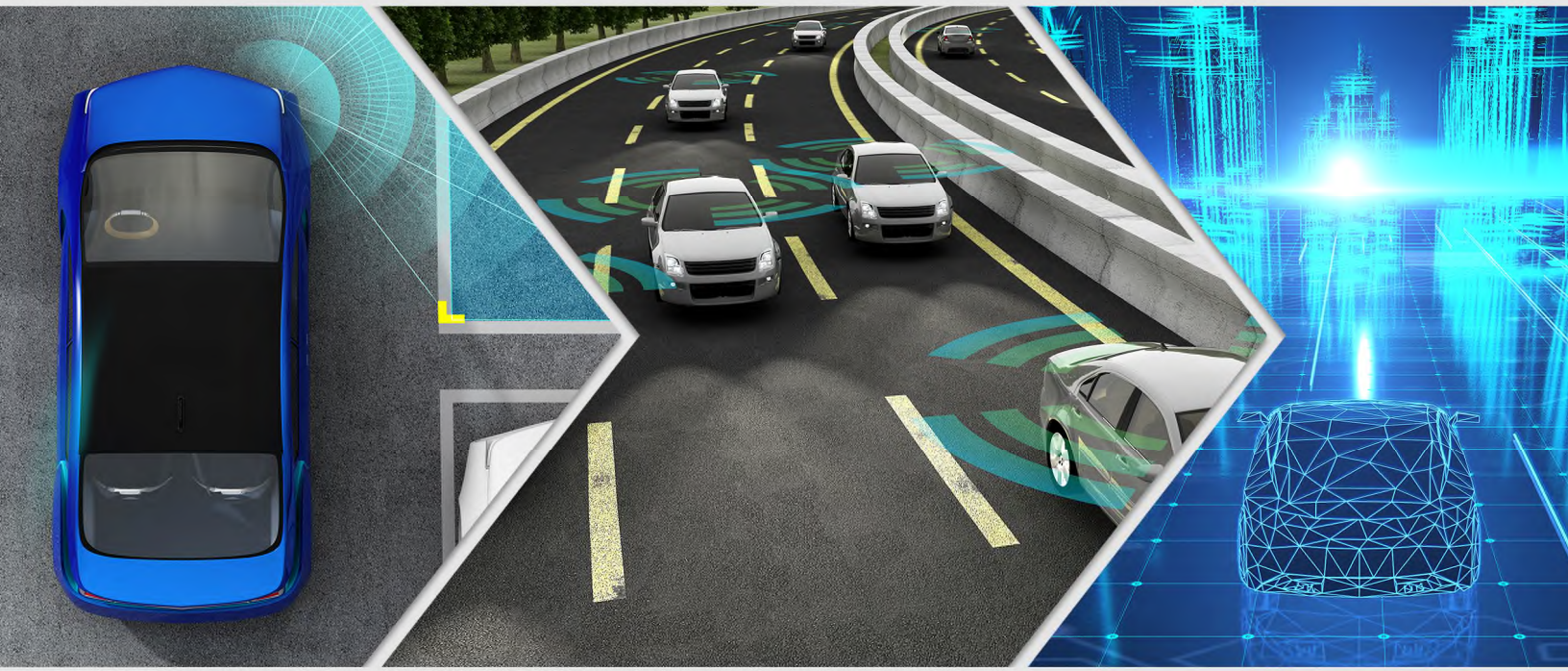
FINAL REPORT

SYNTHESIS ON VEHICLE TRAJECTORY DATA APPLICATIONS

Contract # C9Y62; TWO # 14



FDOT

FORECASTING AND TRENDS OFFICE

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1.0 Introduction

> ***Vehicle trajectory data*** *provides location and time information of individual vehicles as they travel on roadway network*

Known by various names, ***vehicle trajectory data*** (e.g., path processed data, breadcrumb data, waypoint data) represents time and space locations of vehicles as they traverse the highway system. Recent technological innovations have allowed the vehicle trajectory data becoming available from several travel time data vendors. Significant amounts of research using vehicle trajectory data have been conducted in universities nationally and internationally. However, practitioners still have very limited experience with these data. The state of the practice is limited in many respects, primarily because, up to only recently, the majority of the continuously collected data that have been available do not represent true travel times as measured by vehicles' movement through time and space. For example, the National Performance Management Research Data Set (NPMRDS) as well as many other similar data sets available from travel time data vendors, are all based on summarizations of vehicle trajectory data along a highway link. Measurements from individual vehicles are not taken at the beginning nor at the end points of the link but rather whenever their time and position are reported. Hence, developing a comprehensive understanding of the data and their applications is important for transportation planning and operations, such as developing new types of performance measures and using the data for model inputs and validation.

2.0 Purpose

The overall objective of this project is to conduct a synthesis on vehicle trajectory data that is available statewide, in the districts, and locally as well as nationally. The data was assessed for their use in existing Florida Department of Transportation (FDOT) analytical processes. Based on the research results, next steps were recommended.

This report consists of the following sections:

- Studies/Research in Florida – A review of studies and research conducted in Florida by FDOT, other agencies, and universities is summarized in this section of the memorandum. This review is a targeted effort focusing on the vehicle trajectory data and its usage.
- National and International Literature Review – This section covers a review of studies and research done nationally and internationally, including information on how various agencies and researchers are utilizing the vehicle trajectory data.
- Stakeholder Survey – A questionnaire is developed to survey stakeholders – FDOT staff and researchers – to assess current use and potential applications of vehicle trajectory data. Summary of discussion with a peer state (Massachusetts DOT) is also provided in this section. Additionally, information from private vendors of vehicle probe data is gathered to determine their current and future expansion into providing vehicle trajectory data.
- Summary and Next Steps – Based on the findings of the literature review and questionnaire/survey, this section identifies the next phase of this research project.

3.0 Studies/Research Conducted in Florida

FDOT and universities have been conducting several studies using the vehicle probe data. However, this report is a targeted effort focusing on the vehicle trajectory data and its usage.

3.1 Tampa Hillsborough Expressway Authority's Connected Vehicle Pilot Program

- Year: 2015-2019
- Country/Agency: Tampa Hillsborough Expressway Authority (THEA)
- Online Access: https://www.tampacvpilot.com/
- Data Description: The latest data from the Tampa Connected Vehicle (CV) Pilot project is available at the Intelligent Transportation Systems (ITS) Data Hub, which provides open data from the three CV technology pilot programs in Wyoming, Tampa, and New York City. The types of data provided are:
  - Basic Safety Messages (BSM): Used to exchange safety data regarding vehicles' current attributes, including speed and path predicted.
  - Traveler Information Messages (TIM): Used to convey important traffic information and provide situational awareness warnings to the drivers.
  - Signal Phasing and Timing (SPaT) Messages: Used to convey the current status of one or more signalized intersections.
- Study Summary: Tampa was one of just three sites in the nation selected for the U.S. Department of Transportation (USDOT) CV Pilot Deployment Program, which seeks to spur innovation among early adopters of CV applications. The four-year effort began in September 2015, when the USDOT awarded THEA a contract to implement its winning proposal. In 2016, the project entered its second phase, which includes design, testing and deployment. The third and final phase, launched in mid-2018, involved the full-scale operation of connected vehicle technology throughout downtown Tampa. The Tampa CV Pilot Program employed innovative vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication technology to improve safety and traffic conditions in downtown Tampa.

