Program Progress Performance Report

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Project Title: Transportation Informatics Tier I University Transportation Center (TransInfo UTC): Harnessing the Power of Big Data in Support of USDOT Strategic Goals

Adel W. Sadek, Ph.D.
Professor and Director of TransInfo UTC
Department of Civil, Structural and Environmental Engineering
University at Buffalo, the State University of New York
Buffalo, NY 14260
E-mail: asadek@buffalo.edu
Phone: (716) 645-4367

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1. Accomplishments

1.1 Major Goals of the Program

The volume, variety, quality and resolution of transportation-related "Big Data" currently present the transportation community with an unprecedented opportunity for improving system performance. Specifically, the wealth of data can be *studied, analyzed, and mined for insights and applications that can improve the efficiency, safety, sustainability, resiliency and reliability of the transportation system, and can inform and guide transportation policy.* It is to this goal that TransInfo's activities are dedicated. TransInfo's mission is to undertake research, education, training, and technology transfer activities aimed at realizing the full potential of "*Big Data" and Transportation Informatics* in: (1) improving transportation system performance; and (2) guiding investments and policies. The activities performed under the umbrella of the TransInfo Center has helped advance the state of knowledge in the emerging field of transportation informatics, while preparing and educating both the existing transportation workforce, as well as the next generation of transportation professionals, in how to harness the power of "Big Data" to address transportation challenges.

Because improved utilization of transportation data helps improve system performance, and because transportation serves as the very foundation of our nation's economy, the Center's activities directly address the US Department of Transportation (US DOT) Strategic Goal of "Economic competitiveness". However, "Economic competitiveness" is not the only goal that TransInfo UTC has been addressing. The common thread behind all of TransInfo's research and educational activities is to compile, fuse, and mine various data streams to support a wide range of transportation applications in traffic operations, safety, emergency operations, travel behavior modeling, and performance measurement. As such, TransInfo also touches upon the goals of "Safety", "Environmental Sustainability", "Livable Communities", and the "State of Good Repair".

1.2 Progress and Accomplishments

TransInfo's progress and accomplishments, during the reporting period covered by this report, are organized under the following three headings: (1) research activities at the different institutions of TransInfo; (2) graduate student activities; and (3) outreach and technology transfer activities. An additional section will summarize some of the recent accomplishments of TransInfo researchers which were facilitated by the support provided by TransInfo.

1.2.1 *Research Activities*

1.2.1.1 Research at the University at Buffalo

a) Inferring Origin-Destination Demand and Utility-Based Travel Preferences in Multi-Modal Travel Environment Using Automatic Fare Collection Data

Summary: The objective of this project is to develop scalable inference methods for understanding and expressing public transit system utilization based on fundamental travel behavior. The researchers have proposed a methodology that identifies both the preference vector and the true OD-pairs by collecting and analyzing Automatic Fare Collection (AFC) system-type data (stop-level ODs), as travelers make their multi-modal route choice decisions within the stochastic travel environment. The proposed methodology captures system-wide demand changes with respect to changes in stochastic travel environment.

Project Status: On going

Milestone accomplishments and dates:

- The research team has developed a methodology to reconstruct the travel environment, which is both dynamic and stochastic. Major environment variables include travel time, level-of-service, transfer time, and cost.

- The research team has estimated travel disutility function based on the observed route choices in multi-modal travel environment (through AFC records).
- The researchers have created synthetic experimental data to be used in estimating the OD demand matrix. The research team then developed and tested methodologies with the synthetic data set generated.
- The research team is currently working on further testing the methodologies for their scalability on real multi-scale cases.

Planned activities:
The research team will focus on studying the scalability of the developed methodologies and applying them to real multi-scale cases.

b) Border Crossing Delay Prediction
Summary: This research developed several models for predicting short-term border crossing traffic, along with queueing models for predicting the anticipated delay. Based on these models, an Android smartphone application called the Toronto Buffalo Border Waiting (TBBW), was designed to collect, share and predict waiting time at the three Niagara Frontier border crossings (i.e., the Lewiston-Queenston Bridge, the Rainbow Bridge, and the Peace Bridge).

Project Status: Nearing completion

Milestone Accomplishments and Dates:
- The paper summarizing the most recent work involving developing a hybrid machine-learning model for predicting a prediction interval within which future traffic volumes are expected to lie with a certain degree of confidence, and which had been submitted for possible publication in the Transportation Research – Part C journal is currently being revised. The paper is entitled, "Hybrid Machine Learning Model for Interval Prediction of Short-term Traffic Volume and its Application to Optimal Staffing Level Plan Development".

Planned Activities: Prepare Final report.

c) Novel Machine Learning Methods for Accident Data Analysis
Summary: With the recent advances in data collection, storage and archival methods, the size of accident datasets has grown significantly. This in turn has motivated research on applying data mining and complex network analysis algorithms, which are specifically designed to handle datasets with large dimensions, to traffic accident analysis. This project explored the potential for using a number of machine learning and data mining methods to accident data analysis.

Project Status: Nearing completion

Planned Activities: Prepare the Final Report.

d) Buffalo-Niagara Transportation Data-warehouse Prototype and Real-time Incident Detection
Summary: We are currently in the process of finalizing the details of our work with the Niagara International Transportation Technology Coalition (NITTEC), as part of their recent "Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Initiative (DTFH6116RA00012)" grant. The work, which will be led by Prof. Qing He from UB will focus on Advanced Traffic Signal and Control applications for the region.

Project Status: Nearing completion.

Planned Activities: Continue collaboration with NITTEC on the ATCMTD project, and prepare final report for the TransInfo project.

e) Variational Inference for Agent-Based Models with Applications to Achieve Fuel Economy - Dong

Summary: This project integrates machine learning, big data, sensor networks, and agent-based transportation modeling to prototype an algorithm that combines the power of a model-driven approach with the power of big data, and promotes responsible driving by showing how different agent trips are associated with different travel time and fuel consumption. The researchers developed optimization and sampling based inference algorithms to track and predict real-time traffic dynamics in a city-scale transportation network from an agent-based transportation model and isolated observations of the trajectories of several hundred probe vehicles. They also demonstrated the value of combining simulation modeling and big data in delivering travel information to drivers and promoting efficient driving through real world road networks and tracking data from mobile phones.

