Statistical Validation of Speeds and Travel Times Provided by a Data Service Vendor

William H. Schneider IV
Shawn Turner
Jennifer Roth
John Wikander

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16. Abstract The provision of real-time traffic and travel time information is becoming increasingly important in urban areas as well as in freight-significant intercity corridors. However, the high cost to install and maintain roadway-based traffic sensors has prevented widespread availability of real-time traffic information in these areas. A market for real-time traffic information is emerging in the United States and several private companies are gathering and distributing traffic information independently of public sector transportation agencies. In this study floating car, probe data, and newly developed Bluetooth device matching methods are developed and used to collect travel times and speeds for 103 centerline miles located in Dayton, Ohio. This reference data are then statistically evaluated with a data service vendor's reported travel times and speeds for 36 travel time segments.

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By
William H. Schneider IV, Ph.D., P.E.,
Jennifer Roth
Department of Civil Engineering
The University of Akron

And

Shawn Turner P.E.,
John Wikander
Texas Transportation Institute

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Federal Highway Administration

DISCLAIMER

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LIST OF ACRONYMS

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
AATT	Applications of Advanced Technology in Transportation
ABJ20	TRB Statewide Transportation Data and Information Systems Committee
ADA70	TRB Access Management Committee
ADT	Average Daily Traffic
ANN	Artificial Neural Network
APBP	Association of Pedestrian and Bicycle Professionals
ASTM	American Society for Testing Materials
ATIS	Advanced Traveler Information System
ATR	Automatic Traffic Recorder
AVL	Automatic Vehicle Location
CCIT	California Center for Innovative Transportation
Co-PI	Co-Principal Investigator
COV	Coefficient of Variation
CPI	Council of Principal Investigators
DMI	Distance Measuring Instrument
DOT	Department of Transportation
DPS	Department of Public Safety
FHWA	Federal Highway Administration
GIS	Geographic Information Systems
GPS	Global Positioning System

LIST OF ACRONYMS (continued)

HOV	High Occupancy Vehicles
HSM	Highway Safety Manual
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
MPO	Metropolitan Planning Organization
NATMEC	North American Traffic Monitoring Exhibition and Conference
NCHRP	National Cooperative Highway Research Program
ODOT	Ohio Department of Transportation or Oregon Department of Transportation
PE	Professional Engineer
PI	Principal Investigator
R&D	Research and Development
RFID	Radio Frequency Identifier
SAF	Seasonal Adjustment Factor
SD	Standard Deviation
SMSC	Small to Medium-Sized Communities
SWUTC	Southwestern Region University Transportation Center
TAMUS	Texas A&M University System
TexITE	Institute of Transportation Engineers, National and Texas Section
TRB	Transportation Research Board
TTECP	Travel Time Estimation Using Cell Phones
TTI	Texas Transportation Institute
TxDOT	Texas Department of Transportation
UC-Berkeley	University of California Berkeley
VISSIM	Visual Solutions Transportation Simulation Software

LIST OF ACRONYMS (continued)

VTRC	Virginia Transportation Research Council

Customary Unit	SI Unit	Factor	SI Unit	Customary Unit	Factor
Length			Length		
inches	millimeters	25.4	millimeters	inches	0.039
inches	centimeters	2.54	centimeters	inches	0.394
feet	meters	0.305	meters	feet	3.281
yards	meters	0.914	meters	yards	1.094
miles	kilometers	1.61	kilometers	miles	0.621
Area			Area		
square inches	square millimeters	645.1	square millimeters	square inches	0.00155
square feet	square meters	0.093	square meters	square feet	10.764
square yards	square meters	0.836	square meters	square yards	1.196
acres	hectares	0.405	hectares	acres	2.471
square miles	square kilometers	2.59	square kilometers	square miles	0.386
Volume			Volume		
gallons	liters	3.785	liters	gallons	0.264
cubic feet	cubic meters	0.028	cubic meters	cubic feet	35.314
cubic yards	cubic meters	0.765	cubic meters	cubic yards	1.308
Mass			Mass		
ounces	grams	28.35	grams	ounces	0.035
pounds	kilograms	0.454	kilograms	pounds	2.205
short tons	megagrams	0.907	megagrams	short tons	1.102

CHAPTER I
INTRODUCTION

The provision of real-time traffic and travel time information is becoming increasingly important in urban areas as well as in freight-significant intercity corridors. However, the high cost to install and maintain roadway-based traffic sensors has prevented widespread availability of real-time traffic information in these areas. A market for real-time traffic information is emerging in the United States and several private companies are gathering and distributing traffic information independently of public sector transportation agencies. In fact, several of these private companies have begun marketing their traffic information to public sector agencies like state departments of transportation (DOTs).

The problem is that some private companies are still developing and/or refining their traffic monitoring technology, whether it is Global Positioning Systems (GPS), probe vehicles or cell phones methods, while at the same time trying to sell the technology as a mature product. For example, several evaluations of cell phone-based traffic monitoring in the past five years have provided poor results. Based on these findings, it is critical that the quality of private sector travel time data be adequately evaluated in fee-for-service contracts with state DOTs.

1.1 Purpose and Objectives

There are four research objectives, which must be met in order to insure that project PS-09-05 "*Statistical Validation of Speeds and Travel Times Provided by a Data Services Vendor*" will be considered a success as described in the request for proposal. These four objectives include:

- **Objective One -** Conduct a data collection GPS floating car methodology along 103 centerline miles (165.8 km) in Dayton, Ohio,
- **Objective Two -** Evaluate the accuracy of travel time data from a service provider,
- **Objective Three -** Provide recommendations for travel time data service evaluation procedures to be used in contract provisions and/or future evaluations, and
- **Objective Four -** Summarize the final results.

1.2 Benefits from this Research

The research described within this report will have both immediate as well as long-term benefits. The immediate benefit of this research project is an assurance that the travel time data service does, or does not, meet contract requirements. If the travel time data service does not meet contract requirements, then Ohio Department of Transportation (ODOT) may not be legally obligated to pay the data service provider. If the travel time data service does meet contract requirements, then ODOT will be assured that state funds have been well spent in acquiring this data service. An additional short-term benefit for ODOT will be the external review of the data. This external review ensures the accuracy of the data, strengthening the initiative's credibility with the public as well as the media. This research will allow ODOT the capability to say an external agency has reviewed and implemented quality control/quality assurance procedures on all data provided from the external vendor.

The main long-term benefit is that ODOT may save money and provide this service much sooner than otherwise possible by purchasing this real-time traffic information service from a private company instead of installing and maintaining a state-owned traffic sensor network.

The overall findings from this research will provide a long-term cost savings for ODOT whether the vendor's travel time data are accurate or inaccurate. If the data are proven accurate, ODOT will be able to use this information to provide reliable travel time information both internally and externally and will lead to a cost savings. If the research proves the data provided by the vendor are inaccurate, ODOT will no longer use this vendor or pay for services that are invalid. The potential benefit to cost ratio of this project is based predominately on three cost saving objectives:

- **Cost Savings Number One** – the potential agency cost savings through private company installation of the network over state-owned traffic sensors,
- **Cost Savings Number Two** – the potential travel time savings for the individual user, and
- **Cost Savings Number Three** – efficiently evaluate vendor's data service.

The actual benefit to cost ratio may be hard to define without the contractual numbers provided by the data vendor, but based on the three described cost savings there is potential for a higher benefit to cost ratio from this research.

1.3 Organization of this Report

This report is divided into six chapters. The first chapter is the introduction of the topic and the statement of the research objectives. The second chapter is the literature review. The literature review will provide the state-of-the-practice for the collection and analysis of speed and travel time data. The third chapter is the research methodology used with collecting the appropriate data for use in the analysis. The fourth chapter is the summary of the results from the data collection. These results will include the average speeds and travel times for the segments of the highway. Additional results include the comparison between the travel times provided by a data service provider and the ground truth results developed from the data collection. The fifth chapter of this report will provide conclusions and recommendations, which are based on the final results. The last chapter will provide suggestions on the best approach to implement the findings from this research.

CHAPTER II
LITERATURE REVIEW

2.1 Introduction

Numerous evaluations of travel time accuracy have been performed in recent years. These evaluations include a wide variety of approaches and data collection parameters to establish travel time accuracy. The most common approach, however, has been to drive one or more GPS-instrumented test vehicles along the roadway or street to be evaluated. Beyond that, many of the details vary considerably, including the headway or spacing if more than one vehicle is used, the number of road segments that should be sampled and the number of days and time periods that should be sampled.

In many evaluations, it appears that sampling parameters are based on the available evaluation budget and not necessarily statistical significance. Often, the evaluation team provides no confidence interval to reinforce the accuracy of their “ground truth” travel time. In some evaluations, the evaluators are not truly independent because they are paid by the private company providing the travel time service. A recent report from National Cooperative Highway Research Program (NCHRP) Project 70-01 provides some insight about the data quality requirements that should be included in a fee-for-service contract with the private sector, but ultimately this report does not provide many data collection and analysis details regarding how to determine whether the private contractor has met these requirements.

With the growth of the real-time traffic information market in the United States, several private companies are aggressively developing traveler information products. Several of these private companies are concerned about the consistency of evaluations and are discussing the possibility of a national or international standard protocol for travel time evaluation. Such a standard would include detailed procedures for evaluating the accuracy of travel time data services. This evaluation protocol standard could then be specified when state DOTs issue a request for proposals or when they sign fee-for-service contracts. If developed, this standard could provide a “level playing field” by which all travel time data service providers could be evaluated and compared.

2.2 Data Collection Methodology

There are two solution types to determine the true average travel time for all vehicles traversing a designated length of roadway for a fixed time period:

- **Cost-Not-An-Issue Solution -** Identify and re-identify (using license plate matching, radio frequency identifier (RFID) tags, GPS receivers, etc.) each vehicle that traverses the designated length of roadway during the fixed time period. This is commonly referred to as the "platinum standard" for ground truth travel time measurement, and

- **Feasible Near-Term Solutions -** Identify and re-identify a statistically valid sample of vehicles. This is referred to as a "gold standard" for ground truth travel time measurement. Alternatively, to use a test vehicle at frequent headways to obtain a statistically valid sample to simplify the identification and re-identification of vehicles in the traffic stream is referred to as the "silver standard" for ground truth travel time measurement.

Various approaches are used to evaluate the accuracy of estimated or predicted travel times. Tables 2.1 through 2.4 summarize these test methods for travel time accuracy evaluation.

2.2.1 Test Vehicle Techniques

The test vehicle data collection techniques, using "average car," "floating car" or "maximum car," provide one scientifically accepted form of data collection. These techniques utilize advanced test vehicle technologies such as a Distance Measuring Instrument (DMI) or GPS, resulting in highly detailed data in regards to vehicle speed over a roadway segment or an entire corridor. The test vehicle data collection technique also has a relatively low initial cost (*Travel Time Data Collection Handbook*). The data collection technique requires high storage capacity because of the GPS ability to record detailed data. Table 2.1 presents various test vehicle data collection techniques used to evaluate travel time accuracy.

Table 2.1. Test vehicle data collection techniques used to evaluate travel time accuracy.

Instrumented Test Vehicles		
Data Collection Approach	**Evaluation Application**	**Reference**
GPS-equipped test vehicles at 5 to 7 minute (or greater) headways (based on sample size formulae)	Evaluate the accuracy of travel time estimation algorithms in Portland, Oregon	Monsere, Breakstone, Bertini, Deeter, and McGill, 2006; Kothuri et al., January 2007
Test vehicles and point-based loop detectors (although the author acknowledged these are comparative data sources, not "ground truth")	Evaluate the accuracy of travel times from cell phone tracking system in Israel	Bar-Gera, November 2006 for 2007 TRB

GPS-equipped test vehicles at randomly spaced headways greater than 60 minutes	Evaluate and compare the accuracy of Inrix and Traffic.com reported travel times in 3 markets	Frost & Sullivan, September 2006
GPS-equipped test vehicles at about 5-minute headways	Develop and validate predictive travel time algorithms from point-based sensor data in Phoenix, Arizona	AZTech, December 2004
GPS-equipped test vehicles at unspecified headways	Evaluate the accuracy of unspecified travel time estimates	CCIT, UC-Berkeley PPT, Sept 2004
GPS-equipped test vehicles at about 10-minute headways	Evaluate the accuracy of bus travel times, collected by AVL	Bertini et al. 2004
GPS-equipped test vehicles or license plate matching (proposed but not actually used)	Proposed guidelines to evaluate the accuracy of advanced traveler information systems	Toppen and Wunderlich June 2003
DMI-equipped test vehicles at scheduled 3-minute headways, using chase car technique	Evaluate the accuracy of toll tag-based traffic monitoring system	Eisele et al. 2002; Eisele et al. 2001
DMI-equipped test vehicles at scheduled 3-minute headways, using chase car technique	Evaluate differences in travel time between test vehicles, toll tag-equipped vehicles, and trucks in the traffic stream.	Eisele et al. 2001
GPS-equipped probe/test vehicles with about 1-2 minute headways	Evaluate the accuracy of travel time predictions developed from GPS probe vehicles and fixed-point sensors in the ADVANCE field operational test in Chicago	ADVANCE Evaluation Reports, http://advance.dis.anl.gov/advance/
GPS-equipped test vehicles at about 15-20 minute headways (200 total runs in about one month)	Evaluate the accuracy of travel time estimation algorithms in San Antonio, Texas	TTI August 2000; Quiroga August 2000
DMI-equipped test vehicles at 3-minute headways during peak period and 12-minute headways during off-peak period	Evaluate the accuracy of travel time from a cell phone probe vehicle field test	CAPITAL-ITS Final Evaluation Report, May 1997

2.2.2 License Plate Matching Techniques

The license plate matching technique, using manual, portable computer, video with manual transcription or video with character recognition methods, has many advantages. It is able to obtain travel times from a large sample of vehicles, which is useful in understanding variability of travel times among vehicles within a specific traffic stream. The license plate matching techniques also provides a continuum of travel times during the collection period, and this technique is able to analyze short periods and the equipment is relatively portable (*Travel Time Data Collection Handbook*). Conversely, the license plate matching technique has some disadvantages, mainly due to limitations from the geographic location per collection period the limitation from the positioning of the camera/observer. Manual or computer-based methods are impractical for high-speed freeways or sections of roadways with relatively low volumes. In addition, accuracy is an issue with manual/portable computer-based methods and skilled personnel are required for operation. Table 2.2 presents license plate matching techniques used to evaluate travel time accuracy.

Table 2.2. License plate matching techniques used to evaluate travel time accuracy.

License Plate Matching		
Data Collection Approach	**Evaluation Application**	**Reference**
Manual license plate matching and toll tag matching	Evaluate the accuracy of travel time estimation algorithms in Hong Kong, China	Chan et al., November 2006 for 2007 TRB
Traditional license plate matching and toll tag matching	Evaluate the accuracy of travel time estimation algorithms in Melbourne, Australia	Li, Rose, and Sarvi, July 2006
Manual license plate matching	Evaluate the accuracy of travel time estimates from point-based sensor data in Northern Virginia	Smith and Fontaine, April 2005; Smith, Holt, and Park, January 2004

2.2.3 Other Techniques Used

Tagged vehicles evaluation, fixed-point traffic sensors, simulated traffic models, and manual measurement from a video recording are also used to evaluate travel time accuracy. These methods are used to evaluate a number of ground truth data sources. All approaches contain a number of advantages and disadvantages, which are evaluated for possible use in this study. Table 2.3 presents other techniques used to evaluate travel time accuracy.

Table 2.3. Other techniques used to evaluate travel time accuracy.

Other Approaches		
Data Collection Approach	**Evaluation Application**	**Reference**
Toll tag-equipped vehicles	Evaluate the accuracy of simulated probe vehicle samples sizes in New York area	Kuchipudi and Chien 2003

Fixed-point traffic sensors	Evaluate the accuracy of travel time from a cell phone probe vehicle field test	Smith et al. June 2003
Fixed-point traffic sensors	Evaluate the accuracy of GPS probe vehicles	Ferman et al. 2004
A calibrated simulation model (VISSIM)	Evaluate the accuracy of simulated average link speeds from a cell-phone based probe system	Fontaine et al. January 2007; Fontaine and Smith December 2004
A carefully calibrated and validated simulation model (INTEGRATION)	Evaluate the accuracy of short-term travel time predictions in Japan	Nanthawichit et al. 2003
Wide area videotape with manual point-to-point travel time measurement	Evaluate the accuracy of link travel time from a fixed-point sensor	Nihan et al., November 1995

2.2.4 Probe Vehicle Sample Sizes

Sufficient sample size is imperative for an accurate evaluation of the travel time ground truth data. In the context of the proposed research, the sample size refers to the number of runs the test vehicle must perform per given roadway within the time period(s) of interest. To reduce cost, the minimum sample size below a specified error range is ideal. The error range is based upon the true average travel time for the entire vehicle population. Traditionally, the ideal sample size is based on three parameters: the t-statistic, the coefficient of variation, and relative allowable error. Table 2.4, shown below, presents the findings or objectives achieved for various research projects conducted to test, verify or define proper sample sizes.

Table 2.4. Research of probe vehicle sample sizes.

Probe Vehicle Sample Sizes		
Research Title	**Objectives or Findings**	**Reference**
Probe Sampling Strategies for Traffic Monitoring Systems Based on Wireless Location Technology	The study reviews probe vehicle sample size requirements	Fontaine et al. January 2007
Travel Time Estimation Using Cell Phones (TTECP) for Highways and Roadways	The study reviews accuracy results of various cell-phone based probe vehicle tests and demonstrations	Wunnava et al. January 2007
Penetration Requirements for Real-Time Traffic Information from Probe Vehicles	The study concludes sample sizes required depend upon accuracy demand	Ferman et al. January 2006

An Analytical Evaluation of a Real-Time Traffic Information System Using Probe Vehicles	The study concludes 3% penetration on freeways and 5% penetration on surface streets is required	Ferman et al. 2005
Factors Affecting Minimum Number of Probes Required for Reliable Estimation of Travel Time	The study estimates travel time error for various probe sample sizes	Cetin et al. 2005
Investigation of Dynamic Probe Sample Requirements for Traffic Condition Monitoring	The study concludes sample sizes vary from 2 to 78 vehicles every 5 minutes based on various factors	Green et al. 2004
Extended Floating Car Data: Traffic Information Potential and Necessary Penetration Rates	The study concludes floating car penetration should be 2-20% of traffic volume and varies for road type	Breitenberger et al. December 2004
Probe Vehicle Population and Sample Size for Arterial Speed Estimation.	This study proposes a methodology for reducing the bias in probe vehicle reports using on stratified sampling techniques	Cheu et al. 2002
Bias in Probe-Based Arterial Link Travel Time Estimates	This study also proposes a methodology for reducing the bias in probe vehicle reports	Hellinga and Fu 2002
Dynamic Freeway Travel Time Prediction with Probe Vehicle Data	The study estimates travel time error based on probe vehicle simulation results	Chen and Chien 2001
Determining the Number of Probe Vehicles for Freeway Travel Time Estimation by Microscopic Simulation	The study estimates required probe sample sizes based on simulation results	Chen and Chien 2000
Travel Time Estimation on the San Francisco Bay Area Network using Cellular Phones as Probes	The study concludes that freeway link travel times could be estimated to within 10% of their actual value if there is at least 5% penetration of wireless devices in the traffic stream.	Ygnace et al. 2000
Assessing Expected Accuracy of Probe Vehicle Travel Time Reports	The study examines the effect of sampling bias on the accuracy of the probe vehicle travel time estimates	Hellinga and Fu 1999
The Grand Draw	The study concludes that approximately 10% probe penetration of the total vehicle population is required for accuracy	Hoogenboom 1999

Determination of Number of Probe Vehicles Required for Reliable Travel Time Measurement in Urban Network	The study concludes that approximately 5% probe penetration of the total vehicle population is required for accuracy	Srinivasan and Jovanis 1996
Probe Vehicle Sample Sizes for Real Time Information: The Houston Experience	The study concludes that probe samples between 1 and 6 vehicles per 5-minute period is required for 95% confidence level and 10% error	Turner and Holdener 1995
Vehicles as Probes	The study concludes that approximately 4% probe penetration of the total vehicle population is required for accuracy	Sanwal and Walrand 1995

2.2.5 Bluetooth Devices

One area that continues to evolve is the development of Bluetooth devices to measure travel times. The use of this new technology in published articles is much more limited than other methods for sampling data. The overall findings from the research shows that Bluetooth devices using media access control address matching is a viable method for collecting travel time estimates (Hazem et al. 2008, Wasson et al. 2008). Another study was developed by The University of Maryland for the I-95 corridor. In this study Maryland evaluated data from Bluetooth devices and floating cars traveling along 40 freeway segments of 4 miles (6.4 km) each and 40 arterial segments of 2 miles (3.2 km) each, for a total of 240 miles (386.2 km) of sample coverage. Upon completion of the data collection, the results were based on a series of speed bins, 0-30 mph (0-48.3 km/h), 30-45 mph (48.3-72.4 km/h), 45-60 mph (72.4 km/h) and greater than 60 mph (96.6 km/h). Similar to the previous studies, the results show that Bluetooth data collection provides an effective methodology for capturing average speeds and travel times for a travel time segment (www.i95coaliation.org).

2.3 Summary of the Data Collection Methodologies

After a review of the state-of-the-practice, this research team feels the floating car methodology using GPS and Bluetooth data collection are the two most appropriate methods to collect travel time data. The Bluetooth devices will capture a larger population of the data on I-70, I-75, and I-675, while the floating cars will provide more data on the lower traveled routes such as US-35, SR-49 and SR-4. Both techniques are independent of each other, which will add to better evaluation of ground truth data. These techniques for collecting data will then be evaluated against travel time data from the data service provider.

CHAPTER III
METHODOLOGY

3.1 Introduction

The objective of this study is to verify the travel times provided by a data service vendor located in Dayton, Ohio are accurate. The current system gathers vehicle speed data from radar sensors located along the highway and uses a variety of algorithms to calculate travel times between points of interest, based on time-of-day, weather event or other roadway conditions. When abnormal travel times are reported, common during rain events and congestion, ODOT has the ability to review real-time video of the corridor in question through Buckeye Travel. The methodology section is comprised of three data collection components. The first component is the location of the data collection. The second component is the time-of-day for the data collection and the third and final component is the method for collecting speed data. Sections 3.2 through 3.4 provide additional information on these components.

3.2 Location of Data Collection

Dayton, Ohio is the location identified by ODOT to study the statistical validation of travel times provided by a data service vendor. Currently, there are 103 centerline miles (165.8 km) within the Dayton area where travel times are provided. These roadways include:

- I-70 – east westbound between mile markers 25.9 and 47.2,
- I-75 – north and southbound between mile markers 40.9 and 65.3,
- I-675 – north and southbound between mile markers 0.6 and 26.5,
- US-35 – north and southbound between mile markers 30.2 and 41.7,
- SR 49 – north and southbound between mile markers 0.0 and 9, and
- SR 4 – north and southbound between mile markers 16.7 and 27.3.