3.2 Utilization of CV Data to Support Traffic Management Decisions

- Year: 2017
- Country/Agency: Florida International University (FIU) and Southwest Research Institute (SwRI)
- Online Access: https://rosap.ntl.bts.gov/view/dot/35836
- Data Description: CV data from onboard units and emulated CV data based on real-world vehicle trajectories was utilized to demonstrate the potential use of such data in supporting traffic management centers.

- Study Summary: This project investigated the utilization of data from CV technologies in support of SunGuide® Traffic Management Center (TMC) operations. As part of this project, the measures of travel time, speed, and acceleration distributions along a roadway section along the I-4 in Central Florida were calculated. The analysis of the CV data revealed the importance of data preprocessing and cleaning due to the existence of erroneous data.

3.3 Development and Testing of Optimized Autonomous and Connected Vehicle Trajectories at Signalized Intersections

- Year: 2017
- Country/Agency: University of Florida Transportation Institute
- Online Access: https://rosap.ntl.bts.gov/view/dot/35087
- Data Description: Autonomous and CV trajectories were simulated using MATLAB for a total of 3,000 scenarios of varying demand levels, communication ranges, automated vehicle percentage, and saturation headways.
- Study Summary: The main objective of this project was to enhance and expand a previously developed optimization algorithm, and assemble, produce, and test the necessary software and hardware for enhancing traffic signal control operations simultaneously with vehicle trajectories, when the traffic stream consisted of connected vehicles, autonomous vehicles, and conventional vehicles (i.e., those with no operating connectivity or automation). The research indicated that the algorithm was capable of providing optimal vehicle trajectories and reducing vehicle delays at intersections.

3.4 Integrated Freeway/Arterial Active Traffic Management

- Year: 2017
- Country/Agency: University of Central Florida
- Online Access: https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/research/reports/fdot-bdv24-977-22-rpt.pdf?sfvrsn=58aa6242_2
- Data Description: High-resolution Global Positioning System (GPS) trajectories were collected in the field by several volunteer drivers when they drove along the whole or part of the corridors (I-4 corridor in Downtown Orlando and SR-417 corridor in East Orlando) by smart phone GPS tracking applications.
- Study Summary: This project aimed at developing a decision support system (DSS) for Integrated Active Traffic Management (IATM) for freeways/expressways as well as arterials/collectors. In part, the study analyzed travel time data from infrastructure-based Bluetooth Detection Systems (BDS) as well as probe data set provided by a private travel time data vendor, HERE. These data were compared to the vehicle trajectories generated as described above. Based on the analysis, it was recommended that BDS data can be used for projects on arterials, while HERE data can be used for urban collectors.

4.0 National and International Literature Review

This section summarizes information on how various agencies and researchers, nationally and internationally, are utilizing the vehicle trajectory data. The literature review is organized in no particular order.

4.1 Application of Travel Time Data and Statistics to Travel Time Reliability Analyses

- Year: Ongoing
- Country/Agency: Federal Highway Administration (FHWA) Office of Operations
- Online Access: Not published yet
- Data Description: The study is utilizing two sets of data from 2018 along a 4.7-mile-long arterial roadway with major interchanges in the State of Maryland. First dataset is the raw vehicle trajectory data provided by INRIX, while the second dataset is the NPMRDS data made available by FHWA through the Regional Integrated Transportation Information System (RITIS).
- Study Summary: The purpose of the study is to develop and compare reliability metrics using the two datasets – raw vehicle trajectory and NPMRDS – as well as conduct a statistical comparison of the two datasets. The study is currently underway and interim results have not been made available.

4.2 Visual Exploration of Utah Trajectory Data and their Applications in Transportation

- Year: 2020
- Country/Agency: University of Utah
- Online Access: https://nitc.trec.pdx.edu/research/project/1264/Visual_Exploration_of_Utah_Trajectory_Data_and_their_Applications_in_Transportation
- Data Description: Detailed GPS trajectory data in Utah from one of the leading GPS data providers was acquired for this project. This data which covered one month of Utah trajectory data, included detailed information about 2.5 million trips that took place in September 2018 (i.e., 130 million recorded locations taking 12 GB of space).
- Study Summary: Using the data acquired from the data provider, the study conducted analysis to help transportation agencies understand the tremendous value of this data source. First, the study demonstrated the computationally intense data processing required to analyze the raw data from the travel time data vendors. Second, the study compared the trajectory data with ground-truth traffic data from detectors to develop a capture rate of the trajectory data. Third, the study developed several interactive animations and visualizations to facilitate understanding of the trajectory data.

4.3 Advanced Vehicle Miles Traveled Estimation Methods for Non-Federal Aid System Roadways Using GPS Vehicle Trajectory Data and Statistical Power Analysis

- Year: 2019
- Country/Agency: University of Maryland
- Online Access: https://journals.sagepub.com/doi/abs/10.1177/0361198119850790?journalCode=trra
- Data Description: Vehicle trajectory data for this study was provided by INRIX for the months of February, June, July and October of 2015. The data, which covers roadway segments for the entire State of Maryland, contains around 20 million trips with over 1.3 billion waypoints.
- Study Summary: The purpose of the study was to develop a methodology to estimate vehicle miles traveled (VMT) on local roads and analyze the feasibility of applying these methods to actual data. The procedure developed by this study used vehicle trajectory data and an all-street road network. Additionally, the study determined the minimum required vehicle trajectory data sample size to generate reliable VMT results. The major challenge identified was that the vehicle trajectory dataset did not match the roadway network perfectly, which resulted in loss of accuracy. The key finding is that it is feasible to use the vehicle trajectory data to estimate VMT on non-Federal Aid System roadways with minimal additional cost requirements.

4.4 Estimation of Queue Lengths, Probe Vehicle Penetration Rates, and Traffic Volumes at Signalized Intersections using Probe Vehicle Trajectories

- Year: 2019
- Country/Agency: University of Michigan
- Online Access: https://journals.sagepub.com/doi/abs/10.1177/0361198119856340?journalCode=trra
- Data Description: Field vehicle trajectory data was obtained from an area in Suzhou, Jiangsu Province, China, which was covered by Didi Chuxing's e-hailing services (input data). The trajectory data contain timestamp, longitude, latitude, speed, etc. on the weekdays of May 8-28, 2018. The penetration rate usually ranged from 5% to 15%. Additionally, most of the intersections in this area were covered by the camera-based automatic vehicle identification systems (ground truth).
- Study Summary: The purpose of the study was to estimate queue lengths, probe vehicle penetration rates, and traffic volumes at signalized intersections using vehicle trajectory data. The study estimated the penetration rate of the probe vehicles from the distribution of their stopping positions at the intersections (used Bayes' theorem). Next, by scaling up the number of probe vehicles in the queues and in the traffic according to the estimated penetration rate, the total queue length and the total traffic volume were generated. The test results have shown that the proposed method is accurate enough for real world applications.

