 31, 2019 (extended)
- 4. Improved Models for Managed Lane Operations**
(PI: Stephen Boyles); Anticipated end date: August 31, 2019

5. **Transit Policy in the Context of New Transportation Paradigms**
(PI: Natalia Ruiz Juri); Anticipated end date: September 30, 2019
6. **Video Data Analytics for Safer and More Efficient Mobility**
(PI: Natalia Ruiz Juri); Anticipated end date: September 30, 2020
7. **Data-Driven, Real-Time Traffic Signal Optimization: A Distributed Approach**
(PI: Stephen Boyles); Anticipated end date: September 30, 2020
8. **Real-time, Targeted Incentives for Strategic Travelers**
(PI: Stephen Boyles); Anticipated end date: September 30, 2020
9. **Tight-coupling of Vision, Radar, and Carrier-phase Differential GNSS for Robust All-weather Positioning**
(PI: Todd Humphreys); Anticipated end date: September 30, 2020
10. **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
11. **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
12. **Sensing and Communications in V2V and V2I Settings**
(PI: Sanjay Shakkottai); Anticipated end date: September 30, 2020
13. **Online Matching, Black-box Optimization and Hyper-parameter Tuning**
(PI: Sanjay Shakkottai); Anticipated end date: September 30, 2020
14. **Solving Perception Challenges for Autonomous Vehicles Using SGD**
(PI: Constantine Caramanis); Anticipated end date: September 30, 2020
15. **Large Scale Optimization with Small Scale Data**
(PI: Constantine Caramanis); Anticipated end date: September 30, 2020

Research Results Disseminated: 18 papers were published and 11 papers are forthcoming in refereed journals based on the research projects associated with D-STOP. Several other papers are in the review process. 34 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.

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

Teagan Webb, Emily Niemeyer (supervised by Chandra Bhat)
James Lentz, Rishabh Thakkar, Mohammad Zaidi (supervised by Stephen Boyles)
Jonathan Butler, Kamran Khan (supervised by Chris Claudel)
Alexander Choy (supervised by Natalia Ruiz Juri)

Grad

Supervised by Chandra Bhat: Felipe Dias (PhD), Joseph Hutchinson (MS), Kamryn Long (MS), Aupal Mondal (PhD), Michael Moore (PhD), Gopindra Nair (PhD), Abhilash Singh (PhD).

Supervised by Stephen Boyles: William Alexander (MS/PhD), Can Gokalp (PhD), Manoj Gedela (MS), Rachel James (PhD), Carlin Liao (PhD), Venktesh Pandey (PhD), Rahul Patel (MS), Cesar Yahia (PhD), Tengkuo Zhu (PhD).

Supervised by Natalia Ruiz Juri: Natalia Zuniga (PhD).

Supervised by Chris Claudel: Abdullah Mohamed (MS).

Supervised by Constantine Caramanis: Tianyang Li (PhD).

Supervised by Robert Heath: Anum Ali (PhD), Preeti Kumari (PhD), Ramakrishna Sai Annaluru (MS).

Supervised by Todd Humphreys: Lakshay Narula (PhD).

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

Supervised by Joydeep Ghosh: Rahi Kalantari (PhD), Taewan Kim (PhD), Michael Motro (PhD).

The D-STOP Center selected MS/PhD student William Alexander (supervised by Dr. Stephen Boyles) as its 2018 Outstanding Student of the Year. Former MS student Pragun Vinayak (supervised by Dr. Chandra Bhat) was awarded the Council of University Transportation Centers (CUTC) 2018 Milton Pikarsky Memorial Award for his MS thesis entitled "Accounting for Multi-Dimensional Dependencies Among Decision-makers Within a Generalized Model Framework: An Application to Understanding Shared Mobility Service Usage Levels". Lisa Macias, Executive Assistant to the D-STOP Center, was awarded the CUTC-ARTBA 2018 Administrative Leadership Award. William, Pragun, and Lisa were recognized at an annual awards banquet in January 2019 in Washington DC before the Transportation Research Board Annual Meeting.



William Alexander



Pragun Vinayak and Lisa Macias

Dr. Robert Heath received the 2019 IEEE Kiyo Tomiyasu Award. This was announced in June of 2018 but the award will be given in December 2019. He received this award with Professor Jeffrey G. Andrews for "contributions to wireless communication systems." The IEEE Kiyo Tomiyasu Award is an IEEE Technical Field Award, meaning it spans all subfields of electrical engineering. It was established in 2001 to recognize "outstanding contributions to technologies holding the promise of innovative applications." The award is sponsored by Dr. Kiyo Tomiyasu, the IEEE Geoscience and Remote Sensing Society, and the IEEE Microwave Theory and Techniques Society. Nominees must be under the age of 45.