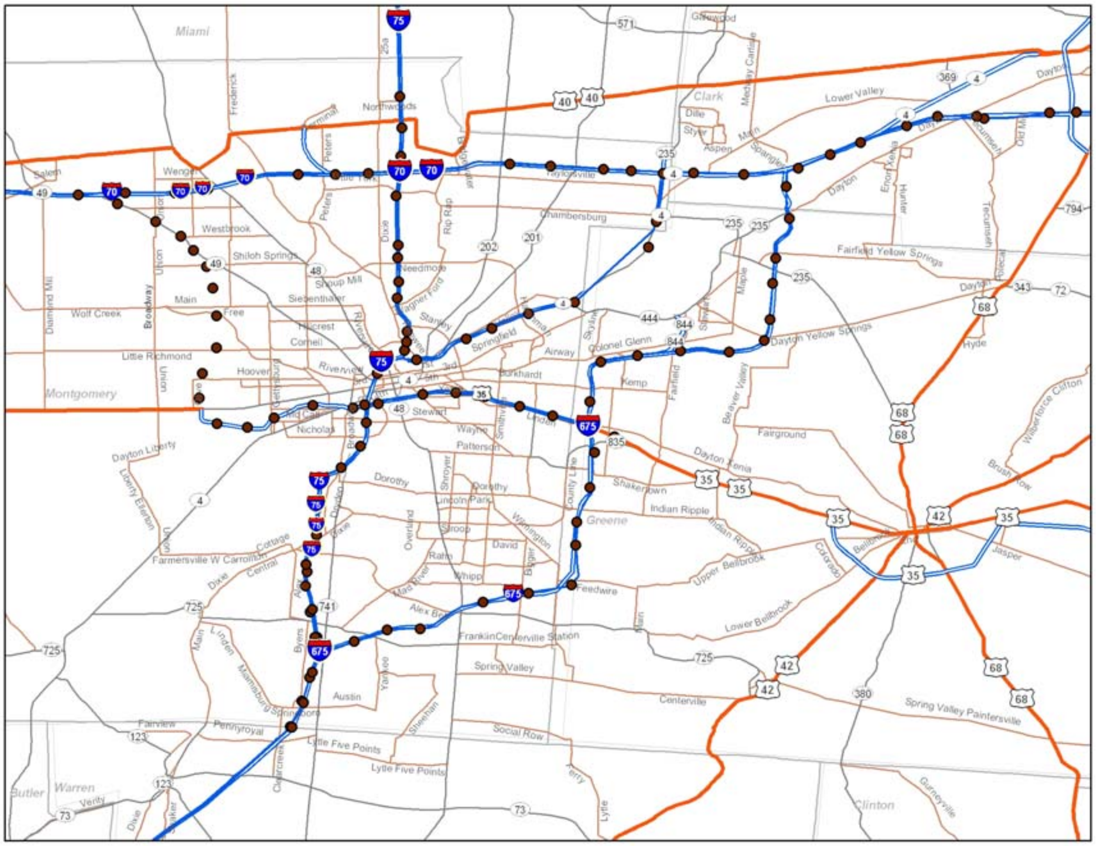


Figure 3.1. Study area aerial photograph.

In total, there were initially 44 travel time segments in June of 2009, and the number of segments was decreased to 36 travel time segments in July. Lowering the number of segments creates a higher level of disaggregation of travel time segments by eliminating overlapping travel times between areas of interest. For example, southbound I-75 between mile markers 52.7 to 61.4 initially included all or part of Segments 14, 16, 18, 20, 36, and 43. The revised data collection includes Segments 14, 16 and 18.

3.3 Temporal Data Collection

The temporal aspect of this data collection is the second component within the research methodology. The temporal aspect includes the month of sampling, the day of the week, the time of the day and when possible, “bad weather”. The temporal aspect is important when establishing variability within the traffic stream. This variability may lead to congestion, which ultimately tests the range of the travel times provided by a data service vendor. All data collection for this project is performed for weekday travel during morning and afternoon rush hour periods. Based on the geographic location of the road with respect to downtown Dayton, the time of the data collection is selected in order to optimize the collection time period when the majority of traffic traveling towards the downtown area for morning data collection, or away from the downtown area for afternoon data collection. Figure 3.2 illustrates the direction of the majority of traffic flow on each of the roadways under investigation during the AM and PM peak periods.

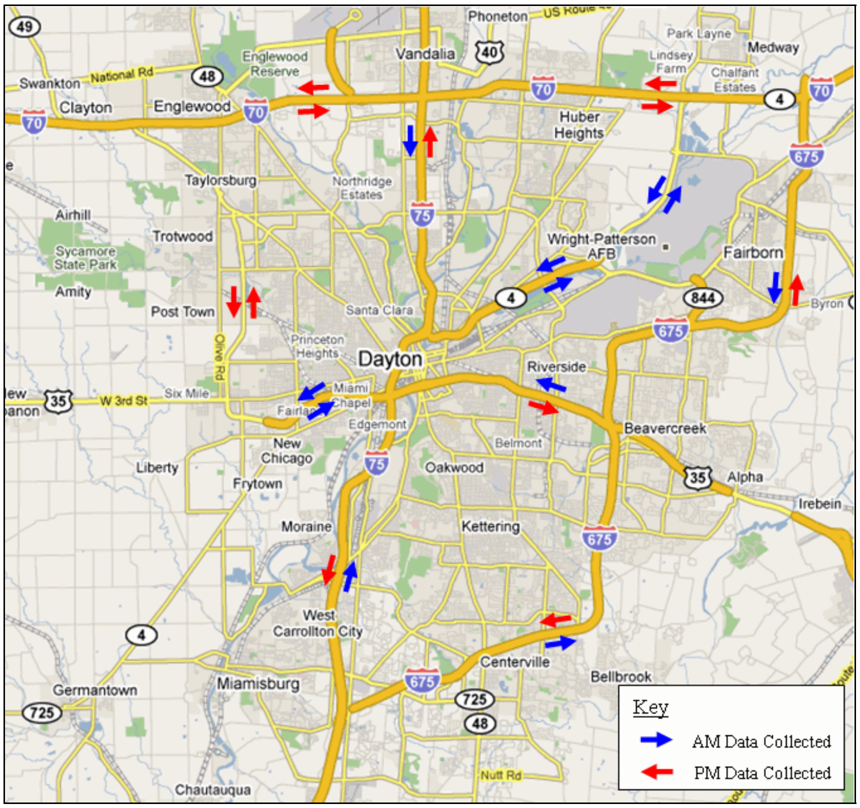


Figure 3.2. Peak period traffic flow. From: 2009 Google – Map data, 2009 – Tele Atlas

There are five data collection trips that are required to capture a large enough sample to evaluate the data service provider. In total, average vehicle speeds and travel times, using floating car and Bluetooth methodologies are evaluated on 100.1 (162.7 km) (floating car) and 96 (154.5 km) (Bluetooth) miles of the total 103 centerline miles (165.8 km). These centerline miles obtained over the five data collection trips include:

- Trip one, 4/13 – 4/14 – pilot evaluation,
- Trip two, 7/15 – 7/17 – refinement of data collection methodology and spot speed,
- Trip three, 7/26 – 7/30 – data collection trip for I-70 and I-75,

- Trip four, 8/16 – 8/20 – data collection trip for I-675, US-35, SR-4, and SR-49, and
- Trip five, 9/2 – 9/3 – data collection trip for I-75, modified for new travel time segments.

3.3.1 Trip One

The first trip is a pilot study conducted on I-75 and SR-49. The objective of this trip is to test the feasibility of data collection techniques used for the calculation of average travel speeds over multiple segments of a roadway. I-75 and SR-49 are selected in order to reflect the range of higher and lower traffic volumes in this data collection.

3.3.2 Trip Two

The second trip is conducted predominately on I-70 and I-75. The objective of this trip is to identify the location of the travel time segments, refine the data collection methodology and focus on shooting spot speeds to validate radar devices with low morning or afternoon average speeds. As shown in Table 3.1, three months worth of data provided by ODOT are evaluated to show the locations and the periods of time when average speeds are considered low for the roadway segment in question. It is unreasonable to compare average travel speeds between roadways with faster speeds, such as I-75, with roadways with slower speeds, such as SR-49. In some cases, spot speed data were unable to be collected due to safety constraints.

Table 3.1. Slow speed data.

Device	AM Speed (mph)	PM Speed (mph)	Avg. Speed (mph)	Road	Direction	Latitude	Longitude
10712	54	25	39.5	I-75	NB	39.76443	-83.1997
10854	56	31	43.5	I-75	NB	39.77583	-83.1858
11121	50	44	47	I-75	NB	39.7906	-83.1849
10004	53	41	47	I-75	NB	39.74869	-83.2058
10756	58	36	47	I-75	NB	39.78	-83.185
11120	41	41	41	I-75	SB	39.7906	-83.1849
10755	45	43	44	I-75	SB	39.78	-83.185
9951	46	43	43.5	I-75	SB	39.78539	-83.1847
10680	47	45	46	I-75	SB	39.78607	-83.1846
10716	45	48	46.5	I-75	SB	39.8022	-83.1898
10853	47	46	46.5	I-75	SB	39.77583	-83.1858

Based upon the results from trip two, the next step is the implementation of a full data collection trip using the methods described in Chapter III, Section IV.

3.3.3 Trip Three

The third trip is located exclusively on I-70 and I-75. The objective of this trip is to collect speed data for both interstate highways based on the June 2009 travel time segments. Trip three consisted of two data collection periods, morning and afternoon, during the weekday.

3.3.4 Trip Four

The fourth trip is located exclusively on I-675, US-35, SR-4, and SR-49. The objective of this trip is to collect speed data for the remaining roadways where travel times are reported. These locations are based on the July 2009 travel time segments. Trip four consists of two sample periods, morning and afternoon, during the weekday. On one day, data are collected throughout the evening hours of 8:00 PM until 2:00 AM the following morning. The objective of this nighttime data collection run is to evaluate the potential effectiveness of Bluetooth data collection, described in more detail in section 4.2.3, during periods of low volume.

3.3.5 Trip Five

Trip five is the last data collection trip. The objective of trip five is to collect data on I-75 based on the July 2009 travel time segment update. As a result of this trip, additional speed data are provided for travel time Segments 13 through 20, located on I-75.

3.4 Data Collection Methodology

Three unique and independent data collection methods are used for evaluation purposes within this study. These data collection methods include spot speed, floating car, and Bluetooth device identification. While the floating car method is the primary interest, as defined in the request for proposal, the other two methods are performed in an effort to validate data obtained from the floating car as well as the data service provider.

3.4.1 Spot Speed Method

The first data collection technique is shooting individual vehicle speeds at fixed locations, commonly referred to as spot speeds. Spot speed data are an effective method for comparing the accuracy of individual radar devices. These devices collect the initial data used in the development of estimated travel times. If these devices are inaccurate, the final travel time will also be inaccurate. The data collection procedure developed for this project includes shooting speeds for 25 minutes per direction of travel. This time interval provides a large enough sample size for comparison with the radar devices. The results from the spot speeds are shown in Appendix A. During the sample period, speeds are shot continuously and randomly sampled across each lane of travel. The end result is one-minute average binned data per lane from the laser guns that will later be compared with individual radar devices maintained by the data service provider for ODOT. Due to the number of radar devices, the locations for spot checks are selected based on the average vehicle speed, a surrogate for congestion, and the location of the device with respect to the sample runs. When possible, spot speeds are collected for two locations within the three to four hour morning or afternoon run. In the case of trip two, there is no additional data recorded while shooting speeds.

3.4.2 Floating Car Method

The second data collection method is the floating car technique. The floating car technique has been used for many years as an accepted way to estimate either the travel time or the average vehicle speed over a particular segment of highway. In this study, as identified in the request for proposal, the floating car is the primary method requested for data collection. The floating car technique requires the driver of the probe vehicle to mimic or match the speed of the traffic stream for a given roadway. When designing a floating car study, the goal is to have a large enough sample which is optimally spaced for the purpose of capturing variability within the traffic stream. There are two major decisions required to achieve the goal of a floating car study. These decisions are the number of floating car "probes" and the number of miles covered per run. In general, the more probes sampled during the run or the decrease in the coverage area will in both cases increase the resolution of the samples. For this study, three probe vehicles are deployed on all roadways with the exception of SR-49. In the case of SR-49, a fourth vehicle is included for the run.

Each car is equipped with a GeoStats GeoLogger GPS unit. Figure 3.3 shows the equipment utilized for the floating car method.

Figure 3.3. Floating car method equipment.

The data logger records data at one-second intervals, reporting information such as the coordinates of the vehicle, the date and time the data point is recorded and the instantaneous speed of the vehicle. The Federal Highway Administration's *Travel Time Data Collection Handbook* provides a guideline for how many trials should be performed, based on Average Daily Traffic (ADT) per freeway lane, amount of traffic signals per mile for arterial streets and the required confidence level of the data collected (FHWA-PL-98-035, 1998). These guidelines are very important if the floating car method is the only data collection method used. For this study, floating car data are collected over a three to four hour period. This period is long enough to sample the traffic stream before and after the morning or afternoon rush hour periods. This time period also provides a sufficient sample size, allowing for the comparison with Bluetooth devices and the current configuration of the data service provider.

Upon completion of the required number of trials, the GeoLogger devices are downloaded to a computer and the data are analyzed to determine the average vehicle speed during each trial, based on the distance traveled. The distance is calculated using the Great Circle Distance formula, which is accurate to approximately fifteen digits (meridianworlddata.com). Table 3.2 provides a sample data set from the data logger.

Table 3.2. Sample data logger output data set.

	A	B	C	D	E	F	G	H	I	J	K	L
1	V	39.96095	N	84.18925	W	104237	300709	23.1	275	912	1.7	0
2	A	39.96097	N	84.18938	W	104238	300709	23.8	275	909	1.2	8
3	A	39.96097	N	84.18952	W	104239	300709	24.7	275	906	1.2	8
4	A	39.96098	N	84.18965	W	104240	300709	24.4	275	906	1.2	8
5	A	39.961	N	84.18977	W	104241	300709	22.7	276	902	1.2	8
6	A	39.961	N	84.18987	W	104242	300709	19.9	277	902	1.2	8
7	A	39.96102	N	84.18995	W	104243	300709	16.4	277	902	1.2	8
8	A	39.96102	N	84.19	W	104244	300709	12.1	277	899	1.2	8
9	A	39.96102	N	84.19005	W	104245	300709	7.2	277	899	1.2	8

Table 3.2 provides a screen shot of the raw data output file created by the data logging unit. The data provided in this table includes (from left to right) a column denoting if the data point is valid or invalid, latitude and longitude of data point, time and date that the data point was recorded, speed calculated based on vehicle position, heading, altitude, HDOP and number of satellites being accessed by the data logging unit. Additional calculations are performed using the raw data to determine the distance between data points and speed based on the time required to travel a known distance. Based on the data shown in Table 3.2, the following equations are used:

$$A = (\sin\frac{lat_1}{57.2958} \times \sin\frac{lat_2}{57.2958}) + (\cos\frac{lat_1}{57.2958} \times \cos\frac{lat_2}{57.2958} \times (\frac{long_2 - long_1}{57.2958}) \qquad (3.1)$$

$$d = R\arctan\sqrt{\frac{1 - A^2}{A}} \qquad (3.2)$$

$$s = \frac{d}{t_2 - t_1} \times \frac{5{,}280}{1.47} \qquad (3.3)$$

where:

lat_i = latitude of point, degrees,

$long_i$ = longitude of point, degrees,

i = 1 for beginning value, 2 for ending value,

d = distance, miles,

R = radius of the earth, approximately 3,963 miles (6,377.8 km),

s = speed, miles per hour, and

t = time, seconds.

This method allows the actual roadway conditions to be analyzed, as the data returned from the test vehicles will reflect the periods of congestion and free-flow speeds experienced by the other motorists.

Although the floating car technique is a widely accepted method for gathering vehicle speed data, this method does present some issues for concern. Significant labor is required to perform this method, making the floating car technique a relatively expensive procedure given the number of data points returned from each test vehicle (Turner, 1996). Turner also suggests that it is often difficult for test drivers to mirror the actions of the traffic stream (Turner, 1996). Test drivers often revert to their own driving habits instead of staying with the majority of traffic, or are faced with the decision of which travel lane most closely represents the average vehicle speed.

3.4.3 Bluetooth Method

As a result of the potential limitations from the floating car, a third data collection method using Bluetooth technology is developed to compliment the findings from the floating car technique. In this methodology, a series of Bluetooth devices are placed at fixed locations near the beginning and ending of the travel time segments. These devices scan the area in search of the presence of other Bluetooth technologies, typically cell phone and headsets for cell phones. The Bluetooth technologies send a signal back to the fixed location Bluetooth devices. This signal contains the date and timestamp as well as the MAC address, a unique identifying number assigned to the device. As the MAC address is unique to each device, privacy concerns will likely arise. The MAC address of a device is assigned to the Bluetooth components when the device is manufactured, and corresponds to the equipment only, rather than a user account (Traffax, 2008). A second, third, or fourth Bluetooth device is placed downstream at the same time as the first and each of these devices record the same information as previously described. The average speed of the vehicle is based on the Bluetooth device recording the same MAC address from the upstream and downstream device. The corresponding MAC addresses are then matched, the time required to travel the distance between the two fixed locations is known, and based on Equation 3.4, the average space mean speed is calculated. Equation 3.4 is shown below as:

$$s = \frac{d}{t_2 - t_1} \times \frac{5280}{1.47} \tag{3.4}$$

where:

d = distance, miles,

s = speed, miles per hour, and

t = time, seconds.

Figure 3.4 shown below illustrates the design setup of the Bluetooth devices.

	
Inside the box	Located in the field

Figure 3.4. Depicts the equipment utilized for the Bluetooth method.

There are several strengths of the Bluetooth method. The first strength is the relatively low cost of setting up one location. Unlike the floating car technique, one person may set up the Bluetooth method in the field. A second strength is the portability of the system. As shown in Figure 3.4, the system is lightweight and easily located. The final strength is the potential for collecting more data points than other methods, especially on high volume roads. These additional data points are effective when describing time periods with high variability within the traffic stream. A study by Tarnoff has shown that 5-7% of vehicles in a traffic stream have Bluetooth enabled devices, providing an adequate sample size (Tarnoff et. al., 2009).

As the Bluetooth method is still in the early development stages, there are still many unknowns associated with this method that will require further research. For example, the analyst must decide how to handle the event of two different MAC addresses recorded at the exact same time. This situation could represent two vehicles traveling side by side in different lanes, but more likely represents two Bluetooth devices detected in one vehicle. In this study, the second data point is eliminated from the data set. The Bluetooth method also returns unreasonable data points on occasion, in the event that a motorist passes the first scanning station, exits the roadway to refuel or stop for a meal, reenters the roadway and passes the second scanning station after an extended amount of time has elapsed. In this situation, the analyst would observe the points recorded before and after to determine that the slow speed is an outlier, which should be discarded.

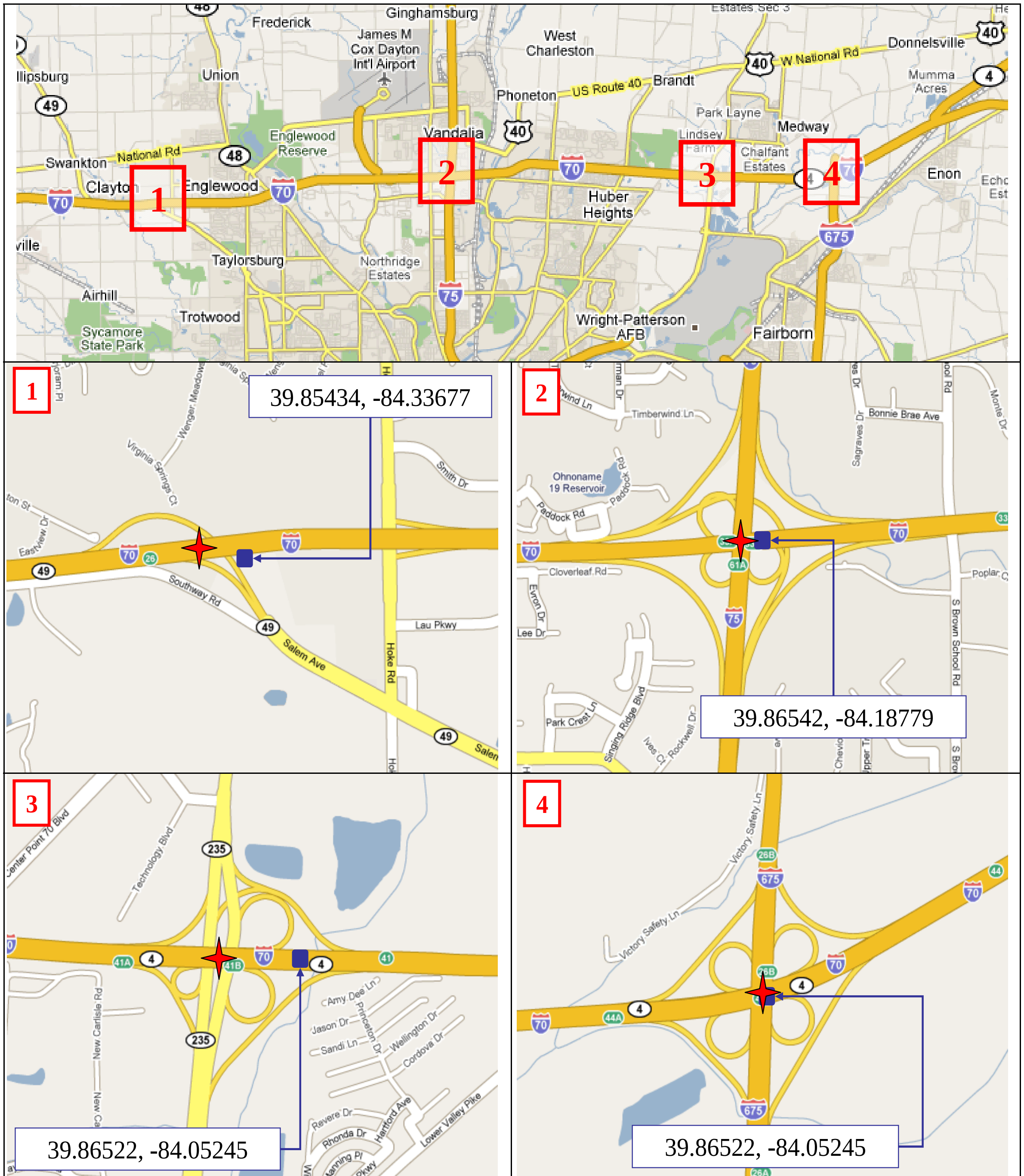
3.5 Roadway Characteristics

The selection of the roadways used in this study is based on the travel time segments provided by ODOT. Segment length varied, with the smallest segment measuring 0.9 miles (1.4 km) to the longest segment measuring 13.2 miles (21.2 km). These segments are located on I-70, I-75, I-675, US-35, SR-49 and SR-4. The remaining portion of Section 3.5 describes the data collection used with each location.

3.5.1 High Volume Access-Controlled Interstate Highways

I-70

Interstate 70 is the first interstate highway with a posted speed limit of 65 mph (104.6 km/h). Figure 3.5 depicts the beginning and ending points of the floating car trials, boxes 1 and 4, the location of Bluetooth scanning devices and locations where spot speed readings are obtained.



Key

- Bluetooth box location
- Suggested Bluetooth location
- Spot speed collection with laser gun

From: 2009 Google – Map data, 2009 – Tele Atlas

Figure 3.5. Data location setup for I-70.

Figure 3.5 also provides the visual description for the location of the Bluetooth devices with respect to the ideal beginning and ending locations of the travel time segments. For I-70, when possible, the two points are the same. In some cases the Bluetooth device locations are adjusted for safety reasons, security of the Bluetooth box and the desire to pick up additional matches from the on and off-ramps. The devices on I-70 are all located within 0.1 miles (0.2 km) from the desired location.

Table 3.3 details the type of data obtained for each travel time segment as well as when the data were collected.

Table 3.3. Travel time segment data collection summary for I-70.

