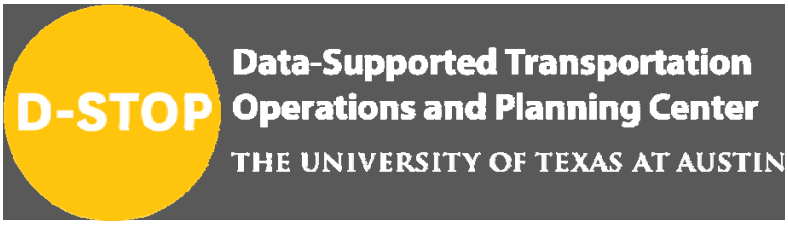
Program Progress Performance Report



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Project Title:	Data-Supported Transportation Operations and Planning (D-STOP) Center
Program Director:	Chandra Bhat, Director, bhat@mail.utexas.edu, 512-471-4535
Submitting Official:	Lisa Macias, Executive Assistant, lisaweyant@mail.utexas.edu, 512-232-6272
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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 14 projects were pursued with partial or full funding support from D-STOP. Of these two projects were completed during this reporting period. Currently, 12 projects are underway.

Completed Projects

1. **The Composite Marginal Likelihood (CML) Inference Approach with Applications to Discrete and Mixed Dependent Variable Models**
   (PI: Chandra Bhat)
   The composite marginal likelihood (CML) inference approach is a relatively simple approach that can be used when the full likelihood function is practically infeasible to evaluate due to underlying complex dependencies. The history of the approach may be traced back to the pseudo-likelihood approach of Besag (1974) for modeling spatial data, and has found traction in a variety of fields since, including genetics, spatial statistics, longitudinal analyses, and multivariate modeling. However, the CML method has found little coverage in the econometrics field, especially in discrete choice modeling. This project will fill this gap by identifying the value and potential applications of the method in discrete dependent variable modeling as well as mixed discrete and continuous dependent variable model systems.

   Objective:
   - Develop a blueprint (complete with matrix notation) to apply the CML estimation technique to a wide variety of discrete and mixed dependent variable models.

2. **A New Estimation Approach to Integrate Latent Psychological Constructs in Choice Modeling (PI: Chandra Bhat)**
   We propose a new multinomial probit-based model formulation for integrated choice and latent variable (ICLV) models, which has several important advantages relative to the traditional logit kernel-based ICLV formulation. Combining this multinomial probit (MNP)-based ICLV model formulation with Bhat's maximum approximate composite marginal likelihood (MACML) inference approach resolves the specification and estimation challenges that are typically encountered with the traditional ICLV formulation estimated using simulation approaches. Our proposed approach can provide very substantial computational time advantages, because the dimensionality of integration in the log-likelihood function is independent of the number of latent variables. Further, our proposed approach easily accommodates ordinal indicators for the latent variables, as well as combinations of ordinal and continuous response indicators. The approach can be extended in a relatively straightforward fashion to also include nominal indicator variables. A simulation exercise in the virtual context of travel mode choice will be designed to evaluate the ability of the MACML approach to recover model parameters.

   Objective:
   - Propose a new multinomial probit-based model for ICLV models

Ongoing Projects

1. **Transit Demand and Routing after Autonomous Vehicle Availability (PI: Stephen Boyles)**
   Autonomous vehicles (AVs) create the potential for improvements in traffic operations as well as new behaviors for travelers such as car sharing among trips through driverless repositioning. Most studies on AVs have focused on technology or traffic operations, and the impact of AVs on planning is currently unknown. Development of a planning model integrating AV improvements to traffic operations and the impact of new traveler behavior options will soon be of practical interest as AVs are currently test-driven on public roads. The altered traveler preferences may affect mode choice, leading to changes in transit demand and transit provider cost. An analysis of the model on metropolitan planning data will provide predictions on the impact of general AV ownership on network conditions.