Dr. Robert Heath also received the IEEE Communications Society's (ComSoc) 2018 Wireless Technical Committee Recognition Award. The commendation recognizes Heath's "high degree of visibility and contribution in the field of 'Wireless and Mobile Communications Theory, Systems, and Networks.'" ComSoc's Wireless Communications Technical Committee confers this distinction on a maximum of two

recipients annually. Prof. Halim Yanikomeroglu of Carleton University in Canada was also given the award for 2018.

Prof. Sanjay Shakkottai received a 2018 Qualcomm Faculty Award. This is the second consecutive year to be awarded the honor. Qualcomm encourages partnerships among engineers from hardware, software, and systems maintain close relationships with key universities to keep track of their latest discoveries and facilitate new collaborations. The Qualcomm Faculty Award (QFA) is one of the programs that the company uses to support key professors and their research at leading universities identified by the company.

Education and Workforce Development Results Disseminated:

Graduates Linked with Undergraduates in Engineering (GLUE)

Graduate student Lakshay Narula (supervised by Prof. Todd Humphreys) is mentoring Roberto Padilla, an undergraduate aerospace engineering student at UT Austin. This is for the Graduates Linked with Undergraduates in Engineering (GLUE) program organized by the Women in Engineering Program (WEP). Roberto is working on analysis and visualization of radar data under Lakshay's guidance for the Spring 2019 semester. The WEP GLUE program is limited to about 30 undergraduates and is open to all degree-seeking engineering students in all majors who have *never* done research in a university setting. Undergraduate participants gain valuable experience working with a graduate mentor on a research project for eight hours per week and participating in a weekly seminar class. The duration of the program is one semester only.

Girl Day at UT Austin

D-STOP Graduate student members of the Institute of Transportation Engineers and Women's Transportation Seminar students groups gave an interactive demonstration to learn how to manage traffic signals and keep traffic flowing safely (Transportation: Getting You Where You Want to Go) during Girl Day on February 23, 2019. Participants tried to get all the traffic through an intersection accident free before time ran out. Girl Day at UT Austin is a free event for K-8 students (for both girls and boys) held on the Cockrell School of Engineering and Natural Sciences complexes at The University of Texas at Austin. Over 8,000 students participated in over 150 free-flowing hands-on activities and demonstrations hosted by volunteers, student organizations, corporate partners and community organizations. Students got the chance to explore engineering, science, math, and technology at their own pace throughout the event.

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 1, 2019. 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

Dr. Robert Heath, Dr. Nuria Gonzalez Prelcic, and Dr. Heath's graduate students gave hands-on demonstrations of how antenna beam patterns change as a car moves in a millimeter wave vehicular communication system (Using the Millimeter Wave for 5G Wireless Communication and Beyond) and on navigation algorithms which use only on-board sensors to decide a trajectory and avoid obstacles during the flight of a UAV (Sensing and Navigation with Unmanned Aerial Vehicles (UAV)) at Explore UT on March 2, 2019. D-STOP Graduate students from the Center for Transportation Research also gave 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 Institute of Transportation Engineers and Women's Transportation Seminar students groups also gave 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 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:

Organize the third board meeting of UT SAVES. In partnership with CTR, WNCG has created this Center to address the challenges of wireless, networking, and sensing in vehicular systems. Continue discussions with the Business Advisory Council (BAC). The University Transportation Center-Undergraduate Internship (UTC-UI) program will be held for a sixth year in the summer of 2019, and organization is underway. Each intern will participate in a research project related to the D-STOP center, and a weekly seminar will be held. Recruit and introduce a fresh batch of graduate students to D-STOP.

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

2018 Texas Wireless Summit

The Texas Wireless Summit (TWS), hosted by the Wireless Networking and Communications Group (WNCG), was held November 6, 2018 at UT Austin. TWS brings together leading figures in industry, academia, and government to discuss the latest developments in information systems technology. "AI and the Mobile Device" marked the 16th summit hosted by the group, and explored an important intersection of technologies. Wireless devices like smartphones and tablets have become ubiquitous in our everyday lives. At the same time, interest in improving technology through the development of artificial intelligence and machine learning techniques is also growing at a rapid pace. Troubleshooting the difficulties in combining the two can improve our experience of both. Over a dozen eminent industry and academe leaders spoke at sessions that tackled these questions over the course of the one-day summit. The event featured thought-provoking keynotes from Dr. Rajiv Laroia, Co-Founder and CTO of Light, and Dr. Thad Starner, Tech Lead for Google Glass. In-depth technical talks offered nuanced perspectives of the intricacies and issues presented by today's wireless/AI research. Panel discussions

delted into the questions “Can ML/AI Help Build Wireless Systems?” and “Edge vs. Cloud: Where should AI Be Done?” Speakers and panelists hailed from technological leaders like Intel, Google, Samsung, and Qualcomm, among others, as well as influential research institutions like Columbia and Virginia Tech. D-STOP’s Dr. Constantine Caramanis co-organized this year’s event, 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).