Project Status: Completed

Milestone accomplishments and dates:

- The research team has benchmarked their approximate algorithms (based on variational inference and Markov chain Monte Carlo) against deep neural networks, recurrent neural networks and extended Kalman filter with the data sets gathered. The results demonstrate the superior performance of the proposed algorithms.
- The researchers have developed the Markov discrete-event decision process to deliver travel information to drivers based on imperfect observations of a city-scale transportation network. The algorithm has superior performance in comparison to the state-of-the-art deep policy network and evolutionary algorithms.
- The researchers have several papers either accepted or in submission to top computer science venues that summarize the main findings of the study.

Planned activities:

The researchers will focus on turning their research results into publications, patents and external funding. Currently, they are preparing three papers for submission to the Conference of Neural Information Processing Systems, one of the top machine learning conferences. They are also working with several coauthors out of UB to publish the major scientific findings in one of: Nature Communications, Nature Scientific Reports, PNAS, Journal of the Royal Society Interface. Finally, they plan to work with UB Tech Transfer office to turn several key algorithms into patents.

f). **Effectiveness of Various Public Private Partnership Pavement Rehabilitation Treatments: A Big Data Informatics Survival Analysis of Pavement Service Life**

Summary: This study first conducted a detailed, multivariate statistical assessment of pavement treatments by PPP type, by studying their performance in terms of how key pavement performance indicators deteriorated over time. The elapsed time until the pavement crossed a threshold that is considered critical was also investigated, using multivariate hazard-based duration models. The findings are expected to improve the process by which pavement rehabilitation treatments are planned and implemented at both the project and network levels.

Project Status: Completed

Key Findings and Insights:

Pavement performance modeling with 3SLS: This system of equation approach allows to simultaneously consider multiple dependent variables. The dependent variables used in this Study are the international roughness index (IRI), rutting depth (RUT), and pavement condition rating (PCR). The three-stage least squares (3SLS) is used in this Study since it can take into account the cross-equation error correlation. For the three pavement condition indicators, pavement condition rating (PCR) is detected by a pavement engineer, who observed any distress on the pavement. The distress can be characterized by depression in the pavement or excessive roughness, since the PCR is a function of either the rutting depth, or the IRI, or of both. The data are available for six public-private partnership type: Performance-based contracting (PBC), Cost-plus, time contracting (A+B), Incentives/disincentives (I/D), design-build, operate-maintain (DBOM), Warranties (WARR) and Lane-rentals (LR); they are also available for six pavement rehabilitation treatments: 2-course HMA, Concrete pavement restoration, 3-course HMA overlay with or without surface milling, 3-course HMA with crack and seat of PCC pavement, 3R&4R overlay, and 3R/4R pavement replacement treatment. These are the most commonly used pavement rehabilitation treatments in the USA. Using those PPP types and pavement rehabilitation treatments, it was demonstrated that the pavement performance indicators are affected by traffic characteristics (AADT, truck traffic, etc), pavement characteristics (pavement indicators, pavement drainage), weather characteristics (temperature, precipitation) and other characteristics (road system).

Pavement service life modeling with hazard-based duration models: The pavement service life can be defined as the time period between two consecutive rehabilitation treatments. To achieve an estimation of the pavement service life, which is the dependent variable, three parametric forms of the hazard-based duration model were explored: Weibull distribution (with fixed or random parameters), log-logistic, and Weibull with Gamma heterogeneity. The data were available for the same six public-private partnership types and six rehabilitating types, as previously described. The results show that the pavement service life is affected by several factors, such as traffic characteristics, pavement characteristics, weather characteristics and other factors. For the traffic characteristics, the truck volume has a significant influence on the pavement service life for any type of treatment or PPP type, with higher truck volumes resulting in shorter pavement service life. For the pavement characteristics, two variables were found as statistically significant: the variables representing the pavement's drainage conditions, and number of lanes. Poor drainage was intuitively found to decrease the pavement service life. Similarly, multi-lane roadways – likely picking up high truck traffic – were also found to reduce pavement service life. The variables reflecting adverse weather conditions (in terms of adverse weather months – October through March – and temperature and precipitation) were intuitively found to reduce pavement service life. Other influential factors affecting the pavement service life included contract- and roadway-specific characteristics. As a last point, the endogenous variables representing the measurable pavement performance indicators (IRI and rutting depth) were also found to be statistically significant determinants of the PCR, in all estimated models.

1.2.1.2 Research at Rensselaer Polytechnic Institute (RPI)

Urban System Modeling and Performance Measurement Using Multiple Data Sources

Summary: As technologies advance, emerging urban data are increasingly available for wide urban areas. Such data are inherently heterogeneous, including both fixed location data (e.g., those from loops) and mobile data (e.g., those from GPS), which we refer to herein as Urban Hybrid Traffic Data (U-HTD). U-HTD provides great opportunities for urban transportation/traffic system performance evaluation, modeling, and management, while posing great challenges in data collection, processing,

storage, and use. This research aims to tackle some of these challenges by developing methods on how to best mine the different data elements in U-HTD, how to protect privacy when processing and using U-HTD, and how to develop novel methods that can best utilize U-HTD for critical urban transportation applications.

Project Status: Ongoing

Planned Activities:

- Continue the planned research on urban traffic system modeling and performance measurement using various data sources
- Continue the joint project with George Mason, focusing on traffic modeling applications and privacy implications of the data sample schemes developed earlier by the team

1.2.1.3 Collaborative Research between Rensselaer Polytechnic Institute & George Mason University
a). Developing a Smartphone App Platform to Decipher Travel Behavior

Summary: This project is focused on the development of a smartphone app for parking management based on cloud sourcing information. Specifically, the app will be designed to collect information about parking usage.