   Objectives:
   - Model the impact of autonomous vehicle availability on traveler behavior.
   - Predict how increasing AV ownership will impact traffic.
   - Provide guidance to school on how household AV ownership will affect bus service.

2. **Cell Phone Data for Travel Forecasting (PI: Jennifer Duthie)**
   Little guidance exists on how to calibrate and validate planning models with anything except for very aggregate count data. With more data available than ever before, guidance is needed on how to calibrate and validate models that take advantage of this data. This project will focus on origin-destination trip matrix data aggregated from cell-phone providers. The research team will acquire a dataset, evaluate its validity by comparing it to other data sources, and will report on the potential for the data to be used as input to a transportation planning model.

   Objective:
   - Evaluate the validity of cellular data-based travel demand matrices.
   - Make recommendations for how cellular data can be incorporated into the planning process.

3. **Semi-Autonomous Parking for Enhanced Safety and Efficiency (PI: Sriram Vishwanath)**
   This project focuses on the use of tools from a combination of computer vision and localization based navigation schemes to aid the process of efficient and safe parking of vehicles in high density parking

spaces. The principles of collision avoidance, simultaneous localization and mapping together with vision based actuation in robotics will be used to enable this functionality.

Objectives:

- Establish a simulation plan for semi-autonomous parking management.
- Building a 4 robotic vehicle test bed to test algorithms in practice.
- Determine if there can be increased efficiency in the use of physical space towards parking.

4. **Combining Millimeter-Wave Radar and Communication Paradigms for Automotive Applications: A Signal Processing Approach**
   (Co-PI: Robert Heath and Chandra Bhat)
   This project proposes to develop a conceptual mathematical model for combined paradigm of millimeter-wave communication and radar using a signal processing perspective. In particular, it will explore and investigate different possible signal frameworks for joint communication and radar paradigms, both with simultaneous or non-simultaneous applications. For these mathematical frameworks, novel algorithms will be developed targeting automotive applications. Our algorithms will leverage the performance of the joint paradigm by sharing information between the radar and communications signal frameworks. These algorithms will be further optimized to meet varied performance objectives in both rural and urban areas. This would require identifying the scenarios of interest in transportation environments. A design-trade off analysis will be carried out to meet the conflicting requirements of both the signal frameworks.

   This project will also address the challenges unique to the combined mathematical framework such as beamforming, signal design and mutual interference. Furthermore, the performance of the combined paradigm would be compared with the individual signal frameworks of radar and communication. This will involve a detailed survey, mathematical model development and simulation of both these systems separately. The outcomes of the project are expected to dramatically improve safety for vehicles, bicycles, and pedestrians in all weather conditions and on all roadways.

   Objectives:

   - Develop a mathematical framework for a single signal combined system of V2V and automotive radar, operating at the millimeter-wave frequency. This will dramatically increase the data rates possible between cars and will allow much more information to be exchanged at 100x lower latency than traditional systems.
   - Algorithms would be devised so that the derived information from communication and radar can be shared to enhance the performance of both the paradigms. Our project would bring out and address new challenges in of the areas of common waveform design, antenna arrays/beamforming and trade-off in design parameters.
   - The outcomes of the project are expected to dramatically improve safety for vehicles, bicycles, and pedestrians in all weather conditions and on all roadways.

5. **Learning Approach to Beam Alignment for mmWave Vehicular Communications**
   (PI: Robert Heath)
   The goal of this project is to develop a learning based approach to significantly reduce the overhead leveraging side information including user positioning information and network geometry. After initial design, we use offline learning to construct an initial mapping from user feedback to the beam selection. During operation, new data are collected and used to refine the initial mapping. The online learning part can be viewed as a multi-armed bandit (MAB) problem and solved by leveraging the existing results on the subject.

   Objectives:

   - Existing methods for beam alignment at mmWave frequency are largely based on beam sweeping, which is not practical for time-varying environment such as vehicular communications. We leverage vehicle position as side information, which could be obtained, for example, from

GPS device. Using a learning approach we avoid idealized assumptions on beam patterns, which will allow the use of low cost hardware.