Autonomous Mobility Panel, Dr. Chandra Bhat, November 2, 2018, Austin TX. A panel of experts and futurists will engage in a “What’s Next?” discussion on Artificial Intelligence, Machine Learning, Robotics, and Sustainability surrounding one of AFC’s most critical modernization priorities.

NCTCOG Workshop, November 5, 2018. Presentation: “CAV/Mixed Transportation Modeling”

TxDOT STIC Meeting: Road Weather Management Project Update, November 6, 2018

TxDOT Weather Project Workshops: Abilene and Austin, December 13 & 14, 2018

Prof. Benjamin Heydecker guest seminar: “Control of Autonomous Vehicles”, February 21, 2019

ESX Standards Meeting (Kick-off meeting of the 6 leaders of the ASCE ESX “6 x 6” standards initiative), March 22, 2019

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

Published:

Pandey, V., and S.D. Boyles (2018). Dynamic pricing for managed lanes with multiple entrances and exits. *Transportation Research Part C*, 96, 304-320.

Pandey, V. and N. Ruiz Juri (2018). Using National Performance Management Research Data Set for Corridor Performance Measures: A US-281N Corridor Case Study. *Transportation Research Record*, 2672(42), 257-267.

Lukose, E., M.W. Levin, and S.D. Boyles (2019). Incorporating insights from signal optimization into reservation-based intersection controls. *Journal of Intelligent Transportation Systems*, 23(3), 250-264.

Perrine, K., M.W. Levin, C.N. Yahia, M. Duell, and S.D. Boyles (2019). Implications of traffic signal security on potential deliberate traffic disruptions. *Transportation Research Part A*, 120, 58-70.

Xie, C., X. Wu, and S.D. Boyles (2019). Traffic equilibrium with a continuously distributed bound on travel weights: the rise of range anxiety and mental account. *Annals of Operations Research*, 273(1-2), 279-310.

Yahia, C.N., V. Pandey, and S.D. Boyles (2018). Network Partitioning Algorithms for Solving the Traffic Assignment Problem using a Decomposition Approach. *Transportation Research Record*, 2672(48), 116-126.

Leung, K.Y.K., S. Astroza, B.P.Y. Loo, and C.R. Bhat (2019). An Environment-People Interactions Framework for Analyzing Children’s Extra-Curricular Activities and Active Transport. *Journal of Transport Geography*, 74, 341-358.

Lavieri, P.S., F.F. Dias, N. Ruiz Juri, J. Kuhr, and C.R. Bhat (2018). A Model of Ridesourcing Demand Generation and Distribution. *Transportation Research Record*, 2672(46), 31-40.