Some of the major challenges identified for the proposed methodology are the study is based on the assumption that the probe vehicles are homogeneously mixed with the regular vehicles; and, the model cannot deal with the non-signalized intersections or the right-turn movements.

Some of the benefits of the proposed methodology are the proposed method applies to both under-saturation and over-saturation scenarios; and, it works even when the penetration rate of the probe vehicles is very low.

4.5 NCHRP Report 868: Cell Phone Location Data for Travel Behavior Analysis

- Year: 2018
- Country/Agency: Cambridge Systematics / Massachusetts Institute of Technology
- Online Access: http://www.trb.org/Main/Blurbs/177847.aspx
- Data Description: The data used for this study was from a case study conducted in Boston which analyzed the cell phone call detail records (CDRs). A CDR is a record produced by a cell phone that documents the details of an incoming or outgoing call, an incoming or outgoing text message, or a connection to an app, web browser, or e-mail database. CDR records contain only metadata (not the actual data being transferred), thus making CDRs ideal for use in anonymized data analytics.
- Study Summary: The objectives of this research were to (i) evaluate the extent to which cell phone data accurately reflect daily travel and (ii) develop guidelines on how to best use these data to understand and model travel behavior. Because the cell phone data was a new and emerging dataset, this study discussed in detail the data's strengths and weaknesses and how the data could be used for planning projects. Next, the study presented an in-depth discussion of how the CDR data could be analyzed to extract vehicle trajectories and the procedures that could be used to apply these data to primary issues affecting travel modeling. The study included a different case study in Boston which compared the results from CDR data to the results from household travel surveys, and the Boston regional travel demand model. The report provided guidelines for practitioners, summarizing key administrative, data-related, and modeling considerations about the potential uses of cell phone data and applications by planning and modeling practitioners.

4.6 Analyzing Travelers' Response to Different Active Traffic Management (ATM) Technologies

- Year: 2018
- Country/Agency: Maryland Transportation Institute (MTI)
- Online Access: https://www.roads.maryland.gov/OPR_Research/MD-18_SHA-UM-4-40_ATM_Report.pdf

- Data Description: The study used data collected in 2015, including hourly traffic counts, corridor-level travel times aggregated in 15-minute intervals, individual vehicle trajectories, and energy consumption at the trip-level.

- Study Summary: The purpose of the study was to analyze travelers' response to different Active Traffic Management (ATM) technologies. The study developed an integrated travel behavior and dynamic traffic assignment modeling tool and adapted the tool for real-time and dynamic analysis of active traffic management (ATM) strategies. The model was applied to evaluate several proposed ATM strategies on the I-270 corridor in Maryland. Several performance measures were developed to assess the effectiveness of each ATM strategy and evaluate the combined effect.

4.7 Learning to Route with Sparse Trajectory Sets

- Year: 2018

- Country/Agency: Denmark

- Online Access: https://arxiv.org/pdf/1802.07980.pdf

- Data Description: Trajectory data were generated from passenger vehicles along two road networks, N1 and N2 in Denmark. The GPS trajectories consisted of more than 180 million GPS records that were collected by 183 vehicles (one GPS record per second) in 2007 and 2008. Additionally, 100 million GPS records were collected by 10,864 taxis in August 2014.

- Study Summary: The purpose of the study was to develop a learn-to-route, a comprehensive trajectory-based routing solution. The study tested the proposed method on both GPS datasets described above. The research constructed a graph-like structure from trajectories as the routing infrastructure. The research also enabled trajectory-based routing given an arbitrary (source, destination) pair.

4.8 Citywide Traffic Volume Estimation Using Trajectory Data

- Year: 2016

- Country/Agency: China

- Online Access: https://www.researchgate.net/publication/309445662_Citywide_Traffic_Volume_Estimation_Using_Trajectory_Data

- Data Description: GPS trajectory dataset from 33,000 Beijing taxis and volume ground truth data were obtained from 4,980 video clips. The road network covered a 40X50 km (2,000 square kilometers) area.

- Study Summary: The purpose of the study was to develop a hybrid framework that integrated both state-of-art machine learning techniques and well-established traffic flow theory to estimate citywide traffic volume from vehicle trajectory datasets. Traffic Volume Estimation (TVE) achieved citywide traffic volume estimation using data from GPS trajectories, road networks, point of interest (POI) information as well as weather conditions, rather than relying on traffic data from road-based sensors.

The results demonstrated effectiveness and potential of the proposed framework in citywide traffic volume estimation. However, the cost associated with installing and maintaining road-based sensors would restrict the applicability of these approaches only to a small fraction of major road segments in the network. Additionally, only coarse-grained estimates of traffic volume could be obtained, such as region-level volume or congestion conditions.

4.9 Vehicle Routing with User-Generated Trajectory Data

- Year: 2015
- Country/Agency: Denmark
- Online Access: http://people.cs.aau.dk/~csj/Papers/Files/2015_SeikuteICMDM.pdf
- Data Description: GPS trajectory data were collected from 285 distinct drivers in Denmark who took part in a “Pay as You Speed” project. The drivers were monitored during a two-year period.
- Study Summary: The purpose of the study was to develop a routing service that would use an existing routing service while exploring the availability of historical route usage data from local drivers. Given a source and destination, the service recommended a corresponding route that was most preferred by local drivers. It used a route preference function that considered the number of distinct drivers and the number of trips associated with a route, as well as temporal aspects of the trips. The evaluation of the proposed framework showed that the use of user-generated GPS data could indeed improve the quality of a routing service.

4.10 Costs of Procuring Private Sector Data to Support WRTM

- Year: 2012
- Country/Agency: U.S. DOT Office of Operations
- Online Access: https://www.itsknowledgeresources.its.dot.gov/ITS/benecost.nsf/0/8D35B7A7943D772985257C3200691D94?OpenDocument&Query=Home
- Data Description: Vehicle trajectory data, collected by vehicles equipped with TomTom GPS devices circulating in New York City area during a two-week period, was used.
- Study Summary: The purpose of the study was to understand the use of mobile data for Weather-Responsive Traffic Management (WRTM) models. The study demonstrated that the vehicle trajectory data could be used to enhance the performance of the WRTM models. The study also reviewed five (5) public agencies which consumed vehicle trajectory data and provided costs and associated parameters of mobile data used for WRTM. The study found that the cost of procuring private sector data to support WRTM could range from $28,000 to $200,000 per year.