- Our objective is to develop offline and online learning algorithm for beam alignment. The offline learning will provide an initial mapping as the starting point for operation. Then we will move on to online learning where data are collected and used to refine the table. Learning will incur overhead, however, inadequate learning results in degraded performance.
- The tradeoff between exploration and exploitation will be studied toward the end of this project. Understanding this tradeoff is very crucial to operation of any learning algorithm.

6. Improved Traffic Operations through Real-Time Data Collection and Control
(Co-PIs: Stephen Boyles and Sanjay Shakkottai)

New data collection technologies enable real-time traffic control more precise and efficient than what was earlier possible. This project develops novel control strategies based on this data, with an emphasis on two types of traffic control: (1) *signalized intersection* control, where cycle lengths and phasing may be adjusted based on observed demands and coordination with nearby intersections, and (2) *pricing* strategies, where tolls are adjusted in real time based on observed demand, in order to influence travelers to avoid congested areas. Both of these share a common methodological basis of adjusting traffic controls to prioritize particular vehicles to minimize congestion, accounting for human behavior and learning. The project will involve combining wireless routing algorithms with traffic engineering knowledge to create innovative control policies.

Objective:

- Develop novel signal control algorithms, combining knowledge from wireless network routing and transportation network analysis and integrating the “within day” and “day-to-day” time scales.
- Develop novel network pricing algorithms based on a similar perspective, both in HOT lanes and in more general networks.
- Demonstrate the effectiveness of these algorithms in simulation.

7. Models for High Dimensional Mixed Regression
(Co-PIs: Constantine Caramanis and Chandra Bhat)

We propose to consider the mixed regression problem in high dimensions, under adversarial and stochastic noise. We will consider convex optimization-based formulations with the aim of showing that it provably recovers the true solution. This agenda will seek to provide upper bounds on the recovery errors for both arbitrary noise and stochastic noise settings. We also will seek matching minimax lower bounds (up to log factors), showing that under certain assumptions, our algorithm is information-theoretically optimal. Our preliminary results represent the first (and currently only known) tractable algorithm guaranteeing successful recovery with tight bounds on recovery errors and sample complexity.

Mixture models treat observed data as a superposition of simple statistical processes. Thus they are particularly relevant in the transportation setting, when city-wide phenomena are often mixtures of simple processes (cut-through traffic, intra-city movement, etc.).

Objective:

- Develop novel regression-based high dimensional modeling methods for phenomena that represent a mixture of different statistical processes.

8. Streaming PCA with Many Missing Entries
(PI: Constantine Caramanis)

We propose to consider the streaming memory-constrained principal component analysis (PCA) problem with missing entries, where the available storage is linear in the dimensionality of the problem, and each vector has so many missing entries that matrix completion is not possible. For this problem, we propose a method based on a block power update approach introduced in our previous work. We show on synthetic as well as benchmark data sets that our approach outperforms existing approaches for streaming PCA by a significant margin for several interesting problem settings. We also consider the popular spiked covariance model with randomly missing entries, and obtain the first

known global convergence guarantees for this problem. We show that our method converges to the true ``spike'' using a number of samples that is linear in the dimension of the data. Moreover, our memory requirement is also linear in the ambient dimension. Thus, both memory and sample complexity have optimal scaling with dimension.

Streaming PCA is extremely relevant in the setting where the resolution of our sensors outpaces our ability to store massive amounts of data. This is precisely the setting we face as we increase the amount of intelligence and high precision/resolution sensors on the fleet of private and commercial vehicles.

Objective:

- High dimensional streaming PCA with limited memory, able to handle massive amounts of missing data.