Project Status: 95%

Milestone Accomplishments and Dates since start of the project:

- The research team reviewed existing literature on using smartphone apps for transportation data collection. Accomplished on 03/30/2016
- The research team is developing an app entitled "GMU Parking Helper" in both iOS and Droid environment. The prototype app has been published in both iTune Store and Google Market. 100% accomplished by 09/30/2016.
- The research team worked with Mason Parking Department to collect historical parking lot usage data. Accomplished by 03/30/2016
- The RPI team has completed the traffic state estimation from reduced GPS data by specially designed sampling techniques based on traffic states. Accomplished by 03/30/2016
- The research team is developing the travel trajectory recording and sharing module that will enhance the "GMU Parking Helper" app, and make it an effective travel behavior data collection platform. 100% accomplished by 09/30/2016.
- The research team has developed an algorithm to estimate real-time parking lot usage information through cloud-sourcing. The algorithm will integrate parking lot usage information submitted by users, historical parking lot usage data, and real-time data reported by Mason Parking Department Officials, and the information will be provided to app users in real time. 100% accomplished by 03/30/2017.
- The research team is deploying the apps to collect travel trajectory data to track longitudinal travel behavior. 100% accomplished by 09/30/2017.
- The research team is developing algorithm to analyze the travel trajectory data collected using the smartphone app and test its capacity as a travel behavior monitoring tool. 100% accomplished by 09/30/2017.

Planned Activities: (next quarter):

The research team is finalizing the final project report summarizing all the findings.

1.2.1.4 Research at George Mason University

a) Monitoring Behavior Reactions to Washington Metro SafeTrack Project Using Advanced Travel Data Collection Techniques

Project Status: 75%

Milestone Accomplishments and Dates:

- The research team has designed a smartphone app based longitudinal travel behavior data collection scheme to track travel behavior changes during the Washington Metro SafeTrack project, a series of transit network disruptions that involve either continuous single track or complete shutdown of a metro segment. Accomplished on 01/30/2017
- The research team has designed a data collection program based on the smartphone app and tested the deployment through a pilot program. 100% on 01/30/2017.
- The research team is conducting a smartphone-based survey to collect travel behavior data during the Washington Metro Safetrack project. 75% on 09/30/2017
- The research team is developing algorithm to analyze the trajectory data collected through the smartphone app to infer important travel behavior information including the mode, departure time, and routes. 50% on 09/30/2017

b) Developing a P3 Projects Database to Support Transportation Planning and Policy Analysis

Summary: This project proposes to develop a P3 project database to support transportation planning practice and policy analysis. This project will review existing data in infrastructure finance and develop a data structure that provides a platform for projects of different sizes, financial sources, ownership, delivery methods, and age to be compared and analyzed. It will pool data collected from sources such as TIFIA, InfraAmerica, OECD, and others to build an initial database. The database will grow as more P3 project get funded and built. The strength of this database will be demonstrated through case studies and pilot transportation planning and policy analysis. Efforts will be dedicated to explore how qualitative features associated with a project could be quantified and analyzed using latest data mining techniques. Findings from this project will inform future decision makings on infrastructure finance.

Project Status: Ongoing

Milestone Accomplishments and Dates: The research team:

- investigated the existing database on P3 transportation projects, including the database compiled by TIFIA, InfraAmerica, OECD, and European banks to identify the gap in existing data sources. The research summarized the existing experience on transportation P3 project through a series of case studies.
- is working with CDM Smith Inc. on a database of toll roads in the U.S. The research team is developing a model for toll elasticity of demand, a key issue for the user-pay model in both P3 projects and conventional design build projects, using empirical data in the U.S
- is developing a model that can inform the decision making process of P3 project using data collected through the case studies.
- is collecting data on Virginia P3 projects and is identifying the gaps between existing P3 data and data needs for effective evaluation of project delivery method.

Planned Activities:

- The research team will continuously develop the P3 model using existing data and new data to estimate the costs and benefits associated with P3 project delivery mechanism. The objective is to identify the comparative advantage and disadvantage of P3 projects delivery compared with conventional project delivery mechanism.

- The research will continue with the data collection efforts to identify new experience on transportation P3s in the U.S as new P3 projects are planned or closed.

1.2.1.5 Research at the University of Puerto Rico at Mayaguez

Due to Hurricane Maria and the crisis in Puerto Rico in the aftermath of the storm, communication with our colleagues at the University of Puerto Rico at Mayaquez has been impossible. We will not be able to report on their ongoing projects at this point.

a) Development of Transit Performance Measures using Big Data

Summary: The purpose of this project is to develop real time performance measures using Big Data generated by GPS or AVL (Automatic Vehicle Locator) devices installed in public transit vehicles, and merging that information with transportation demand related data available from other sources, including the Census. This type of synthesized real time information has the capability to improve decision making at the operational and planning levels. This type of performance measures can be used to evaluate the system in both real time day to day operations as well as in the short term and medium term planning. This project is taking place using the Metropolitan Bus Authority system (AMA, for its acronyms in Spanish), which is the main public transit operator in the San Juan Metropolitan Area of Puerto Rico.
Project Status: On going

b). Development of a Mobile Computer Application for the Process of Data Collection and Data Sharing for Vehicle Accidents

Summary: The research project focuses in developing two mobile applications to be used by police officers in Puerto Rico: one for vehicle crash reports (CARS – Car Accident Reporting System) and one for traffic citations (E-TICS – Electronic Traffic Infraction and Citation System). The data collected by these applications could be used for easy sharing between the pertinent agencies as well as investigations focused in reducing the number of vehicle crashes.
Project Status: On going

1.2.1.6 Research at Calspan / University at Buffalo Research Center

a) Highway Safety Performance Metrics and Emergency Response in an Advanced Transportation Environment

Summary:

Traditional highway safety performance metrics have been largely based on fatal crashes and more recently serious injury crashes. In the near future however, there may be less severe motor vehicle crashes due to advances in driver assistance systems, infrastructure and vehicle based communication technologies, active traffic management systems, and vehicle design. To understand the impact that these technologies will have on highway safety, emergency response, and performance metrics this paper evaluates the state of the art practices and technologies that will transform future transportation systems. In addition, event scenarios in which crashes or safety critical events could still occur are examined. Finally, alternative highway safety performance measures and response are identified.
Project Status: Completed
Key Findings and Insights:

