

**Program Progress Performance Report**

**Submitted to**

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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**

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**Signature:**

A handwritten signature in black ink, appearing to read "Adel W. Sadek". The signature is written in a cursive style with a long horizontal stroke at the end.

## **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 will be 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. We anticipate that the activities performed under the umbrella of the TransInfo Center will advance the state of knowledge in the emerging field of transportation informatics, and will better prepare and educate 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 will help improve system performance, and because transportation serves as the very foundation of our nation’s economy, the Center’s activities are envisioned to 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 will address. 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**

In addition to the projects outlined below, two additional projects from the University at Buffalo were funded during this reporting period and will begin during the next. They are (1) Effectiveness of Various Public Private Partnership Pavement Rehab Treatments and (2) Quality Aware Big Data Integration for Crowdsourced Road Sensing Systems

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

Summary: Objective of this project is to develop scalable inference methods for understanding and expressing public transit system utilization based on fundamental travel behavior. We propose a

methodology that identifies both the preference vector and 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 to 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 that are both dynamic and stochastic. Major environment variables include travel time, level-of-service, transfer time, and cost.
- The research team is now currently working on estimating travel disutility function based on the observed route choices in multi-modal travel environment (through AFC records).
- We have created synthetic experiment of estimating OD demand matrix. Currently, we are developing methodologies and experimenting them with the synthetic data set we generated.

Planned activities:

- The research team will focus on fine tuning the proposed Origin-Destination Matrix estimation methodology and applying it to our data set.
- will present “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).
- PIs will develop an on-campus data competition for students to participate in.

## **b) Border Crossing Delay Prediction**

Summary: This research developed several models for predicting short-term border crossing traffic, along with queuing models for predicting the anticipated delay. Based on these models, an Android smartphone application called the Toronto Buffalo Border Waiting (TBBW), 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: Most recently,

- The project developed 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. The model combines Particle Swarm Optimization (PSO) and Extreme Learning Machine (ELM) neural network. The PSO-ELM models require no statistical inference nor distribution assumption of the error item, but rather focus on generating the prediction intervals that can minimize a multi-objective function, which considers two criteria, reliability and interval sharpness. The project also developed a comprehensive optimization framework to make staffing plans for border crossing authority based on bounds of PIs and point predictions.
- A paper summarizing this most recent work has been submitted for possible publication in the Transportation Research – Part C journal. 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 explores 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: The overall goal of this study was to not only design a transportation data-warehouse prototype for the Buffalo-Niagara region, but also to demonstrate its usefulness through a specific application. Recently, the Niagara International Transportation Technology Coalition (NITTEC), our partner in this project, has applied and was awarded one of the “Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Initiative (DTFH6116RA00012)” for a project entitled “A Connected Region: Moving Technological Innovations Forward in the NITTEC Region”. TransInfo is a partner with NITTEC on this project, particularly as it relates to Advanced Traffic Signal and Control applications. Among the primary objectives of the recently awarded project, which builds on some of the initial work that TransInfo and NITTEC has worked on in the previous few years, is to enhance data collection, fusion, distribution and archiving, an objective which is perfectly aligned with TransInfo’s focus.

Project Status: Nearing completion.

Milestone Accomplishments and Dates: Participated in the kick-off meeting for ATCMTD project, “A Connected Region: Moving Technological Innovations Forward in the NITTEC Region”.

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**

Summary: In this project, we will develop an approximate inference algorithm to track and predict real-time traffic dynamics in a transportation network from an agent-based transportation model and multiple streaming data sources. The inference result enables providers of transportation informatics to deliver travel information to drivers and promote efficient driving.

Project Status: On going

Milestone accomplishments and dates:

- We have benchmarked our 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 we gathered, demonstrating the superior performance of our algorithms.

- We 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 with the state-of-the-art deep policy network and evolutionary algorithm.
- Based on the milestone accomplishments, we have several papers either accepted or in submission to top computer science venues.

