End of Project Report

1. Project Information:

1a. Project No. and Title:

141OSUY2.1 – Research, Education and Outreach from Campus Transit Laboratory

172OSUY2.2 – Campus Transit Laboratory: Infrastructure for Research, Education, and Outreach

1b. Principal Investigator(s): Mark McCord and Rabi Mishalani, The Ohio State University

1c. Start Date:

141OSUY2.1 – Feb. 1, 2012

172OSUY2.2 – July 1, 2015

1d. End Date: Dec. 31, 2017

1e. Report Date: March 13, 2018

2. Project Benchmarks:

2a. Students:

		Voluntary Information (for aggregate demographic trending only)		
Name	**Undergrad/ Graduate**	Male/Female	US/Foreign	Ethnicity
Paul Beck	Undergrad	Male	US	White
Victoria Bias	Undergrad	Female	US	White
Serkan Bicici	Graduate	Male	Foreign	White
Jason Biltz	Undergrad	Male	US	White
Josh Bradford	Undergrad	Male	US	White
Brad Brickman	Undergrad	Male	US	White
Gregory Burch	Graduate	Male	US	White
Bryan Check	Undergrad	Male	US	White
Aijing Chen	Undergrad	Female	Foreign	Asian
Cheng Chen	Graduate	Male	Foreign	Asian
Shanshan Chi	Undergrad	Female	Foreign	Asian
Mariel Colman	Graduate	Female	US	White
Mahsa Ettefagh	Graduate	Female	US	White
Sarah Fox	Undergrad	Female	US	White
Nick Goodman	Undergrad	Male	US	White
Sydney Gravitt	Undergrad	Female	US	White
Hafiz Gulam	Graduate	Male	Foreign	Asian
Andrew Gyde	Undergrad	Male	US	White
Giovani Hansel	Undergrad	Male	Foreign	Asian
Giovani Hansel	Graduate	Male	Foreign	Asian
Daniel Hayes	Undergrad	Male	US	White
Gregory Hertler	Graduate	Male	US	White
Jiecheng Huang	Undergrad	Male	Foreign	Asian
Rashed Islam	Graduate	Male	Foreign	Asian
Mohammad Kocache	Undergrad	Male	Foreign	White
Tatjana Kotautaite	Undergrad	Female	US	White

Ryan Laber	Undergrad	Male	US	White
Andrew Landgraf	Graduate	Male	US	White
Nathaniel Lang	Undergrad	Male	US	White
Adam Lipps	Undergrad	Male	US	White
Yingyu Ma	Undergrad	Female	US	Asian
Erica Mange	Undergrad	Female	US	White
Declan McCord	Undergrad	Male	US	White
Jacob Mix	Undergrad	Male	US	White
John Moody	Undergrad	Male	US	Asian
Stevenson Morency	Undergrad	Male	US	African American
RubénMorgan	Undergrad	Male	US	Hispanic
Lesia Mural	Undergrad	Female	US	White
Kyle O'Hara	Undergrad	Male	US	White
John O'Neill	Undergrad	Male	US	White
Matthew Pallone	Undergrad	Male	US	White
Adam Pelligrini	Undergrad	Male	US	White
Emily Reed	Undergrad	Female	US	White
Ted Reinhold	Graduate	Male	US	White
Jeannie Ricca	Undergrad	Female	US	White
Andy Rutkowski	Undergrad	Male	US	White
Nicole Sell	Graduate	Female	US	White
Nathan Shay	Graduate	Male	US	White
Zhen Shuai	Undergrad	Female	Foreign	Asian
Sonja Summer	Undergrad	Female	US	White
Joseph Traini	Undergrad	Male	US	White
Andrew Tucker	Undergrad	Male	US	White
Ryan Tucker	Undergrad	Male	US	White
Emma van Dommelen	Undergrad	Female	US	White
Zach Wedekind	Undergrad	Male	US	White
Yuanzhi Xu	Undergrad	Male	Foreign	Asian
Yifang Yuan	Graduate	Female	Foreign	Asian
Jiaqi Zaetz	Graduate	Female	Foreign	Asian
Amirul Zamri	Undergrad	Male	Foreign	Asian
Yangyang Zhou	Graduate	Female	Foreign	Asian
Ningling Zhu	Undergrad	Female	Foreign	Asian
Xingyu Zhu	Undergrad	Male	Foreign	Asian
Xulei Zhu	Undergrad	Male	Foreign	Asian
Jakob zumFelde	Graduate	Male	US	White