9. Greedy Subspace Clustering
(PI: Constantine Caramanis)

We propose to consider the problem of subspace clustering: given points that lie on or near the union of many low-dimensional linear subspaces, recover the subspaces. To this end, one first identifies sets of points close to the same subspace and uses the sets to estimate the subspaces. As the geometric structure of the clusters (linear subspaces) forbids proper performance of general distance based approaches such as K-means, many model-specific methods have been proposed. In this paper, we provide new simple and efficient algorithms for this problem. Our statistical analysis shows that the algorithms are guaranteed exact (perfect) clustering performance under certain conditions on the number of points and the affinity between subspaces. These conditions are weaker than those considered in the standard statistical literature. Experimental results on synthetic data generated from the standard unions of subspaces model demonstrate our theory. We also show that our algorithm performs competitively against state-of-the-art algorithms on real-world applications such as motion segmentation and face clustering, but with much simpler implementation and lower computational cost.

Objective:

- How to efficiently do subspace clustering in the large-scale setting.

10. An Empirical Investigation into the Time-Use and Activity Patterns of Dual-Earner Couples With and Without Young Children
(PI: Chandra Bhat)

This proposal examines the time-use patterns of adults in dual-earner households with and without children as a function of several individual and household socio-demographics and employment characteristics. A disaggregate activity purpose classification including both in-home and out-of-home activity pursuits will be used because of the travel demand relevance of out-of-home pursuits, as well as to examine both mobility-related and general time-use related social exclusion and time poverty issues. The study uses the Nested Multiple Discrete Continuous Extreme Value (MDCNEV) model, which recognizes that time-decisions entail the choice of participating in one or more activity purposes along with the amount of time to invest in each chosen activity purpose, and allows generic correlation structures to account for common unobserved factors that might impact the choice of multiple alternatives. The 2010 American Time Use Survey (ATUS) data is used for the empirical analysis.

Objective:

- Focus on mobility-related social exclusion issues in American society
- Use a multivariate model that recognizes the multiple discrete nature of time-use
- Inform policies to address time poverty & mobility-related social exclusion issues.

11. A New Generalized Heterogeneous Data Model (GHDM) to Jointly Model Mixed Types of Dependent Variables
(PI: Chandra Bhat)

This proposal formulates a generalized heterogeneous data model (GHDM) that jointly handles mixed types of dependent variables—including multiple nominal outcomes, multiple ordinal variables, and multiple count variables, as well as multiple continuous variables—by representing the covariance relationships among them through a reduced number of latent factors. Sufficiency conditions for identification of the GHDM parameters are presented. The maximum approximate composite marginal likelihood (MACML) method is proposed to estimate this jointly mixed model system. This estimation method provides computational time advantages since the dimensionality of integration in the likelihood function is independent of the number of latent factors. The study undertakes a simulation experiment within the virtual context of integrating residential location choice and travel behavior to evaluate the ability of the MACML approach to recover parameters.

Objective:

- Formulate a generalized heterogeneous data model for big data applications in transportation planning and operations, using a practical estimation approach

12. A New Spatial (Social) Interaction Discrete Choice Model Accommodating for Unobserved Effects due to Endogenous Network Formation
(PI: Chandra Bhat)

This proposal formulates a model that extends the traditional panel discrete choice model to include social/spatial dependencies in the form of dyadic interactions between each pair of decision-makers. In addition, the formulation accommodates spatial correlation effects as well as allows a global spatial structure to be placed on the individual-specific unobserved response sensitivity to exogenous variables. We interpret these latter two effects, sometimes referred to as spatial drift effects, as originating from endogenous group formation. To our knowledge, we are the first to suggest this endogenous group formation interpretation for spatial drift effects in the social/spatial interactions literature. The formulation is motivated in a travel mode choice context, but is applicable in a wide variety of other empirical contexts.

Objective:

- Accommodate agent interactions in travel mode choice decisions, while controlling for group formation effects and unobserved heterogeneity

Research Results Disseminated: Two papers have been published, and one paper is forthcoming, in refereed journals, based on the research projects associated with D-STOP. Several other papers are in the review process. Four conference presentations have been made, and many papers have been submitted for presentation consideration at the Transportation Research Board Annual Meeting in January 2015.