Planned activities:

In the next reporting period, we will focus on turning our research results into publication, patents and external funding. We are preparing three papers to submit to the conference of Neural Information Processing Systems, one of the top machine learning conferences. We are working with several coauthors out of UB to publish the major scientific findings to one of: Nature Communications, Nature Scientific Reports, PNAS, Journal of the Royal Society Interface. We 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 conducts a detailed, multivariate statistical assessment of pavement treatments by PPP type, by studying their performance in terms of how key pavement performance indicators deteriorate over time. The elapsed time until the pavement crosses a threshold that is considered critical is 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: On going

Milestone accomplishments and dates: Following the original plan, the research team has so far completed the following tasks:

- The literature on pavement survivability has been thoroughly reviewed. Pavement performance modeling, pavement life analysis, and PPP state-of-practice have been examined, and the factors that may affect the choice of specific pavement rehabilitation types and PPP contract types under various conditions have been identified.
- The database has been collated and enriched with additional variables and observations. The analysis dataset consists of 812 pavement segments that were rehabilitated through various PPP types (performance-based contracting, cost-plus-time, incentives/disincentives, design-build and their derivatives, warranties, and lane rentals) and that were let or completed in the United States between 1996 and 2011.
- Three-stage least squares (3SLS) models of the three studied pavement condition indicators (i.e., pavement roughness, rut depth, and pavement condition rating) have been estimated by rehabilitation type and PPP approach. For the pavement service life analysis, fully parametric hazard-based duration models have also been estimated by rehabilitation type and PPP approach.

- The research team is in the process of outlining frameworks and approaches for using the study results to estimate the effects of different types of pavement rehabilitation treatments by PPP contract types. This task also includes the development of an Excel-based application.

Planned activities:

- Finalize the statistical models.
- Develop and test the Excel-based application.
- Prepare a final, comprehensive report summarizing the literature review, data collection process, data analysis, decision-support framework, implications of findings, and user's manual for the Excel-based application.

### **1.2.1.2 Research at Rensselaer Polytechnic Institute (RPI)**

#### **a). Urban System Modeling and Performance Measurement Using Multiple Data Sources**

(formerly Developing Big Data Analytics Methods for Urban Transportation Modeling)

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**

Milestone Accomplishments and Dates:

- The team presented the research results at the poster session during the TransInfo Reception at TRB (January, 2016).
- The team submitted a paper to Transportation Research Part C, titled "Fine-grained arterial traffic modeling: A data fusion and information integration approach", co-authored with Dr. Zhanbo Sun from Western Michigan State University (March, 2016)

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
- Continue to conduct education and outreach activities

### **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: 90%

Milestone Accomplishments and Dates:

- 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. 75% accomplished by 03/30/2017.
- 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. 50% accomplished by 03/30/2017.

Planned Activities: (next quarter):

- The GMU team and PRI team will complete the analysis of the travel trajectory data collected using the smartphone app and test its capacity as a travel behavior monitoring tool.
- The research team will draft a final project report summarizing all the findings.

#### **1.2.1.4 Research at George Mason University**

##### **a). 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.

#### **b). Monitoring Behavior Reactions to Washington Metro SafeTrack Project Using Advanced Travel Data Collection Techniques**

Project Status: 50%

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.

### Planned Activities

- The research team is conducting a smartphone-based survey to collect travel behavior data during the Washington Metro Safetrack project. 50% on 03/31/2017
- 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. 25% on 03/31/2017

#### **1.2.1.5 Research at the University of Puerto Rico at Mayaguez**

##### **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

Milestone accomplishments and dates: During this reporting performance period, the research team has worked on three main areas:

- with the data gathering process - the main milestone accomplished during this period was the development of an affordable solution for our big data gathering requirement. This includes the development of new software and the installation of new GPS systems in the AMA buses. The research team has been working to develop a functional prototype allowing us to obtain the data required to continue and finish our project.
- with the use of a big data software to work with the data already obtained - we have been using the software KNIME Analytics Platform (a typical big data software) to reproduce the analysis that have been already elaborated in the past using Matlab. It is expected that using this software, the incorporation of demand related data bases will be easier.
- to incorporate strategies developed to improve transit ridership by restructuring the transit network - our research team collaborated in an AMA related research project to generate new data and generate a conceptual redesign of the San Juan transit network. We have been working during this period to incorporate the results obtained and the data gathered as part of this collaborative project.

### Planned activities:

In the next period our research team plans to use the new equipment installed in AMA buses and the software developed. We will use these tools to collect the final set of data to complete the data set that we already have, test the performance measures developed and prepare the reporting of our project with recommendations. Workshops and other training activities are also planned as part of the technology transfer activities in this project.