2b. Presentations (Title, Date, Authors, Event)**:**

1. Burch, G., Chen, C., Ettefagh, M., Reinhold, H., McCord, M.R., Mishalani, R.G., April 23, 2012. Campus Transit Lab (CTL): Select Activities. Presentation to OSU donor.
2. McCord, M.R., Mishalani, R.G., April 20, 2012. Campus Transit Lab (CTL): Select Research Activities. Presentation to Xerox, Columbus, OH.
3. Mishalani, R.G., McCord, M.R., April 20, 2012. Overview of Campus Transit Lab (CTL) at The Ohio State University. Presentation to Xerox, Columbus, OH.
4. McCord, M.R., Mishlani, R.G., Goel, P.K., et al., April, 10, 2012. Campus Transit Lab (CTL): Research, Education, and Outreach Activities. Presentation to EU COST project team representative, Columbus, OH.
5. Mishalani, R.G., McCord, M.R., Goel, P.K., April, 9, 2012. Overview of Campus Transit Lab (CTL) at The Ohio State University. Presentation to EU COST project team representative, Columbus, OH.
6. Ji, Y., Mishalani, R.G., McCord, M.R., 2012. Transit Route-level Passenger Origin Destination Flow Estimation: Empirical Evaluation of a Heuristic Expectation Maximization Methodology. 12th Conference on Advanced Systems for Public Transport, Santiago, Chile.

7. McCord, M.R., and Mishalani, R.G., August 27, 2012. The OSU Campus Transit Lab (CTL) and Transit-related Activities at The Ohio State University. Presentation to Federal Transit Administration representative, The Ohio State University, Columbus, OH.
8. Ettefagh, M., September 24, 2012. Effect of Passenger Information System (TRIP) on OSU Travelers' Attitudes and Perceptions. Presentation to OSU donor and development personnel, The Ohio State University, Columbus, OH.
9. Hertler, G., September 24, 2012. Factors Affecting Intra-Campus Origin Destination Passenger Flows. Presentation to OSU donor and development personnel. The Ohio State University, Columbus, OH.
10. McCord, M.R., and Mishalani, R.G., September 24, 2012. Campus Transit Lab (CTL): Introduction to Select Activities and Institutional Updates. Presentation to OSU donor and development personnel, The Ohio State University, Columbus, OH.
11. Reinhold, H., September 24, 2012. Combining Route-specific OD Flows into an Integrated OD Flow Matrix. Presentation to OSU donor and development personnel, The Ohio State University, Columbus, OH.
12. Ji, Y., Mishalani, R.G., McCord, M.R., 2012. Transit Route-level Passenger Origin Destination Flow Estimation: Empirical Evaluation of a Heuristic Expectation Maximization Methodology. 12th Conference on Advanced Systems for Public Transport, Santiago, Chile.
13. Ji, Y., Mishalani, R.G., and McCord, M.R., 2013. Estimating Transit Route-level OD Flow Matrices from APC Data on Multiple Bus Trips Using the IPF Method with an Iteratively Improved Base. Transportation Research Board 92nd Annual Meeting, Washington, D.C.
14. McCord, M.R., Mishalani, R.G., June 3, 2013. OSU Campus Transit Lab (CTL): Background, Data, Applications, and Outreach. Presentation to OSU Chief Data Officer, The Ohio State University, Columbus, OH.
15. Ji, Y. Mishalani, R.G., McCord, M.R., 2013. Iteratively Improving the Base Matrix of the IPF Method for Estimating Transit Route-Level OD Flows from APC Data. 13th World Conference on Transportation Research, Rio de Janeiro, Brazil, 2013.
16. McCord, M.R., and Mishalani, R.G., 2013. Using APC Data for Estimating Boarding to Alighting Bus Passenger Flows. American Public Transportation Association 2013 ITS Transit Best Practices Workshop, Detroit, MI.
17. Ettefagh, M., Mishalani, R.G., McCord, M.R., 2013. Effects of Transit Passenger Information System on User and Nonuser Preferences and Perceptions. Ohio Transportation Engineering Conference, Columbus, OH.
18. McCord, M.R., Mishalani, R.G., August 2, 2013. OSU Campus Transit Lab (CTL): Background, Data, Applications, and Outreach. Presentation to OSU Chief Data Officer Team, The Ohio State University, Columbus, OH.
19. McCord, M.R., Mishalani, R.G., November 13, 2013. Overview of Campus Transit Lab related activities at OSU. Presentation to Catherine Ross, Professor, City and Regional Planning and Director, Center for Quality Growth and Regional Development, Georgia Institute of Technology.
20. Mishalani, R.G., McCord, M.R., October 18, 2013. Overview of Campus Transit Lab related activities at OSU. Presentation to Steve Schneider, President of Schneider Engineering, PLLC and OSU alum.
21. Mishalani, R.G., McCord, M.R., McLaughlin, K.A., Reinhold, H. (The Ohio State University Transit Lab), January 21, 2014. Comparison of COTA Boarding-to-Alighting (B2A) and APC Data. Teleconference presentation to the Ohio Department of Transportation and ETC.
22. Mishalani, R.G., McCord, M.R., McLaughlin, K.A., Reinhold, H. (The Ohio State University Transit Lab, in collaboration with AECOM and ETC), May 13, 2014. Transit Passenger Flow