Plans for Next Reporting Period to Accomplish Research Goal: Have all D-STOP research efforts identified, initiated, and underway. Continue to identify and invite individuals from industry to be members of the Center's Business Advisory Council (BAC). Provide support, guidance, and assistance to project Principal Investigators so individual research project objectives can be achieved. Students will be involved much more from the next reporting period, because of the new academic cycle that started September 1, 2014.

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
Rachel Allensworth, supervised by Stephen Boyles
Shubodeep Mukherji, supervised by Todd Humphreys
Daniel Porter, supervised by Sriram Vishwanath
Stephen Svatek, supervised by Chandra Bhat
Ben Wallach, supervised by Jen Duthie

Grad
Swati Agarwal, MS, (supervised by Chandra Bhat)
Sebastian Astroza, PhD, (supervised by Chandra Bhat)
Alice Chu, MS, (supervised by Chandra Bhat)
Subodh Dubey, PhD, (supervised by Chandra Bhat)
Megan Hoklas, MS, (supervised by Chandra Bhat)
Vivek Kumar, MS, (supervised by Chandra Bhat)
Patricia Lavieri, PhD, (supervised by Chandra Bhat)
Zeina Wafa, MS, (supervised by Chandra Bhat)
Tan Wang, MS, (supervised by Chandra Bhat)
Sudesh Agrawal, MS, (supervised by Stephen Boyles)
Michael Levin, MS, (supervised by Stephen Boyles)
Tarun Rambha, PhD, (supervised by Stephen Boyles)
Shoupeng Tang, PhD, (supervised by Stephen Boyles)
Tyler Beduhn, MS, (supervised by Jennifer Duthie)
Rachel James, PhD, (supervised by Jennifer Duthie)
Ankita Chaudhary, MS, (supervised by Jennifer Duthie)
Xinyang Yi, PhD, (supervised by Constantine Caramanis)
Ioannis Mitliagkas, PhD, (supervised by Constantine Caramanis)
Dohyung Park, PhD, (supervised by Constantine Caramanis)
Preeti Kumari, MS, (supervised by Robert Heath)
Vutha Va, PhD, (supervised by Robert Heath)
Tzu-Ling Kan, MS, (supervised by Sanjay Shakkottai)
Yan Gao, MS (supervised by Sriram Vishwanath)

KIPP-Austin:
D-STOP has built connections with the education community by solving the bus routing problem for KIPP. KIPP is a charter school for low socio-economic students with two campuses in Austin and in previous years has been choosing bus routes by hand. Besides being suboptimal in operating cost, the previous year's bus routes often had varying loads of students and travel times. The constraints of maximum student travel time and bus capacity were not well utilized because there are many feasible solutions for the 40-50 bus stops. To improve the routing, vehicle routing problem techniques were used. The Clarke-Wright heuristic was implemented to choose bus routes, using traffic network topology and travel times from a dynamic traffic assignment (DTA) model. Bus stop demand was estimated geographically based on student addresses. The new routes were predicted to significantly reduce operating time while guaranteeing adherence to all constraints.

The routing software was used for the first time this semester. KIPP reported that in addition to reductions in total operating time, significant increases in reliability were observed. First, in previous years some bus routes would often have demand that exceeded the capacity of a single bus, necessitating having a second bus on the same route to carry the excess demand. This was rather costly as the second bus was mostly empty. After using the developed routing software, demand predictions were more accurate and a second bus was not necessary. Second, in previous years travel time predictions were often inaccurate, and buses would frequently arrive late at the bus stop relative to the published schedule. This led to a number of complaints by students and parents dropping off young students at bus stops. **The use of a calibrated DTA model improved the accuracy of travel time predictions, resulting in a significant drop in the number of complaints despite greater bus ridership this year**.