## **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

### Milestone accomplishments and dates:

- CARS mobile application: Web services have been developed for the following tabs in the application:
- General Information of the Vehicle Crash, Crash Conditions, Person Registration, Vehicle Registration, Crash Details.
- Since the application was developed using Swift, the login was also developed which is using the web services. This task has been completely in its entirety.
- The web services have been finished for the search of a person by using his or her driver's license identification number and search for a vehicle by its license plate.
- The database has been updated. For this task it was taken into consideration the information of a person in the crash report as well as the information for the vehicle involved in the crash. Several statements were identified for this task, such as:
  - Every crash report must have a crash detail and a crash condition
  - A person must "belong" to a crash
  - A vehicle must "belong" to a crash
- The collision diagram was migrated from Objective-C to Swift and the Core Data functions for local storage have been developed. Similarly, the web services for the application, especially the communication between the application and the servers to establish searches, storages, and the links between persons and vehicles involved in a crash.
- The analysis of the data collected from the surveys was completed. Traffic violations were categorized into moving violations (a traffic violation due to driving behavior) and non-moving violations (traffic violation due to vehicle's conditions). A stepwise multiple regression analysis was performed to obtain the subset of predictor variables that would provide the best model for estimating a driver's crash involvement. Three variables were found to be significant: years of driving experience, gender, and traffic violations. Age and daily hours spent driving were not included in the model as these were found not be significant, according to the regression model. Odd ratios were determined for all explanatory variables considered in the model, even if they were not included in the final model. The odd ratios resulting from the multiple regression analysis performed in this study indicated the following:
  - An increase in years of driving experience indicated an increase in the odds of being involved in a traffic crash while an increase in daily hours spent driving showed a decrease in the odds of being involved in a traffic crash.
  - Older participants were shown to have increased odds of being involved in a vehicle crash when compared to younger drivers.

- Male participants have decreased odds of being involved in a traffic crash than females
- Participants that indicated to have committed at least one moving violation showed increased odds of being involved in a traffic crash than participants who indicated not to have committed traffic violations.
- Participants that indicated to have committed at least one non-moving violation also showed increased odds of being involved in a traffic crash than participants who indicated to not have committed traffic violations.

Planned activities:

For the following period, the research team will:

- develop the web services for the crash report. In the mobile application, the following tabs are still under development: Person registration, Person information, Vehicle registration, Vehicle information, Crash narrative, Crash report.
- implement the web services to the front-end of the application, including the list of persons per vehicle, the list of vehicles per person, and the list of reports.
- integrate the collision diagram to the application and will develop a web application in order for the supervisor at the police station be able to read, edit, and approve submitted reports.

**c). Development of a Prediction Model for Crash Occurrence by Analyzing Traffic Crash and Citation Data**

Summary: . This research project aims to estimate the likelihood of a driver being involved or not in a vehicle crash by performing stepwise multiple logistic regression analyses. The data used was obtained by performing a survey on a sample of the driving population of Puerto Rico. Information such as age, gender, years of driving experience, daily hours spent driving and traffic violation and crash history were determined for a sample of the driving population of Puerto Rico. Results indicate that years of driving experience, gender and traffic violations history are significantly associated with being involved in a vehicle crash.

Project Status: Completed

**1.2.1.6 Research at Calspan / University at Buffalo Research Center**

**a). 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 would be 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 3<sup>rd</sup>, 2016 presented summary of project at TransInfo Symposium.
- September 23<sup>rd</sup>, 2016 completed summary document on the state of the art and best practices for research in big data transportation research. 6.) January 27<sup>th</sup>, 2017 finished performing benchmark testing on the operational environment.

Planned activities: Summarize findings and produce final report.

### *1.2.2 TransInfo Educational Activities*

#### **1.2.2.1 New Interdisciplinary Degree in Sustainable Transportation and Logistics**

TransInfo researchers at the University at Buffalo have been working on developing 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 will be accepting its first students in Fall 2017 (<https://www.buffalo.edu/istl/Education.html>). It has generated great interest both in the US and abroad. We currently have 15 student applications under review and 5 students have already been offered admission to the program.

#### **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:

- Students from several TransInfo partner universities attended and participated in the 96<sup>th</sup> Annual Meeting of the Transportation Research Board. Maria Torres, a graduate student from University of Puerto Rico at Mayagüez was honored as TransInfo's UTC Outstanding Student of the Year at the 96<sup>th</sup> Annual Meeting of the Transportation Research Board. <https://www.buffalo.edu/transinfo/Research/TRB2017.html>
- The Student Chapter of the Institute of Transportation Engineers of the University of Puerto Rico at Mayaguez (ITEUPRM) celebrated its annual Transportation Week between March 7 and 9, 2017. The event took place in the Civil Engineering Building where various professionals, from

both the private and public sector, presented several topics related to the future of the transportation in Puerto Rico. Eng. Carlos Contreras, Secretary of the Department of Transportation of Public Works of Puerto Rico, was the keynote speaker on Tuesday, March 7, followed by the President of ITE - Puerto Rico Chapter, Ivelisse Gorbea. Transportation Week was dedicated to Dr. Ivette Cruzado who is the ITE-UPRM adviser.