Estimation and Characteristics Expansion. Research Review Presentation to the Ohio Department of Transportation, Columbus, OH.

23. Mishalani, R.G., McCord, M.R., Colman, M.G., Yuan, Y. (The Ohio State University Transit Lab), November 5 and 12, 2014. OSU Progress Update on Transit Passenger Flow Estimation and Characteristics Expansions Project. Teleconference presentation to the Ohio Department of Transportation, Mid-Ohio Regional Planning Commission, Federal Transit Agency, and other Project Team Members (AECOM, ETC).
24. McCord, M.R., Mishalani, R.G., Ettefagh, M, 2015. The Effect of Real-time Passenger Information Systems on the Perceptions of Transit's Favorable Environmental and Traffic Reduction Roles. Transportation Research Board 94th Annual Meeting, Washington, D.C.
25. Ji, Y., Mishalani, R.G., McCord, M.R., 2015. An Efficient Transit Passenger Origin Destination (OD) Flow Estimation Method Combining Automatic Passenger Count (APC) and Onboard OD Flow Survey Data: Empirical Evaluation Under Varying APC and Survey Sample Sizes. Transportation Research Board 94th Annual Meeting, Washington, D.C.
26. McCord, M.R., Bicici, S., Mishalani, R.G., 2015 Using Error Distributions with Model Output to Acknowledge Prediction Uncertainty: Results using Travel Demand and Transit Flow Models. 15th TRB National Transportation Planning Applications Conference, Atlantic City, NJ.
27. Mishalani, R.G., McCord, M.R., Reinhold, H., 2016. Transit Route-level OD Flow Determination from Passengers' Mobile Devices' Wi-Fi Signals: Methodology and Empirical Evaluation. Transportation Research Board 95th Annual Meeting, Washington, D.C.
28. Landgraf, A.J., Mishalani., R.G., McCord, M.R., Goel, P.K. 2015. Estimating Transit OD Flows using Boarding and Alighting Data: An Efficient Variational Bayes Method and Clustering-based Extension that Recognizes Multiple Latent OD Flow Matrices. Transportation Research Board 95th Annual Meeting, Washington, D.C.
29. Mishalani, R.G, McCord, M.R., 2016. Using Available Data Sources to Correct Biases in Socio-economic and Travel Characteristics, Ohio Transportation Engineering Conference, Columbus, OH.
30. McCord, M.R., Mishalani, R.G., 2016. Determining Transit Passenger Boarding-to-Alighting Flows using Mobile Device Wi-Fi Signals: Empirical Results, Ohio Transportation Engineering Conference, Columbus, OH.
31. May, A.A., Sivandran, G., Mishalani, R.G., McCord, M.R., Zou, Y., La Susa, T., Liyanaarachchi, S., Van Dommelen, E., Wildey, B., 2016. Using a Transit System as a Mobile Platform for Air Quality Monitoring in Urban Areas, Ohio Transportation Engineering Conference, Columbus, OH.
32. May, A.A., Sivandran, G., Mishalani, R.G., McCord, M.R., Zou, Y., La Susa, T., Liyanaarachchi, S., Van Dommelen, E., Wildey, B., 2016. Using a Transit System as a Mobile Platform for Air Quality Monitoring in Urban Areas, Innovative Environmental Monitoring Technology Symposium, Athens, OH.
33. Mishalani, R.G, McCord, M.R., 2016. Sensitivity of Transit Onboard Survey Passenger Socioeconomic & Travel Characteristic Sample & Response Bias Corrections Using OD Flows Determined from APC & AFC Data. TransitData2016: 2nd International Workshop on Automatic Data Collection Systems, Boston, MA.
34. McCord, M.R, Bicici, S., Mishalani, R.G., 2017. Incorporating Uncertainty in Model Predictions: Evaluating Transferability. 16th TRB National Transportation Planning Applications Conference, Raleigh, NC.
35. zumFelde, J., Carrel, A., Mishalani, R.G. McCord, M.R., 2017. Considering Urban Geography in Quantifying and Correcting Sample and Response Biases in Estimated Transit Passenger