Travel Time Segment ID	Road Name	Description	Direction	Segment Length (mi)	Segment Length (km)	Start Milepost	End Milepost	Coverage		Data Collection Period
								Floating Car	Bluetooth	
1	I-70	SR 49 to I-57	E	8.0	12.9	25.9	33.9	X	X	Trip 3
3	I-70	I-75 to SR 4 (South)	E	7.2	11.6	33.9	41.1	X	X	Trip 3
5	I-70	SR 4 (South) to I-675	E	3.2	5.1	41.1	44.3	X	X	Trip 3
7	I-70	I-675 to SR 4 (Enon)	E	2.9	4.7	44.3	47.2			
2	I-70	SR 49 to I-57	W	8.0	12.9	25.9	33.9	X	X	Trip 3
4	I-70	I-75 to SR 4 (South)	W	7.2	11.6	33.9	41.1	X	X	Trip 3
6	I-70	SR 4 (South) to I-675	W	3.2	5.1	41.1	44.3	X	X	Trip 3
8	I-70	I-675 to SR 4 (Enon)	W	2.9	4.7	44.3	47.2			

The data collection from this study recorded values from six of the eight travel time segments. Segments 7 and 8 are not included in the final results. Based on field observations over a one-week period and the analysis of the three-month speed data, this area, Segments 7 and 8, seems to be separate from the more congested areas of Dayton. This data suggests that this area is mainly free-flow.

I-75

Interstate 75 is the second interstate highway. This highway has three lanes in each direction with a two-lane construction work zone located near mile marker 53.8. As a result of this construction, there are periods of congestion that occur during morning and afternoon rush hour. The posted speed limit of this road varies, due to the construction areas, between 45 and 65 miles per hour (72.4 km/h and 104.6 km/h). Figures 3.6 through 3.8 depict the beginning and ending points of the floating car trials, location of Bluetooth scanning radios and locations where spot speed-readings are obtained. In both of these figures, there are four Bluetooth locations shown in Figure 3.6, five locations in Figure 3.7 and four locations in Figure 3.8. In all three figures, there are two boxes, numbers 1 and 2. These boxes represent areas where there are potential differences between the suggested and the actual location of the devices. In all cases, the final location of the box is within close proximity to the suggested area.

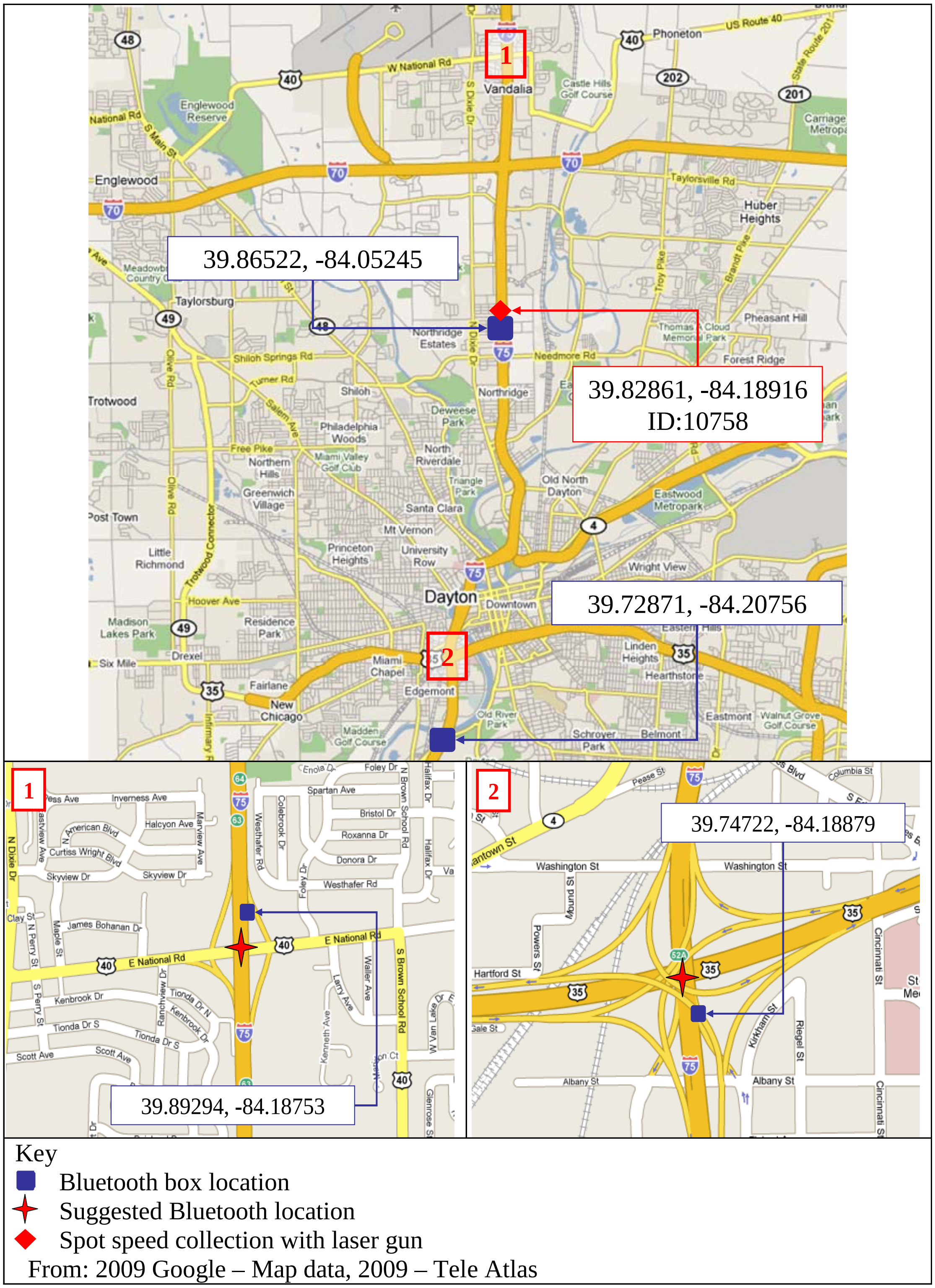


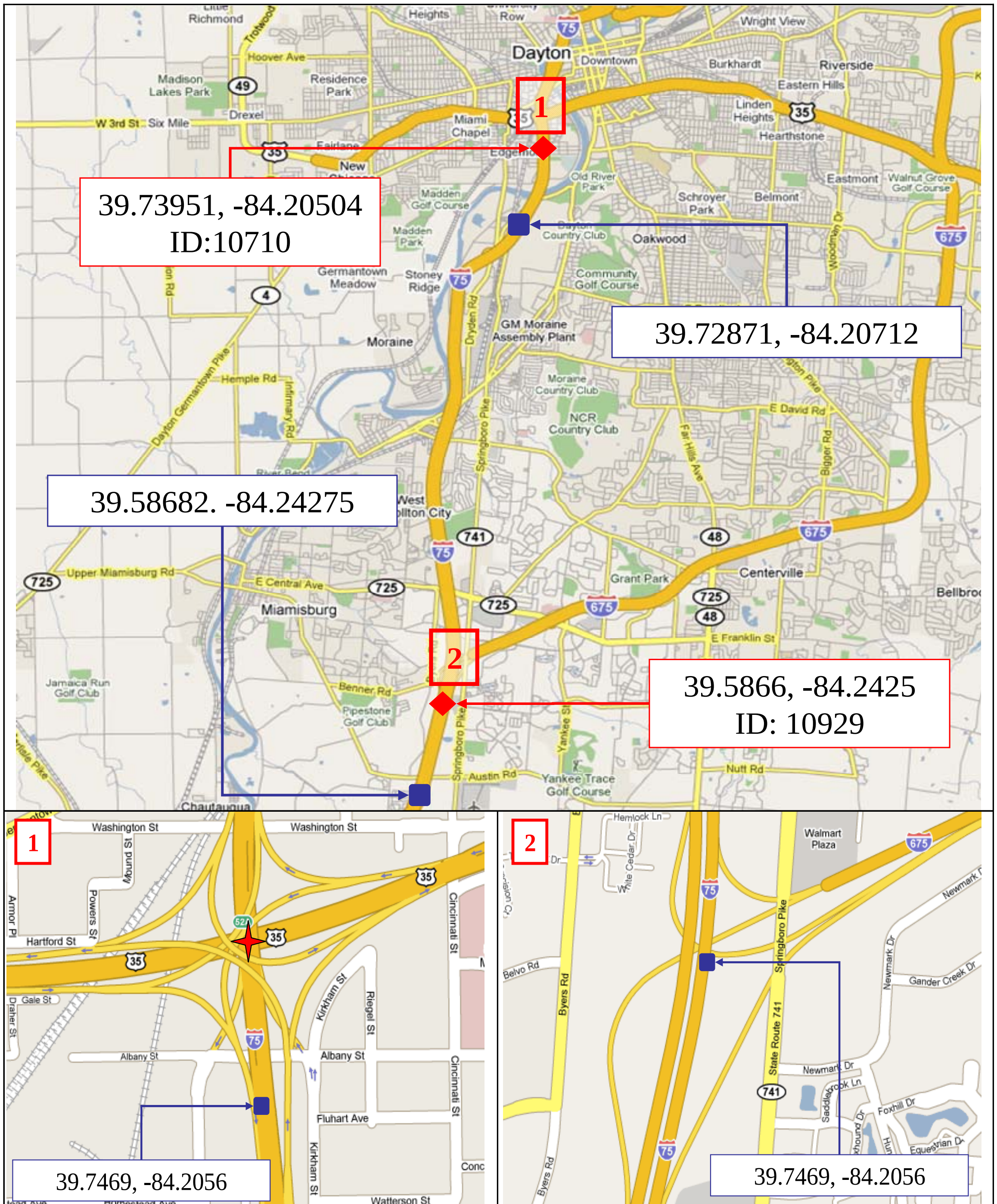
Figure 3.6. Data collection location north of Dayton, July 2009.

Key

- Bluetooth box location
- Suggested Bluetooth location
- Spot speed collection with laser gun

From: 2009 Google – Map data, 2009 – Tele Atlas

Figure 3.7. Data collection location north of Dayton.



Key
- Bluetooth box location
- Suggested Bluetooth location
- Spot speed collection with laser gun

From: 2009 Google – Map data, 2009 – Tele Atlas

Figure 3.8. Data collection location south of Dayton.

Figure 3.8 shown on the previous page is for the Bluetooth locations that are south of Dayton. Table 3.4 details the type of data obtained for each travel time segment as well as when the data are collected.

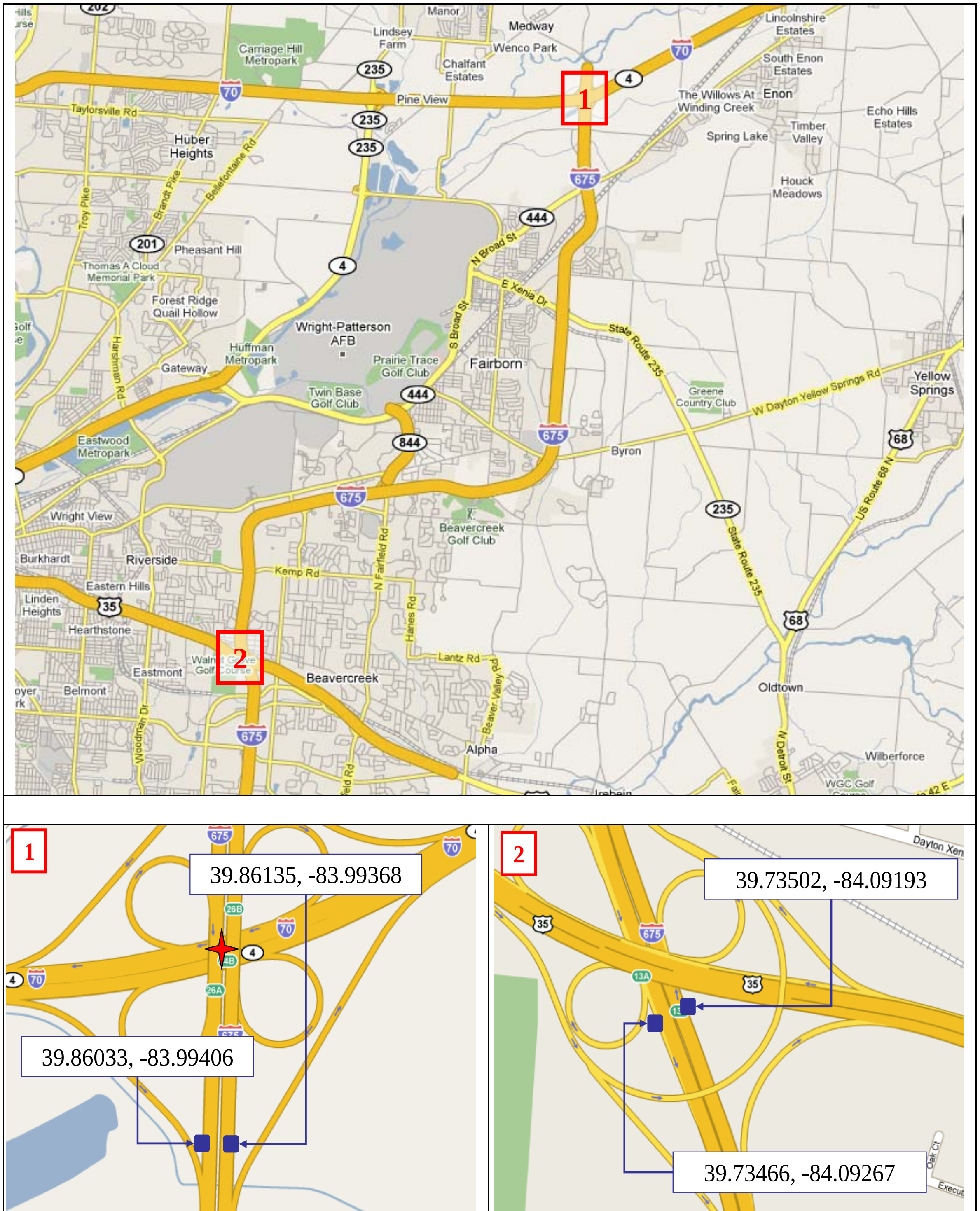
Table 3.4. Travel time segment data collection summary I-75.

Travel Time Segment ID	Road Name	Description	Direction	Segment Length (mi)	Segment Length (km)	Start Milepost	End Milepost	Coverage		Data Collection Period
								Floating Car	Bluetooth	
9	I-75	County Line (Warren) to I-675	N	2.6	4.2	40.9	43.5	X	X	Trip 3
11	I-75	I-675 to Carillon Blvd.	N	8.3	13.4	43.5	51.8	X	X	Trip 3
13	I-75	Carillon Blvd. to US 35	N	0.9	1.4	51.8	52.7	X	X	Trip 3, Trip 5
15	I-75	US 35 to SR 4	N	2.1	3.4	52.7	54.8	X	X	Trip 3, Trip 5
17	I-75	SR 4 to Timber Ln.	N	2.9	4.7	54.8	57.7	X	X	Trip 3, Trip 5
19	I-75	Timber Ln. to I-70	N	3.7	6.0	57.5	61.4	X		Trip 3, Trip 5
21	I-75	I-70 to US 40	N	1.8	2.9	61.4	63.2	X	X	Trip 3
23	I-75	US 40 to County Line (Miami)	N	2.1	3.4	63.2	65.3	X	X	Trip 3
10	I-75	County Line (Warren) to I-675	S	2.6	4.2	40.9	43.5	X	X	Trip 3
12	I-75	I-675 to Carillon Blvd.	S	8.3	13.4	43.5	51.8	X	X	Trip 3
14	I-75	Carillon Blvd. to US 35	S	0.9	1.4	51.8	52.7	X	X	Trip 3, Trip 5
16	I-75	US 35 to SR 4	S	2.1	3.4	52.7	54.8	X	X	Trip 3, Trip 5
18	I-75	SR 4 to Timber Ln.	S	2.9	4.7	54.8	57.7	X	X	Trip 3, Trip 5
20	I-75	Timber Ln. to I-70	S	3.7	6.0	57.7	61.4	X		Trip 3, Trip 5
22	I-75	I-70 to US 40	S	1.8	2.9	61.4	63.2	X	X	Trip 3
24	I-75	US 40 to County Line (Miami)	S	2.1	3.4	63.2	65.3	X	X	Trip 3

There are 16 travel time segments located on I-75. As a result of the data collection trips, Bluetooth data are provided for 14 travel time segments and floating car data are provided for all the segments.

I-675

The third interstate is I-675. I-675 is a three-lane, each direction, highway with a 65 mile per hour (104.6 km/h) speed limit. During the data collection trips, there are limited times when there is congestion on this interstate highway. Figure 3.9 north of US-35, and Figure 3.10, south of US-35, depict the beginning and ending points of the floating car trials, location of Bluetooth scanning radios and locations where spot speed readings are obtained.

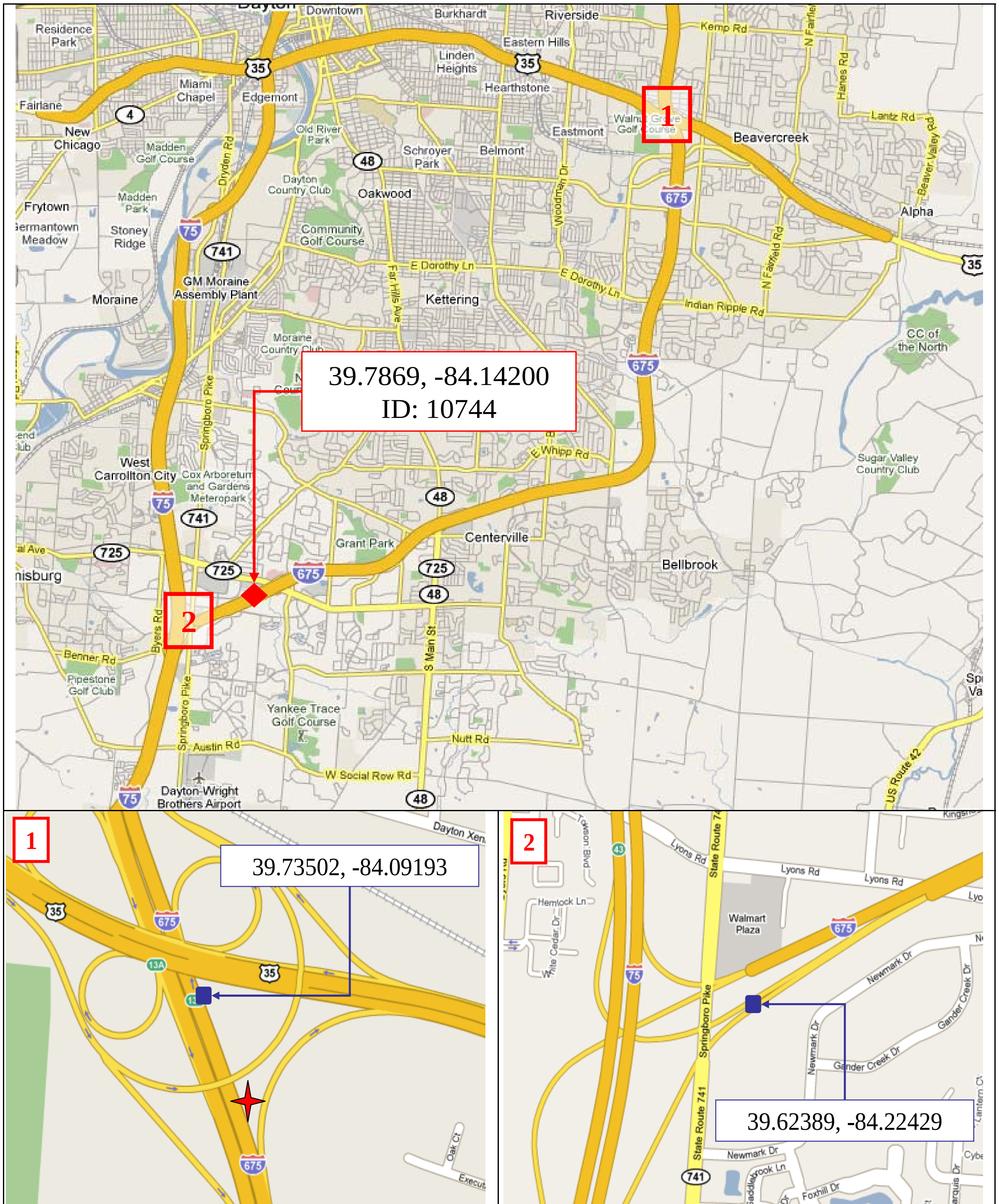


Key
- Bluetooth box location
- Suggested Bluetooth location
- Spot speed collection with laser gun

From: 2009 Google – Map data, 2009 – Tele Atlas

Figure 3.9. I-675 data collection north of US-35.

Both Bluetooth devices at location one, Figure 3.9, are approximately 0.1 miles (0.2 km) from the suggested location as defined by ODOT. The rationale for this alternative location is to capture vehicles travelling eastbound on I-70 merging southbound onto I-675, and vehicles travelling northbound on I-675 merging onto I-70 eastbound. By capturing these two turning movements, the number of Bluetooth targe radios increases, allowing for more matches. The negative to this setup is the slight difference in the travel time segment distances and locations. This method for capturing more vehicles by modifying the travel time segments slightly occurs throughout this study. As shown in boxes 1 and 2 in Figures 3.9 and 3.10, there are no additional obstructions that will significantly alter the travel times. In the final analysis, the travel times are updated and adjusted according to the new setup.



Key

- Bluetooth box location
- Suggested Bluetooth location
- Spot speed collection with laser gun

From: 2009 Google – Map data, 2009 – Tele Atlas

Figure 3.10. I-675 data collection south of US-35.

The Bluetooth devices for location two, Figure 3.10, are modified from the suggested location. The rationale for the alternate setup is similar to the previous location. Moving the Bluetooth devices closer to the on and off ramps potentially increases the sample size. There are no obstructions between these points and the actual suggested placement. As with the other locations, the travel times are modified according to the modified setup.

Table 3.5 details the type of data obtained for each travel time segment as well as when the data are collected. In this study, all four segments are covered with Bluetooth and floating car data.

Table 3.5. Travel time segment data collection summary I-675.

Travel Time Segment ID	Road Name	Description	Direction	Segment Length (mi)	Segment Length (km)	Start Milepost	End Milepost	Coverage		Data Collection Period
								Floating Car	Bluetooth	
25	I-675	I-75 to US 35	N	12.7	20.4	0.6	13.3	X	X	Trip 4
27	I-675	US 35 to I-70	N	13.2	21.2	13.3	26.5	X	X	Trip 4
26	I-675	I-75 to US 35	S	12.7	20.4	0.6	13.3	X	X	Trip 4
28	I-675	US 35 to I-70	S	13.2	21.2	13.3	26.5	X	X	Trip 4

3.5.2 Urban Arterial Streets and State Highways

US-35

US-35 is a four-lane highway with the functional classification of other urban freeway and expressway. Figure 3.11 depicts the beginning and ending points of the floating car trials, the location of Bluetooth devices and the location where spot speed readings were obtained.

Key
- Bluetooth box location
- Suggested Bluetooth location
- Spot speed collection with laser gun

From: 2009 Google – Map data, 2009 – Tele Atlas

Figure 3.11. US-35 data collection.

Location one is the beginning of travel time Segment 30 and the ending of travel time Segment 29. There are two Bluetooth devices located within location one. The first box is located at mile marker 30.2 and the second box is placed at the beginning of SR-49. The decision to place the two boxes allows for a greater number of matches between locations one and two, which correspond to travel time Segments 29 and 30. The first box, 39.7463, -83.28966, captures the vehicles travelling west, while the second box, 37.74789, -83.20482, captures the vehicles that are continuing north onto SR-49. At no point are there duplicate matches within this setup.