4.11 The Use of Cell Phone Network Data in Traffic Data Collection and Long-Haul Truck Shed (Geographic Extent) Tracking

- Year: 2012
- Country/Agency: Mid-America Transportation Center
- Online Access: https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1096&context=matcreports
- Data Description: The cell phone data was provided by AirSage, Inc. The accuracy of location estimation at the time of research was 50-300 meters. The data was provided on a 30-second basis. The cell phone location data were mapped out in a freight analysis network using a geographic information system (GIS) to plot the trajectories of the cell phones in the transportation network.
- Study Summary: The purpose of the study was to analyze the potential of cell phone data in freight truck data collection and to determine the geographic extent of long-haul trucks. In this study, cell phones leaving the test logistics distribution center were tracked and classified based on the developed tracking algorithms. The results showed that the proposed tracking algorithms could identify a similar percentage of freight truck data from the test facility compared with manual counts. The use of cell phone tracking technology could assist in updating past traffic data and reduce the frequency of exhaustive data collection efforts. However, it was also identified that a complete freight GIS analysis network around the study area would be needed before processing the study to understand the likely truck destinations.

4.12 Traffic Flow Estimation Models Using Cellular Phone Data

- Year: 2012
- Country/Agency: Spain
- Online Access: https://www.researchgate.net/publication/260543536_Traffic_Flow_Estimation_Models_Using_Cellular_Phone_Data
- Data Description: Cellular phone location data was used in the study.
- Study Summary: The purpose of the study was to develop models to estimate traffic flows using cell phone data. The study used the motion of phones while being involved in calls as an easily accessible, fast, and low-cost option to derive volume data. The study compared the results from cellular phone data to volume measurements collected by detectors and found that the results are comparable. The study summarized that utilizing existing cellular data to capture traffic volume had a major advantage compared with other solutions, since it avoided new and expensive hardware installations of sensors, with a large number of cellular phones acting as probes.

  However, one significant challenge to the study was that the cellular phone activity strongly depended on time. The number of calls was significantly high in the period from 8 a.m. to 9 p.m. This pattern could result in erroneous results of traffic volumes for the beginning of the morning peak hours between 7 a.m. and 8 a.m.

4.13 Real-Time Urban Monitoring Using Cell Phones: A Case Study in Rome

- Year: 2011
- Country/Agency: TILab, Telecom Italia, and Massachusetts Institute of Technology
- Online Access: https://dspace.mit.edu/bitstream/handle/1721.1/101712/Ratti_Real-time%20urban.pdf?sequence=1&isAllowed=y
- Data Description: Telecom Italia provided anonymous mobile cellular data. In addition, instantaneous positions of buses and taxis were gathered to provide information about urban mobility in real time, ranging from traffic conditions to the movements of pedestrians throughout the city. The taxis carried GPS devices and reported each vehicle's location to a server in real time using a radio transmission.
- Study Summary: This study described a real-time urban monitoring system developed in Rome. It marked the unprecedented monitoring of a large urban area, in real time using a variety of sensing systems. The acquired data could be analyzed to evaluate the usability of the data for urban-planning purposes and tourist management, etc.

4.14 Next Generation Simulation (NGSIM) Vehicle Trajectories and Supporting Data

- Year: 2007
- Country/Agency: FHWA
- Online Access: https://ops.fhwa.dot.gov/trafficanalysistools/ngsim.htm
- Data Description: Detailed vehicle trajectory data was gathered along southbound US 101 and Lankershim Boulevard in Los Angeles, California, eastbound I-80 in Emeryville, California and Peachtree Street in Atlanta, Georgia. This data was collected through a network of synchronized digital video cameras.
- Study Summary: The goal of the project was to develop a core of open behavioral algorithms in support of traffic simulation. NGSIM data can be used for the research, development, and validation of behavioral algorithms and for use by the simulation community. The NGSIM data sets, algorithms, and reports are freely available for download at the U.S. DOT Intelligent Transportation Systems (ITS) Public Data Hub.

5.0 Questionnaire/Survey

A questionnaire was developed to survey relevant stakeholders – FDOT staff, and regional and local practitioners – to assess current use and potential applications of vehicle trajectory data.

The survey respondents include staff from FDOT Central Office, Districts, Metropolitan Planning Organizations (MPOs), Transportation Planning Agencies (TPAs), counties and cities throughout Florida. A vast majority (75%) of the respondents indicate that their agencies use travel time data such as data from loop detectors and vehicle probes. Majority (75%) of the respondents have not conducted any studies involving vehicle trajectory data nor contacted travel time data vendors for such information. More than a third (35%) of the respondents state that they have been working with vehicle trajectory data. Almost all the agencies expressed an interest in either using the vehicle trajectory data or knowing more about the pros and cons of the data.

Researchers at Florida universities were also surveyed and based on their responses, vehicle trajectory data is being used for the following research projects:

- Develop optimal trajectories for Connected and Automated Vehicles (CAVs), and compare actual to optimal/recommended trajectories,
- Evaluate car-following and lane-changing models ,
- AVIAN project to develop and test the necessary software and hardware for enhancing traffic signal control operations simultaneously with vehicle trajectories, when the traffic stream consists of connected vehicles, autonomous vehicles, as well as conventional vehicles,
- Assess freeway and arterial measures as part of multiple projects,
- Evaluate and assess vehicle conflicts, and
- Develop microscopic measures to estimate freeway mobility and safety performance as well as supplement other sensing technologies to estimate arterial performance.

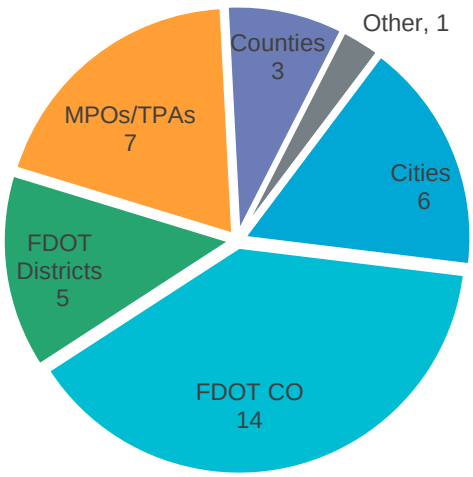
Additionally, some of the key observations from the survey are:

- Survey respondents have used vehicle trajectory data for the following applications:
  - In SERPM and STOPS modeling efforts,
  - To gather Origin-Destination (OD) data for determining which signals should be coordinated,
  - To evaluate new corridor and determine existing travel patterns, and
  - In an analysis to justify a toll plaza upgrade.

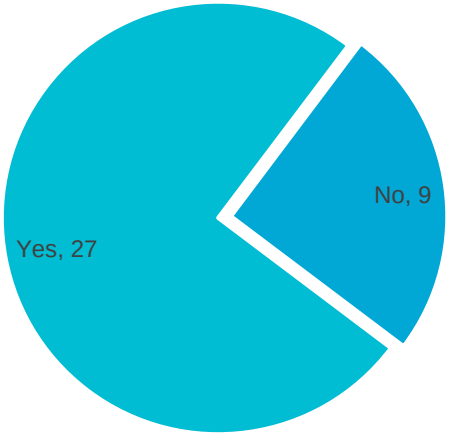
- Survey respondents indicated that the vehicle trajectory data could be used for the following applications in the future:
  - Transportation Systems Management and Operations (TSM&O) projects such as ramp metering, Advanced Traffic Management System (ATMS),
  - Mine the data from automated and connected vehicles for analyze detailed travel flow,
  - Model calibration, analysis of vehicle flows, hurricane evacuation,
  - Origin-Destination analysis,
  - Validate and calibrate upcoming SERPM 9 Activity Based Model,
  - Analyze the impact of new development and the impact of SunRail,
  - Identify near misses crashes at intersections, allow for more up to date data for signal timing and traffic volumes, and
  - For more accurate short-term modeling and tracking the trends.
- Survey respondents indicated the following for vehicle trajectory data acquisition:
  - Data availability, analysis and funds will determine "when" the data will be acquired, and
  - Need to understand the allowable data acquisition contractual method by FDOT.