- 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 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 to Host the 2017 CUTC Annual Summer Meeting**

TransInfo was selected to host the 2017 Annual Summer Meeting of the Council of the University Transportation Centers (CUTC). The meeting will take place from **June 19<sup>th</sup> to June 21<sup>st</sup>**, 2017 at the Canalside in Downtown Buffalo. <https://www.buffalo.edu/transinfo/Events/2017CUTC.html>. The CUTC Summer Meeting attracts the nation's leading transportation professionals from the academia and industry along with U.S. DOT and other transportation agency officials. The meeting serves as a venue to exchange information and enhance collaboration between university transportation centers, and between centers, the US Department of Transportation, and other agencies. TransINFO has been working closely with the US DOT and CUTC to organize the meeting. The three-day event will feature distinguished speakers including keynote addresses, presentations, panels and guided discussions covering a broad range of topics related to transportation. The TransINFO research will be showcased on Tuesday, June 20<sup>th</sup> with a dedicated session while the technical tour on opening day will feature TransINFO's work on Connected & Automated Vehicles.

#### **1.2.3.2. Twitter data could improve subway operations during big events**

A preliminary study by TransINFO researchers suggests that data from Twitter, and possibly other social media platforms, can be used to improve event planning, route scheduling, crowd regulations and other subway operations. The study was conducted by Dr. Qing He, Stephen Still Assistant Professor at UB's Department of Civil, Structural and Environmental Engineering and the Department of Industrial and Systems Engineering. Co investigators are Dr. Jing Gao, Assistant Professor in UB's Department Computer Science and Engineering, and Ming Ni, PhD candidate at UB's Department of Industrial and Systems Engineering. An early version of the study, "[Forecasting the Subway Passenger Flow under Event Occurrences with Social Media](#)", was published online in October in the journal IEEE Transactions on Intelligent Transportation Systems. The study will appear in an upcoming print edition of the journal. Articles also appeared in news outlets that include [Gizbot](#), [Business Standard](#), [Gadgets Now](#), [Science Daily](#) and [CXO Today](#).

### **1.2.3.3. 96<sup>th</sup> Annual Meeting of the Transportation Research Board Reception**

The Transportation Research Board (TRB) 96th Annual Meeting took place January 8-12, 2017 at the Walter E. Washington Convention Center, in Washington, D.C. The TransInfo University Transportation Center alongside the University of Buffalo hosted a reception on Monday evening welcoming over 150 attendees of the meeting. In addition to hosting the reception, a large contingent of TransINFO faculty and students participated in the conference with presentations, papers and posters.

### **1.2.3.4. 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 is planning to recruit 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. A total of 110 students have so far attended our prior NSTIs.

### **1.2.3.5. Request for Proposals (RFP) for new projects**

TransInfo issued an RFP for new projects to its members on December 16<sup>th</sup>, 2016 in search of projects that would further support its 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. Fourteen proposals were submitted and are currently under review. Funds will help support the education of graduate students focused on the field of transportation analytics.

### **1.2.3.6. TransINFO Researchers awarded MRI Grant for a Testbed for Connected & Automated Vehicles**

The National Science Foundation has awarded \$1.2 million grant to a multidisciplinary team of TransINFO investigators to create a multifaceted research facility for connected and autonomous cars. The University at Buffalo will contribute \$500,000 in matching funds toward the project. The UB researchers are also collaborating with Cisco, Carnegie Mellon University and the Southwest Research Institute (SwRI). The project develops an integrated 5-in-1 instrument for Connected and Autonomous Vehicle Evaluation and Experimentation (iCAVE2). It is the first-of-its-kind with unprecedented capabilities, not offered by any simulator-based instrument or test-beds in academic, industrial or government-based R&D laboratories. Furthermore, it bridges the gap between existing simulators and road testing facilities by providing a flexible, scalable (and yet low-cost) and more importantly, safe (and yet realistic) platform for comprehensive and holistic evaluation and experiments of CV/AV technologies and their applications. It is particularly suitable for answering various "what-if" questions related to safety, efficiency and sustainability arising from human-automation interactions with not-yet-available technologies and rare/extreme events (e.g. severe weather or emergency situations). The instrument is useful to researchers in academia and IT industry as well as developers and decision makers in the auto-manufacturing, auto-insurance and government transportation agencies. The instrument will also be useful to run CV/AV algorithms and applications to collect data and enable many advanced research

activities related to Big Data in transportation systems. The development effort will train graduate and undergraduate students as well as high-school students in the STEM field. It will also contribute to better driver training and driver rehabilitation related studies and programs.