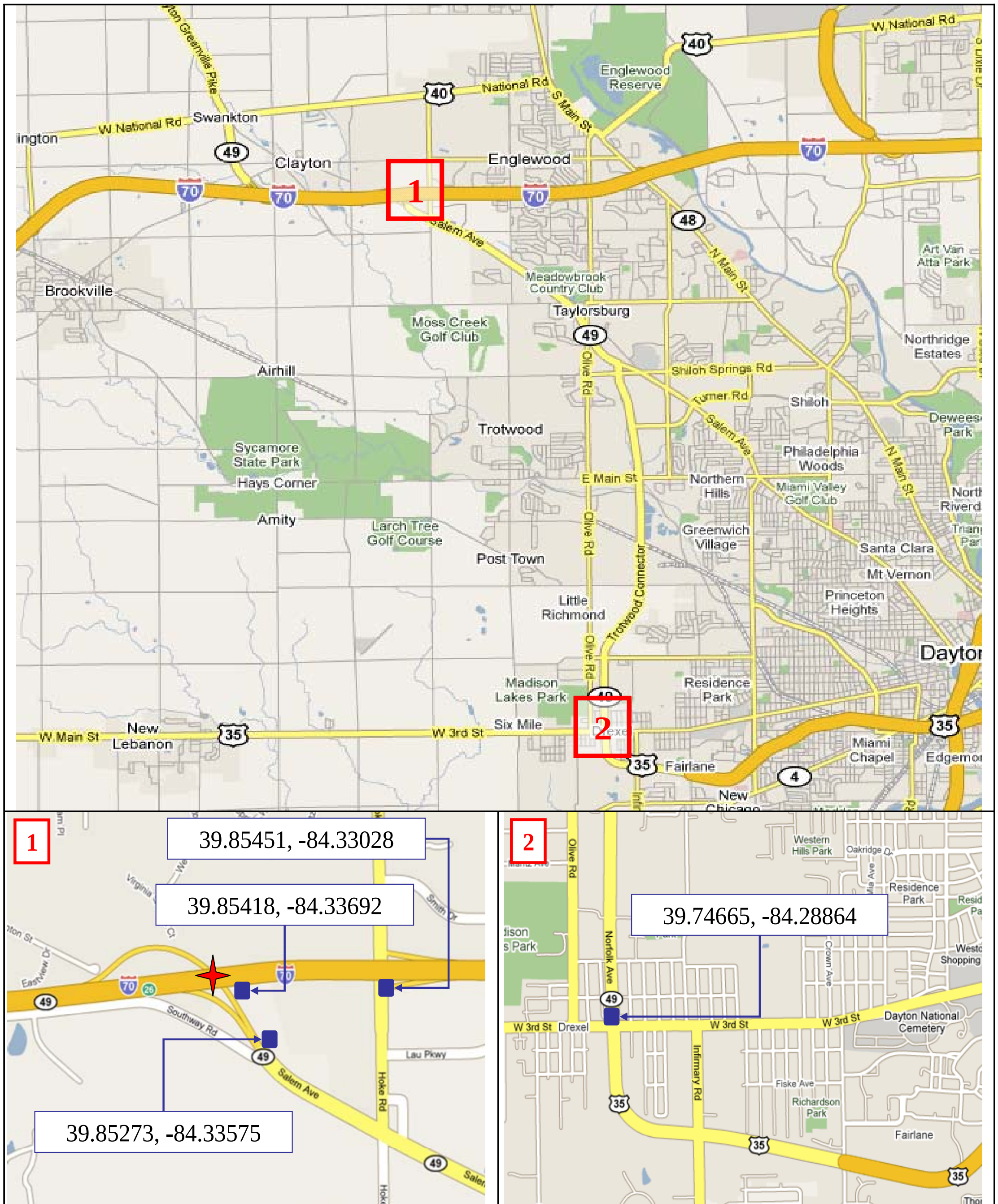
Table 3.6 details the type of data obtained for each travel time segment as well as when the data are collected. All four travel time segments are covered with Bluetooth and floating car data.

Table 3.6. Travel time segment data collection summary US-35.

Travel Time Segment ID	Road Name	Description	Direction	Segment Length (mi)	Segment Length (km)	Start Milepost	End Milepost	Coverage		Data Collection Period
								Floating Car	Bluetooth	
29	US 35	SR 49 to I-75	E	5.1	8.2	30.2	35.3	X	X	Trip 4
31	US 35	I-75 to I-675	E	6.4	10.3	35.3	41.7	X	X	Trip 4
30	US 35	SR 49 to I-75	W	5.1	8.2	30.2	35.3	X	X	Trip 4
32	US 35	I-75 to I-675	W	6.4	10.3	35.3	41.7	X	X	Trip 4

SR-49

State Route 49 is the fourth road with travel time segments. Figure 3.12 depicts the beginning and ending points of the floating car trials, location of Bluetooth scanning radios and locations where spot speed readings were obtained. Table 3.7 details the type of data obtained for each travel time segment as well as when the data are collected.



Key

- Bluetooth box location
- Suggested Bluetooth location
- Spot speed collection with laser gun

From: 2009 Google – Map data, 2009 – Tele Atlas

Figure 3.12. Data collection located on SR-49.

Three Bluetooth box locations are shown in Figure 3.12. The first box, located at 39.85273, -83.33575, is the starting and ending location of the floating car runs. At this location, there is a side street that allows for easy turnaround, lowering the amount of time between data collection runs. The second box is located at 39.85471, -83.33692. This is one of two potential ending mile markers associated with the data collection run. At this location, the vehicles must enter onto I-70 travelling west. The third box is located at 39.85451, -83.33028. At this location, the vehicles may enter onto I-70 travelling east. Based on the initial setup, the third box and the first box are both used in the analysis. The first box corresponds well with the floating car route and vehicles that are traveling north onto I-70 west. The third box captures the vehicles that are traveling north on SR-49 and turning onto I-70 east. As a result of the extended segment length and the number of exit points along the route, the effectiveness of Bluetooth data will come into question. Adding the second end point increases the potential for a greater number of Bluetooth matches.

Table 3.7 details the type of data obtained for each travel time segment as well as when the data are collected. Both travel time segments are covered with Bluetooth and floating car data.

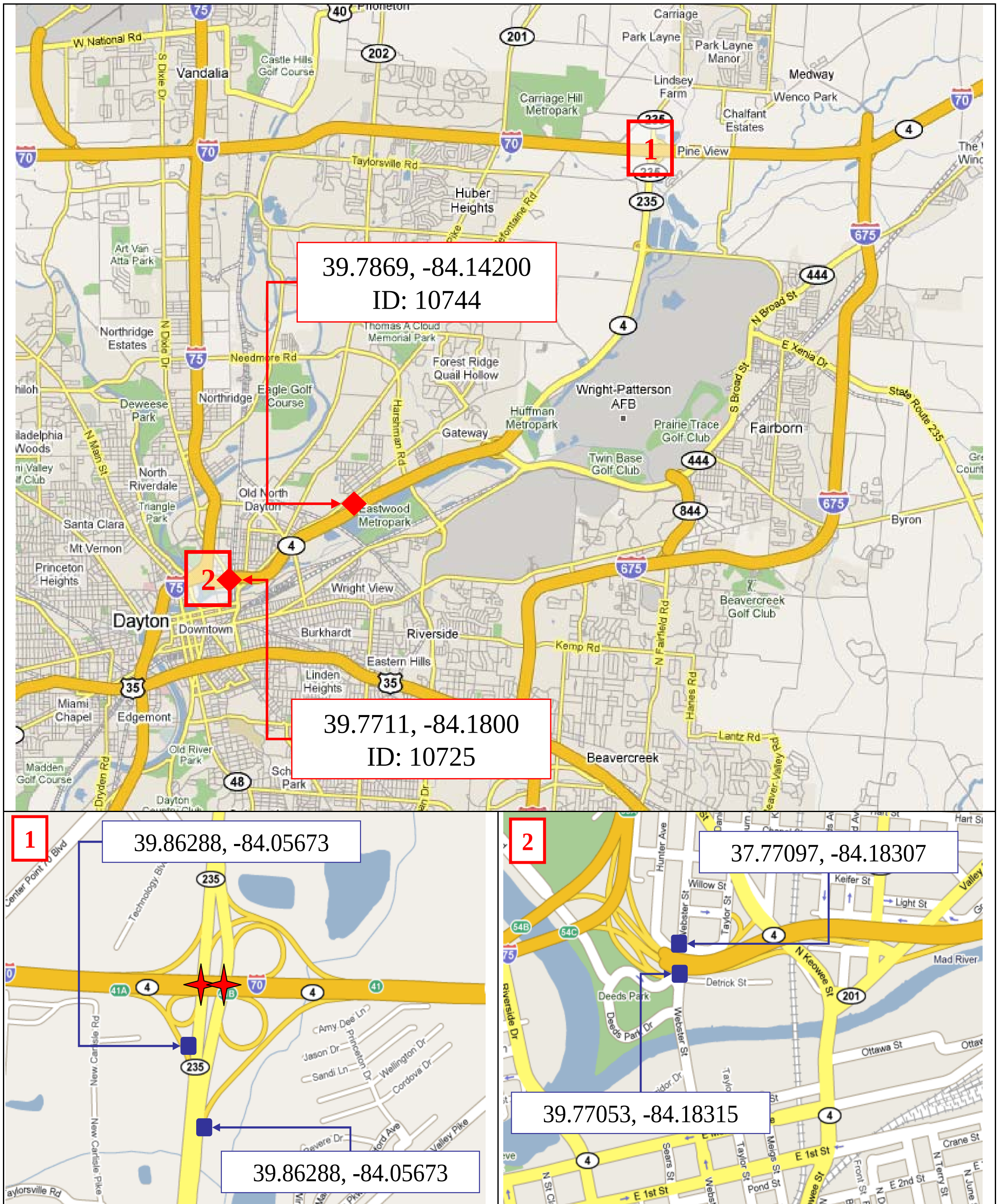
Table 3.7. Travel time segment data collection summary SR-49.

Travel Time Segment ID	Road Name	Description	Direction	Segment Length (mi)	Segment Length (km)	Start Milepost	End Milepost	Coverage		Data Collection Period
								Floating Car	Bluetooth	
35	SR 49	US 35 to I-70	N	9.0	14.5	0	9	X	X	Trip 4
36	SR 49	US 35 to I-70	S	9.0	14.5	0	9	X	X	Trip 4

SR-4

State Route 4 is the sixth roadway investigated in this study. The functional classification of the roadway varies from urban principal arterial west of the downtown area to urban minor arterial within the downtown area.

Location of Bluetooth scanning devices, floating car trial beginning and ending points and spot speed reading locations are shown in Figure 3.13. Four Bluetooth boxes are located along this route. Box 1 is located at 39.86288, -83.05673, the ramp from I-70 westbound to SR-4 southbound. Box 2, located at 39.77097, -83.18307, marks the beginning and ending point of the floating car trials. The third box is located near the Keowee Street exit at 39.77053, -83.18315. Box 4 is located at 39.86076, -83.05637, near the entrance ramp to I-70. The locations of box 1 and box 4 vary slightly from the suggested box placement locations in order to capture travel time data from vehicles entering and exiting I-70. Modifying the locations leads to slightly different travel time segment lengths, but this setup allows for more Bluetooth data to be obtained, resulting in more potential matches. The effects on the travel times from this modification are accounted for in the final analysis.



Key

- Bluetooth box location
- Suggested Bluetooth location
- Spot speed collection with laser gun

From: 2009 Google – Map data, 2009 – Tele Atlas

Figure 3.13. SR-4 data collection.

Table 3.8 details the type of data obtained for each travel time segment as well as when the data are collected. Floating car and Bluetooth data are provided for both travel time segments.

Table 3.8. Travel time segment data collection summary SR-4.

Travel Time Segment ID	Road Name	Description	Direction	Segment Length (mi)	Segment Length (km)	Start Milepost	End Milepost	Coverage		Data Collection Period
								Floating Car	Bluetooth	
33	SR 4	I-75 to I-70	N	10.7	17.2	16.7	27.4	X	X	Trip 4
34	SR 4	I-75 to I-70	S	10.7	17.2	16.7	27.4	X	X	Trip 4

3.6 Data Cleaning and Quality Control

Several data cleaning and quality control techniques are implemented to verify the validity of the data collected. The first quality control check occurs when the GeoLogger units lose satellite communication. In this situation, the data points collected immediately after the GeoLogger units lose communication with the satellites are discarded, as the weak signal often returns inaccurate data.

A second check of the data is developed specifically for the GeoLogger. In this case, the GeoLogger unit computes speed based on the distance the test vehicle has traveled between data points, also known as space mean speed. When the data are free of suspicious values, the space mean speed and time mean speed should be approximately equal. Other statistical measures include the calculation of the standard deviation of the individual floating car speeds. A large standard deviation represents periods of congestion, while a small value would indicate that the roadway is operating near free-flow conditions. The standard deviation of data collected by each driver may then be compared with other drivers in order to verify that the very high or very low data point makes sense in the context of the trial. Additional performance criteria include the maximum and minimum speeds recorded by the GeoLogger unit. Generally, data points with speeds greater than 80 miles per hour (128.7 km/h) are discarded and speeds of 0 miles per hour (0 km/h) are further investigated to observe if the vehicle is truly decelerating to such a slow speed, as it is unlikely to come to a complete stop on I-70, but this event may happen on SR-49.

Table 3.9 provides an example of unreasonable speeds collected on SR-49. Table 3.9 illustrates how an unreasonable speed is identified. Calculated maximum and minimum speeds are scanned for values that seem suspiciously high or low. In this instance, further examination of the data is necessary. As it is unlikely that the traffic stream will be traveling over 80 miles per hour (128.7 km/h), this is used as the criteria for determining if a speed is unreasonably high. However, speeds falling very near to this boundary require best judgment to be considered as to whether the data point should be included in the data set, as the probe driver may momentarily attain a high speed while overtaking another vehicle. More often than not, an unreasonably high speed occurs from an improper distance calculation due to bad data received by the data logging unit. Unreasonably low speeds occur much more frequently than unreasonably high speeds, resulting from periods of congestion. If a clear deceleration period is demonstrated in the data set, then the point should be included in the analysis. In the case presented, speeds of approximately 129 miles per hour (207.6 km/h) and 31 miles per hour (49.9 km/h) are out of context within a grouping of speeds in the mid 60 miles per hour range (96.6 km/h). These values should be discarded from the data set.

Table 3.9. Example of unreasonable speeds obtained on SR-49.

	A	B	C	D	E	F	H	I	J	K	Q	R	S
1	Valid Data	Lat		Long		Time	Mod Time	Seconds	Date	Speed	Distance	Cal_Speec	Trial
4419	D	39.73797	N	84.0935	W	203538	16:35:38	74138	190809	63.8	0.018091	64.98112	3
4420	D	39.73822	N	84.0936	W	203539	16:35:39	74139	190809	63.7	0.017808	63.96228	3
4421	D	39.73847	N	84.09368	W	203540	16:35:40	74140	190809	63.6	0.017942	64.44544	3
4422	D	39.73872	N	84.09377	W	203541	16:35:41	74141	190809	63.6	0.017808	63.96228	3
4423	D	39.73897	N	84.09385	W	203542	16:35:42	74142	190809	63.6	0.017688	63.53282	3
4424	D	39.73922	N	84.09392	W	203543	16:35:43	74143	190809	63.8	0.017584	63.15817	3
4425	A	39.73947	N	84.09398	W	203544	16:35:44	74144	190809	63.8	0.035848	128.7606	3
4426	V	39.73998	N	84.0941	W	203545	16:35:45	74145	190809	0	0.017365	31.18664	3
4427	D	39.74023	N	84.09413	W	203547	16:35:47	74147	190809	63.9	0.017422	62.57779	3
4428	D	39.74048	N	84.09417	W	203548	16:35:48	74148	190809	64.1	0.018743	67.32273	3
4429	D	39.74075	N	84.0942	W	203549	16:35:49	74149	190809	64.3	0.018705	67.18694	3
4430	D	39.74102	N	84.09422	W	203550	16:35:50	74150	190809	64.8	0.017292	62.10943	3

A third check of the data includes the comparison of the number of records in each trial. A clean data set from each of the probe vehicles should, under free-flow conditions, have approximately the same sample size. As the probe vehicles are deployed into the same traffic stream with approximately equal spacing, each GeoLogger unit should return nearly the same number of records. An uncharacteristically small number of records may signify that the GeoLogger equipment is not operating properly, while an exceptionally large number of records may signify that the driver of the probe vehicle has stopped within the study area during the test period for a reason unrelated to the traffic conditions.

Additional checks of the data are based on plotting the results. One common check is plotting the vehicle start time against the mean speed for each floating car trial and for each matched Bluetooth point. Each method should return similar results; therefore, any outliers or suspicious points are further investigated, with consideration given to the issues discussed within this section. Figure 3.14 demonstrates outliers within the Bluetooth method data.

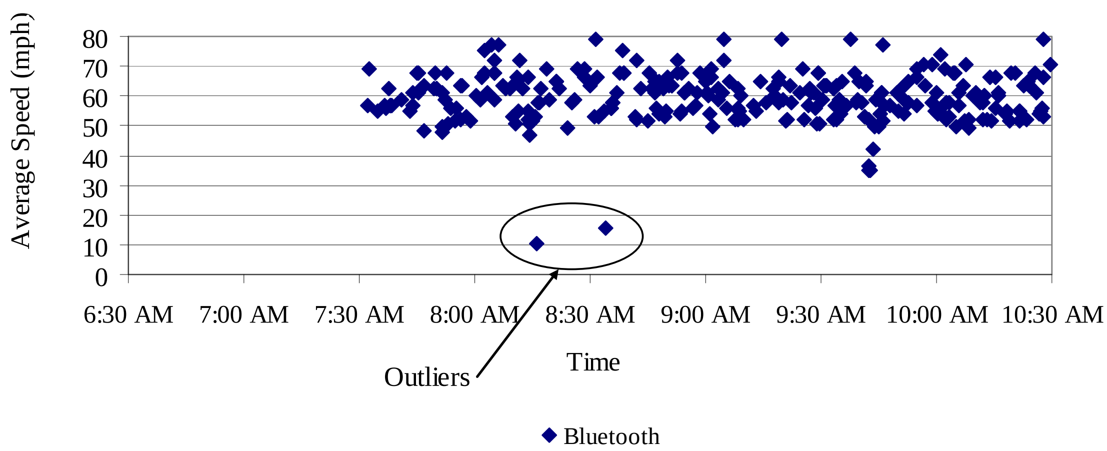


Figure 3.14. Example of outliers within the Bluetooth method data.

Average speeds as calculated by the Bluetooth method that are much faster than those reported by the floating car method may signal an additional issue with the Bluetooth method data analysis. This situation may indicate that an incorrect distance between the Bluetooth scanning radios is used during the analysis, and the distance should be verified against the sum of the incremental distances from the floating car trials. Figure 3.15 provides an example of a case in which the Bluetooth speeds are significantly faster than the floating car speeds.

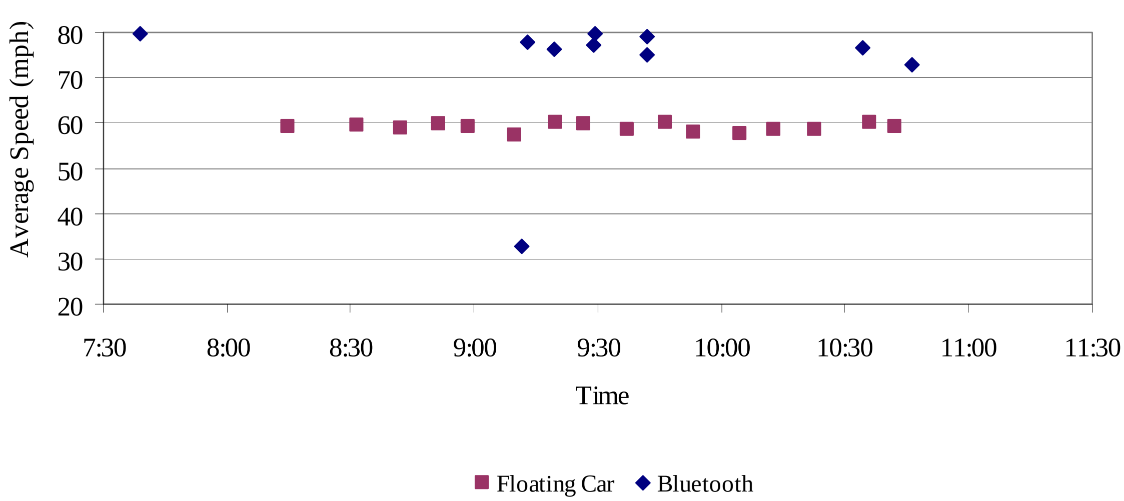


Figure 3.15. Example of widely varying floating car speeds and Bluetooth speeds.

3.7 Summary of Data Collection Methods

In summary, three methods of data collection are developed for this study. These methods include spot speeds, floating cars, and Bluetooth devices. Analysis of the Bluetooth method has returned similar average vehicle speeds, therefore validating the data obtained by the floating car method. Of the 36 travel time segments of interest in Dayton, Ohio, floating car data are obtained for 34 segments and Bluetooth data are obtained for 32 segments. In terms of the travel time segment coverage, the Bluetooth data are collected on 96 and the floating car on 100.1 centerline miles (154.5 and 161.1 km). The segment coverage is summarized in Table 3.10.

Table 3.10. Summary of travel time segment coverage.