The following charts summarize the survey results. Detailed survey results are presented in **Appendix A**.

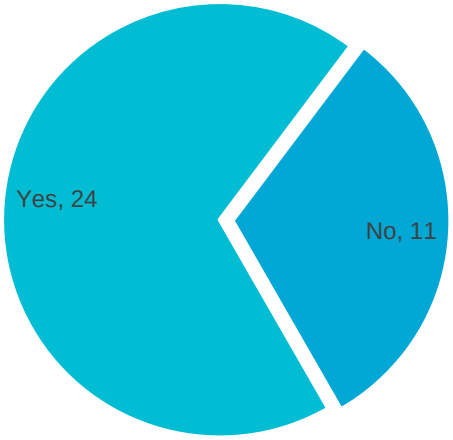
1. Please identify the organization where you are employed.



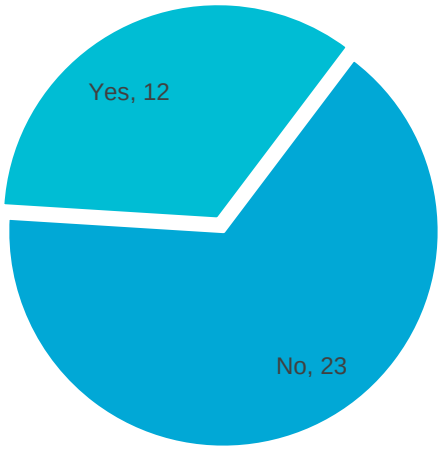
2. Do you or your agency deal with travel time data in any form, such as data from loop detectors, vehicle probes such as the data provided by HERE, or BlueToad data?



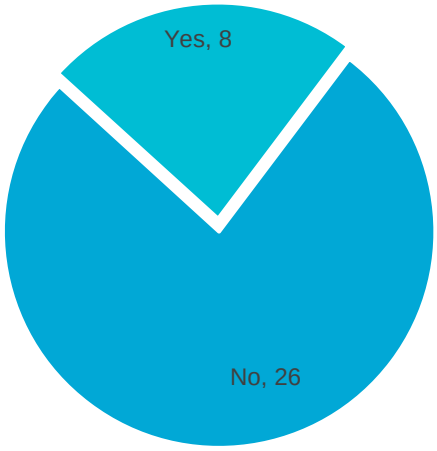
3. Have you ever used travel time data in studies?



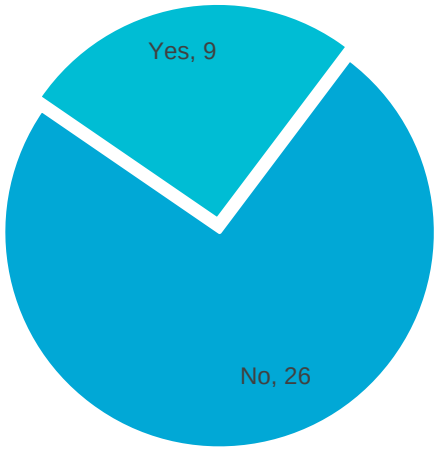
4. Do you or your agency deal with vehicle trajectory data?



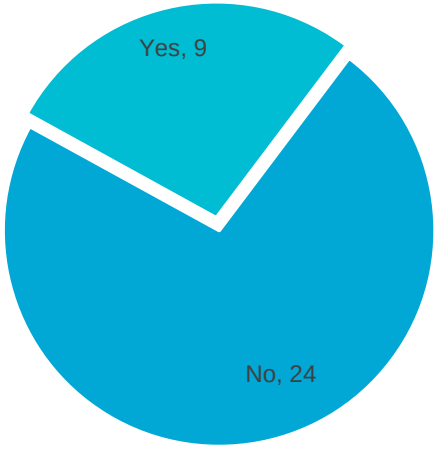
5. Have you conducted any studies using vehicle trajectory data? If so, describe the studies.



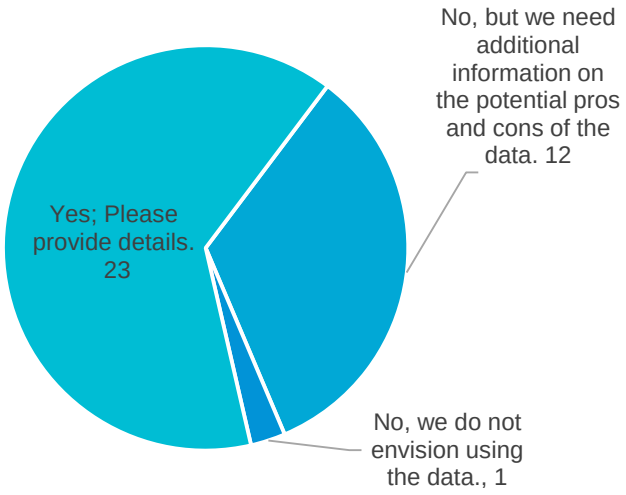
6. Have you contacted any vendors for vehicle trajectory data to gather information?



7. Have you collaborated or are you planning a collaboration with any agency/university in Florida or elsewhere to explore the use of vehicle trajectory data?



8. Do you or your agency envision a need for using vehicle trajectory data?



6.0 Outreach to Travel Time Data Vendors

In addition to the literature review and the survey, a direct outreach to the travel time vendors was also conducted to understand the latest offerings in the field of vehicle trajectory data. The research team reached out to several travel time data vendors – HERE, INRIX, Streetlight, Waze and Waycare. The following are the main observations from the travel time data vendor discussions:

- Travel time data Vendors acquire vehicle trajectory data by partnering with third party companies and postprocess this data to clean up and conduct a quality analysis.
- Due to privacy concerns, the travel time data vendors indicated that they do not anticipate the raw vehicle trajectory data would be made available as a product for sale.
- Broadly, vehicle trajectory data can be categorized into two groups:
  - Discrete data: This type of data is gathered from applications on mobile devices when those applications are in use. As such, this data is discontinuous in nature and provides location and speed information at discrete time points during the day.
  - Continuous data: This type of data is generally gathered from GPS devices and sensor data from vehicles which are always turned on. As such, this data is continuous in nature and provides location and speed information while tracking the vehicles as they travel the roadway network.
- Currently, the travel time data vendors have developed a variety of products – such as origin-destination data, volume estimation, etc. – using the raw vehicle trajectory data and have been marketing them to agencies. Specifically, through I-95 Corridor Coalition, a travel time data vendor has made the trajectory data available to several agencies. Massachusetts DOT is utilizing this data for the following three applications:
  - Origin Destination analysis to identify the travelers' origins and destinations,
  - Route analysis to identify the routes taken by travelers, and
  - Segment analysis to conduct before and after analysis.