Socioeconomic and Travel Characteristics. National Science Foundation Mobility Workshop, Columbus, OH.

36. Mishalani, R.G, and McCord, M.R., 2017. Sample and Response Bias Corrections of Transit Passengers' SE&T Characteristics Collected via Onboard Surveys: Sensitivity to B2A Estimates. 16th TRB National Transportation Planning Applications Conference, Raleigh, NC.
37. Mishalani, R.G., June 8, 2017. The Road to Autonomous Vehicles: A Transportation Systems Perspective. Panelist, invited by the Harvard Business School Club Columbus and hosted by the Center for Automotive Research, The Ohio State University, Columbus, OH, June 8, 2017
38. McCord, M.R., Mishalani, R.G., Coifman, B., 2017. Determining Traffic Flows and Speeds across Spatially Extensive Urban Areas from Transit Buses, Ohio Transportation Engineering Conference, Columbus, OH.
39. May, A.A., Mishalani, R.G., McCord, M.R., Zou, Y., 2017. Using a Transit System as a Mobile Platform for Air Quality Monitoring in Urban Areas, Ohio Transportation Engineering Conference, Columbus, OH.
40. Mishalani, R.G., 2017. Transportation Systems and "Big" Data: Pathways to Decision- and Policy-Making for Smarter Cities. Keynote lecture, National Science Foundation Smart Vehicle Concepts Center Meeting, Columbus, OH.
41. Mishalani, R.G., 2017. Public Transportation, Big Data, and Smarter Cities: Advances in Monitoring, Analysis, and Modeling Methods. 3rd NYUAD Transportation Symposium (by invitation), Abu Dhabi, UAE.
42. Landgraf, A.J., Mishalani, R.G., McCord, M.R., Goel, P.K., 2016. Variational Bayes Method for Estimating Transit Route OD Flows using Boarding and Alighting Data in the Presence of Multiple Latent Flow Patterns: Methodology, Evaluation, and Validation. 14th World Conference on Transportation Research, Shanghai, China.
43. Ji, Y. Mishalani, R.G., McCord, M.R., 2016. Transit Route-level Passenger Alighting Probability, Probability OD Flow and Expected OD Flow Matrices: Estimates from Boarding and Alighting Counts and Relationships among the Representations. 14th World Conference on Transportation Research, Shanghai, China.