If automation proceeds as expected, the changes will be revolutionary. The role of the driver will be modified (perhaps even eliminated) as in-vehicle and roadside technologies become more advanced. This paper examined both the in-vehicle and infrastructure-based technologies which are emerging in the next five to eight years to assess how these technologies might impact emergency responders, particularly EMS. A qualitative score was assigned (in Tables 1 and 3) as a way of ranking technologies to identify those which might be considered a priority for incorporating into emergency vehicles, as well as identifying

those with marginal utility for EMS. Examples of technologies which were assigned a High priority included Forward Collision Warning, Intersection Movement Assistance, Do Not Pass Warnings and Emergency Vehicle Signal Preemption. Examples of those assigned a Low score included Stop and Go Cruise Control and Traffic Jam Assist, since ambulances intentionally violate many of the normal rules-of-the-road (and such violations would trigger repeated warnings to the driver). Still other technologies (Hard Shoulder Running, Lane Departure Warning), earned a mixed rating since their benefits for EMS were situation dependent.

There will clearly be a transition period during which automated and traditional vehicles are operating on the same roadways. Policies must therefore be developed which govern how these two fleets will share roadway resources. In considering next steps, topics which require further study include the design of standards and protocols which will govern operation of (and response to) emergency vehicles in this new transportation environment. Key topics might include: Ambulance Right-of-Way Ambulance in Platoon Autonomous Vehicles they recognize and respond to emergency vehicles. Proper handling of emergency vehicles (and emergencies incidents) is an important issue since it could be a key factor in giving the public the confidence needed to accept and support automation - and embrace the changes ahead.

b) An Evaluation of Knowledge Discovery Techniques for Big Transportation Data

Summary: As an extension of the work that was completed for "Developing Highway Safety Performance Metrics in an Advanced Connected Vehicle Environment Utilizing Near-Crash Events from the SHRP 2 Naturalistic Driving Study" this project is investigating the application of knowledge discovery (KD) techniques to analyze the same data. The primary output of this research will be the identification of methodologies used in other areas of data science that are applicable to transportation safety research.

Project Status: On going

Milestone accomplishments and dates:

- November 20th, 2015: Finalized the compilation of research database s. The datasets being utilized for this project include the SHRP2 Roadway Inventory Data (RID), Archived Clarus weather data and the traffic safety database compiled in CUBRC's previous UTC project.
- January 8th, 2016: Finished ingesting and aligning databases in the Hadoop Distribution environment to enable initial data search, query and mining techniques.
- February 12th, 2016: Compiled a summary list of the advanced analytics and KD techniques which would be run against the ingested data.
- August 3rd, 2016: Presented summary of project at TransInfo Symposium.
- September 23rd, 2016: Completed summary document on the state of the art and best practices for research in big data transportation research.
- January 27th, 2017: Finished performing benchmark testing on the operational environment.
- April 28th,2017: Completed model evaluation and validation
- September 29th, 2017: Adjusted optimization strategies to improve benchmark measures

Planned activities:

Document components, best practices, state-of-the-art technologies, and lesson learned; summarize overall findings and produce final report. The findings of this project will be provided in written form as well a final report and a journal submission. Parts of this research will also be presented at the annual TRB Meeting in January 2018.

TransInfo Educational Activities

1.2.2.1 New Interdisciplinary Degree in Sustainable Transportation and Logistics

TransInfo researchers at the University at Buffalo have developed a new interdisciplinary Masters' degree in Sustainable Transportation and Logistics. The new program is a 30-credit, full-time, 3-semester

program, jointly administered by UB's School of Engineering and the School of Management. It can also be pursued on a part-time basis to enable those working in industry to benefit from the program. The curriculum consists of five courses that are designed to provide a common platform of relevant engineering principles & practices, coupled with managerial concepts & practices. Upon entering the program, the candidates will complete these five core courses as a cohort, followed by five courses in one of the following two tracks: (1) Sustainable Transportation; and (2) Logistics. The program is designed to train globally competitive graduates who are well rounded technically and managerially, and who intend to assume leadership positions in transportation and logistics, which have emerged as major sectors of the economy. The program welcomed its first students in Fall 2017. More students are expecting to join the program for Spring and Fall 2018 (https://www.buffalo.edu/istl/Education.html).

1.2.2.2. TransInfo graduate student activities

The TransINFO consortium continues to engage dozens of undergraduate or graduate students in its research activities with each project facilitating the involvement of at least one student. Some highlights of TransInfo engaged students during this reporting period include:

- A paper jointly written by PacTrans researcher, Dr. Xuegang (Jeff) Ban, his research group and his collaborators from the Automotive Engineering Department of Tsinghua University, China (Mr. Biao Xu, Prof. Keqiang Li, Mr. Yougang Bian, and Prof. Jianqiang Wang) recently **received the Best Paper Award (2nd Prize) from the IEEE Intelligent Vehicles Symposium 2017**. The paper titled "**V2I Based Cooperation between Traffic Signal and Approaching Automated Vehicles**" aims to develop cooperative methods between traffic signal control systems and automated vehicles to reduce urban traffic congestion and fuel consumption. The paper is one of the two papers selected from over 300 papers submitted to the Symposium.
- The TransINFO sponsored project: **Developing a Smartphone App Platform to Decipher Travel Behavior has** supported **two students** at RPI working on topics related to mobile app development and traffic state estimation, vehicle-traffic integration, arterial performance measurements.
- Laiyun Wu, Ph.D. student at UB working on the project: Inferring Origin-Destination Demand and Utility-Based Travel Preferences in Multi-Modal Travel Environment Using Automatic Fare Collection Data has presented initial findings at INFORMS Annual Meeting in November 2016 and will also present in this upcoming 2017 INFORMS Annual Meeting.