Travel Time Segment ID	Road Name	Description	Direction	Segment Length (mi)	Segment Length (km)	Start Milepost	End Milepost	Coverage		Data Collection Period
								Floating Car	Bluetooth	
1	I-70	SR 49 to I-57	E	8.0	12.9	25.9	33.9	X	X	Trip 3
3	I-70	I-75 to SR 4 (South)	E	7.2	11.6	33.9	41.1	X	X	Trip 3
5	I-70	SR 4 (South) to I-675	E	3.2	5.1	41.1	44.3	X	X	Trip 3
7	I-70	I-675 to SR 4 (Enon)	E	2.9	4.7	44.3	47.2			
2	I-70	SR 49 to I-57	W	8.0	12.9	25.9	33.9	X	X	Trip 3
4	I-70	I-75 to SR 4 (South)	W	7.2	11.6	33.9	41.1	X	X	Trip 3
6	I-70	SR 4 (South) to I-675	W	3.2	5.1	41.1	44.3	X	X	Trip 3
8	I-70	I-675 to SR 4 (Enon)	W	2.9	4.7	44.3	47.2			
9	I-75	County Line (Warren) to I-675	N	2.6	4.2	40.9	43.5	X	X	Trip 3
11	I-75	I-675 to Carillon Blvd.	N	8.3	13.4	43.5	51.8	X	X	Trip 3
13	I-75	Carillon Blvd. to US 35	N	0.9	1.4	51.8	52.7	X	X	Trip 3, Trip 5
15	I-75	US 35 to SR 4	N	2.1	3.4	52.7	54.8	X	X	Trip 3, Trip 5
17	I-75	SR 4 to Timber Ln.	N	2.9	4.7	54.8	57.7	X	X	Trip 3, Trip 5
19	I-75	Timber Ln. to I-70	N	3.7	6.0	57.5	61.4	X		Trip 3, Trip 5
21	I-75	I-70 to US 40	N	1.8	2.9	61.4	63.2	X	X	Trip 3
23	I-75	US 40 to County Line (Miami)	N	2.1	3.4	63.2	65.3	X	X	Trip 3
10	I-75	County Line (Warren) to I-675	S	2.6	4.2	40.9	43.5	X	X	Trip 3
12	I-75	I-675 to Carillon Blvd.	S	8.3	13.4	43.5	51.8	X	X	Trip 3
14	I-75	Carillon Blvd. to US 35	S	0.9	1.4	51.8	52.7	X	X	Trip 3, Trip 5
16	I-75	US 35 to SR 4	S	2.1	3.4	52.7	54.8	X	X	Trip 3, Trip 5
18	I-75	SR 4 to Timber Ln.	S	2.9	4.7	54.8	57.7	X	X	Trip 3, Trip 5
20	I-75	Timber Ln. to I-70	S	3.7	6.0	57.7	61.4	X		Trip 3, Trip 5
22	I-75	I-70 to US 40	S	1.8	2.9	61.4	63.2	X	X	Trip 3
24	I-75	US 40 to County Line (Miami)	S	2.1	3.4	63.2	65.3	X	X	Trip 3
25	I-675	I-75 to US 35	N	12.7	20.4	0.6	13.3	X	X	Trip 4
27	I-675	US 35 to I-70	N	13.2	21.2	13.3	26.5	X	X	Trip 4
26	I-675	I-75 to US 35	S	12.7	20.4	0.6	13.3	X	X	Trip 4
28	I-675	US 35 to I-70	S	13.2	21.2	13.3	26.5	X	X	Trip 4
29	US 35	SR 49 to I-75	E	5.1	8.2	30.2	35.3	X	X	Trip 4
31	US 35	I-75 to I-675	E	6.4	10.3	35.3	41.7	X	X	Trip 4
30	US 35	SR 49 to I-75	W	5.1	8.2	30.2	35.3	X	X	Trip 4
32	US 35	I-75 to I-675	W	6.4	10.3	35.3	41.7	X	X	Trip 4
33	SR 4	I-75 to I-70	N	10.7	17.2	16.7	27.4	X	X	Trip 4
34	SR 4	I-75 to I-70	S	10.7	17.2	16.7	27.4	X	X	Trip 4
35	SR 49	US 35 to I-70	N	9.0	14.5	0	9	X	X	Trip 4
36	SR 49	US 35 to I-70	S	9.0	14.5	0	9	X	X	Trip 4

The next chapter of this report provides the results from the data collection methodology.

CHAPTER IV
RESULTS

The fourth chapter within this research report contains the results from the five data collection trips. The first set of results is the comparison between the individual radar devices and the spot speeds collected by the research team. The second set of results compares the effectiveness between the data collection from the floating car and the Bluetooth devices. The final set of results is the comparison between the travel times and speeds developed by the research team and the data service provider.

4.1 Comparison between the Spot Speed Readings and Sensor Speeds

The first set of results is the comparison between the spot speeds. In this section, the spot speeds obtained from the laser speed gun are compared to those obtained from the radar sensors currently being used in Dayton, Ohio. Due to the large number of radar device locations, only a select portion of these locations are evaluated. Per contract requirements from ODOT, the data service provider should be within four miles per hour (6.4 km/h) faster or slower than the laser speed gun. The evaluation of speeds is based on the methodology previously described and the results are presented as a series of histograms used to visualize the frequency of speed differentials at a number of radar sensor locations. Histograms are developed for each device id location sampled, with a select number of histograms shown in this section of the report. The additional raw data files for all locations are found in Appendix A, while the corresponding histograms are shown in Appendix B of this report.

Figures 4.1 through 4.3 are representative results from the comparison of the spot speeds. In these figures, the y-axis is the number of observations with a one mile per hour (1.6 km/h) bin. The x-axis is the speed differential between the spot speeds. In this comparison, the laser gun speeds are considered correct for comparison purposes. Based on this assumption, a speed differential less than 0 miles per hour (0 km/h) indicates the radar devices are recording a one-minute average speed that is faster than the one-minute average speed collected by the research team. When the speed differential is faster than zero miles per hour the opposite is true. In general, the spot speeds collected by the research team are faster than the spot speeds from the radar devices. The fourth figure, Figure 4.4, is the summary of all the spot speed locations.

Figure 4.1 illustrates the difference between the laser gun reading and the radar speed sensor data, obtained from sensor number 10681, located on I-70. The majority of vehicles, 88%, are observed to be within the four miles per hour (6.4 km/h) target range. The remaining 12%, or three-minutes of observations, are traveling outside the suggested speed range.   The results show that 56% of the time the speed differential between the two data collection methodologies is within one mile per hour (1.6 km/h). In general, the speed differential for vehicles traveling past device number 10681 is minimal and the speed sensor during this period appears to be working properly.

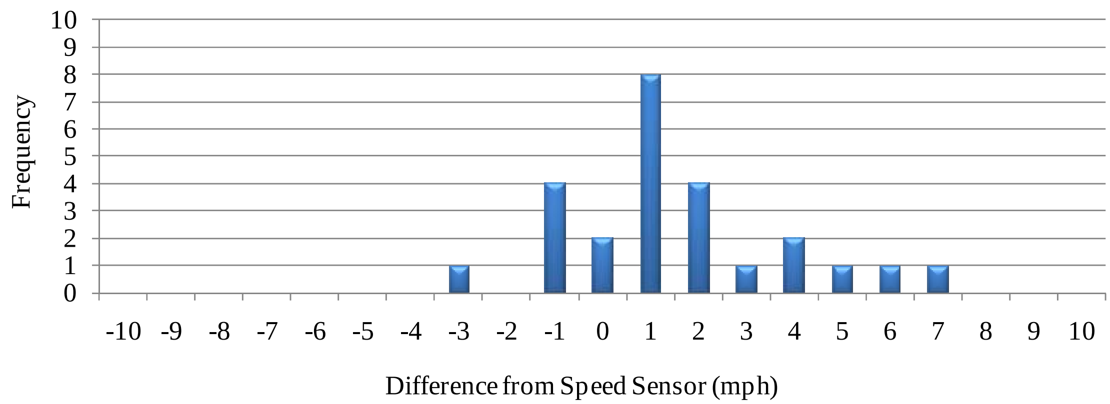


Figure 4.1. Device number 10681, I-70, 7/27/2009, morning rush hour.

The second individual result is from device number 10697, which is also located on I-70. Figure 4.2 depicts the distribution of speed differentials between the laser speed gun readings and data returned by the radar speed sensor. The x-and y-axis remain consistent with Figure 4.1. The speed differential for sensor number 10691 is more widely varied than that of sensor 10681. The larger distribution shown in the histogram may be the result of variations within the traffic pattern as well as the location of the speed collection with respect to the device id location. Speeds reported by the laser speed gun are not significantly slower than those recorded by the radar speed sensor, but several vehicles are found to be traveling slightly faster than the reported speeds. In this sample, 60% of the speeds are within the desirable range. The results displayed in this histogram suggest that the speeds collected by the laser gun are in general faster than the radar devices.

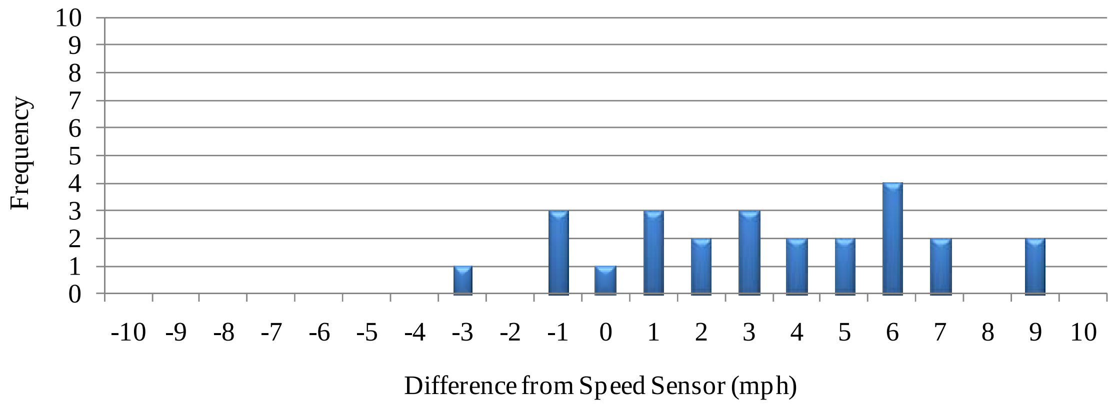


Figure 4.2. Device number 10691, I-70, 7/27/2009, morning rush hour.

A third individual sample is illustrated in Figure 4.3. Spot speed information is obtained from sensor number 10777, located along I-75. The x-and y-axis remain consistent with the previous figures. The results show that 80% of the average one-minute time intervals are within the desirable speed range, and 56% of the data are within one mile per hour (1.6 km/h) of the radar speed sensor. The remaining 20% of the data are outside the target speed range. In some cases, these outside values suggest the radar devices are shooting faster speeds than the laser speed gun, while other times the radar devices are shooting slower speeds. This finding is different from Figure 4.1, where the results consistently show the radar device is shooting slower speeds in comparison to the laser gun. In general, the results during this time period show the two methods are consistent and provide reliable input for the ODOT travel time algorithm.

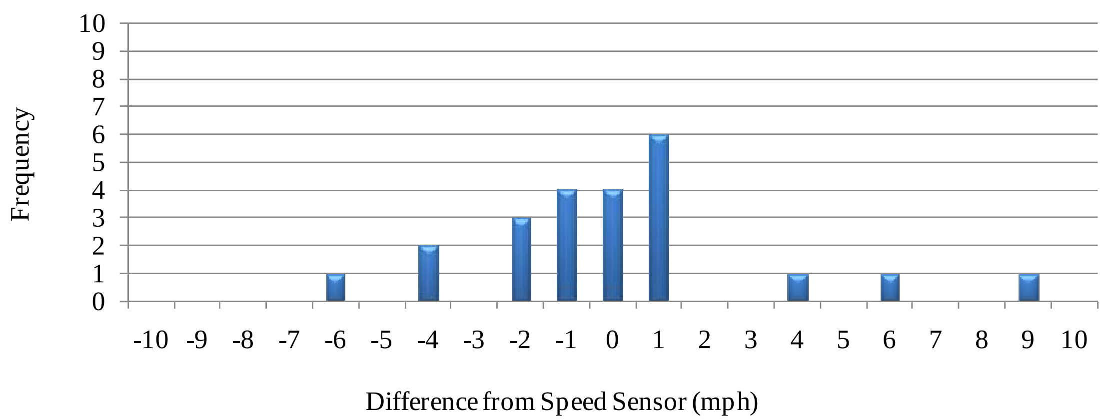


Figure 4.3. Device number 10777, I-75, 8/17/2009, afternoon rush hour.

4.1.1 Discussion of Results

Figure 4.4 shows the frequency of all speed differential observations, compiled from data recorded from each radar speed sensor location included in the within the study area.

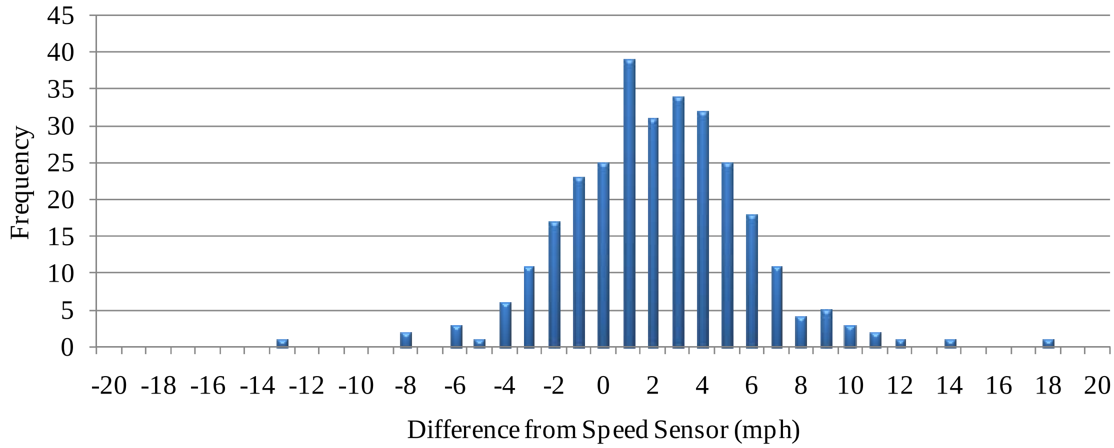


Figure 4.4. Summary of speed differential across all radar sensor locations.

According to Figure 4.4, 75% of laser gun spot speed readings are within four miles per hour (6.4 km/h) of those reported by the radar speed sensor.

4.2 Comparison of Bluetooth and Floating Car Methods

The second set of results within this study is the evaluation of data collection techniques for the floating car and Bluetooth devices. The Bluetooth method is in the early stages of development and it is important to evaluate these results against a widely accepted, more traditional method, such as the floating car method, in order to determine the feasibility of implementing a Bluetooth travel time network. As described previously in the methodology section, there are potential positives and negatives associated with the selection of which technique is the most effective method for collecting travel times and speeds for an identified travel time location. If the two methods provide similar results, it may be said that the Bluetooth method is an acceptable method. The results and the implementation of the Bluetooth methodology vary based on the type of roadway, the time of day and the length of the travel time segment. The results presented within this section are developed for high volume access-controlled interstate highway roads, I-70, I-75 and I-675, urban arterial US-35, and state roads SR-4 and SR-49. Additional results are based on individual Bluetooth data collection for low volume nighttime hours and congestion resulting from construction in a work zone. A summary of all findings is presented in Appendix C for the July 2009 travel time segments.

4.2.1 High Volume Access-Controlled Interstate Highways

The first set of results between the two data collection methodologies is developed for high volume roads. In this study, the high volume roads include I-70, I-75 and I-675. There are, however, some differences between the travel time segments per roadway. In the case of I-70, which travels east and west, north of Dayton, the travel time segments are consistently separated between three and eight miles (4.8 and 12.9 km) per segment with limited accessibility. I-75 has the most segments, 16, and with the exception of travel time Segments 11 and 12, the remaining segment lengths are less than three miles (4.8 km) in length. Unlike I-70, there are many access points on I-75, and the reduction in the travel time segment length is an important consideration in the implementation of Bluetooth travel times. The final high volume road, I-675, is significantly different in regards to the data collection setup than I-70 and I-75. In the case of I-675, four travel times are reported. In each case, the travel time lengths are approximately 12 to 13 miles (19.3 to 20.9 km) in length, significantly longer than the other two interstate roadways. I-675 is similar to I-75 in regards to accessibility to other roadways. A sample comparison of the three roadways is shown in Figures 4.5 through 4.7. In each of these figures, the y-axis is the average speed over the duration of the travel time segment and the x-axis is the time of the day of the data collection. In general, the time of the day is based on capturing the morning or afternoon rush hour.

Bluetooth and floating car data collected from I-70 are shown in Figure 4.5. During this period, vehicles are traveling at free-flow conditions. The two methods provide similar results, with speeds obtained from the probe vehicles complimenting speeds obtained from the Bluetooth method.

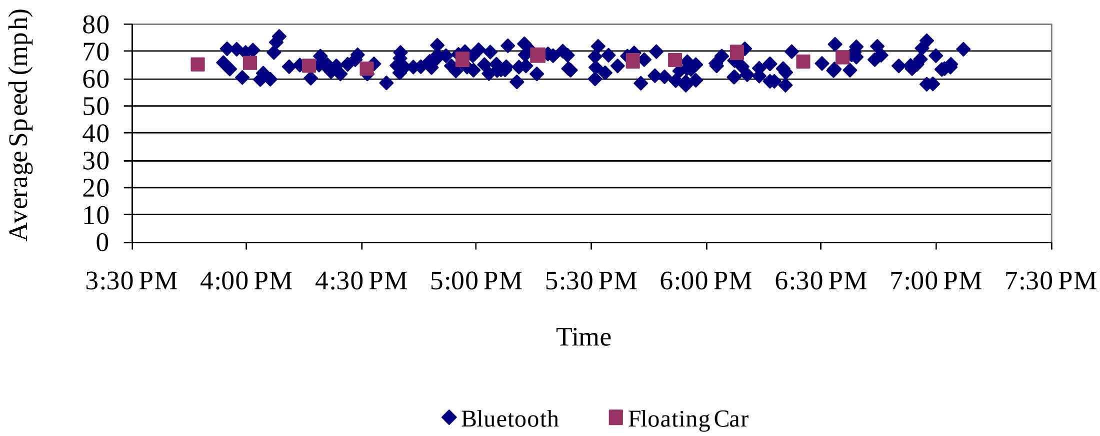


Figure 4.5. Travel Time Segment ID 1, 8.0 miles, 7/27/2009, afternoon rush hour.

The second finding is an example of data recorded during a time of congestion due to a period of rain on I-75. During the data collection period at 4:30 PM, the traffic begins to slow down, but the average vehicle speed is free-flow, in comparison to the previous hour. A light to moderate rainfall begins during this period. Following the initial rain, heavy rain proceeds to fall around 5:00 PM. At this point, the heavy rain in concert with the afternoon rush hour triggers a period of congestion along this travel time segment. During this event, the average vehicle speed decreases to 40 miles per hour (64.4 km/h) around 5:20 PM. Once the rain subsides, the average vehicle speed increases to free-flow conditions just after 5:30 PM.

Several results are shown within Figure 4.6. The first set of results is the overall comparison between the two data collection methodologies. In the case of the floating car data, the drivers are instructed to maintain a “normal” speed with respect to the traffic, while the Bluetooth data are independent of speed. This means that it will be possible for a difference in speeds, especially under free-flow conditions. In Figure 4.6, many Bluetooth reads are faster than 75 miles per hour (120.7 km/h). A second finding shows there are significantly more data points reported by the Bluetooth reader. This is especially important during a period of congestion, 5:00 PM to 5:20 PM. During this period, both data collection methods show a decrease in average vehicle speed. In the case of the floating car, there are three data points, while the Bluetooth is an order of magnitude greater. The larger sample allows for a more descriptive explanation of the travel time during congestion. The speeds decrease at a uniform rate and then increase at a uniform rate, both of which are consistent with congestion based on weather. It may be seen that the data points recorded by the floating car and Bluetooth device are closely related, illustrating that the Bluetooth method is able to accurately portray periods of congestion.

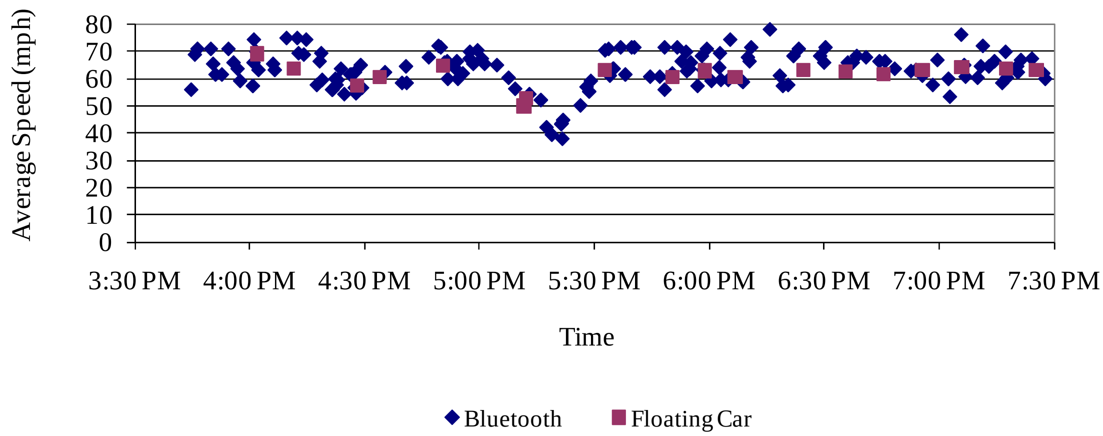


Figure 4.6. Travel Time Segment ID 10, 2.6 miles, 7/29/2009, afternoon rush hour.

The third set of results associated with high volume roads is developed for I-675. I-675 maintained free-flow speeds throughout the majority of the data collection period. The results for I-675 are based on the four travel time segments identified by ODOT. These travel time segments are substantially longer than the travel time segments for I-70 and I-75. As a result of the increased length, there are two sets of findings worth noting.

The first finding, shown in Figure 4.7, is the decrease in Bluetooth matches in comparison to the other two interstates. There may be two reasons for this finding. The first reason is during the data collection period, the volume of traffic on I-675 is less than the traffic on the other two roadways, which lowers the anticipated number of potential matches. The second reason is expressed as the length of the travel time segment. The travel time segments on I-675 are between 12 and 13 miles (19.3 and 20.9 km) in length. This added length increases the opportunity for a vehicle to leave I-675 before the vehicle reaches the end location where the second Bluetooth device is located. Without the second hit, the travel time per Bluetooth device is unable to be calculated, and therefore the speed is not reported.

In addition to the missed Bluetooth hits because of vehicles exiting the roadway prior to the end of the travel time segment, there are instances when the vehicle exits prior to the end of the travel time segment and then re-enters the roadway and continues past the endpoint. In these cases, the recorded speeds are 20 to 30 miles per hour (32.2 to 48.3 km/h) slower than the actual speed. These speeds are not based on the actual travel time, but the total time while the vehicle exits I-675 and then re-enters I-675 20-minutes later. This delay increases the travel time by 20 minutes and provides a significantly slower speed for this segment.

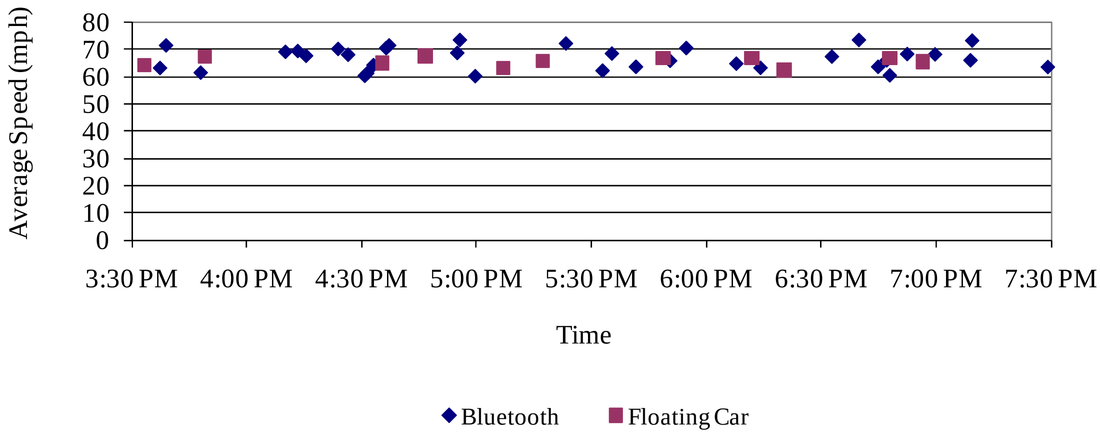


Figure 4.7. Travel Time Segment ID 27, 13.2 miles, 8/19/2009, afternoon rush hour.

A third set of results shown in Figure 4.7 is the relatively low variability within the data set of the data collection period. This result is influenced by the length of the travel time segment. Field observations during this study observe a small length on I-675 with slow speeds as a result of rain. The extended segment length with “normal” speeds offsets the impact of variability during the rain event.

In summary, the results for the floating car and the Bluetooth devices on high volume roads are similar for both the calculation of travel times and speeds and the change in variability associated with congestion. Under free-flow conditions, the Bluetooth devices will have a higher frequency of speeds that are faster than the speed limit. These values should be capped and lowered for the comparison of travel times and speeds over the duration of travel. Other key findings include the impact of travel time segment lengths. The results show the number of Bluetooth matches decreases as the travel time segment length increases.