- Vinayak, P., F.F. Dias, S. Astroza, C.R. Bhat, R.M. Pendyala, and V.M. Garikapati (2018), Accounting for Multi-Dimensional Dependencies Among Decision-Makers Within a Generalized Model Framework: An Application to Understanding Shared Mobility Service Usage Levels. *Transport Policy*, 72, 129-137.
- Lavieri, P.S., Q. Dai, and C.R. Bhat (2018). Using Virtual Accessibility and Physical Accessibility as Joint Predictors of Activity-Travel Behavior. *Transportation Research Part A*, 118, 527-544.
- Nair, G.S., S. Astroza, C.R. Bhat, S. Khoeini and R.M. Pendyala (2018). An Application of a Rank Ordered Probit Modeling Approach to Understanding Level of Interest in Autonomous Vehicles. *Transportation*, 45(6), 1623-1637.
- Krishnasamy, S., P.T. Akhil, A. Arapostathis, R. Sundaresan and S. Shakkottai (2018). Augmenting Max-Weight with Explicit Learning for Wireless Scheduling with Switching Costs. *IEEE/ACM Transaction on Networking*, 26(6), 2501-2514, December. doi: 10.1109/TNET.2018.2869874
- Meirom, E.A., C. Caramanis, S. Mannor, A. Orda, and S. Shakkottai (2018). Detecting Cascades from Weak Signatures. *IEEE Transactions on Network Science and Engineering*, 5(4), 313-325, Oct.-Dec. doi: 10.1109/TNSE.2017.2764444
- Myers, N.J., A. Mezghani and R.W. Heath (2019). Swift-Link: A Compressive Beam Alignment Algorithm for Practical mmWave Radios. *IEEE Transactions on Signal Processing*, 67(4), 1104-1119, February. doi: 10.1109/TSP.2018.2886168
- Mirzaei, H., G. Sharon, S. Boyles, T. Givargis and P. Stone (2018). Enhanced Delta-tolling: Traffic Optimization via Policy Gradient Reinforcement Learning. *2018 21st International Conference on Intelligent Transportation Systems (ITSC)*, Maui, HI, pp. 47-52. doi: 10.1109/ITSC.2018.8569737
- Narula, L., M. J. Murrian, and T. E. Humphreys (2018). Accuracy Limits for Globally-Referenced Digital Mapping Using Standard GNSS. *2018 21st International Conference on Intelligent Transportation Systems (ITSC)*, Maui, HI, pp. 3075-3082. doi: 10.1109/ITSC.2018.8570019
- Pandey, V., and S. D. Boyles (2018). Multiagent Reinforcement Learning Algorithm for Distributed Dynamic Pricing of Managed Lanes. *2018 21st International Conference on Intelligent Transportation Systems (ITSC)*, Maui, HI, pp. 2346-2351. doi: 10.1109/ITSC.2018.8569317
- Gross, J.N., C. Kilic and T.E. Humphreys (2019). Maximum-Likelihood Power-Distortion Monitoring for GNSS-Signal Authentication. *IEEE Transactions on Aerospace and Electronic Systems*, 55(1), 469-475, February. doi: 10.1109/TAES.2018.2848318
- Forthcoming:*
- Green, G.N., and T.E. Humphreys (2019). Data-Driven Generalized Integer Aperture Bootstrapping for High-Integrity Positioning. *IEEE Transactions on Aerospace and Electronic Systems*, 55(2), pp. 757-768, April 2019. doi: 10.1109/TAES.2018.2864770
- Levin, M. W., H. Smith, and S. D. Boyles. A dynamic four-step planning model of empty repositioning trips for personal autonomous vehicles. *Journal of Transportation Engineering*, 145(5), May 2019.
- Astroza, S., V.M. Garikapati, R.M. Pendyala, C.R. Bhat, and P.L. Mokhtarian, Representing Heterogeneity in Structural Relationships Among Multiple Choice Variables Using a Latent Segmentation Approach. *Transportation*, forthcoming.
- Lavieri, P.S., and C.R. Bhat. Modeling Individuals' Willingness to Share Trips with Strangers in an Autonomous Vehicle Future. *Transportation Research Part A*, forthcoming.
- Boyles, S., and N. Ruiz Juri. Queue spillback and demand uncertainty in dynamic network loading. Accepted for publication in *Transportation Research Record*, 2019.

James, R., B. E. Hammit, and S. D. Boyles. Methods to obtain representative car-following model parameters from trajectory-level data for use in microsimulation. Accepted for publication in *Transportation Research Record*, 2019.

Pandey, V., and S. D. Boyles. Comparing route choice models for managed lane networks with multiple entrances and exits. Accepted for publication in *Transportation Research Record*, 2019.

Patel, R., P. Venkatraman, and S. D. Boyles. Optimal placement of reservation-based intersections in urban networks. Accepted for publication in *Transportation Research Record*, 2019.

Dias, F.F., P.S. Lavieri, T. Kim, C.R. Bhat, and R.M. Pendyala. Fusing Multiple Sources of Data to Understand Ride-Hailing Use. Accepted for publication in *Transportation Research Record*, 2019.

Long, K., D. Capasso da Silva, F.F. Dias, S. Khoeini, A.C. Bhat, R.M. Pendyala, and C.R. Bhat. The Role of Childhood Context and Experience in Shaping Activity-Travel Choices in Adulthood. Accepted for publication in *Transportation Research Record*, 2019.

Nair, G.S., C.R. Bhat, R.M. Pendyala, B.P.Y. Loo, and W.H.K. Lam. On the Use of Probit Based Models for Ranking Data Analysis. Accepted for publication in *Transportation Research Record*, 2019.

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

Presented:

Bhat, C.R., "On Modeling the Adoption, Frequency, and Characteristics of Ride-Hailing Trips." *Invited seminar*, Dept of Civil Engineering, Università "Roma Tre", October 2018.