1.2.3 Outreach and technology transfer activities

1.2.3.1 TransInfo Hosted the 2017 CUTC Annual Summer Meeting

More than 135 transportation professionals from the academia and industry along with U.S. Department of Transportation and other transportation agency officials gathered for 2017 Annual Summer Meeting of the Council of the University Transportation Centers (CUTC) in downtown Buffalo on June 19th, 20th, & 21st, 2017.

The three-day event featured distinguished speakers including presentations, panels and guided discussions covering a broad range of topics related to transportation. The meeting provided the opportunity to the attendees to exchange information and enhance collaboration between university transportation centers and the US Department of Transportation and other government agencies. The meeting was sponsored by the Stephen Still Institute for Sustainable Transportation & Logistics.

The TransINFO research was showcased on Tuesday, June 20th with a dedicated session while the technical tour on opening day featured TransINFO's work on Connected & Automated Vehicles (https://www.buffalo.edu/transinfo/Events/2017CUTC.html).

1.2.3.2 Self-Driving Vehicles for Smart & Sustainable Mobility - Evaluation and Feasibility Study for Educational and Medical Campuses

Researchers at UB's School of Engineering & Applied Sciences received funding from the New York State Energy Research and Development Authority (NYSERDA) to purchase and test an Olli bus. Olli is a self-driving, electric vehicle that can accommodate up to 12 passengers and uses sensors, including radar and cameras, to monitor the driving environment. UB plans to test the bus later this year.

The project will help answer questions that relate to the technical feasibility, safety and reliability of using Autonomous Vehicle (AV) technology and the public policy changes needed to allow for AVs to be driven on New York State public roads. Furthermore, the project will conduct a detailed evaluation of the costs and benefits of using AV technology on a realistic case study involving the Buffalo Niagara Medical Campus (BNMC) in downtown Buffalo.

For this research, a highly qualified team is assembled. The team consists of: (1) an interdisciplinary team of faculty members and researchers from the University at Buffalo, specializing in three fields of inquiry, Civil Engineering, Computer Science, and Public Policy; and (2) practicing engineers from Wendel, a 220+ employee architecture and engineering firm. The team combines not only expertise in computer science, travel demand modeling and transportation simulation, but also extensions of those tools to capture performance differentiation when modeling alternative futures of vastly different technologies.

1.2.3.3 2017 University at Buffalo National Summer Transportation Institute (UB NSTI)

For the fifth consecutive year, Dr. Qing He, Dr. Adel Sadek and Dr. Qian Wang were awarded a grant by the Federal Highway Administration to host the 2017 UB National Summer Transportation Institute (UB NSTI) in August 2017. The Institute recruited up to 30 students into this excellent program that seeks to introduce to high school students a broad range of transportation careers through lectures, hands-on challenges, field trips, and enhancement activities. Read More

1.2.3.4 TransINFO funds eight new projects - TransINFO awarded funding to eight new research projects, each promoting the TransInfo mission to undertake research, education, training and technology transfer activities aimed at realizing the full potential of Big Data and Transportation Informatics, effecting change in system performance, guiding investments and improving policies. Funds will help support the education of ten graduate students focused on the field of transportation analytics. Congratulations to the funding recipients!

- **Predictive Analytics for No-Shows and Cancellations for Paratransit Operations** - Jee Eun Kang, PhD - University at Buffalo and Daniel Rodríguez Román, PhD - University of Puerto Rico, Mayagüez.
- **Improving the Service Quality of Bike Sharing Systems via the Analysis of Real-Time User Data** - Jose Walteros, PhD - University at Buffalo
- **Green Navigation: A Big Data Approach Towards Sustainable Transportation** - Lu Su, PhD and Chunming Qiao, PhD - University at Buffalo
- **City-wide Transportation Information Estimation with Heterogeneous Urban Data** - Jing Gao, PhD - University at Buffalo
- **R2Deep: Recharging Recommendation System for Electric Taxis based on Deep Learning** - Chunming Qiao, PhD and Lu Su, PhD and Wen Dong, PhD - University at Buffalo

- **Using Social Media Data to Enhance Up-to-date O-D Demand Modeling** - Qing He, PhD University at Buffalo and Shanjang Zhu, PhD - George Mason University
- **Predicting changes in driving safety performance on an individualized level under naturalistic Driving Conditions** - Lora Cavuoto, PhD - University at Buffalo
- **Factors affecting perceived and observed aggressive driving behavior: An empirical analysis of driver fatigue, and distracted driving** - Panos Anastasopoulos, PhD - University at Buffalo

1.2.3.5 Miscellaneous Activities

- **Prof. Qiao named SUNY Distinguished Professor**: Chunming Qiao was one of three University at Buffalo faculty members to be named a State University of New York Distinguished Professor, the highest faculty rank in the SUNY system. Qiao, professor and chair of the Department of Computer Science and Engineering in the School of Engineering and Applied Sciences, is one of the world's leading authorities on network protocols and architectures, and the inventor of optical burst switching. He also has been at the forefront of pioneering research on integrated wireless systems that have revolutionized the smartphone industry and profoundly impacted the communication infrastructure of the internet, as well as that of video, multimedia and high-end digital services.
- Drs. He and Batta awarded an $369,965 NSF grant entitled "**Collaborative Research: Advancing Supply Prepositioning for Emergency Preparedness by Social Sensing**".
- Drs. He and Aref awarded a $346,266 grant from Federal Rail Administration (FRA) entitled "**Data-Driven Optimization and Planning of Multi-Component Track Responsive Maintenance with Defect Deterioration Modeling**"
- TransInfo published and delivered **one issue of its newsletter** during the reporting period in an effort to continue to provide information on the Center and updates on transportation informatics more generally. The newsletter mailing continues to increase, with over 525 qualified recipients.
- PIs for the project titled **"Inferring Origin-Destination Demand and Utility-Based Travel Preferences in Multi-Modal Travel Environment Using Automatic Fare Collection Data"** have obtained an access to UB Parking & Transportation database where individual students' card swipes for UB bus system are recorded.
- NSF ERC Proposal: TransInfo researchers, Prof. Qiao and Prof. Sadek, are currently working with Prof. Krishna Rajan of the Department of Materials Design and Innovation (MDI) on an NSF ERC proposal in the area of Active Cyber Transportation Systems (ACTS).
- On July 14, 2017, professors from the Civil Engineering and Surveying Department from the University of Puerto Rico at Mayaguez (UPRM) met with the Secretary of Puerto Rico's Department of Transportation and Public Works (DTPW), Eng. Carlos Contreras. The group discussed Puerto Rico's needs and priorities regarding its transportation systems and the current research projects being conducted at UPRM.