7.0 Summary and Next Steps

This project provides a synthesis on vehicle trajectory data that is available statewide, in the districts, and locally as well as nationally. Specifically, the project team (a) reviewed studies and research conducted in Florida by FDOT, other agencies, and universities focusing on the vehicle trajectory data and its usage; (b) reviewed studies and research conducted nationally and internationally, including how various agencies and researchers are utilizing the vehicle trajectory data; (c) surveyed relevant stakeholders in Florida's agencies to assess the current use and potential applications of vehicle trajectory data; and, (d) contacted private travel time data vendors of vehicle probe data to determine their current and future expansion into providing vehicle trajectory data.

This section summarizes the findings from this project, identifies the potential applications of vehicle trajectory data for FDOT and provides recommendations for the next phase of this research project.

The significant findings from this study are:

- Extensive studies have been conducted nationally and internationally to explore the uses of vehicle trajectory data,
- Universities in Florida in partnership with FDOT have also been studying the vehicle trajectory data,
- Travel time data vendors have begun offering products to agencies using the vehicle trajectory data.,
- The literature review identified that some agencies (such as Massachusetts DOT) are beginning to use the vehicle trajectory data to address their business needs, and
- Based on the research findings, the use cases can potentially be applied by agencies as a practical application. Some of the applications are:
  - Analyzing traffic behavior and travel patterns, estimating origin-destination (OD) matrices,
  - Predicting travel time, analyzing route choice decisions, and
  - Estimating vehicle miles traveled and traffic emissions.

7.1 Need for Vehicle Trajectory Data

FDOT currently has a strong data collection program for highway, traffic, travel time, multimodal, and freight and passenger data information. Vehicle trajectory data can be used to supplement the existing data collection techniques and helps FDOT in the following aspects:

- Support and bolster reporting of performance measures. Vehicle trajectory data can be used to not only support the existing performance reporting, but also enhance it by developing new performance measures, granular reporting, mobility performance monitoring during emergency events, etc.
- Provide a historical perspective. Vehicle trajectory data is being made available by vendors starting in 2018, thus providing a capability to track performance monitoring over time.
- Analyze the economic drivers. Vehicle trajectory data can be used to supplement the capabilities of travel demand model by analyzing the economic drivers of the state such as tourist activity and freight movement.

7.2 Potential Applications of the Vehicle Trajectory Data for FDOT

FDOT can use vehicle trajectory data for a variety of applications. Some of the examples are listed below.

- Development of trip-based mobility performance measures
  - FDOT, as well as several other agencies, have been utilizing probe data to calculate facility-based mobility measures. The current link-based travel time measuring techniques consider travel times

only as a summation of travel times on individual links at a single time. Utilizing vehicle trajectory data, route-based or trip-based performance measures can be developed by considering the dynamic path congestion over the duration of trips during specific periods, thereby providing a better estimation of travel times for specific trips.

- Validation and enhancement of travel demand model
  - Using location based services (LBS) data, it is possible to obtain the trip and tour flow information and this information can be compared against the Florida Statewide model to obtain a picture of travel flow within the state. Information from LBS data can also be used to provide a picture of tourist travel in the state and allow for updating the statewide model to include a tourism component in the statewide model.
  - Another application of LBS data is to use it with the statewide travel demand model to understand traffic flow along corridors that traverse multiple districts. A combination of LBS and statewide model data will help provide an understanding of travel along corridors and true origin/destination of trips that traverse these corridors along with an understanding of the travel behavior of the people who use these corridors.
  - A third application of LBS data is to use it for urban evacuation. LBS data can be used to develop hourly profiles at different geographies, and coupled with information from regional travel demand models on mode and destination choice, can help redirect resources in a more efficient manner during emergencies.
- Estimation of vehicle miles traveled
  - FDOT has a need for estimating vehicle miles traveled on local roads to conduct safety analysis as well as to meet the federal reporting requirements. However, utilizing the traditional data collection techniques to estimate vehicle miles traveled on local roads would be a daunting challenge. FDOT can develop methodologies and procedures to analyze the vehicle trajectory data and estimate vehicle miles traveled on non-Federal Aid System roadways. These techniques could be used to update VMT estimates with minimum additional cost requirements.
- Development and validation of behavioral algorithms used by the traffic simulation models
  - Based on current practices, traffic simulation models are calibrated and validated using macroscopic measures such as 15-minute averages of traffic counts or average point-to-point travel times. For an emerging number of applications, including connected vehicles, the realism of simulated driver dynamics at the second-by-second or sub-second trajectory level plays an important role. Utilizing the vehicle trajectory data, FDOT can model the benefits of safety and mobility of emerging transportation technologies, such as connected vehicles, by realistically capturing how drivers accelerate, decelerate, select speeds and change lanes.
- Estimation of queue lengths and traffic volumes at signalized intersections
- Analysis of travelers' response to different active traffic management (ATM) technologies
- Development of weather-responsive traffic management (WRTM)

7.3 Next steps and Recommendations

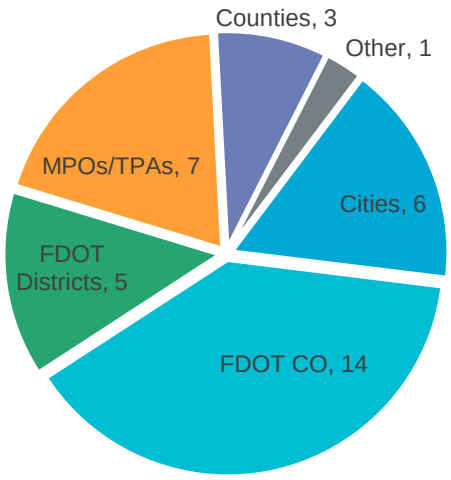
As noted earlier, a lot of research continues to be done using the vehicle trajectory data in academia and practical applications are being offered by travel time data vendors.

The project team makes the following recommendations for the next phase of this research:

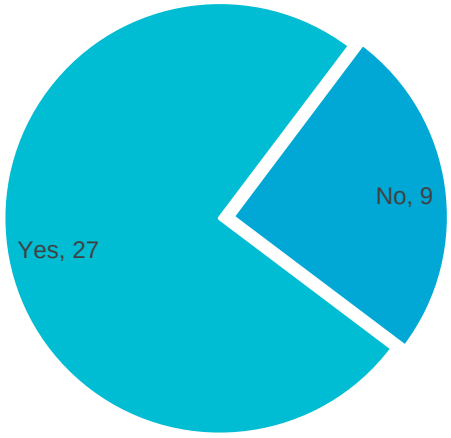
- FDOT Advisory Panel selects 1-2 potential applications of the vehicle trajectory data to be tested using sample data.
    - Of the potential applications listed in the previous section, the project team suggests the following two applications to be considered by the Advisory Panel:
        - » Development of trip-based mobility performance measures – Specifically, utilize the vehicle trajectory data to develop trip-based performance measures such as delay, travel time, and planning time index.
        - » Validation and enhancement of travel demand model – Utilize the vehicle trajectory data to provide a picture of tourist travel in the state and identify steps to include a tourism component in the statewide model.
- Reach out to travel time data vendors for procuring a sample data on a limited geographic extent.
    - The project team recommends reaching out to data vendors such as HERE, INRIX, Streetlight, and other LBS data providers as they are being currently utilized by FDOT.
- If procuring the sample data is not feasible, explore if virtual trajectory data can be generated using modeling techniques.
- Utilize the sample data and implement the selected applications.