Kim, T., M. Motro, P. Lavieri, S. Oza, J. Ghosh, and C. Bhat, "Pedestrian Detection with Simplified Depth Prediction." Presented at the *21st IEEE International Conference on Intelligent Transportation Systems (ITSC18)*, Maui, HI, November 2018.

Mirzaei, H., G. Sharon, S. Boyles, T. Givargia, and P. Stone, "Enhanced Delta-Tolling: Traffic Optimization via Policy Gradient Reinforcement Learning." Presented at the *21st IEEE International Conference on Intelligent Transportation Systems (ITSC18)*, Maui, HI, November 2018.

Narula, L., M. J. Murrian, and T. E. Humphreys. "Accuracy Limits for Globally-Referenced Digital Mapping Using Standard GNSS," Presented at the *21st IEEE International Conference on Intelligent Transportation Systems (ITSC18)*, Maui, HI, November 2018.

Pandey, V., and S.D. Boyles. "Multiagent Reinforcement Learning Algorithm for Distributed Dynamic Pricing of Managed Lanes." Presented at the *21st IEEE International Conference on Intelligent Transportation Systems (ITSC18)*, Maui, HI, November 2018.

Bhat, C.R., "CAV/Mixed Transportation Modeling," Project Workshop, North Central Texas Council of Governments (NCTCOG), Arlington, TX, November 2018.

Ali, A., "Radar aided mmWave beam training." Poster presented at the *Texas Wireless Summit*, Austin, TX, November 2018.

Kumari, P., "Adaptive IEEE 802.11ad Waveform Design for a Joint Automotive Communication-Radar System." Poster presented at the *Texas Wireless Summit*, Austin, TX, November 2018.

Bhat, C.R., "Predictive Analytics for Transportation in a New Technology-Transformed Data Landscape: The Excitement and the Challenges." Plenary session presentation at the *23rd International Conference of the Hong Kong Society for Transportation Studies (HKSTS)*, Hong Kong, December 2018.

Bhat, C.R., "Activity-Based Modeling: Recent Advances and Possible Application to Hong Kong." Keynote presentation at the *International Post-Conference (HKSTS) Workshop on "Advances in Supernetwork Modeling and Mobility Pattern Analysis"*, Hong Kong, December 2018.

Heath Jr., R.W., A. Ali, and N. Gonzalez-Prelcic, "Radar aided V2X communications at mmWave." Presentation to Nokia Bell Labs, January 2019.

Heath Jr., R.W., "5G for Vehicle-to-X Communications." *Keynote Presentation*, DesignCon 2019 Conference, Santa Clara, CA, January 2019.

Bhat, C.R., "Travel Demand Forecasting in the CAV World." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Boyles, S., and N. Ruiz Juri, "Queue spillback and demand uncertainty in dynamic network loading." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Chen, A., N. Ruiz Juri, H. Westerfield Ross, Y. Li, and T. Zhu, "Understanding the impacts of freeway lane closures through data: a combined analysis of NPMRDS and fixed-sensor data." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Dias, F.F., P.S. Lavieri, T. Kim, C.R. Bhat, and R.M. Pendyala, "Fusing Multiple Sources of Data to Understand Ride-Hailing Use." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Dunn, M.R., H. Westerfield Ross, C. Baumais, J. Wall, J. Lammert, J. Duthie, N. Ruiz Juri, R.B. Machemehl, "A Data-Driven Methodology for Prioritizing Traffic Signal Retiming Operations." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Gokalp, C., and S. D. Boyles, "Mean-Standard Deviation Model For Minimum Cost Flow Problem." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Hutchinson, J., D. Capasso da Silva, F.F. Dias, C.R. Bhat, S. Khoeini, R.M. Pendyala, and W.H.K. Lam "Exploring Patterns of Heterogeneity in Activity-Travel Behaviors of the Elderly." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

James, R., B. E. Hammit, and S. D. Boyles. "Methods to obtain representative car-following model parameters from trajectory-level data for use in microsimulation." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Lavieri, P., and C.R. Bhat, "A Joint Model of Experience and Frequency of Use of Solo and Pooled Ride-Hailing Services in Dallas, Texas." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Lavieri, P., and C.R. Bhat, "Modeling Individuals' Willingness to Share Trips with Strangers in an Autonomous Vehicle Future." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Lavieri, P., and C.R. Bhat, "Investigating Potential Externalities of Ride-Hailing Adoption: A Multivariate Model of Ride-Hailing Trip Characteristics." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Leung, K.Y.K., S. Astroza, B.P.Y. Loo, and C.R. Bhat, "An Environment-People Interactions Framework for Analyzing Children's Extra-Curricular Activities and Active Transport." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