2014 Summer Internship:
Five interns were supported by D-STOP in the inaugural University Transportation Center-Undergraduate Internship (UTC-UI) program hosted at The University of Texas at Austin. The interns were Rachel Allensworth, Ben Wallach, Daniel Porter, Shubodeep Mukherji, and Stephen Svatek. Each intern participated in a research project related to the D-STOP center. Two interns were assigned to faculty members associated with the Wireless Networking & Communications Group, and three to faculty and researchers associated with the Center for Transportation Research. A weekly seminar was held, consisting of lectures by experts in both wireless networking and transportation research, and served as the basis for conversations on research lying at the intersection of these fields. The interns were also involved in professional development and social activities organized by the student chapters of the Institute of Transportation Engineers and ITS America.

Education and Workforce Development Results Disseminated:
Outreach Activity: In May, Dr. Sanjay Shakkottai was a distinguished lecturer at the tenth annual Edison Lecture Series (the event was originally scheduled on Feb 5, 6 and 7, but due to inclement weather the Feb 6 and 7 days were postponed until May). The theme for 2014 was on 'Mobile Computing'. The Edison Lecture Series, a Science, Technology, Engineering and Mathematics (STEM) Education Coalition program, invites middle and high school students and their teachers to a three-day workshop on the UT-Austin campus.

Plans for Next Reporting Period to Accomplish Education and Workforce Development Goal:
Involve more graduate and undergraduate students in the research being conducted by the Center. Plan and organize a monthly lecture series for our D-STOP students. Dr. Sanjay Shakkottai is also planning to present a lecture in December 2014 on 'Mobile Computing' to local Austin middle school students through Breakthrough Austin. Breakthrough Austin is a community program that provides a path through college, beginning in middle school, for low-income students who will become first-generation college graduates. Dr. Bhat is a member of the Engineering Advisory Board of Westwood High School and will continue to advise the school on engineering curriculum issues.

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 was launched and provides information about the Center. It 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

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

Published:

Bhat, C.R. (2014), "The Composite Marginal Likelihood (CML) Inference Approach with Applications to Discrete and Mixed Dependent Variable Models," *Foundations and Trends in Econometrics*, Vol. 7, No. 1, pp. 1-117.

Bhat, C.R., and S.K. Dubey (2014), "A New Estimation Approach to Integrate Latent Psychological Constructs in Choice Modeling," *Transportation Research Part B*, Vol. 67, pp. 68-85.

Forthcoming:

Boyles, S., S. Tang, and A. Unnikrishnan, "Parking Search Equilibrium on a Network," *Transportation Research Part B*, accepted for publication September 2014.

Under review:

Bernardo, C., R. Paleti, M. Hoklas, and C.R. Bhat, "An Empirical Investigation into the Time-Use and Activity Patterns of Dual-Earner Couples With and Without Young Children," submitted to *Transportation Research Part A*.

Bhat, C.R., "A New Generalized Heterogeneous Data Model (GHDM) to Jointly Model Mixed Types of Dependent Variables," submitted to *Transportation Research Part B*.

Bhat, C.R., "A New Spatial (Social) Interaction Discrete Choice Model Accommodating Self-Selection in Group Formation," submitted to *Transportation*.

Jafari, E., M. Gemar, N. N. Ruiz Juri, and J. Duthie, "An Investigation of Centroid Connector Placement for Advanced Traffic Assignment Models with Added Network Detail," submitted to *Transportation Research Record*.

Levin, M., and S. Boyles, "Intersection Auctions and Reservation-based Control in Dynamic Traffic Assignment," submitted to *Transportation Research Record*.

Levin, M., and S. Boyles, "Effects of Autonomous Vehicle Ownership on Trip, Mode, and Route Choice," submitted to *Transportation Research Record*.

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

Presented:

Bhat, C.R. and S. Dubey, "New Estimation Approach to Integrate Latent Psychological Constructs in Choice Modeling," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2014.

Boyles, S., S. Tang, and A. Unnikrishnan. "Dynamic traffic assignment and the parking search process." Presented at the 5th International Symposium on Dynamic Traffic Assignment (DTA2014), Salerno, Italy, June 2014.