Appendix A. Detailed Survey Results

1. **Please identify the Organization where you are employed.**



2. **Do you or your agency deal with travel time data in any form, such as data from loop detectors, vehicle probes such as the data provided by HERE, or BlueToad data?**



If you answered NO, please provide any comments:

- Yes, I would like the data for our critical intersections.

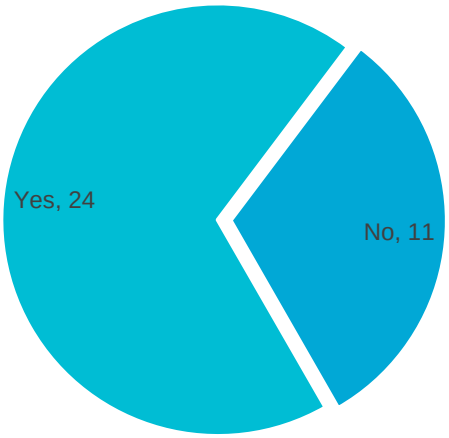
If you answered YES, please provide any comments:

- Yes, the Transportation Data and Analytics Office and FDOT Districts are likely testing, piloting and using vehicle probe data.

- The Modeling Office has conducted several studies into these data sources. We've also used it to assist with Model calibration/validation.
- Our Traffic Operations Department have acquired this data.
- We have collected O&D data from Bluetooth and Street light data platforms for our planning studies.
- CM Reports - Bluetooth - Blue Argus
- We use the data to assess annual system performance and mobility, we use all forms of data within our model development and specific project evaluations (this includes loop detectors, HERE travel time for VISSIM calibration and BlueToad or Origin/Destination data from vendor.
- BlueToad (BT) and Microwave Vehicle Detector Systems (MVDS)
- Yes, we have Miovision and have collected Bluetooth data for corridor studies. we also purchased a streetlight license for 3 months last year.
- We have used the BlueToad data for some of our PD&E and feasibility studies.
- Vehicle probes, HERE data, etc.
- Limited use for origin destination studies related to traffic diversion or urban parking demand.
- Our county utilizes various devices that provide traffic reporting.
- Traffic design collects the data. Transportation planning has not used it yet.
- For analysis of the speed of the vehicles within roadway segments and overall performance of corridors.
- Yes, we have used INRIX, HERE, Streetlight.
- Microwave detectors. Bluetooth readers, HERE.
- We have Iteris Velocity installed at approximately eighty signalized intersections. It is used to help develop coordination timing and troubleshooting signal timing complaints.
- BlueToad, HERE, PTMS sites
- We use data from all the example sources given.
- Microwave Vehicle Detection System, HERE, RITIS, and Bluetooth readers
- Yes, all that is mentioned
- BlueToad data, HERE data.
- We use travel time data in our SERPM and STOPS modeling efforts

- Travel time alerts are used to find crashes

3. Have you ever used travel time data in studies?



If you answered NO, please provide any comments:

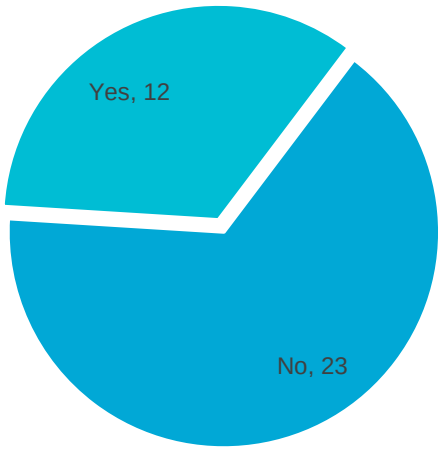
- We will be applying this to before and after for retiming in January

If you answered YES, please provide any comments:

- Statewide Bluetooth study (Freight)
- We used travel time data when we analyzed the congestion in I-4 at the D1 segment/area.
- Corridor vision studies and feasibility studies
- CM Report and AM Report
- Travel time data is used to calibrate micro-simulation models.
- Corridor performance measures and freight tracking.
- Complete streets corridor studies, signal retiming studies & bike / ped safety action plan
- Most corridor studies and system performance measures
- Was used in a TSMO Master Plan
- Long range planning when employed by MPO
- Travel time, rerouting behaviors, parking demand.

- I have used the data for the travel time and delay studies that the county does. Also, we have seen it used in area studies by the county and FDOT.
- Used travel time in comparison to calculated level-of-service to verify operation.
- Mostly for travel patterns and O/D information.
- SW 8 Street ASCT (before/after evaluation) 95 Express Palmetto Express
- FDOT consultant is using Iteris Velocity Bluetooth data to assist them in developing signal timings for a current project.
- We use travel time data to evaluate arterial operation.
- Studies focused on reducing delay
- Review of congestion locations on the Turnpike System. Coordination with TSM&O Task Work Order efforts.
- We use travel time data in our SERPM and STOPS modeling efforts, hence use the data in output reports

4. Do you or your agency deal with vehicle trajectory data?



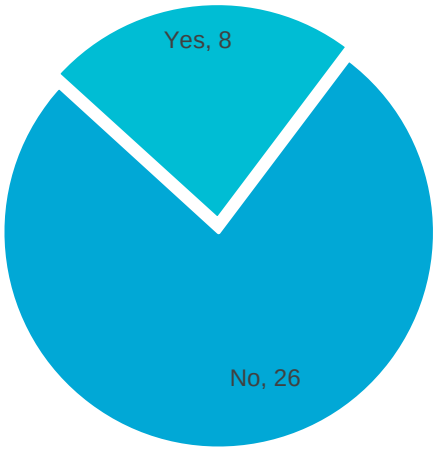
If you answered NO, please provide any comments:

- But this is why we're sending the survey out to see if there's trajectory data use out there.
- Not sure what that means, never heard the terminology or buzz word.
- I am always interested in learning more.
- We usually don't use such a specific and detailed data source, but this could be useful in the future and depending on price we may want to use this data.
- Would like to know more
- I am interested in knowing more about this.
- I am interested in how this could be used.
- Yes. We would be interested especially since many citizens claim all the traffic is cut through and we would like to see the data.
- Interested in knowing more.
- Interested in knowing more about it.
- My office does not but would like to learn more.