4.2.2 Urban Arterial Streets and State Highways

In addition to the high volume interstates, this study focused on lower functional class roads, as described in the methodology section. The x-axis and the y-axis remain the same as Figures 4.5 through 4.7. In some cases, these roads have traffic signals, which may affect the overall travel time. Figure 4.8 shows the results from travel time Segment 29, collected on August 18, 2009 during the morning rush hour period. The travel time segment length is approximately 5.1 miles (8.2 km), with vehicles traveling eastbound on US-35. There are two main results from this comparison. The first result is based on the number of Bluetooth matches. As described previously, there is a decrease in the number of Bluetooth matches, which may be explained by the lower volume of traffic. Shown in Figure 4.8, the number of Bluetooth observations are still significantly greater than the floating car method, but unlike the high volume roads, there are now periods, for example 10:00 AM, with no data. In comparison to the floating car data, the Bluetooth data provides similar speed estimates. The second result shows the potential impact from vehicles stopping at traffic signals. For example, the increased number of results around 8:00 AM coupled with the slower average vehicle speed may suggest a platoon of vehicles commonly associated with signals.

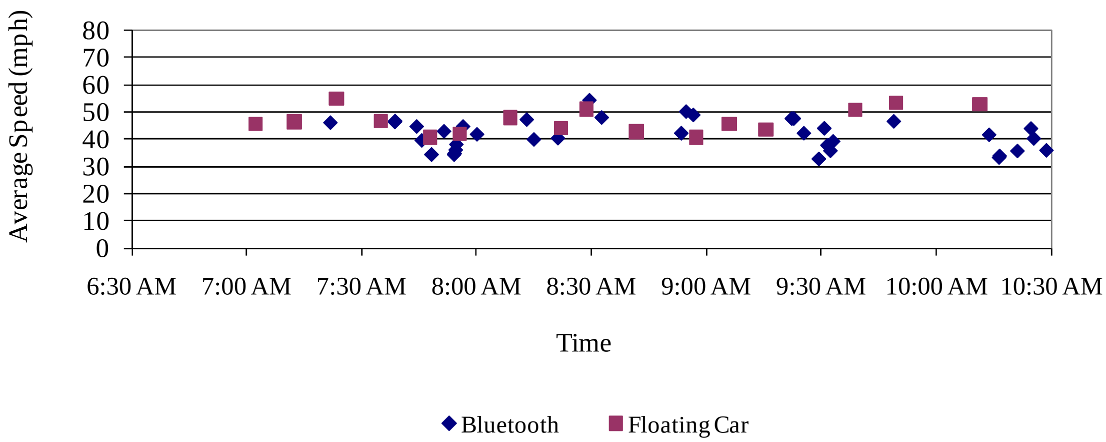


Figure 4.8. Travel Time Segment ID 29, 5.1 miles, 8/18/2009, morning rush hour.

The third series of results are shown for SR-49 from August 18, 2009 during the afternoon rush hour. The results from travel time Segment 36 show the impact of high accessibility with extended travel time segments. The travel time segment length is approximately nine miles (14.5 km) and travels through a populated area with restaurants and other commercial activities. Based on these conditions, the Bluetooth results do not support an effective data collection methodology on their own. In order to increase the number of Bluetooth matches, the location of the Bluetooth boxes should be decreased from the entire travel time segment to one to two-mile (1.6 to 3.2 km) intervals. Lowering the distance between boxes will increase the probability for Bluetooth matches.

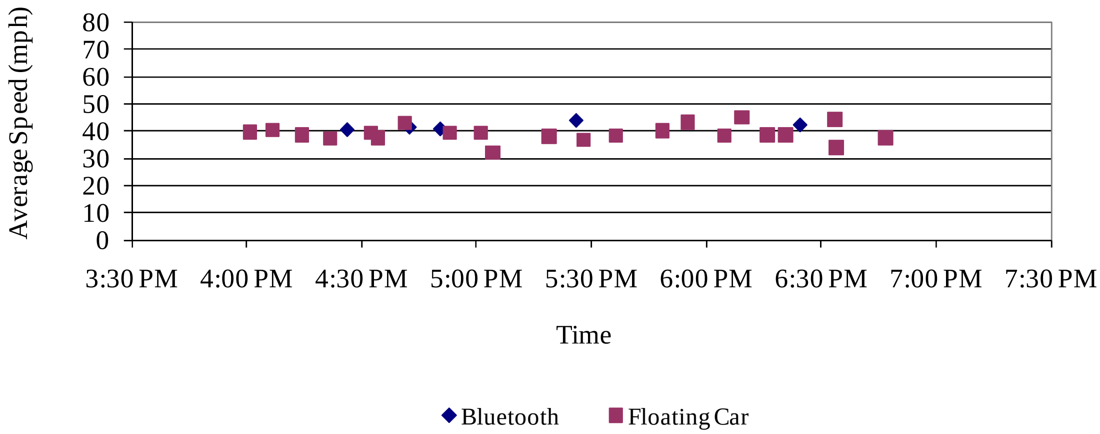


Figure 4.9. Travel Time Segment ID 36, 9.0 miles, 8/18/2009, afternoon rush hour.

A fourth finding is the comparison between the average speeds. Although the number of Bluetooth matches is significantly less than the four instrumented floating car vehicles, when Bluetooth matches do occur, the average speeds between the floating car and the Bluetooth devices are similar. This suggests that the two methods on lower volume streets with accessibility and traffic signals will produce similar speed estimates.

4.2.3 Implementation of Bluetooth based on Time of Day

The implementation of Bluetooth data collection during different times of the day is also investigated within this study. Unlike the floating car methodology, which is dependant solely on the driver's schedule, the Bluetooth data collection is based on actual Bluetooth matches. In order to test the feasibility of Bluetooth during periods of low volume on interstates, Bluetooth data are collected during the evening and early morning hours. The results are based on data collected on August 19, 2009 along I-675. There are no floating car runs for this data collection period. The results show, not surprisingly, a high frequency of Bluetooth matches remain during the evening hours. Around midnight, the number of matches decreases to only a few over the next one-hour period. This is a direct result of the number of vehicles on the road at that time. The low number of vehicles suggests free-flow conditions with no delays. It is unreasonable to suggest that the proportion of Bluetooth radios per vehicle would vary based on daytime and nighttime activity.

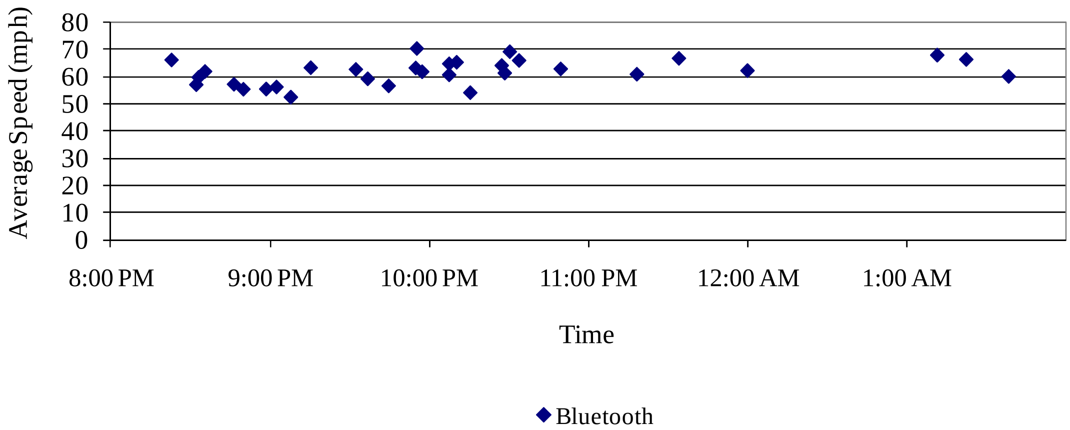


Figure 4.10. Travel Time Segment ID 28, 13.2 miles, 8/19/2009, PM

4.2.4 Work Zone Related Congestion

Figure 4.11 provides another example of the ability of the Bluetooth method to accurately record periods of congestion. This figure represents a queue building on I-75 around 4:00 PM, due to work zone congestion. Vehicle speeds are slow near the beginning of this data collection period, a result of a sudden influx of traffic comprised mainly of commuters traveling home from their places of employment during the evening peak period. Data points are tightly clustered during this period, as the congestion limits speed variability. The queue begins to disperse around 5:30 PM and the traffic stream returns to normal conditions around 6:00 PM. Data points become loosely clustered once the queue is dispersed, as roadway conditions allow for more speed variability. In contrast to the data presented in Figure 4.8, it may be seen that the number of Bluetooth data points increases due to an increase in the number of vehicles on the roadway. Figure 4.11 demonstrates that the Bluetooth method for calculating vehicle speed and travel time is able to successfully report the building and dispersion of a queue resulting from work zone congestion.

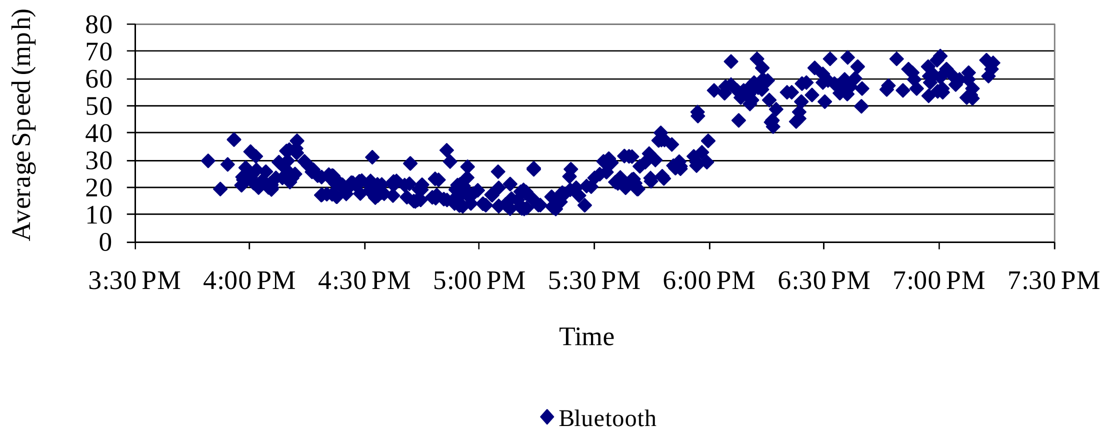


Figure 4.11. Travel Time Segment ID 15, 2.1 miles, 9/3/2009, afternoon rush hour.

4.2.5 Summary of Results

The figures in the preceding section demonstrate that the Bluetooth method is capable of reproducing floating car data, while providing a significantly higher number of data points. The Bluetooth method provides a sample that theoretically represents a larger majority of the traffic stream travelling along a roadway segment. This allows for a more complete spectrum of vehicle speeds to be reported and investigated. The Bluetooth method also provides data from vehicles exceeding the speed limit, while floating car drivers are typically instructed to remain within five miles per hour (8.0 km/h) of the speed limit. Therefore, Bluetooth data may be adjusted to account for this before travel time can be predicted.

4.3 ODOT Travel Time Data Comparison

The third set of results within this study provide a comparison of the travel time data developed by ODOT and the travel time calculated from the floating car and Bluetooth methods. The findings presented in this section are reported as average travel time in minutes and average speed with units of miles per hour. Travel time data provided by ODOT are capped to exclude data points with excessive speeds on the roadway, while the data provided by the floating car and Bluetooth methods includes data at all speeds. There are six summary findings discussed in this section:

- Free-flow conditions,
- Periods of congestion,
- The improvement in data resolution using Bluetooth method in addition to the floating car method,
- The underreporting of travel times, especially on arterial roadways,
- The influence of rounding travel times to the nearest minute on short segment lengths, and
- The occurrence of unexplained differences in reported travel times.

Tables are provided for each travel time segment illustrating the mean absolute difference and the mean difference bias, reported for slow speeds, medium speeds and fast speeds. The actual speed range per bin varies between interstates and arterials. The mean absolute difference is a positive value, which describes the magnitude of the error, while the mean difference bias may be presented as both a positive or negative value, which shows whether the travel time or the speed is over- or underreported. A negative mean difference bias for travel time indicates that ODOT is reporting faster travel times than the floating car and Bluetooth data. However, the travel time and speed are inversely related, a negative mean difference bias for speed indicates the ODOT speed data are slower than the floating car and Bluetooth speed data. The tables shown in this section as well as Appendix D provide a summary of the results for each segment. In addition to these tables, individual comparisons are shown through figures in this section as well as Appendix D. The figures are provided for the travel time versus time of day and the speed versus time of day. Time of day is plotted on the x-axis and the travel time in minutes or the speed in miles per hour, respectively, are plotted on the y-axis. Some figures provide a composite of both floating car and Bluetooth data, while others show floating car only or Bluetooth only data.

4.3.1 Free-flow Conditions

The first set of results is developed for roadways where the data collection period occurs during free-flow conditions. Travel time Segments 3 and 21 are provided as examples of free-flow data comparisons. Under these conditions, the current method used by ODOT to calculate travel times and speeds for a travel time segment is effective. Tables 4.1 and 4.2 summarize the results for these travel time segments. Figures 4.12 through 4.15 depict the travel time segments.

Table 4.1 shown on the next page is the summary of the mean absolute difference and the mean bias difference for travel time Segment 3, which is located on I-70. In total, there are 94 travel time comparisons within this segment. In this table, there are no speeds that are slower than 45 miles per hour (72.4 km/h). In general, the average travel time is within 30 seconds and the speed range between the ODOT travel time algorithm and the reference field data is less than 5 miles per hour (8.0 km/h). When the speed bin is between 45 and 60 miles per hour (72.4 and 96.6 km/h), ODOT is reporting faster travel times than the field. When the speed range is faster than 60 miles per hour (96.6 km/h), ODOT is reporting slower travel times. This difference is explained by the individual vehicles that are travelling faster than the ODOT cap. In this case, it is important to note that the roadway is operating under ideal conditions.

Table 4.1. Summary of results, Segment 3, 7.2 miles (11.6 km).

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (miles per hour)	Travel Time (minutes)	Speed (miles per hour)	
0 to 30 miles per hour	-	-	-	-	0
30 to 45 miles per hour	-	-	-	-	0
45 to 60 miles per hour	0.3	2.6	-0.3	2.6	6
60+ miles per hour	0.5	5.0	0.5	-5.0	88

Figures 4.12 and 4.13 shown on the next page provide the individual results for the travel times and the speeds for Segment 3. In these figures, there is an inverse relationship. When the travel times are high, the individual speeds are slow. Conversely, if the travel times are low, the speeds are fast.   In these figures, the ODOT reference is consistently reporting an average travel time of seven minutes with an average vehicle speed of 62 miles per hour (99.8 km/h).   The reference data are traveling slightly faster as a result of the free-flow conditions, but in general, there is a nice correlation between the ODOT travel time algorithm and the reference field data.

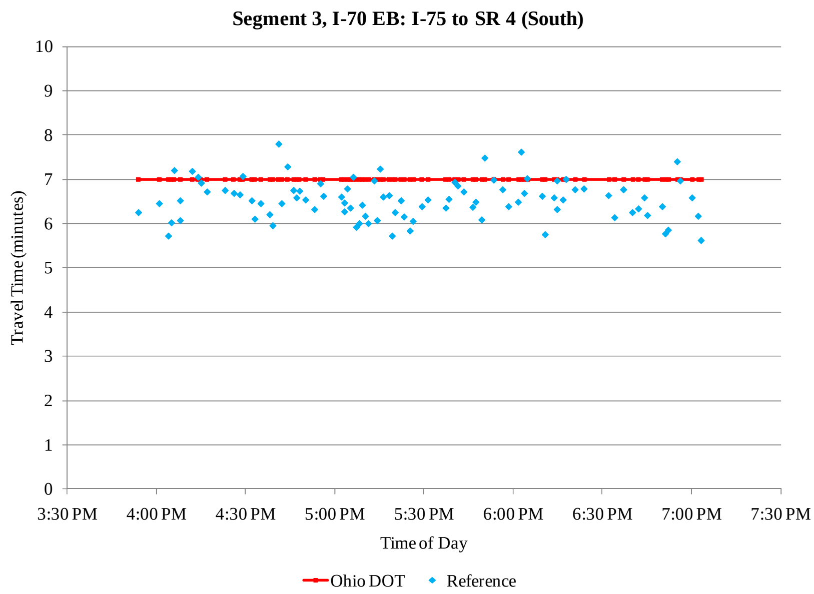


Figure 4.12. Travel time according to time of day, Segment 3, 7.2 miles (11.6 km).

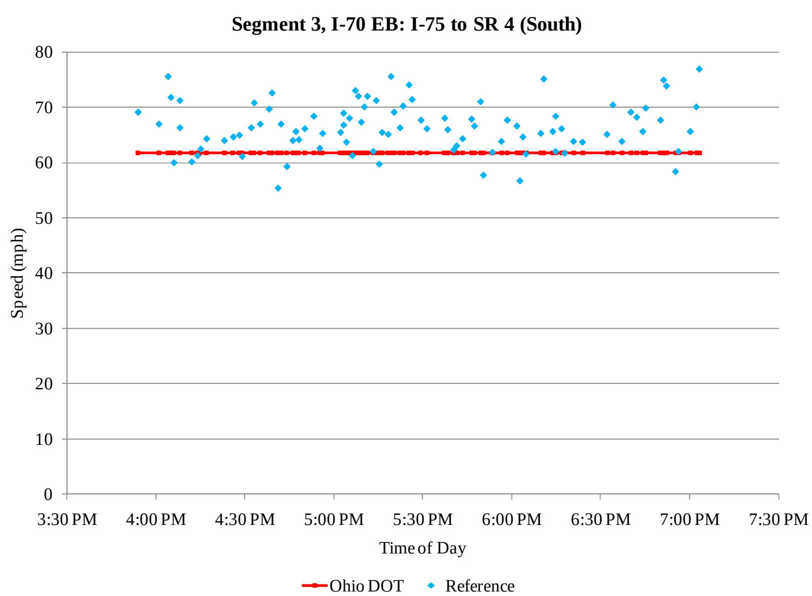


Figure 4.13. Speed according to time of day, Segment 3, 7.2 miles (11.6 km).

Travel time Segment 21 is the second example of free-flow conditions during data collection. Table 4.2 shown below provides a summary of the four reference speed bins. In this comparison, there are 101 individual travel time comparisons. Similar to Segment 3, there are no speeds slower than 45 miles per hour (72.4 km/h). The results for Segment 21 show a nice correlation for both the mean absolute difference and the mean bias difference. In both cases, the average travel time is the same and the speeds are within four miles per hour (6.4 km/h).

Table 4.2. Summary of results, Segment 21, 1.8 miles (2.9 km).

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (miles per hour)	Travel Time (minutes)	Speed (miles per hour)	
0 to 30 miles per hour	-	-	-	-	0
30 to 45 miles per hour	-	-	-	-	0
45 to 60 miles per hour	0.0	3.0	0.0	3.0	15
60+ miles per hour	0.0	4.0	0.0	1.8	86

Figures 4.14 and 4.15 shown on the next page are the individual comparisons between the travel times and the speeds for travel time Segment 21. There are two periods provided in these figures. The first period represents the morning rush hour and the second period represents the afternoon rush hour. The results are similar to the findings for Segment 3. Under free-flow conditions, the reference data from the field shows vehicles are travelling faster than the capped ODOT values. This creates, on average, faster travel times in the field as compared with the reported ODOT estimates. Similar to the findings from Segment 3, there are nice correlations in both the travel times and speeds between the ODOT algorithm and the field reference data.

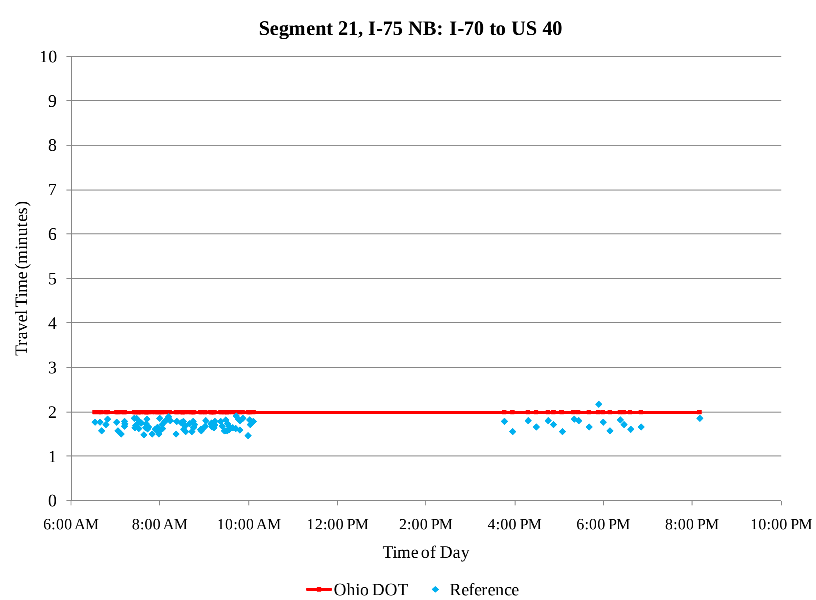


Figure 4.14. Travel time according to time of day, Segment 21, 1.8 miles (2.9 km).

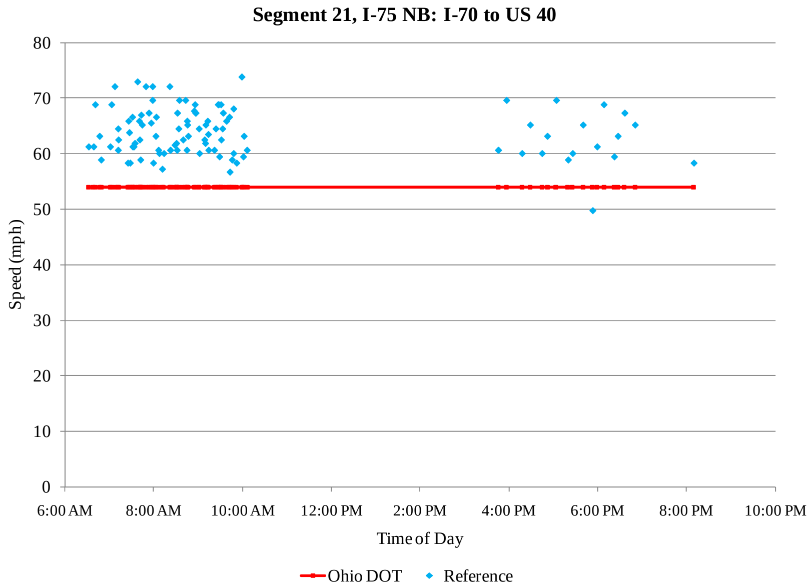


Figure 4.15. Speed according to time of day, Segment 21, 1.8 miles (2.9 km).

4.3.2 Periods of Congestion

The second set of results is developed for periods of congestion. Under these conditions, the travel times and speeds vary during the period of data collection. As described in the methodology section, the desirable data collection duration is long enough to capture both free-flow and congested conditions. One example of congestion is the result of work zone related activities. The results for travel time segment 15 are presented in Table 4.3, while Figures 4.16 and 4.17 display the travel times and speeds for this segment, which is 2.1 miles (3.4 km) in length.

There are 206 individual observations within Table 4.3. Two sets of results are presented for segment 15. The first set is for the travel times and the second set is for the speeds. In the case of the mean absolute difference and the mean bias difference, the travel times are between 0.4 and 1.3 mintues. From a travel time persepective these results seem reasonable. The results of the speeds are significantly impacted by the rounding of the travel times. In terms of speeds for both the mean absolute difference and the mean bias difference, the speeds range between -1.7 miles per hour (-2.7 km/h) to faster than -20.5 miles per hour (-33.0 km/h). The main explanation for this difference is the impact of rounding the travel times, especially on a shorter length segment.