- Long, K., D. Capasso da Silva, F.F. Dias, S. Khoeini, A.C. Bhat, R.M. Pendyala, and C.R. Bhat, "The Role of Childhood Context and Experience in Shaping Activity-Travel Choices in Adulthood." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Nair, G.S., C.R. Bhat, R.M. Pendyala, B.P.Y. Loo, and W.H.K. Lam, "On the Use of Probit Based Models for Ranking Data Analysis." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Pandey, V., and S. D. Boyles, "Comparing route choice models for managed lane networks with multiple entrances and exits." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Patel, R., P. Venkatraman, and S. D. Boyles, "Optimal placement of reservation-based intersections in urban networks." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Sharda, S., S. Astroza, S. Khoeini, I. Batur, R.M. Pendyala, and C.R. Bhat, "Do Attitudes Affect Behavioral Choices or Vice-Versa? Uncovering Latent Segments Within a Population." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Singh, A.C., K. Abel, J. Hutchinson, K. Faust, and C.R. Bhat, "Food Access for Low Income Individuals." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Zhu, T., N. Ruiz Juri, S.D. Boyles, K. Perrine, A. Chen, Y. Li, "An Efficient Simulation Framework for Estimating Work Zone Impacts." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Zuniga-Garcia, N., M. Tec, J.C. Scott, N. Ruiz Juri, R.B. Machemehl, "Evaluation of Ride-Sourcing Search Frictions and Driver Productivity: A Spatial Denoising Approach." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Hanna, J. P., G. Sharon, S. D. Boyles, and P. Stone, "Selecting compliant agents for opt-in micro-tolling." Presented at the *33rd AAAI Conference on Artificial Intelligence (AAAI-19)*, Honolulu, HI, January 2019.
- Bhat, C.R., "Emerging New Directions and Challenges in Choice Analysis." *Invited seminar*, Center for infrastructure, Sustainable Transportation & Urban Planning (*CiSTUP*), Indian Institute of Science (IISc) Bangalore, Bengaluru, India, February 2019.

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 (2018). Dynamic pricing for managed lanes with multiple entrances and exits. *Transportation Research Part C*, 96, 304-320.

Pandey, V. and N. Ruiz Juri (2018). Using National Performance Management Research Data Set for Corridor Performance Measures: A US-281N Corridor Case Study. *Transportation Research Record*, 2672(42), 257-267.