If you answered YES, please provide any comments:

- We use the NPMRDS for several studies. Also, we've looked into acquiring trajectory data from private sources but a statewide application is prohibitively expensive.
- We use this data in transportation planning.
- Assessment of congestion at systemwide level and to identify hot spot areas where short term improvements are needed, identify the origin-destination for demand forecast model calibration
- Allows us to determine problems by setting alarms. When traffic is outside the norm, the RTMC investigates and provides solutions. Do it through RITIS.
- Yes, we purchased AirSage in 2014 and 2015 and most recently purchased streetlight.
- Police and enforcement
- Traffic design collects the data. Transportation planning has not used it yet.
- We use vehicle trajectory in our SERPM and STOPS modeling efforts. and for our future land use and SMART plan integration.
- OD for determining which signals should be coordinated

5. Have you conducted any studies using vehicle trajectory data? If so, describe the studies.



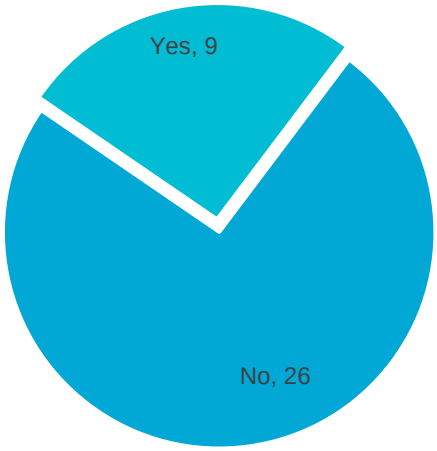
If you answered NO, please provide any comments:

- Traffic Operations may be using vehicle trajectory data for ped safe and as part of the active traffic management systems. Currently planning is not using.

If you answered YES, please provide any comments:

- Yes, we used this data in our planning studies.
- It has also been used on new corridor evaluations to determine existing travel patterns.
- We use HERE data to identify congestion hot spots.
- Used for freight study.
- Summarized O/D and travel time for corridor studies and travel time for performance based planning prioritization.
- In order to justify a toll plaza upgrade, we used vehicle trajectory data.
- Retiming

6. Have you contacted any vendors for vehicle trajectory data to gather information?



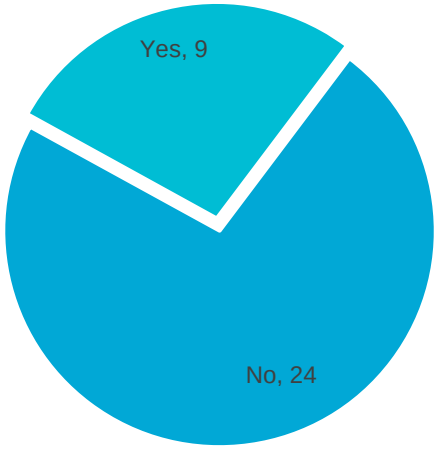
If you answered NO, please provide any comments:

- None

If you answered YES, please provide any comments:

- Held discussions with Streetlight, Moovit, INRIX, ATRI, and AirSage.
- Turnpike currently has a contract with Streetlight.
- INRIX approached us, but they were cost prohibitive.
- Streetlight, AirSage & other small vendors
- We utilized a Vendor to obtain the information needed in order to produce vehicle trajectories.
- Have not contracted, but did discuss options for getting origin destination data from firms.
- Looking to get vehicle trajectory data to validate and calibrate our upcoming SERPM 9 Activity Based Model
- Five years ago we contacted HERE and INRIX

7. Have you collaborated or are you planning a collaboration with any agency/university in Florida or elsewhere to explore the use of vehicle trajectory data?



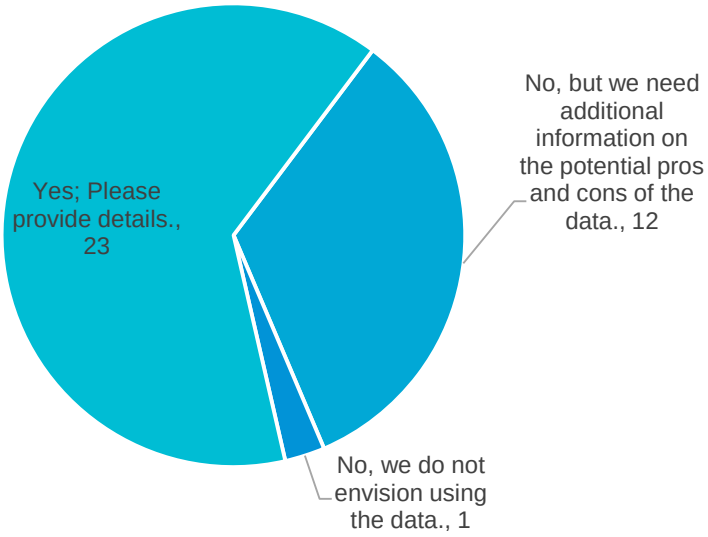
If you answered NO, please provide any comments:

- None

If you answered YES, please provide any comments:

- Working with the University of Florida on a tourist project. Using information from AirSage.
- The region's transportation planning partners are looking for a way to acquire accurate systemwide trajectory data for planning purpose.
- Working with UNF but need the funds first.
- With local government partners
- UCF is conducting research on data and technology where vehicle trajectory data may be utilized.
- No current plans, but will be looking into it.
- With UF to determine crash detection, signal coordination. With UCF to determine queue length

8. Do you or your agency envision a need for using vehicle trajectory data?



If you answered NO, please provide any comments:

- I think that it could have some benefits in looking at immediate operational issues and for transportation systems management and operations (TSM&O) recommendations including ramp metering. These types of studies are not typically completed in planning; however, the data could be useful in refining and understanding travel flow. As the world becomes more automated and connected mining trajectory data could be useful.
- Would not be a bad thing to plan on using.

If you answered YES, please provide any comments:

- Yes, the vision is there. It's the data availability, analysis and funds that will determine "when."
- Supplemental to other data sources, data fusion, model calibration, vehicle flows, hurricane evacuation etc.
- We desperately needing the data and need to know the allowable data acquisition contractual method.
- For more accurate short-term modeling and tracking the trends. a need for travel time reliability for non-NHS roadways in performance-based planning prioritization process
- We need to be more aware of where vehicles are going for some of our studies.
- As the City moves into Vision One, this info is needed
- Traffic impacts related to redevelopment efforts in the city

- Vehicle trajectory data could be used to identify near misses at intersections, allow for more up to date data for signal timing and traffic volumes.
- The data could be very useful in the future to indicate the impact of new development and the impact of SunRail.
- I really do not know; we have a blue tooth system in place. Traffic design collects the data. Transportation planning has not used it yet.
- Once the ATMS project is constructed, we will see a need for this data.
- For origin and destination data in support of upcoming projects.
- Unsure
- Can you please provide more background information about vehicle trajectory data so we can make an informed decision? This type of data may be useful for Connected Vehicle activities that we're considering.
- Looking to get vehicle trajectory data to validate and calibrate our upcoming SERPM 9 Activity Based Model
- We will continue to connect it to agency priorities.