Bringardner, J., M. Gemar, N. Ruiz Juri, S. Boyles, and R. Machemehl. "Subnetwork Analysis for Dynamic Traffic Assignment Models: Impacts of Subnetwork Size and Stochastic Model Components." Poster presented at the 5th International Symposium on Dynamic Traffic Assignment (DTA2014), Salerno, Italy, June 2014.

Zhou, X., and N. Ruiz Juri. "On the Computation of Time Dependent Shortest Paths for Simulation-Based Dynamic Traffic Assignment Applications." Presented at the 5th International Symposium on Dynamic Traffic Assignment (DTA2014), Salerno, Italy, June 2014.

Under review:

Bhat, C.R. "A New Generalized Heterogeneous Data Model (GHDM) to Jointly Model Mixed Types of Dependent Variables." Submitted for consideration for presentation at the 94th Annual Meeting of the Transportation Research Board, Washington, DC, January 2015.

Bhat, C.R. "A New Spatial (Social) Interaction Discrete Choice Model Accommodating Self-Selection in Group Formation." Submitted for consideration for presentation at the 94th Annual Meeting of the Transportation Research Board, Washington, DC, January 2015.

Boyles, S., L. Gardner, and H. Bar-Gera. "Incorporating departure time choice into high-occupancy/toll (HOT) algorithm evaluation." Submitted for consideration for presentation at the 21st International Symposium on Transportation and Traffic Theory (ISTTT), Kobe, Japan, July 2015.

Duthie, J. "An Investigation of Centroid Connector Placement for Advanced Traffic Assignment Models with Added Network Detail." Submitted for consideration for presentation at the 94th Annual Meeting of the Transportation Research Board, Washington, DC, January 2015.

Rambha, T., and S. Boyles. "Applications of dynamic pricing in day-to-day equilibrium models." Submitted for consideration for presentation at the 94th Annual Meeting of the Transportation Research Board, Washington, DC, January 2015.

Plans for Next Reporting Period to Accomplish Technology Transfer Goal: Update D-STOP website with the most current project, educational, and technology transfer information. Continue to support researchers as they present their research results through peer-reviewed publications and professional presentations. Organize an International Choice Modeling Conference (ICMC) in Austin, to be held May 10-13, 2015.

2. PRODUCTS

Publications, conference papers, and presentations:

Journal Publications - Published

Bhat, C.R. (2014), "The Composite Marginal Likelihood (CML) Inference Approach with Applications to Discrete and Mixed Dependent Variable Models," *Foundations and Trends in Econometrics*, Vol. 7, No. 1, pp. 1-117.

Bhat, C.R., and S.K. Dubey (2014), "A New Estimation Approach to Integrate Latent Psychological Constructs in Choice Modeling," *Transportation Research Part B*, Vol. 67, pp. 68-85.

Journal Publications - Accepted

Boyles, S., S. Tang, and A. Unnikrishnan, "Parking Search Equilibrium on a Network," *Transportation Research Part B*, accepted for publication September 2014.

Journal Publications – Under Review

Bernardo, C., R. Paleti, M. Hoklas, and C.R. Bhat, "An Empirical Investigation into the Time-Use and Activity Patterns of Dual-Earner Couples With and Without Young Children," submitted to *Transportation Research Part A*.

Bhat, C.R., "A New Generalized Heterogeneous Data Model (GHDM) to Jointly Model Mixed Types of Dependent Variables," submitted to *Transportation Research Part B*.

Bhat, C.R., "A New Spatial (Social) Interaction Discrete Choice Model Accommodating Self-Selection in Group Formation," submitted to *Transportation*.

Jafari, E., M. Gemar, N. N. Ruiz Juri, and J. Duthie, "An Investigation of Centroid Connector Placement for Advanced Traffic Assignment Models with Added Network Detail," submitted to *Transportation Research Record*.

Levin, M., and S. Boyles, "Intersection Auctions and Reservation-based Control in Dynamic Traffic Assignment," submitted to *Transportation Research Record*.