#### **1.2.3.7. Miscellaneous Activities**

- NYSERDA PONS proposal focused on an autonomous shuttle bus has been submitted. The proposed project has three inter-related objectives: to evaluate the technical feasibility, safety and reliability of using AV technology, and in particular the Olli bus, to research the public policy changes needed to allow for AVs to be driven on New York State public roads and to 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.
- TransINFO researchers are part of \$7.8 million Advanced Transportation and Congestion Management Technology Deployment (ATCMTD) project, entitled "A Connected Region: Moving Technological Innovations Forward in the NITTEC Region". The project is led by NFTA on behalf of NITTEC and NYSDOT, and focused on improving border crossing, commercial vehicle operations, expanding regional smart mobility, improving incidence management, providing for operational integration, using real time weather data, providing enhanced traveler information and enhancing data collection, fusion, distribution and archiving.
- **Dr. Qing He** has been awarded funding from NSF CMMI 1637604. "EAGER: Collaborative Proposal: Towards Dynamic Social Ride-sharing: An Essential Component in Envisioned Smart Communities". August 2016 - July 2018
- **Dr. Qing He and Dr. J. Gao** have been awarded funding from UTRC2 "Inferring High-Resolution Individual's Activity and Trip Purposes with the Fusion of Social Media, Land Use and Connected Vehicle Trajectories", September 2016 -December 2017
- **Dr. Qing He and Dr. Amjad Aref** have been awarded funding (\$346k) from USDOT/Federal Rail Administration for the project titled "Data-Driven Optimization and Planning of Multi-Component Track Responsive Maintenance with Defect Deterioration Modeling".
- **Prof. Jamie Kang and Prof. Mark Karwan** received funding from the National Science Foundation for a project entitled Household-Level Use of Autonomous Vehicles: Modeling Framework, Traveler Adaptation, and Infrastructure to Mitigate Negative Effects (\$200,000) 2015-2018.
- **Prof. Jamie Kang and Prof. Alexander Nikolaev** have been awarded funding from NSF, for EAGER: Inferring Comprehensive Individual Traveler Information in Multi-Modal Travel Environment Using Automatic Fare Collection Data (\$149,999) 2016-2018
- **Assistant Professor Panagiotis Ch. Anastasopoulos** received the 2016 Early Career Researcher of the Year Award for important contributions to transportation engineering, with emphasis on roadway vehicle crashes and strategies to reduce such crashes.
- 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. <http://www.buffalo.edu/transinfo/News/Enewsletter.html>

## 2. Products

### 2.1 Publications, conference papers, and presentations

In addition to those cited below, TransInfo researchers presented several dozen papers, presentations or posters at the 2017 TRB Meeting in Washington, D.C. this last January. Several of those papers are expected to be later published in the *Journal of the Transportation Research Board*. A listing of those papers presented can be found at: <http://www.buffalo.edu/transinfo/Events/TRB2017.html>. Also, multiple poster presentations based on TransINFO sponsored projects will be given during the 2017 Annual Summer Meeting of the Council of the University Transportation Centers (CUTC).

#### UTRC SPONSORED Projects

- Jee Eun Kang: "A Random Utility Based Estimation Framework for the Household Activity Pattern Problem"
- Dr. Qing He: "Smarter Multi-modal Traffic Signal Control with both Floating SensorNetwork and Fixed Sensor"
- Dr. Panagiotis Anastasopoulos, Dr. Adel Sadek, Dr. Nallan Suresh: "Evaluation of Public-Private Partnership Contract Types for Roadway Construction, Maintenance, and Rehabilitation". [Read more.](#)
- Dr. JiYoung Park, Dr. Changhyun Kwon: "The Ties that Bind: Bi-national Trade and its Implications of the U.S. and Canada Using Bi-national Freight Movement Network via Border Crossings". [Read more.](#)
- Dr. JiYoung Park: "Panama Canal Expansion: The Effect of Imports and Exports Diverted from California Seaports on the Port of New York and New Jersey". [Read more.](#)
- Xi Zhou, Dr. Mohan M Venigalla, and Dr. Shanjiang Zhu: "A Bounding Box Approach to Network Pruning for Efficient Path Search through Large Networks", ASCE's Journal of Computing in Civil Engineering (2017). The paper is focusing on data driven approach for network analysis.