2c. Journal Papers/Reports (full citation)**:**

1. McCord, M.R., Mishalani, R.G., and Hu, X., 2012. Grouping of Bus Stops for Aggregation of Route-Level Passenger Origin-Destination Flow Matrices. Transportation Research Record, No. 2277, pp. 38-48, 2013.
2. Ji, Y., Mishalani, R.G., McCord, M.R., 2012. Transit Route-level Passenger Origin Destination Flow Estimation: Empirical Evaluation of a Heuristic Expectation Maximization Methodology. Proceedings of the 12th Conference on Advanced Systems for Public Transport, Santiago, Chile.
3. Ji, Y., Mishalani, R.G., McCord, M.R., 2012. Transit Route-level Passenger Origin Destination Flow Estimation: Empirical Evaluation of a Heuristic Expectation Maximization Methodology. 12th Conference on Advanced Systems for Public Transport, Santiago, Chile.
4. Cheng, C., April 2013. Using Archived Bus Automatic Vehicle Location Data to Identify Indications of Recurrent Congestion. Ph.D. dissertation, The Ohio State University, Columbus, OH.
5. Ettefagh, M., April 2013. Effects of Real-time Passenger Information Systems on Perceptions of Transit Services: Investigations of The Ohio State University Community. M.S. thesis, The Ohio State University, Columbus, OH.
6. Hertler, G., April 2013. Effect of Service, Temporal, and Weather Variables on Short Bus

Transit Passenger Trips: Investigations of OSU's Intra-campus Transit Demand. M.S. thesis, The Ohio State University, Columbus, OH.
7. Reinhold, H.E., April 2013. Combining Transit Route Origin-Destination Passenger Flow Matrices into Integrated Area or Corridor Matrices: Evaluating Flow Patterns on the OSU Campus and along a Columbus Corridor. M.S. thesis, The Ohio State University, Columbus, OH.
8. Ji, Y., Mishalani, R.G., McCord, M.R., 2014. Estimating Transit Route OD Flow Matrices from APC Data on Multiple Bus Trips Using the IPF Method with an Iteratively Improved Base: Method and Empirical Evaluation. Journal of Transportation Engineering, ASCE, No. 140, Vol. (5), pp. 040140081-040140088.
9. Ji, Y. Mishalani, R.G., McCord, M.R., 2013. Iteratively Improving the Base Matrix of the IPF Method for Estimating Transit Route-Level OD Flows from APC Data. Select Proceedings of the 13th World Conference on Transportation Research, Rio de Janeiro, Brazil, 2013.
10. McCord, M.R., Mishalani, R.G., Ettefagh, M., 2015. The Effect of Real-time Passenger Information Systems on the Perceptions of Transit's Favorable Environmental and Traffic Reduction Roles. Transportation Research Record, No. 2538, pp. 102–109.
11. Ji, Y., Mishalani, R.G., McCord, M.R., 2015. Transit Passenger Origin-Destination Flow Estimation: Efficiently Combining Onboard Survey and Large Automatic Passenger Count Datasets. Transportation Research Part C: Emerging Technologies (Special Issue: Big Data in Transportation and Traffic Engineering), Vol. 58, pp. 178-192.
12. Mishalani, R.G., McCord, M.R., Reinhold, T., 2016. Transit Route-level Passenger OD Flow Determination from Mobile Device Wi-Fi Signals: Methodology and Empirical Evaluation. Transportation Research Record, No. 2544, pp. 123-130.
13. Shay, N.M., 2016. Investigating Real-Time Employer-Based Ridesharing Preferences Based on Stated Preference Survey Data. M.S. Thesis, Graduate Program in Civil Engineering, The Ohio State University, Columbus, OH.
14. Landgraf, A.J., Mishalani, R.G., McCord, M.R., Goel, P.K., 2016. Variational Bayes Method for Estimating Transit Route OD Flows using Boarding and Alighting Data in the Presence of Multiple Latent Flow Patterns: Methodology, Evaluation, and Validation. Transportation Research Procedia: Select Proceedings of the 14th World Conference on Transportation Research, Shanghai, China.
15. Ji, Y. Mishalani, R.G., McCord, M.R., 2016. Transit Route-level Passenger Alighting Probability, Probability OD Flow and Expected OD Flow Matrices: Estimates from Boarding and Alighting Counts and Relationships among the Representations. Transportation Research Procedia: Select Proceedings of the 14th World Conference on Transportation Research, Shanghai, China.

2d. New Courses (Title, Undergraduate/Graduate, Date)**:**

We added CTL-based modules to several transportation courses, as follows, because of the developments that allowed using the Campus Transit Laboratory infrastructure for instructional purposes:

1. CIVILEN 3700 Transportation Engineering and Analysis: Undergraduate Civil Engineering students must choose six "select core" courses from a set of eight courses, which includes CIVILEN 3700. Typically, 150-200 students per year take this course. Some undergraduate students take additional transportation courses after CIVILEN 3700, but this is the only transportation course taken by the majority of the students. A module on scheduled transit

services is included, where the Campus Transit Lab (CTL) is highlighted. We recently added a module on sustainability in transportation related applications that focuses on CTL applications in an attempt to provide readily interpretable examples. Assignments involve the processing of APC and AVL data automatically collected as part of the CTL and a manual data collection exercise, as well as the interpretation of the processed and manually collected data.