2. Products

2.1 Publications, conference papers, and presentations

Publications

- Dr. Shanjiang Zhu , Hamza Masud, Chenfeng Xiong, Zhuo Yang, Yixuan Pan, and Lei Zhang, (2017) "Travel Behavior Reactions to Transit Service Disruptions: Case Study on Washington, D.C., Metro SafeTrack Project", *Transportation Research Record: Journal of the Transportation Research Board, No. 2649, DOI:10.3141/2649-09.*

- Dr. Shanjiang Zhu, Gege Jiang, Hong Lo: "Capturing Value of Reliability through Road Pricing in Congested Traffic under Uncertainty", is forthcoming in the Procedia of the *22nd International Symposium on Transportation and Traffic Theory (ISTTT 2017).*
- Lei Lin, John C Handley, Adel W Sadek, "Interval Prediction of Short-Term Traffic Volume Based on Extreme Learning Machine and Particle Swarm Optimization", *Transportation Research Board 96th Annual Meeting Transportation Research Board Proceedings (Paper 17-04796).*
- Andrew P Bartlett, Adel W Sadek, "Public Acceptance of Driver-Assist and Warning Technologies", *Transportation Research Board 96th Annual Meeting Transportation Research Board Proceedings (Paper 17-03595)*.
- Ming Ni, Qing He, Jing Gao, "Forecasting the subway passenger flow under event occurrences with social media", *IEEE Transactions on Intelligent Transportation Systems, 18, 1623-1632.*
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- Zhen Xu, Wen Dong, Sargur (Hari) Srihari. Using Social Dynamics to Make Individual Predictions: Variational Inference with Stochastic Kinetic Model <https://papers.nips.cc/paper/6453-using-social-dynamics-to-make-individual-predictions-variational-inference-with-a-stochastic-kinetic-model.pdf>. *Advances in Neural Information Processing Systems 29* (NIPS 2016, acceptance rate 22.7%).
- Wen Dong. Variational Inference with Agent-Based Models. In *Proceedings of the 2016 International Conference on Autonomous Agents & Multiagent Systems*, pp. 854-863. International Foundation for Autonomous Agents and Multiagent Systems, 2016 (AAMAS 2016, acceptance rate 25%). https://arxiv.org/pdf/1605.04360.pdf
- Kumar AA, JE Kang, C Kwon, and A Nikolaev (2016) Inferring Origin-Destination Pairs and Utility-Based Travel Preferences for Shared Mobility System Users in a Multi-Modal Environment, *Transportation Research Part B: Methodological*, 91, 270-291
- Wu L, JE Kang, Y Chung, and A Nikolaev (2017), Monitoring Multimodal Travel Environment Using Automated Fare Collection Data, To be submitted to *Transportation Research Part C: Emerging Technologies.*
- A paper jointly written by PacTrans researcher, Dr. Xuegang (Jeff) Ban, his research group and his collaborators from the Automotive Engineering Department of Tsinghua University, China (Mr. Biao Xu, Prof. Keqiang Li, Mr. Yougang Bian, and Prof. Jianqiang Wang) recently received the Best Paper Award (2nd Prize) from the IEEE Intelligent Vehicles Symposium 2017. The paper titled "**V2I Based Cooperation between Traffic Signal and Approaching Automated Vehicles**" is one of the two papers selected from over 300 papers submitted to the Symposium.
- Laiyun Wu, Jee Eun Kang, Younshik Chung, and Alexander Nikolaev "Monitoring Multimodal Travel Environment Using Automated Fare Collection Data: *Data Processing and Reliability Analysis*" in submission.

- A paper, "Modeling Revealed Mode Choices using Emerging Data Sources: A Case Study on the Washington Metro SafeTrack Project", is under review at *Transportation Research Part C: Emerging Technology* (Project: Monitoring Behavior Reactions to Washington Metro SafeTrack Project Using Advanced Travel Data Collection Techniques).

Presentations:

- Multiple poster presentations based on TransINFO sponsored projects were given during the Council of University Transportation Center's Annual Meeting on June 20th, 2017 in Buffalo, NY:

- **An Evaluation of Knowledge Discovery & Dissemination Tools for Big Data Transportation Research**, Kevin Majka, Eric Nagler, Alan Blatt, CUBRC
- **Behavior-based Traveler Classification Using High-Resolution Connected Vehicles Trajectories and Land Use Data**, Yu Cui, Qing He, University at Buffalo
- **Traffic Control at Freeway Work Zones Using Connected Vehicles Technology**, Salaheldeen Seliman, Qing He, Adel Sadek, University at Buffalo
- **Development of iCAVE2: instrument for Connected and Autonomous Vehicle Evaluation and Experimentation**, Xin Liu, Chunming Qiao, University at Buffalo
- **Impact of Bikeshare Pricing on Ridership and Revenue**, Shruthi Kaviti, Shanjiang Zhu, Mohan Venigalla, George Mason University
- **Assessing Travel Behavior Responses to Washington Metro SafeTrack Project using Smartphone App Data**, Zhuo Yang, Shanjiang Zhu, George Mason University, Lei Zhang, University of Maryland
- **Improving Incident Response Strategies using Simulated Optimization Method**, Guanqi Liu, Shanjiang Zhu, George Mason University
- **CARS: Mobile Application for Vehicle Accident Report Submission**, Jessica Cotrina, Manuel Rodriguez, Ivette Cruzado, University of Puerto Rico, Mayaquez
- **Development of Transit Performance Measures using Big Data**, Juan Martinez, Yindhira Taveras, Didier Valdes, Ivette Cruzado, University of Puerto Rico, Mayaquez
- **Development of Collision Diagram for CARS Mobile Application**, Alfredo Pomales, Manuel Rodriguez, Ivette Cruzado, University of Puerto Rico, Mayaquez

Future presentations:

- "Inferring Origin-Destination Demand Matrix and Utility-Based Travel Preferences in Multi-Modal Travel Environment Using Automatic Fare Collection Data" At this upcoming INFORMS Annual Meeting (October 22-25, 2017, Houston, TX).
- A second paper summarizing finding from the smartphone-based survey, "Assessing Travel Behavior Responses to Washington Metro SafeTrack Project using Smartphone App Data", will be presented at the 2017 INFROMS Annual Meeting to be held in Houston, Texas, October 22-25.
- Research related to the TransINFO project "An Evaluation of Knowledge Discovery Techniques for Big Transportation Data" was presented at the 10th SHRP2 Safety Data Symposium on October 6th, 2017.