#### 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 Transportation Research Board (2017).
- 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). The paper focuses on using pricing as a tool to capture the value of reliability.
- Fan Yang and Wen Dong. Integrating Simulation and Signal Processing with Stochastic Social Kinetic Model. To appear: Proceedings of the 9th International Conference on Social, Cultural, and Behavioral Modeling & Prediction and Behavior Representation in Modeling and Simulation (SBP-BRiMS 2017, full paper acceptance rate: 20%).
- Fan Yang, Zhen Xu and Wen Dong. "Tracking Large Social System to Predict Time-Varying Traffic: Particle Filter with Stochastic Kinetic Model". In submission.
- Fan Yang, Wen Dong and Bo Liu. "Multi-Agent Discrete Event Decision Process: Online Planning through Expectation Maximization". In submission.

- Le Fang and Wen Dong. “Expectation Propagation for Approximate Inference in Event-based Complex Systems”. In submission.
- Zhu, Shanjiang, Hamza Masud, Chenfeng Xiong, Zhuo Yang, Yixuan Pan, and Lei Zhang, 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
- 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

### Presentations:

- Future presentation: “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).
- *Zhu, Shanjiang, Hamza Masud, Chenfeng Xiong, Zhuo Yang, Yixuan Pan, and Lei Zhang, Travel Behavior Reactions to Transit Services Disruptions: A Case Study on the Washington D.C. Metro SafeTrack Project* - presented at the Transportation Research Board 96<sup>th</sup> Annual Meeting, Washington D.C. January 8-12, 2017
- 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 INFORMS 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” were presented to:
  1. The Greater Buffalo Niagara Regional Transportation Council (GBNRTC), the local Metropolitan Planning Organization, and the Niagara International Transportation Technology Coalition (NITTEC), the operators of the local Traffic Management Center on January 26<sup>th</sup>, 2017.
  2. At the 10<sup>th</sup> SHRP2 Safety Data Symposium on October 6<sup>th</sup>, 2017.
- “Understanding Traveler Route Choices in Stochastic Multimodal Travel Environment Using Automatic Fare Collection Data”. presented the 2016 INFORMS Annual Meeting (November 13-16, 2016, Nashville, TN)

### **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** have been used in the study to assess the impact of the Washington Metro SafeTrack projects,

which is funded by National Science Foundation, TransInfo UTC, and National Transportation Center at the University of Maryland.

- The smartphone app, entitled “Mason Parking Helper” is available in both iTunes 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 smartphome 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.
- Experiences of using smartphone app as a travel behavior data collection tool and technologies developed in this project have been used in the study to assess the impact of the Washington Metro SafeTrack projects.
- The research team (project - Monitoring Behavior Reactions to Washington Metro SafeTrack Project Using Advanced Travel Data Collection Techniques) 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. The research team has designed a data collection program based on the smartphone app and tested the deployment through a pilot program. The research team will work closely with regional partners, including VDOT, Washington Metropolitan Area Transit Authority (WMATA), and Maryland State Highway Administration, to better plan for future transit network disruption event. The research has attracted board interest from the research community. Part of the research was subsequently funded by the National Science Foundation.

#### ***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 3 <sup>rd</sup> &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 MSP-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**

**Project Title: Development of a Mobile Computer Application for the Process of Data Collection and Data Sharing for Vehicle Accidents**

- The “open house” activity that we wanted to realize during this reporting period has been postponed since the web services tasks have not been completed. We are hopeful that it could be realized during the following months.

**Project Title: Developing a Smartphone App Platform to Decipher Travel Behavior**

- Due to fact that the deployment of the app has to be coordinated with the start of the semester, the research team would like to request a four-month no-cost extension to account for the extra time needed to complete the data collection and analysis. The project is expected to be completed in 08/2017.

**Project Title: Development of Transit Performance Measures using Big Data**

- Our research team has worked to develop the needed tools according to the specifications that we have so far. There may be additional time needed to complete the final stages of our project to incorporate the data gathered using our new system and the analysis using the new big data software.

**Project Title: Inferring Origin-Destination Demand and Utility-Based Travel Preferences in Multi-Modal Travel Environment Using Automatic Fare Collection Data**

- Our earlier request of no-cost extension of 6 months was granted and we are working towards finishing this project by 6/30/2017.