Table 4.3. Summary of results, Segment 15, 2.1 miles (3.4 km).

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (miles per hour)	Travel Time (minutes)	Speed (miles per hour)	
0 to 30 miles per hour	1.3	4.7	-0.8	-1.7	96
30 to 45 miles per hour	0.7	10.4	0.3	-8.9	12
45 to 60 miles per hour	0.6	21.5	0.6	-20.5	78
60+ miles per hour	0.4	20.4	0.4	-20.4	20

Figures 4.16 and 4.17 show the impact of congestion and non-congestion traffic flows travelling on Segment 15. The first set of results show the inverse relationship between segment travel times and speeds. Between 4:00 PM and 5:30 PM there is work zone related congestion on this travel time segment. The heavest congestion occurs around 5:15 PM to 5:30 PM. After 5:30 PM, the congestion begins to dissipate back to free-flow conditions around 6:30 PM. As the volume decreases around 6:00 PM, the reference data show significant variability within the traffic stream. With regards to the ODOT travel time algorithm, the estimated travel time varies between 4 and 6 minutes, while the reference travel time varies between 4 and 9.5 minutes. A difference of 3.5 minutes is substainial for a travel time segment which is less than 2.5 miles (4.0 km) in length. The speed comparison between the ODOT algorithm and the reference data show the reference data are slower than the ODOT comparison during the period of high congestion. During the transitional period between congestion and non-congestion, both the reference and the ODOT speeds show significant variability, with speeds ranging between 42 and 65 miles per hour (67.6 and 104.6 km/h).

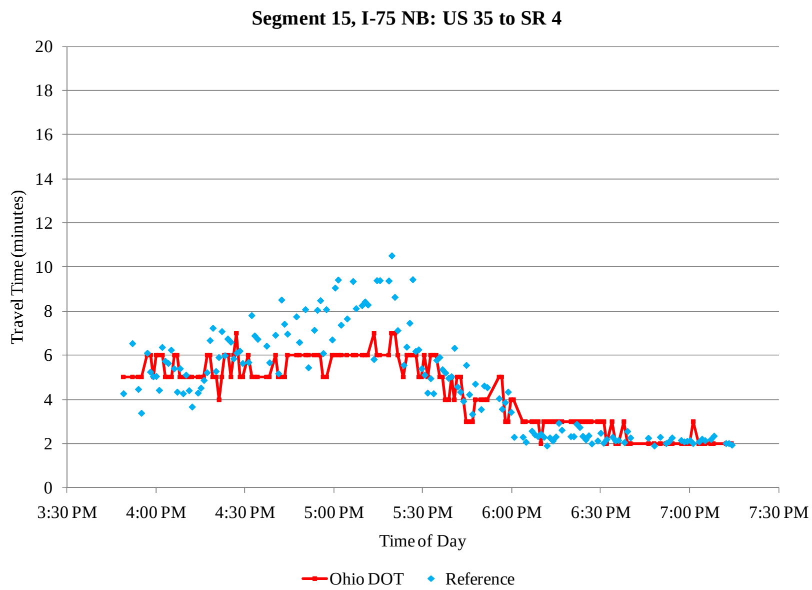


Figure 4.16. Travel time according to time of day, Segment 15, 2.1 miles (3.4 km).

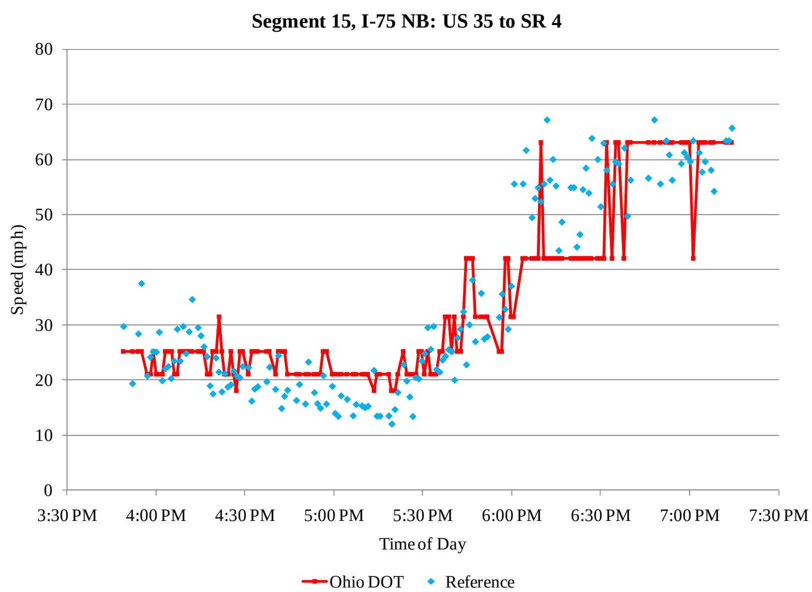


Figure 4.17. Speed according to time of day, Segment 15, 2.1 miles (3.4 km).

4.3.3 Advantages of Bluetooth Method

The third set of results will highlight the advantages of data provided by the Bluetooth method over the floating car method. Travel time Segment 9, I-75 northbound between the county line and I-675, is used to show the impact of additional data points from Bluetooth data collection. There are two sets of results provided for this travel time segment. The first set of results is the average travel times and average speeds. Table 4.4 is a summary of these findings. The second set of results are the plots of the individual travel times and speeds. Figures 4.18 and 4.19 provide a comparison of the two methods, the composite of both the Bluetooth and floating car data obtained during the AM peak period, which are compared with the floating car only data obtained during the PM peak period.

The summary results provided in Table 4.4 are reported as the average travel times and speeds during the data collection. In total, there are 149 travel time comparisons reported for Segment 9. There are four speed bins and the slowest speed range is between 45 and 60 miles per hour (72.4 to 96.6 km/h). Table 4.4 is a demonstration of the importance in evaluating both the travel times and speeds together. In the case of the travel times for both speed ranges, the correlation is within 0.7 minutes or 42 seconds. However, the average difference in speeds is between -2.8 miles per hour to 18.4 miles per hour (-4.5 to 29.6 km/h). On average, the ODOT algorithm is reporting faster travel times over this segment. One additional finding shown in Table 4.4 is the impact of the ODOT travel time algorithm varying between 2 and 3 minutes for the travel time. Based on the reference data, this period is considered free-flow with speeds of approximately 60 to 65 miles per hour (96.6 to104.6 km/h). As a result of varying the ODOT algorithm, the reported ODOT speeds range from 52 miles per hour to 80 miles per hour (83.7 to 128.7 km/h), creating the large difference in reported speeds.

Table 4.4. Summary of results, Segment 9, 2.6 miles (4.2 km).

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (miles per hour)	Travel Time (minutes)	Speed (miles per hour)	
0 to 30 miles per hour	-	-	-	-	0
30 to 45 miles per hour	-	-	-	-	0
45 to 60 miles per hour	0.7	18.4	-0.7	18.4	29
60+ miles per hour	0.5	13.6	0.1	-2.8	120

Figures 4.18 and 4.19 shown below provide an example of the importance of adding Bluetooth data collection in concert with floating car data. In general, as shown in section 4.2 of

this report, the two methods provide similar results for travel times and speeds. Figures 4.18 and 4.19 show the impact of adding a significantly greater number of data points by incorporating Bluetooth into the reference data. In these figures, the left side of the graphs is the morning data collection time period, and is generated using both Bluetooth and floating car data, while the right side of the figures, the afternoon data collection, is generated using only floating car data. The additional data points allow for more variation in travel times and speeds within a particular data collection period. For instance, in Figure 4.19, the area of the figure showing both the Bluetooth and floating car data illustrates many instances where the travel time is fluctuating between 2 minutes and 3 minutes. The area of the figure showing floating car data alone is only able to recognize a few instances of travel time fluctuation, occurring around 4:00 PM and 7:00 PM. As the number of data points increases, so too does the ability to more accurately reflect vehicle behavior, especially during periods of delay.

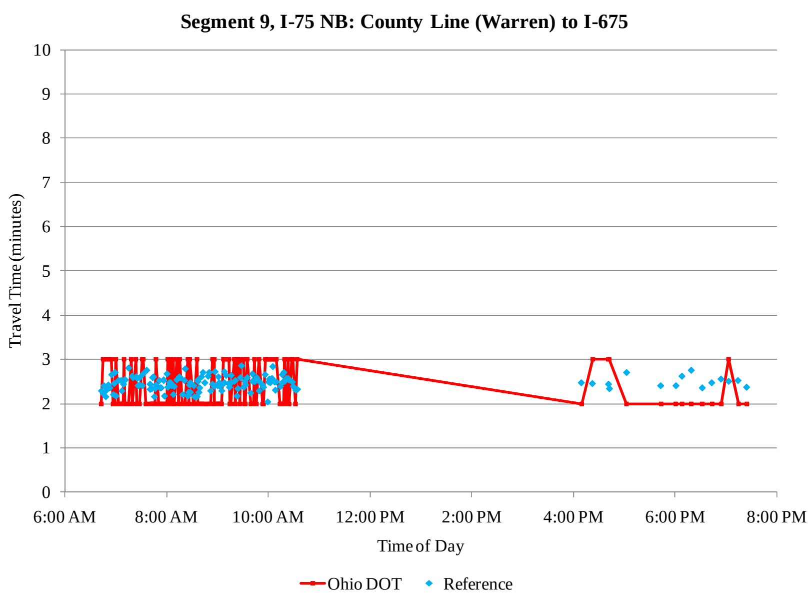


Figure 4.18. Travel time according to time of day, Segment 9, 2.6 miles (4.2 km).

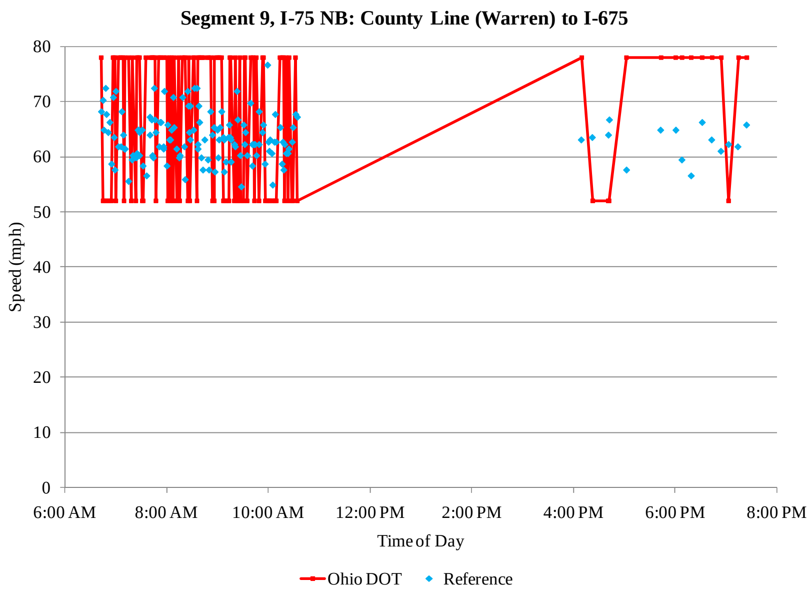


Figure 4.19. Speed according to time of day, Segment 9, 2.6 miles (4.2 km).

4.3.4 Underreported Travel Times

The fourth common finding in this result section is the ODOT reported travel times are faster than the observed travel times. Several instances of underreported travel time occur on arterial roadways, especially roadways that are signalized. Two examples of this type of result are summarized in Tables 4.5 and 4.6, for travel time Segments 29 and 30. In addition to the summary tables, individual comparisons are provided in Figures 4.20 through 4.23.

Table 4.5 shows the average travel time and speed comparisons for travel time Segment 29. Travel time Segment 29 is US-35 eastbound between SR-49 and I-75. There are 47 individual observations within the segment. Unlike the previous examples, the overall sample size is smaller for this travel time segment. There are a few possible explanations. The first explanation is the impact of lower volumes of traffic. The second is the increased difficulty in matching Bluetooth reads on more accessible roadways and the third explanation is the segment length for this arterial may be too long for the optimal number of Bluetooth reads. There is a second difference between Table 4.5 and Tables 4.1 through 4.4, which is the different speed bin ranges. In this case, the speeds are slower due to the fact that Segment 29 is an arterial roadway. The findings show there are four observations with speeds between 20 and 35 miles per hour (32.2 and 56.3 km/h), 36 observations between 35 and 50 miles per hour (56.3 and 80.5 km/h) and 7 observations with speeds faster than 50 miles per hour (80.5 km/h). When the speeds are slow, the ODOT algorithm is reporting, on average, travel times that are 3.3 minutes faster than the reference data. As the speed bins increase, the mean bias improves to 1.4 minutes and 0.3

minutes. This difference in travel time may be explained by the difficulty in modeling more congested flow, which occurs during the period with the slower speed bin.

Table 4.5. Summary of results, Segment 29, 5.1 miles (8.2 km).

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (miles per hour)	Travel Time (minutes)	Speed (miles per hour)	
0 to 20 miles per hour	-	-	-	-	0
20 to 35 miles per hour	3.3	20.6	-3.3	20.6	4
35 to 50 miles per hour	1.4	12.1	-1.4	12.1	36
50+ miles per hour	0.3	4.5	-0.3	4.5	7

Figures 4.20 and 4.21 are the individual travel time results from Segment 29. In general, the results show the ODOT algorithm remains relatively constant, with travel times between 5 and 6 minutes.   The reference data shows travel times, on average, are 1 to 2 minutes longer. Also shown in these figures is the comparison of the vehicle speeds. In this case, the ODOT speeds range between 52 and 62 miles per hour (83.7 and 99.8 km/h), while the reference speeds are slower, ranging between 40 and 50 miles per hour (64.4 and 80.5 km/h). In both cases, the difference between the ODOT algorithm and the reference data are consistent, suggesting a possible recalibration of the ODOT algorithm may be required to improve the overall correlation between the two methods.

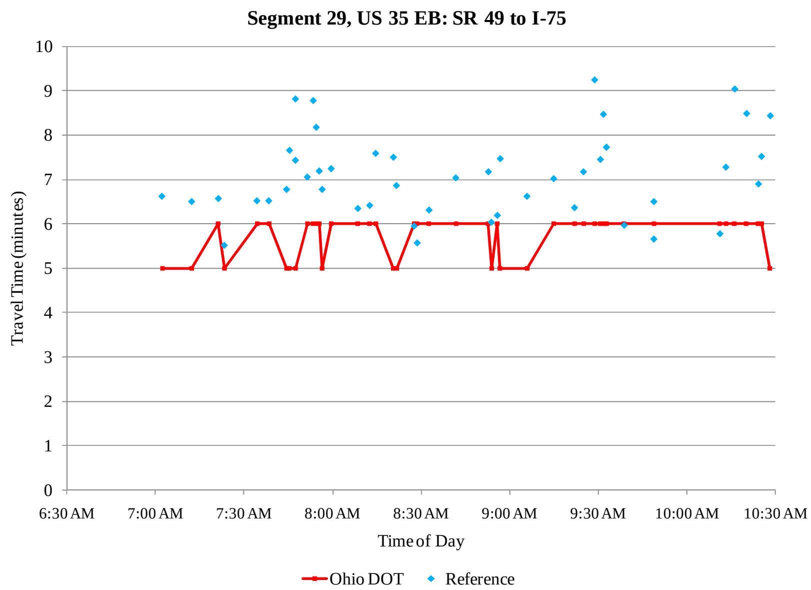


Figure 4.20. Travel time according to time of day, Segment 29, 5.1 miles (8.2 km).

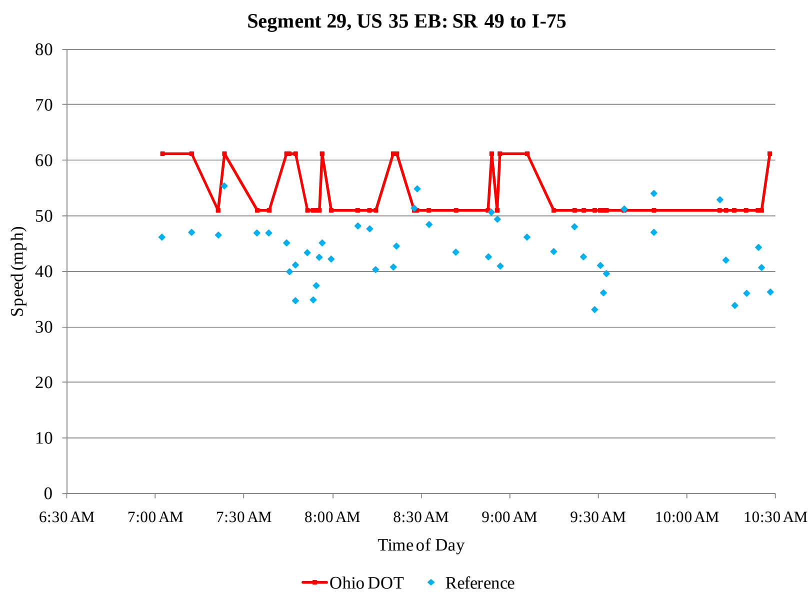


Figure 4.21. Speed according to time of day, Segment 29, 5.1 miles (8.2 km).

Table 4.6 is the second example of consistent lower travel times and faster speeds reported by ODOT. Similar to Table 4.5, there are 26 reported individual observations used in the comparison. The explanation for the smaller sample size is the same as Table 4.5. The results show the travel time comparison ranges from 0 minutes to 0.8 minutes, or 48 seconds.

Based on the mean bias difference, on average, the ODOT algorithm is reporting faster travel times than the reference data.

Table 4.6. Summary of results, Segment 30, 5.1 miles (8.2 km).

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (miles per hour)	Travel Time (minutes)	Speed (miles per hour)	
0 to 20 miles per hour	-	-	-	-	0
20 to 35 miles per hour	-	-	-	-	0
35 to 50 miles per hour	0.8	6.3	-0.8	6.3	21
50+ miles per hour	0.4	3.6	0.0	0.7	5

Figures 4.22 and 4.23 shown on the next page are developed for Segment 30. In this comparison, the ODOT travel time algorithm varies between 5 and 7 minutes, while the reference travel times remain near 6.5 to 7 minutes. The change in travel times corresponds to an estimated speed of 52 to 62 miles per hour (83.7 and 99.8 km/h) for the ODOT algorithm and 42 to 50 miles per hour (67.6 and 80.5 km/h) for the reference data. In general, the results remain consistent with the ODOT algorithm, estimating slightly faster travel times. One potential improvement, which is similar to Figures 4.20 and 4.21, is the recalibration of the ODOT algorithm, which may include adding 1 to 2 minutes to the travel time estimate.

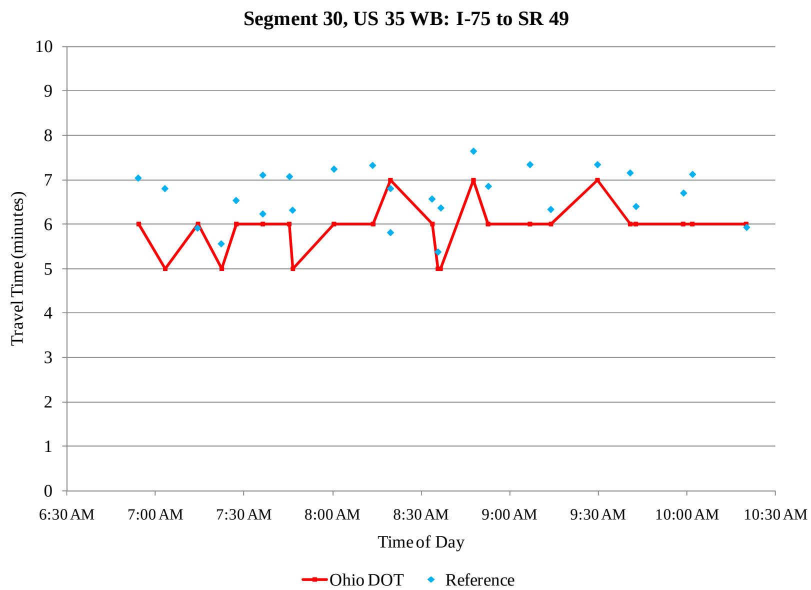


Figure 4.22. Travel time according to time of day, Segment 30, 5.1 miles (8.2 km).

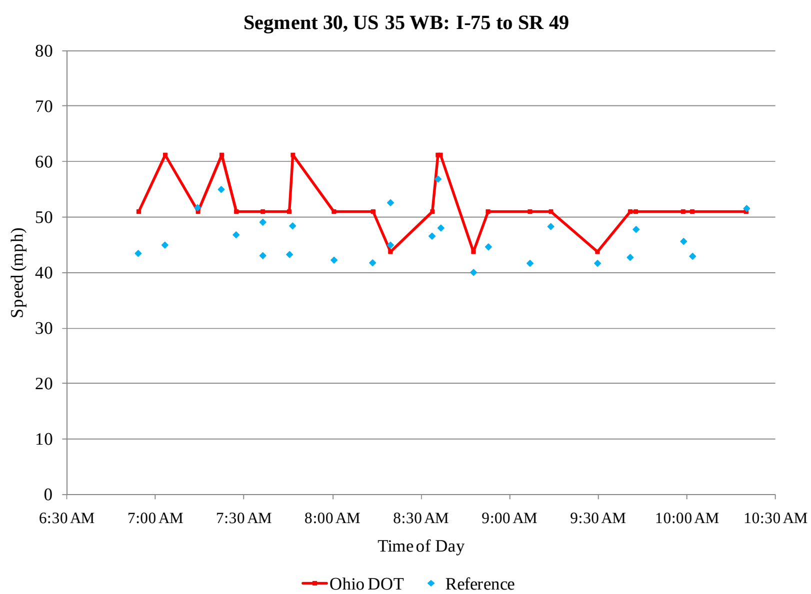


Figure 4.23. Speed according to time of day, Segment 30, 5.1 miles (8.2 km).

4.3.5 Effects of Travel Time Rounding on Short Segments

The fifth set of results within this section is the impact of rounding the travel times to the nearest minute on short segment lengths. In general, this is a good policy, as mororists are better able to comprehend an anticipated travel time of 5 minutes, for example, instead of 4.7 minutes. The effects of this policy are rather insignificant over the course of several miles. However, this study considers a wide range of travel time segment length, with some segments as short as 0.9 miles (1.4 km), while other segment lengths are as long as 13.2 miles (21.2 km).

Table 4.7 provides a summary of results for Segment 16. There are 193 individual samples within Segment 16.   When comparing the average mean absolute difference and mean bias difference with respect to the travel times, the differences between the ODOT algorithm and the reference data are, on average, within one minute of each other. The mean absolute difference and the mean bias difference, in regards to vehicle speeds, are significantly different between the two methods. This difference is the direct result of rounding the travel times. In this case, the values vary by 15 to 18 miles per hour (24.1 to 29.0 km/h).

Table 4.7 Summary of results, Segment 16, 2.1 miles (3.4 km).

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (miles per hour)	Travel Time (minutes)	Speed (miles per hour)	
0 to 30 miles per hour	-	-	-	-	0
30 to 45 miles per hour	1.0	15.0	-1.0	15.0	1
45 to 60 miles per hour	0.5	18.9	0.4	-17.3	180
60+ miles per hour	0.4	17.8	0.4	-17.8	12

Figures 4.24 and 4.25 show the individual comparisons of travel times and speeds between the ODOT algorithm and the reference method. The results show the ODOT algorithm oscilates between two and three minutes during a period of free-flow. Although this ocsillation is within an acceptable travel time range in comparison to the reference data, this ocialltion, as shown in Figure 4.25, corresponds to an approximate estimated speed range of 20 miles per hour (32.2 km/h) for free-flow conditions. This is particually important on short sections when travel times are based on free-flow conditions. Assuming congestion resulting in travel times increasing to 5 to 6 minutes, the corresponding range in speed would decrease to 5 miles per hour (8.0 km/h), which indicates the potential variation in speeds between free-flow and congested conditions. This is a 15 miles per hour (24.1 km/h) decrease in the range of speeds between free-flow and congestion.