2.2 Website(s) or other Internet site(s)

Two Websites were developed during this period: CUTC 2017 Annual Summer Meeting (http://www.buffalo.edu/transinfo/Events/2017CUTC.html) and the Master's Program in Sustainable Transportation & Logistics (https://www.buffalo.edu/istl/education.html).

2.3 Technologies or techniques

- Experiences of using smartphone app as a travel behavior data collection tool and technologies developed in the project "Developing a Smartphone App Platform to Decipher Travel Behavior"project have been used in the study to assess the impact of the Washington Metro SafeTrack projects.
- The smartphone app, entitled "Mason Parking Helper" is available in both iTune Store and Google Market. The app is designed to provide real-time parking lot usage information at George Mason University based on data from different sources. The updated version has the capacity of disseminate on campus special event information and sends app users notifications if they choose to receive them.
- The above smartphone app may become a transportation data collection platform that can benefit other studies or data collection efforts.
- The GMU research team is developing the travel trajectory recording and sharing module that will enhance the "GMU Parking Helper" app, and make it an effective travel behavior data collection platform.
- An algorithm was developed to estimate real-time parking lot usage information through cloud-sourcing. The algorithm will integrate parking lot usage information submitted by users, historical parking lot usage data, and real-time data reported by Mason Parking Department Officials, and the information will be provided to app users in real time.
- The research team has designed a smartphone app based longitudinal travel behavior data collection scheme to track travel behavior changes during the Washington Metro SafeTrack project, a series of transit network disruptions that involve either continuous single track or complete shutdown of a metro segment (Monitoring Behavior Reactions to Washington Metro SafeTrack Project Using Advanced Travel Data Collection Techniques).
- The research team has designed a data collection program based on the smartphone app and tested the deployment through a pilot program (Monitoring Behavior Reactions to Washington Metro SafeTrack Project Using Advanced Travel Data Collection Techniques).
- Regarding the mobile application for traffic citations, Electronic Traffic Infraction and Citation System (E-TICS), this application is completely finished in terms of performance. There are some minor changes planned for the next period that focused on the application to be more "user-friendly". The application includes the option of determining the exact location of the traffic violation. This information could be used in future research projects that wish to determine locations in which driver behavior can be considered risky (Development of a Prediction Model for Crash Occurrence by Analyzing Traffic Crash and Citation Data).
- Developed software and installed new GPS systems in the AMA buses to replace the old ones that had problems providing the information that the project was using. The new GPS and the software developed by the research team will be installed in several buses the next month therefore obtaining real time data once again (New Performance Metrics and Operational Strategies based on Bus Location and Passenger Count Data).
- Functional prototype to obtain the data required to continue and finish project. It is expected that the installation of equipment and testing the new software will be performed in May (Application Development for Mobile Data Collection and Sharing for Vehicle Accidents).
- Mobile app on collecting mobile trace data at varying locations and time intervals, based on traffic states learned from the data (Urban System Modeling and Performance Measurement Using Multiple Data)

2.4 Inventions, patent applications, and/or licenses

- Multi-agent Simulation of Partially Observed Complex Systems, under submission (Variational Inference for Agent-Based Models with Applications to Achieve Fuel Economy)
- Event-Based Social Network Construction Using Distributed Wi-Fi Access Points, under submission (Variational Inference for Agent-Based Models with Applications to Achieve Fuel Economy)

2.5 Other products

- Final version of the research databases needed to support "An Evaluation of Knowledge Discovery (KDD) Techniques for 'Big' Transportation Data"
- Revised traffic safety database as an update to last reporting period's database to include the revised elements of the SHRP2 NDS data available through the InSight website (Developing Highway Safety Performance Metrics in an Advanced Connected Vehicle Environment Utilizing Near-Crash Events from the SHRP 2 Naturalistic Driving Study)
- A survey was developed in order to gather data regarding traffic violations and crash history. The survey is available on both paper and electronic forms (Development of a Prediction Model for Crash Occurrence by Analyzing Traffic Crash and Citation Data)
- A day of population and travels on UB's North Campus, synthesized data set (Variational Inference for Agent-Based Models with Applications to Achieve Fuel Economy)

3. Participants and Collaborating Organizations

Work on TransInfo projects have involved close collaborations across traditional disciplinary lines. For several of our research projects and initiatives, transportation researchers (from the Departments of Civil Engineering) are working very closely with their counterparts in the Departments of Computer Science and Engineering. In addition TransInfo researchers are collaborating with government, private industry, and other academic partners on several projects including (1) Connected Vehicle Pilot Deployment proposal, (2) the USDOT Smart Cities Challenge, (3) MRI Proposal for Connected and Autonomous Vehicle Evaluation and Experimentation, and (3) BNMC Green Commons & Living Transportation Lab.