2. CIVILEN 5720 Transportation Engineering Data Collection Studies: This course is typically taken by 15-25 students per year and is comprised of undergraduate and graduate Civil Engineering students and graduate City and Regional Planning students. It is a required course in the Dual Civil Engineering – City and Regional Planning M.S. Program in Urban Transportation Planning. We introduced a module on estimating traffic flows from a modified moving observer method we developed with the vision of collecting data from transit buses. We include an assignment where students board CABS buses to collect traffic data and process the data to produce traffic flow estimates.
3. CIVILEN 5770 Urban Public Transportation: Like CIVILEN 5720, CIVILEN 5770 is a required course in the Dual Civil Engineering – City and Regional Planning M.S. Program in Urban Transportation Planning and is taken by undergraduate and graduate Civil Engineering students and graduate City and Regional Planning students. It is a required course in the Dual Civil Engineering – City and Regional Planning M.S. Program in Urban Transportation Planning. Typically, more than 30 students take this course in a year. A major course requirement consists of a semester long project based on CTL carried out in teams of three to four students. Students collect field data on CABS vehicle and passenger movements and use these data along with CTL's automatically collected APC and AVL data to analyze and model various aspects of the supply of and demand for service. Based on the results, students comment on performance and make recommendations to the operators of CABS.
4. CIVILEN 7730 Urban Transportation Forecasting: This course is offered once every two years. Like CIVILEN 5720 and 5770, it is a required course in the Dual Civil Engineering – City and Regional Planning M.S. Program in Urban Transportation Planning. It is not open to undergraduate students. Over the duration of this project, approximately 10 students have taken the course on average. Students conduct a term project, which is generally presented to others in the class. Approximately one quarter of the students use data from the Campus Transit Lab in their project.
5. Individual Studies: Several students undertook independent studies for credit that relied on automatically collected CTL data or data they manually collected as part of their independent study course and on methods we developed to process the data into estimates of vehicle or passenger movements. In addition, CTL infrastructure and data formed the basis of a summer-long study of one Summer Research Opportunities Program (http://www.btaa.org/resources-for/students/srop/introduction) student. Furthermore, one student in the Dual Civil Engineering – City and Regional Planning M.S. Program in Urban Transportation Planning conducted his required "practicum" course – consisting of an internship at a transportation agency or company and regular academic reporting on the experience to the course instructor – at OSU's TTM, where he provided an interface between CTL activities and TTM needs.

2e. Outreach Conference (Title, Location, Type of Audience, Total Participants)**:**

1. Ettefagh, M., Mishalani, R.G., McCord, M.R., 2013. Effects of Transit Passenger Information System on User and Nonuser Preferences and Perceptions. Ohio Transportation Engineering

Conference, Columbus, OH.
2. McCord, M.R., Mishalani, R.G., 2016. Determining Transit Passenger Boarding-to-Alighting Flows using Mobile Device Wi-Fi Signals: Empirical Results, Ohio Transportation Engineering Conference, Columbus, OH.
3. May, A.A., Sivandran, G., Mishalani, R.G., McCord, M.R., Zou, Y., La Susa, T., Liyanaarachchi, S., Van Dommelen, E., Wildey, B., 2016. Using a Transit System as a Mobile Platform for Air Quality Monitoring in Urban Areas, Ohio Transportation Engineering Conference, Columbus, OH.
4. McCord, M.R., Mishalani, R.G., Coifman, B., 2017. Determining Traffic Flows and Speeds across Spatially Extensive Urban Areas from Transit Buses, Ohio Transportation Engineering Conference, Columbus, OH.
5. May, A.A., Mishalani, R.G., McCord, M.R., Zou, Y., 2017. Using a Transit System as a Mobile Platform for Air Quality Monitoring in Urban Areas, Ohio Transportation Engineering Conference, Columbus, OH.