Levin, M., and S. Boyles, "Effects of Autonomous Vehicle Ownership on Trip, Mode, and Route Choice," submitted to *Transportation Research Record*.

Conference Presentations

Bhat, C.R. and S. Dubey, "New Estimation Approach to Integrate Latent Psychological Constructs in Choice Modeling," *Transportation Research Board (TRB) Annual Meeting*, Washington, DC, January 2014.

Boyles, S., S. Tang, and A. Unnikrishnan. "Dynamic traffic assignment and the parking search process." Presented at the 5th International Symposium on Dynamic Traffic Assignment (DTA2014), Salerno, Italy, June 2014.

Bringardner, J., M. Gemar, N. Ruiz Juri, S. Boyles, and R. Machemehl. "Subnetwork Analysis for Dynamic Traffic Assignment Models: Impacts of Subnetwork Size and Stochastic Model Components." Poster presented at the 5th International Symposium on Dynamic Traffic Assignment (DTA2014), Salerno, Italy, June 2014.

Zhou, X., and N. Ruiz Juri. "On the Computation of Time Dependent Shortest Paths for Simulation-Based Dynamic Traffic Assignment Applications." Presented at the 5th International Symposium on Dynamic Traffic Assignment (DTA2014), Salerno, Italy, June 2014.

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

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?

Dallas Police Department, Dallas, TX (in-kind support).
The city of Dallas, TX is working with vendors to evaluate services, technology, and equipment in the area of automatic parking sensor technology. The aim is to modernize parking operations to create "seamless, efficient, customer-friendly, and cost-effective parking operations that are flexible and can easily be modified to fit the needs of various types of parking areas." DSTOP is participating in this effort by assisting the Dallas Police Department with evaluating the quality of data recorded in this pilot project.

Have other collaborators or contacts been involved?

KIPP Austin Public Schools, Austin, TX

We have had several conversations with the City of Austin's Traffic Management Center about DSTOP. They are very interested and have engaged us in their effort to learn more about the data they are gathering, and the data they should consider gathering. We have also had conversations about DSTOP with the CapMetro transit agency. They are very interested in efforts related to transit data.

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

We have also discussed DSTOP with other companies including Nokia and Intel.

4. IMPACT

Impact on the development of the principal disciplines of the program:
Two papers published by DSTOP-supported research presented the first models which can be used to integrate parking management into the transportation planning process. These do so by incorporating behavioral considerations into parking search: parking availability depends on where drivers search, but drivers' search based on their experience of where parking is available. This was resolved with an innovative network transformation. The resulting flow conservation equations form a nonlinear system, which is apparently unique and novel in network flow problems. Considerable efforts have been made to understand the behavior of such systems, as a fundamental advance in transportation science.

Five papers prepared based on D-STOP research develop methods to deal with latent variables in land use-transportation modeling and joint analysis of mixed types of variables.

Impact on other disciplines:
The D-STOP research projects involve collaborations with faculty in other disciplines, including electrical engineering and computer science. Several papers contribute in substantive ways to econometric techniques, high dimensional statistical analysis, optimization methods, and data fusion approaches.

Impact on the transportation workforce development:
D-STOP activities related to education (including the undergraduate summer internship program) are initiated to familiarize young individuals with transportation career opportunities.

Impact on physical, institutional, and information resources at the university or other partner institutions: Nothing to report for this period.

Impact on technology transfer:
The collaborative work with the Dallas Police Department is leading to results on automated parking technology that we hope to transfer to that government agency.

Impact on society beyond science and technology:
Improved bus routing for KIPP, and collaborations with city of Dallas parking pilot. The use of our routing models for school bus routing has greatly improved the KIPP charter school's bus performance: there has been a substantial increase in on-time performance (and decrease in complaints) since adopting the routes identified in our outreach efforts. More generally, the models developed under DSTOP-supported research can lead to more efficient use of transportation infrastructure, decreasing congestion and supporting the economic competitiveness of the nation.

5. CHANGES/PROBLEMS

Nothing to report.