- Lukose, E., M.W. Levin, and S.D. Boyles (2019). Incorporating insights from signal optimization into reservation-based intersection controls. *Journal of Intelligent Transportation Systems*, 23(3), 250-264.
- Perrine, K., M.W. Levin, C.N. Yahia, M. Duell, and S.D. Boyles (2019). Implications of traffic signal security on potential deliberate traffic disruptions. *Transportation Research Part A*, 120, 58-70.
- Xie, C., X. Wu, and S.D. Boyles (2019). Traffic equilibrium with a continuously distributed bound on travel weights: the rise of range anxiety and mental account. *Annals of Operations Research*, 273(1-2), 279-310.
- Yahia, C.N., V. Pandey, and S.D. Boyles (2018). Network Partitioning Algorithms for Solving the Traffic Assignment Problem using a Decomposition Approach. *Transportation Research Record*, 2672(48), 116-126.
- Leung, K.Y.K., S. Astroza, B.P.Y. Loo, and C.R. Bhat (2019). An Environment-People Interactions Framework for Analyzing Children's Extra-Curricular Activities and Active Transport. *Journal of Transport Geography*, 74, 341-358.
- Lavieri, P.S., F.F. Dias, N. Ruiz Juri, J. Kuhr, and C.R. Bhat (2018). A Model of Ridesourcing Demand Generation and Distribution. *Transportation Research Record*, 2672(46), 31-40.
- Vinayak, P., F.F. Dias, S. Astroza, C.R. Bhat, R.M. Pendyala, and V.M. Garikapati (2018). Accounting for Multi-Dimensional Dependencies Among Decision-Makers Within a Generalized Model Framework: An Application to Understanding Shared Mobility Service Usage Levels. *Transport Policy*, 72, 129-137.
- Lavieri, P.S., Q. Dai, and C.R. Bhat (2018). Using Virtual Accessibility and Physical Accessibility as Joint Predictors of Activity-Travel Behavior. *Transportation Research Part A*, 118, 527-544.
- Nair, G.S., S. Astroza, C.R. Bhat, S. Khoeini and R.M. Pendyala (2018). An Application of a Rank Ordered Probit Modeling Approach to Understanding Level of Interest in Autonomous Vehicles. *Transportation*, 45(6), 1623-1637.
- Krishnasamy, S., P.T. Akhil, A. Arapostathis, R. Sundaresan and S. Shakkottai (2018). Augmenting Max-Weight with Explicit Learning for Wireless Scheduling with Switching Costs. *IEEE/ACM Transaction on Networking*, 26(6), 2501-2514, December. doi: 10.1109/TNET.2018.2869874
- Meirom, E.A., C. Caramanis, S. Mannor, A. Orda, and S. Shakkottai (2018). Detecting Cascades from Weak Signatures. *IEEE Transactions on Network Science and Engineering*, 5(4), 313-325, Oct.-Dec. doi: 10.1109/TNSE.2017.2764444
- Myers, N.J., A. Mezghani and R.W. Heath (2019). Swift-Link: A Compressive Beam Alignment Algorithm for Practical mmWave Radios. *IEEE Transactions on Signal Processing*, 67(4), 1104-1119, February. doi: 10.1109/TSP.2018.2886168
- Mirzaei, H., G. Sharon, S. Boyles, T. Givargis and P. Stone (2018). Enhanced Delta-tolling: Traffic Optimization via Policy Gradient Reinforcement Learning. *2018 21st International Conference on Intelligent Transportation Systems (ITSC)*, Maui, HI, pp. 47-52. doi: 10.1109/ITSC.2018.8569737
- Narula, L., M. J. Murrian, and T. E. Humphreys (2018). Accuracy Limits for Globally-Referenced Digital Mapping Using Standard GNSS. *2018 21st International Conference on Intelligent Transportation Systems (ITSC)*, Maui, HI, pp. 3075-3082. doi: 10.1109/ITSC.2018.8570019
- Pandey, V., and S. D. Boyles (2018). Multiagent Reinforcement Learning Algorithm for Distributed Dynamic Pricing of Managed Lanes. *2018 21st International Conference on Intelligent Transportation Systems (ITSC)*, Maui, HI, pp. 2346-2351. doi: 10.1109/ITSC.2018.8569317

Gross, J.N., C. Kilic and T.E. Humphreys (2019). Maximum-Likelihood Power-Distortion Monitoring for GNSS-Signal Authentication. *IEEE Transactions on Aerospace and Electronic Systems*, 55(1), 469-475, February. doi: 10.1109/TAES.2018.2848318

Presentations

Bhat, C.R., "On Modeling the Adoption, Frequency, and Characteristics of Ride-Hailing Trips." *Invited seminar*, Dept of Civil Engineering, Università "Roma Tre", October 2018.

Kim, T., M. Motro, P. Lavieri, S. Oza, J. Ghosh, and C. Bhat, "Pedestrian Detection with Simplified Depth Prediction." Presented at the *21st IEEE International Conference on Intelligent Transportation Systems (ITSC18)*, Maui, HI, November 2018.

Mirzaei, H., G. Sharon, S. Boyles, T. Givargia, and P. Stone, "Enhanced Delta-Tolling: Traffic Optimization via Policy Gradient Reinforcement Learning." Presented at the *21st IEEE International Conference on Intelligent Transportation Systems (ITSC18)*, Maui, HI, November 2018.

Narula, L., M. J. Murrian, and T. E. Humphreys. "Accuracy Limits for Globally-Referenced Digital Mapping Using Standard GNSS," Presented at the *21st IEEE International Conference on Intelligent Transportation Systems (ITSC18)*, Maui, HI, November 2018.

Pandey, V., and S.D. Boyles. "Multiagent Reinforcement Learning Algorithm for Distributed Dynamic Pricing of Managed Lanes." Presented at the *21st IEEE International Conference on Intelligent Transportation Systems (ITSC18)*, Maui, HI, November 2018.

Bhat, C.R., "CAV/Mixed Transportation Modeling," Project Workshop, North Central Texas Council of Governments (NCTCOG), Arlington, TX, November 2018.

Ali, A., "Radar aided mmWave beam training." Poster presented at the *Texas Wireless Summit*, Austin, TX, November 2018.

Kumari, P., "Adaptive IEEE 802.11ad Waveform Design for a Joint Automotive Communication-Radar System." Poster presented at the *Texas Wireless Summit*, Austin, TX, November 2018.

Bhat, C.R., "Predictive Analytics for Transportation in a New Technology-Transformed Data Landscape: The Excitement and the Challenges." Plenary session presentation at the *23rd International Conference of the Hong Kong Society for Transportation Studies (HKSTS)*, Hong Kong, December 2018.