3.1 Organizations which have been involved as partners

Organization Name	Location	Contribution to the Project
Committee for Traffic Safety, Puerto Rico	Minillas Government Center, South Tower, Suite 5, Santurce	
District Department of Transportation (DDOT)	55 M Street, SE, Suite 400, Washington, DC 20003	
George Mason University Parking Department	Fairfax, Virginia	In-kind support
Governors Traffic Safety Council (GTSC)	Albany, NY	Provided project guidance in selecting research area
CDM Smith Inc.	Fairfax, Virginia	Collaboration on database development
Greater Buffalo Niagara Regional Transportation Council (GBNRTC)	Buffalo, NY	Provided database of traffic volumes and turning count movements for Erie County, NY
INRIX		Data for research
Korea Transport Institute (KOTI)	370 Sicheong-daero, Sejong-si, 339-007, Republic of Korea	
Metropolitan Bus Authority (AMA, by its acronym in Spanish)	Puerto Rico	GPS and APC data sharing, in-kind support (data)
National Science Foundation	Maryland	

National Transportation Center at the University of Maryland	Maryland	
New York State Department of Transportation – Region 5 (NYSDOT)	Buffalo, NY	In kind labor hours to compile crash statistics for selected locations throughout Erie County, NY
New York State Department of Transportation (NYSDOT)	Albany, NY	In kind labor hours to generate extract from Safety Management System Crash Database
New York State Thruway Authority	Albany, NY	In-kind support (data)
Niagara Falls Bridge Commission	Niagara Falls, NY	In-Kind support (data)
Niagara International Transportation Technology Coalition (NITTEC)	Buffalo, NY	In-kind support and personnel exchanges
Peace Bridge Authority, Niagara Falls Bridge Commission	Buffalo, NY	In-kind support (data)
Police Workforce (Hormigueros Municipality)	Puerto Rico	In-kind support
Police Workforce (San German Municipality)	Puerto Rico	In-kind support
Puerto Rico Department of Transportation and Public Works (DTOP, by its acronym in Spanish)	Puerto Rico	In-kind support (data)
Puerto Rico Integrated Transportation Authority	Minillas Government Center, South Tower, 17th Floor, Ave.De Diego, Santurce	
SAMMAT Engineering Services, LLC	P.O. Box 780 Mount Airy, MD 21771	
SUNY-Albany	Albany, NY	Collaboration on organizing the third Symposium on Connected and Automated Vehicles and on submitting a proposal for Connected Vehicle Deployment in NY State.
TrafficCast, Inc.	Madison, Wisconsin	Proposal collaborations
University at Buffalo	Amherst, NY	Developed advanced analytics for the prediction of motor vehicle crashes.
University of Puerto Rico, Medical Science Campus	Gobernador Piñero, San Juan, 00921, Puerto Rico	
University Transportation Research Center (UTRC)	New York, NY	Research Funding and Collaboration on organizing the 3rd &4th Symposium on Connected and Automated Vehicles, the First Annual Symposium on Transportation Informatics, and on submitting a proposal for Connected Vehicle Deployment in NY State.
Urban Transportation Associates (UTA)	Cincinnati, OH	APC Installation and file sharing
Virginia Department of Transportation	Richmond, VA	In-kind support
Virginia Office of Public-Private Partnerships	Richmond, Virginia	

4. Impact

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

TransInfo activities are envisioned to help advance the state-of-the-art in the application of advanced data mining, Artificial Intelligence (AI), Social Network analysis and Advanced Statistical and Econometric models to transportation Big Data. Applying such methods is envisioned to result into invaluable insight into how to improve transportation system efficiency, safety, sustainability, resiliency and reliability. It is also envisioned to help support sound transportation decision making through the development and application of appropriate performance metrics. Our research to-date has already resulted in the development of new methods for data analysis. Examples include the recently developed combined M5P-HBDM model for incident duration prediction, and the new methods developed at RPI for probe vehicle data fusion and analysis.

4.2 What is the impact on other disciplines?

TransInfo activities are likely to have an impact on the field of Big Data Analytics, as it pertains specifically to transportation data. The transportation Big Data context has several unique features which distinguish it from other application domains of Big Data. TransInfo research and educational initiatives are thus likely to have an impact on the emerging field of Transportation Informatics and Analytics.

4.3 What is the impact on the development of human resources?

Several graduate students are supported by TransInfo either through fellowships or graduate research assistantships. TransInfo also has held a number of outreach initiatives aimed at encouraging high school students to consider careers in transportation, including the National Summer Transportation Institute at UB. Moreover, TransInfo's project focused on the development of a mobile computer application for vehicle accidents also presents an opportunity in training police officers in using the mobile application for accident reports. We also hope to contribute toward improving the diversity of the workforce.

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

TransInfo work is helping build several important data repositories which can help support future research in the area of Big Data Analytics. These repositories could be made available to other researchers via our website to promote research and technology transfer in this field of inquiry.

4.5 What is the impact on technology transfer?

The vision is for many of the transportation research projects undertaken by TransInfo to result in either products which can be implemented to address transportation challenges or improve the traveler experience (e.g., the smart phone app which was already developed for predicting border crossing delay), or in strategies and/or policies to improve transportation system performance and to support sound decisions regarding transportation investments. We hope to work with our stakeholders and partners in the future to make sure that TransInfo research and educational initiatives are having a positive impact on technology transfer.

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

The benefits to individual drivers and society in general with respect to the Android smartphone application, the Toronto Buffalo Border Waiting (TBBW) can be tremendous. For individual drivers, the app can help them choose the right crossing and the arrival time which would minimize their wait time,

thereby saving them time, gas, and money. For society, the app can help reduce the cost of border crossing delay on a region's economy as well as on the environment in the area, which is estimated to be in the order of billions of dollars annually in lost business productivity, wasted fuel, traffic-related pollutants and associated health hazards. The same can also be used about other TransInfo initiatives and projects such as the work aimed at improving incident management in Northern Virginia, and at building a P3 (Public-Private-Partnership) projects database to support transportation planning and policy analysis. Such projects have the potential to benefit society at large and to save tax-payers millions of dollars.

5. Changes/Problems

The two TransInfo research projects being conducted at the University of Puerto Rico at Mayaguez (UPRM) requested a no cost extension of one year (until September 30, 2018) due to the recruitment and training of new students.

The TransINFO project titled "An Evaluation of Knowledge Discovery Techniques for Big Transportation Data"requested a no cost extension until 03/31/18 in order to ensure that a product is produced during the next reporting period.