3. Project Impacts:[1]

3a. USDOT Priorities:

In general, improved transit services result in improved overall transportation performance across all modes and, as a result, improved traveler mobility.

Short-Term Impacts: CTL data are used to validate rigorous, but presently available or recently developed approaches that can be immediately used with data already being collected by transit agencies to provide improved information for transit planning and operations. In addition to validating approaches with CTL data, the data and the approaches are used to provide information for targeted studies of interest to various stakeholders. CTL data and context are used to support modules and projects in multiple classes, offering students hands-on experience with data-driven analyses in a familiar setting.

Long-Term Impacts: New research questions are developed that can eventually lead to improved methodological approaches and new applications that take advantage of data already being collected by transit agencies and new types of data that could be available to transit agencies in the longer run. The proposed approaches and applications are evaluated in an operating environment. The educational component also has long-term impacts by exposing a large group of students to issues and technologies employed in public transportation and to the concept of learning through the use of a living laboratory infrastructure. The successful demonstration of the transit living lab are starting to motivate living labs in other domains.

Advanced Research: The research tasks are motivated by a desire to take advantage of the advanced technologies that automatically sense passenger boarding and alighting activity, passenger movements, and bus locations, to integrate behavioral and physical data with statistical methods and rigorous models, and to produce numerical results using efficient computational methods.

[1] Please provide description of accomplishments with background and impact or value in terms of its significance to the ultimate customers or beneficiaries, which can be used in NEXTRANS and USDOT publications.

3b. Significant Accomplishments in Research, Education and Technology Transfer (Please list any patents, copyrightable material, new processes, algorithms, textbooks, chapters, etc.):

Research

Data collected in the CTL were used to investigate the effect of passenger information on perception of transit services; effect of weather on transit short trips; effect of a base matrix on OD flow estimates using APC data; use of mobile device Wi-Fi signals to determine passenger OD flows; stated preferences for real-time employer-based ridesharing considering personal and travel characteristics; use of OD flows determined from APC and AFC data to correct sample and response biases in transit onboard survey results; sampling biases in transit onboard surveys and associated impacts on resulting passenger socioeconomic and travel characteristics; relationships among transit route-level passenger alighting probability, probability OD flow, and expected OD flow matrices; air quality monitoring from transit buses; traffic sensing from transit buses; and use of data on requests for real-time transit information made through the use of a mobile app.

These investigations are leading to new applications for automatically sensed data for transit systems. The promising results are also leading to new research funding from other sources.

Education

CTL data and infrastructure were effectively used in undergraduate and graduate courses through class lectures, assignments, data collection exercises, and exam questions. The exposure of students to state-of-the-art technologies and the reinforcement of basic concepts using real-world data from a familiar operating transit system is seen to be of great value by students and university leadership.

Technology Transfer

This report documents the activities conducted within the Campus Transit Lab (CTL) at The Ohio State University for the purposes of research, education, and outreach from Spring 2012 through Autumn 2017. CTL investigators utilized automatically and manually collected data from CABS to support these goals. CTL investigators conducted outreach with CABS to assess night service ridership, support campus planning efforts, fill in and correct ridership reports produced by off-the-shelf software, support campus sustainability policy efforts, advise on the management of the data for a new campus bike-sharing service, provide lessons learned regarding ridership reporting from APC data to Washington Metro, and share extensive documentation of inferring OD flows from APC data with Washington Metro.

The value added to CABS and other transit operators is leading to improved service planning and design tools and customer satisfaction.

3c. Challenges and Lessons Learned:

The results reinforce the belief that there is great value in basing research, education, and outreach on a living lab that is geographically and institutionally accessible to researchers and students and offers transit service that is sufficiently complex to capture realistic issues for

urban transit operations but sufficiently contained to allow extensive *in situ* observations across the system.

The undertaken efforts and results motivate many more research, education, and outreach activities that could be pursued in the near and long term, including use of the campus living lab for applications that go beyond public transportation such as traffic and air quality monitoring. While some of the novel smart transit ideas promoted by CTL investigators are becoming mainstream, developing a plan that allows investment for sustained activities and expansion in using living labs to support smart cities broadly defined is seen as a primary challenge and opportunity.

3d. Photographs for NEXTRANS Publications (please attach separately)**:**

None