Bhat, C.R., "Activity-Based Modeling: Recent Advances and Possible Application to Hong Kong." Keynote presentation at the *International Post-Conference (HKSTS) Workshop on "Advances in Supernetwork Modeling and Mobility Pattern Analysis"*, Hong Kong, December 2018.

Heath Jr., R.W., A. Ali, and N. Gonzalez-Prelcic, "Radar aided V2X communications at mmWave." Presentation to Nokia Bell Labs, January 2019.

Heath Jr., R.W., "5G for Vehicle-to-X Communications." *Keynote Presentation*, DesignCon 2019 Conference, Santa Clara, CA, January 2019.

Bhat, C.R., "Travel Demand Forecasting in the CAV World." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Boyles, S., and N. Ruiz Juri, "Queue spillback and demand uncertainty in dynamic network loading." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

- Chen, A., N. Ruiz Juri, H. Westerfield Ross, Y. Li, and T. Zhu, "Understanding the impacts of freeway lane closures through data: a combined analysis of NPMRDS and fixed-sensor data." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Dias, F.F., P.S. Lavieri, T. Kim, C.R. Bhat, and R.M. Pendyala, "Fusing Multiple Sources of Data to Understand Ride-Hailing Use." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Dunn, M.R., H. Westerfield Ross, C. Baumais, J. Wall, J. Lammert, J. Duthie, N. Ruiz Juri, R.B. Machemehl, "A Data-Driven Methodology for Prioritizing Traffic Signal Retiming Operations." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Gokalp, C., and S. D. Boyles, "Mean-Standard Deviation Model For Minimum Cost Flow Problem." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Hutchinson, J., D. Capasso da Silva, F.F. Dias, C.R. Bhat, S. Khoeini, R.M. Pendyala, and W.H.K. Lam "Exploring Patterns of Heterogeneity in Activity-Travel Behaviors of the Elderly." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- James, R., B. E. Hammit, and S. D. Boyles. "Methods to obtain representative car-following model parameters from trajectory-level data for use in microsimulation." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Lavieri, P., and C.R. Bhat, "A Joint Model of Experience and Frequency of Use of Solo and Pooled Ride-Hailing Services in Dallas, Texas." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Lavieri, P., and C.R. Bhat, "Modeling Individuals' Willingness to Share Trips with Strangers in an Autonomous Vehicle Future." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Lavieri, P., and C.R. Bhat, "Investigating Potential Externalities of Ride-Hailing Adoption: A Multivariate Model of Ride-Hailing Trip Characteristics." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Leung, K.Y.K., S. Astroza, B.P.Y. Loo, and C.R. Bhat, "An Environment-People Interactions Framework for Analyzing Children's Extra-Curricular Activities and Active Transport." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Long, K., D. Capasso da Silva, F.F. Dias, S. Khoeini, A.C. Bhat, R.M. Pendyala, and C.R. Bhat, "The Role of Childhood Context and Experience in Shaping Activity-Travel Choices in Adulthood." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Nair, G.S., C.R. Bhat, R.M. Pendyala, B.P.Y. Loo, and W.H.K. Lam, "On the Use of Probit Based Models for Ranking Data Analysis." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Pandey, V., and S. D. Boyles, "Comparing route choice models for managed lane networks with multiple entrances and exits." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.
- Patel, R., P. Venkatraman, and S. D. Boyles, "Optimal placement of reservation-based intersections in urban networks." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Sharda, S., S. Astroza, S. Khoeini, I. Batur, R.M. Pendyala, and C.R. Bhat, "Do Attitudes Affect Behavioral Choices or Vice-Versa? Uncovering Latent Segments Within a Population." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Singh, A.C., K. Abel, J. Hutchinson, K. Faust, and C.R. Bhat, "Food Access for Low Income Individuals." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Zhu, T., N. Ruiz Juri, S.D. Boyles, K. Perrine, A. Chen, Y. Li, "An Efficient Simulation Framework for Estimating Work Zone Impacts." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

Zuniga-Garcia, N., M. Tec, J.C. Scott, N. Ruiz Juri, R.B. Machemehl, "Evaluation of Ride-Sourcing Search Frictions and Driver Productivity: A Spatial Denoising Approach." Presented at the *98th Annual Meeting of the Transportation Research Board*, Washington, DC, January 2019.

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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: Nothing to report for this period.

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

Kirthevasan Kandasamy, School of Computer Science, Carnegie Mellon University: 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-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.

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.

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.

5. CHANGES/PROBLEMS

Nothing to report.