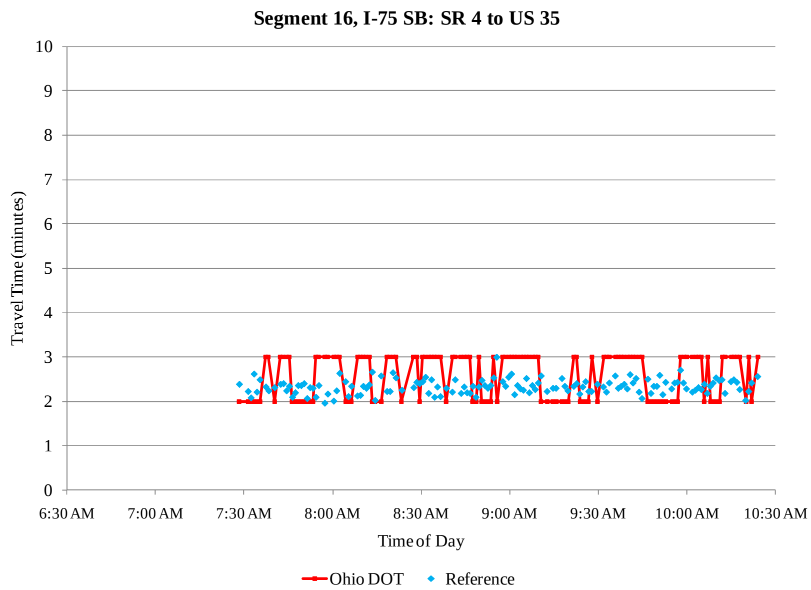


Figure 4.24. Travel time according to time of day, Segment 16, 2.1 miles (3.4 km).

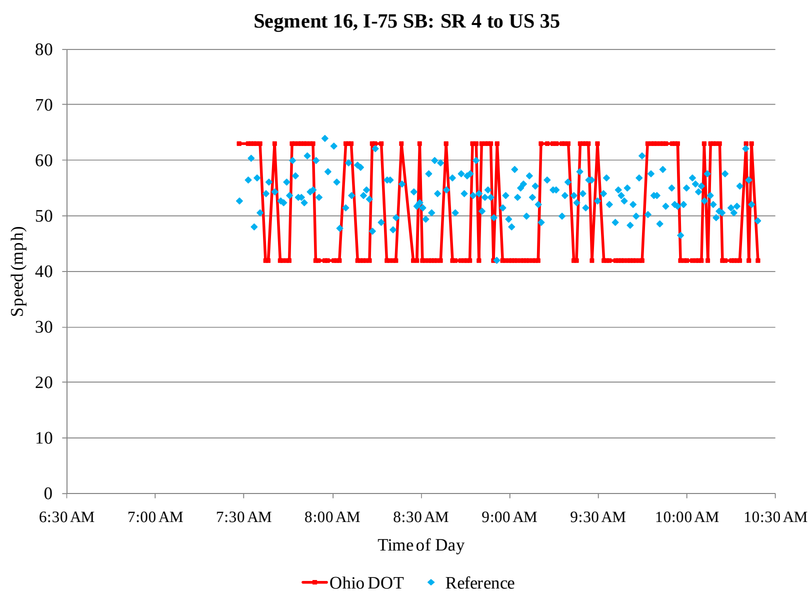


Figure 4.25. Speed according to time of day, Segment 16, 2.1 miles (3.4 km).

4.3.6 Occurrence of Unexplained Differences in Reported Travel Time

In the first five sets of results, the comparisons between the reported ODOT travel times and speeds with the Bluetooth and floating car reference data may be explained. However, some travel time segments produce results with unexplained differences between the reported and observed average speeds and average travel times. One significant difference between this data and the previous data is the period in which the data are collected. The initial data collection began near 3:30 PM in the afternoon, which is consistent with other afternoon data collection periods. The difference involves the ending time. In this case, Bluetooth devices record data until 2:00 AM, the following day, which is well past the 7:00 PM time when most data collection ends. The evening period represents a period with relatively free-flow conditions as well as a time when the data service provider samples the data stream less frequently. A sample of these results is shown in Tables 4.8 and 4.9, and Figures 4.26 through 4.29.

Table 4.8 is developed for data collected from Segment 27, which is I-675 northbound between US-35 and I-70. In this data collection duration, there are 76 individual reference samples. In terms of reportable results, Table 4.8 shows both the travel times and the average speeds vary significantly between the two reference methods. The travel times vary between 7 and 17 minutes, while the speeds vary from -12.6 to -25.8 miles per hour (-20.3 to -41.5 km/h). When comparing the mean biased difference, the ODOT travel time algorithm at a minimum is 7 minutes and 13 miles per hour slower than the reference data.

Table 4.8. Summary of results, Segment 27, 13.2 miles (21.2 km).

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (miles per hour)	Travel Time (minutes)	Speed (miles per hour)	
0 to 30 miles per hour	-	-	-	-	0
30 to 45 miles per hour	-	-	-	-	0
45 to 60 miles per hour	17.3	26.6	17.3	-25.8	6
60+ miles per hour	7.0	15.3	6.8	-12.6	68

Figures 26 and 27 shown on the next page are examples of unexplainable differences between the ODOT travel time algorithm and the reference data. In both figures, the Bluetooth data and the floating car data remain consistent across the period. The floating car data collection ends at 7:15 PM. After that time, only Bluetooth data are used in the comparison. In both of these figures, there are dramatic variations in travel times and speeds after 6:30 PM and this variation continues throughout the evening hours and well into the morning. In the case of travel time, using the ODOT algorithm reports travel times approaching 50 minutes, while the reference data remains relatively constant, reporting travel times between 10 to 15 minutes. In addition to the times, the speeds reported by ODOT decrease to 20 to 30 miles per hour (32.2 to 48.3 km/h), while the reference data remains consistent with speeds between 60 to 70 miles per hour (96.6 to 112.7 km/h).

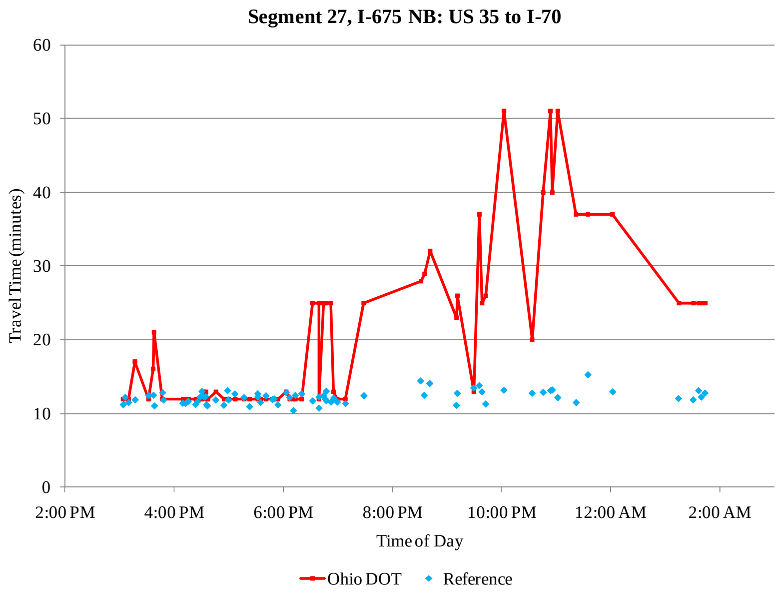


Figure 4.26. Travel time according to time of day, Segment 27, 13.2 miles (21.2 km).

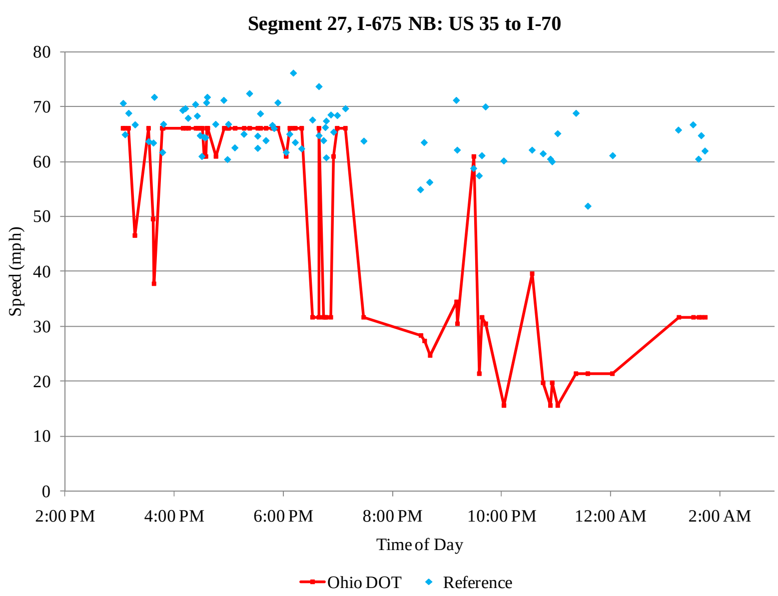


Figure 4.27. Speed according to time of day, Segment 27, 13.2 miles (21.2 km).

A second example of unexplained differences between the ODOT travel times and the reference data is shown for Segment 28, which is I-675 southbound between I-70 and US-35. There are 79 individual observations that populate this travel time segment example. The date and time of the reference data are the same as Table 4.8. Similar to the previous example, both the mean absolute difference and the mean bias difference for both the average travel times and average speeds vary dramatically between the ODOT algorithm and the reference data. The mean bias difference travel times ranges from 5 to 32.1 minutes, and the mean bias difference average speeds ranges from -8.8 miles per hour to -32.4 miles per hour (-14.2 to -52.1 km/h).

Table 4.9. Summary of results, Segment 28, 13.2 miles (21.2 km).

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (miles per hour)	Travel Time (minutes)	Speed (miles per hour)	
0 to 30 miles per hour	-	-	-	-	0
30 to 45 miles per hour	-	-	-	-	0
45 to 60 miles per hour	32.5	34.5	32.1	-32.4	11
60+ miles per hour	5.1	11.6	5.0	-8.8	68

Figures 4.28 and 4.29 are the results from the individual travel time and speed observations between the ODOT algorithm and the reference data. These results are similar to the previous example. Before 6:30 PM, the comparisons between the two methods are relatively consistent, while the comparisons vary dramatically during the evening hours. The travel times spike to 60 plus minutes, while the speeds decrease to 20 to 25 miles per hour (32.2 to 40.2 km/h) for the ODOT reported values. The reference data, similar to the previous findings, remain consistent with travel times between 10 and 15 minutes and speeds between 60 and 70 miles per hour (96.6 and 112.7 km/h).

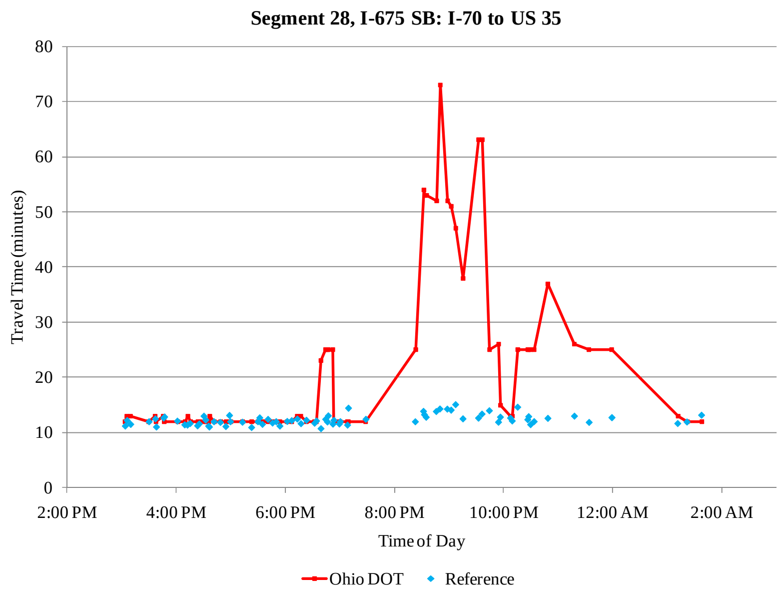


Figure 4.28. Travel time according to time of day, Segment 28, 13.2 miles (21.2 km).

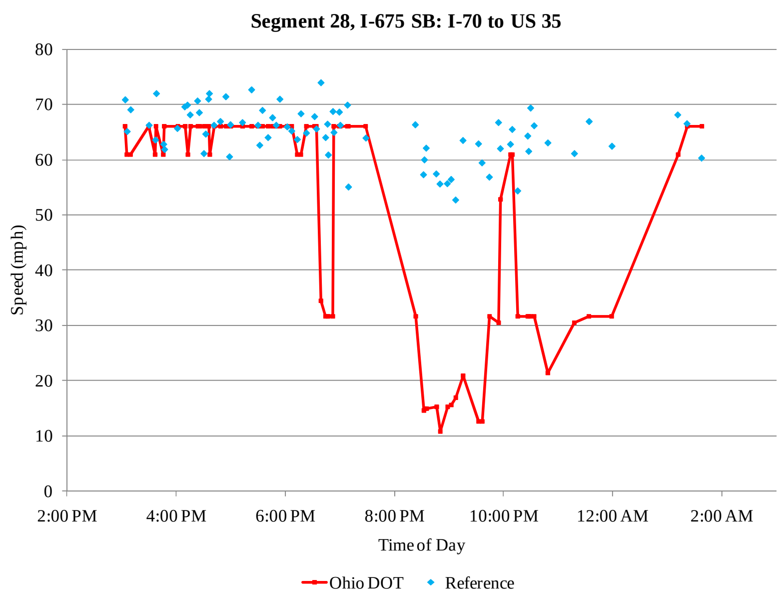


Figure 4.29. Speed according to time of day, Segment 28, 13.2 miles (21.2 km).

4.4 Summary of Findings

The mean absolute difference and mean difference bias across all travel time segments included in this study are shown in Tables 4.10, 4.11, 4.12 and 4.13. Table 4.10 summarizes the results for access-controlled interstate highways, Table 4.11 summarizes the results for arterial streets and highways, Table 4.12 summarizes the results for US-35 and Table 4.13 summarizes the results according to segment length. In total, there are 3,267 observations provided in Table 4.10, 140 observations provided in Table 4.11, 111 observations provided in Table 4.12 and 3,518 observations provided in Table 4.13. Even though the data collection time periods are developed around morning and afternoon rush hour, in all three cases the majority of the data are collected during free-flow conditions, 62% in Table 4.10, 79% Table 4.11 and 50% Table 4.12.

Table 4.10. Summary of results for access-controlled interstate highways (I-70, I-75, I-675).

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (miles per hour)	Travel Time (minutes)	Speed (miles per hour)	
0 to 30 miles per hour	1.1	5.6	-0.8	1.3	176
30 to 45 miles per hour	0.3	5.7	0.1	-0.8	211
45 to 60 miles per hour	0.9	10.1	0.7	-5.4	860
60+ miles per hour	0.7	6.1	0.7	-3.1	2020

Table 4.11. Summary of results for US-35.

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 20 miles per hour	n.a.	n.a.	n.a.	n.a.	n.a.
20 to 35 miles per hour	3.3	20.6	-3.3	20.6	4
35 to 50 miles per hour	1.2	9.9	-1.2	9.9	58
50+ miles per hour	0.5	4.7	0.3	-2.5	78

Table 4.12. Summary of results for arterial streets and highways (SR 4, SR 49).

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	

0 to 20 miles per hour	n.a.	n.a.	n.a.	n.a.	n.a.
20 to 35 miles per hour	4.4	12.1	-4.4	12.1	5
35 to 50 miles per hour	1.4	5.3	-1.4	5.3	50
50+ miles per hour	3.3	9.6	3.1	-7.2	56

A summary of results according to segment length is presented below in Table 4.13. From the table, the effects of rounding on short segment length can be clearly seen. For segments up to 1 mile (1.6 km) in length, a mean absolute difference in speed of 3.8 miles per hour (6.1 km/h) results in a travel time mean absolute difference of 0.2 minutes. For segments between 2 and 4 miles (3.2 and 6.4 km), a mean absolute difference in speed of 9.0 miles per hour (14.5 km/h) is reported, along with a mean absolute travel time difference of 0.4 minutes.

Table 4.13. Summary of results according to segment length.

Segment Length Miles	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 1	0.2	3.8	0.1	-2.8	484
1 to 2	0.04	4.9	0.04	0.8	269
2 to 4	0.4	9.0	0.1	-3.9	1523
4 to 8	0.6	6.0	0.1	-1.2	324
8+	1.0	5.4	0.7	-1.7	856

Table 4.14 presents the findings from all travel time segments studied. Overall, the current system for reporting travel times to motorists appears to be working sufficiently well. Values highlighted in "bold" signify trouble spots within the system. The individual segment summaries are provided in Appendices D and E of this report.

Table 4.14. General summary of results for all travel time segments included in this study.

Segment #	Route	Segment Length (mi)	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
			Travel Time (minutes)	Speed (miles per	Travel Time (minutes)	Speed (miles per	

				hour)		hour)	
1	I-70 EB: SR 49 to I-75	8.0	0.6	4.8	0.5	-3.8	111
2	I-70 WB: I-75 to SR 49	8.0	0.6	5.3	0.5	-3.5	96
3	I-70 EB: I-75 to SR 4 (South)	7.2	0.5	4.9	0.4	-4.5	94
4	I-70 WB: SR 4 (South) to I-75	7.2	0.5	5.0	0.5	-4.8	90
5	I-70 EB: SR 4 (South) to I-675	3.2	0.1	3.6	0.0	1.1	70
6	I-70 WB: I-675 to SR 4 (South)	3.2	0.0	2.9	0.0	1.0	95
7	I-70 EB: I-675 to SR 4 (Enon)	2.9	-	-	-	-	0
8	I-70 WB: SR 4 (Enon) to I-675	2.9	-	-	-	-	0
9	I-75 NB: County Line (Warren) to I-675	2.6	0.6	**14.6**	0.0	1.3	149
10	I-75 SB: I-675 to County Line (Warren)	2.6	0.5	**13.2**	0.4	**-9.3**	156
11	I-75 NB: I-675 to Carillon Blvd	8.3	0.5	4.6	0.4	0.2	146
12	I-75 SB: Carillon Blvd to I-675	8.3	0.7	4.8	0.5	-1.0	186
13	I-75 NB: Carillon Blvd to US 35	0.9	0.3	6.5	0.2	-5.2	256
14	I-75 SB: US 35 to Carillon Blvd	0.9	0.0	0.8	0.0	-0.1	228
15	I-75 NB: US 35 to SR 4	2.1	0.9	11.5	-0.3	-9.5	209
16	I-75 SB: SR 4 to US 35	2.1	0.5	18.8	0.4	-17.1	193
17	I-75 NB: SR 4 to Timber Ln	2.9	0.2	4.6	0.1	2.6	223
18	I-75 SB: Timber Ln to SR 4	2.9	0.6	6.4	0.1	0.5	175
19	I-75 NB: Timber Ln to I-70	3.7	0.4	7.0	0.2	-3.5	49
20	I-75 SB: I-70 to Timber Ln	3.7	0.4	8.2	0.1	-1.1	52
21	I-75 NB: I-70 to US 40	1.8	0.0	3.9	0.0	2.0	101
22	I-75 SB: US 40 to I-70	1.8	0.1	5.5	0.1	0.2	169
23	I-75 NB: US 40 to County Line (Miami)	2.1	0.0	0.0	0.0	0.0	50
24	I-75 SB: County Line (Miami) to US 40	2.1	0.0	0.0	0.0	0.0	104
25	I-675 NB: I-75 to US 35	12.7	0.4	3.0	0.3	0.1	59
26	I-675 SB: US 35 to I-75	12.7	0.7	3.8	0.5	-0.5	53

27	I-675 NB: US 35 to I-70	13.2	**7.8**	**16.3**	**7.6**	**-13.7**	74
28	I-675 SB: I-70 to US 35	13.2	**8.9**	**14.8**	**8.8**	**-12.1**	79
29	US 35 EB: SR 49 to I-75	5.1	1.4	**11.7**	-1.4	**11.7**	47
30	US 35 WB: I-75 to SR 49	5.1	0.7	5.8	-0.7	5.2	26
31	US 35 EB: I-75 to I-675	6.4	0.4	3.7	0.1	-1.3	36
32	US 35 WB: I-675 to I-75	6.4	0.7	6.2	0.6	-5.6	31
33	SR 4 NB: I-75 to I-70	10.7	1.2	6.3	1.1	-5.5	29
34	SR 4 SB: I-70 to I-75	10.7	**5.5**	**13.0**	**5.4**	**-9.0**	27
35	SR 49 NB: US 35 to I-70	9.0	1.5	5.8	-1.5	5.8	29
36	SR 49 SB: US 35 to I-70	9.0	1.8	6.1	-1.8	6.1	26
Average across all 36 routes			**0.8**	**7.3**	**0.5**	**-2.9**	**3518**

CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

Chapter V provides the conclusions and recommendations from this research study. Over the five data collection trips, data are collected from three main sources used to record vehicle speeds. The first source is spot speeds, the second source is a traditional approach using floating car probe data and the third source is a newly developed technique using Bluetooth device matches. These three methods for estimating traffic flow, more specifically vehicle speed over a segment of roadway, are used to estimate the actual travel time required by a driver to travel between the beginning and ending mile point of the 36 travel time segments located in Dayton, Ohio. These estimated travel times are then posted on changeable message boards for real-time route information. If the travel times are inaccurate, the posted information will not provide additional benefit to the user. To ensure accuracy of the estimated travel times, it is paramount that the system used with these estimations is audited for accuracy. In this study, the conclusions are presented concerning the following subject matters:

- Comparison between spot speed readings and sensor speeds,
- Evaluation of Bluetooth and floating car methods, and
- The comparisons of ODOT travel times and speeds with field reference data.

Brief descriptions of each task along with recommendations derived from the assessment of the results are provided in the following sections.

5.2 Comparison Between Spot Speed Readings and Sensor Speeds

The first conclusion is based on the comparison between spot speed readings and sensor speeds. Shown in Figure 3.1 of the methodology section, there are many radar speed locations throughout Dayton that are used as part of the ODOT travel time algorithm to estimate speeds. If the speeds recorded from the spot speed locations are inaccurate, reading faster or slower than the actual traffic stream, it may lead to inaccurate input into the ODOT travel time algorithm. Although there are many radar device locations within the study area, the research team sampled areas with known congestion as well as individual devices within the travel time segment area. In most cases, spot speed comparisons are made during data collection runs. In the data collection associated with the spot speeds, the research team uses laser guns, which sample across all lanes of traffic in random order for a period of 25 minutes. The collected speeds are then averaged on a per minute basis and compared with the ODOT reported speeds based on the device id. Figure 4.4 in the results section shows on average, 75% of the one-minute intervals are within the ODOT required four miles per hour range (6.4 km/h).

There are only a few samples that are significantly different between the field data and the radar device data. In some cases, these differences may be the result of highly variable traffic in combination with the location for which each device recorded speeds. In some cases, due to safety reasons and limited accessibility, the research team is not able to sample in the most desirable location. A second reason for the difference is the influence of the sample size. The field data collection team is not able to capture the speeds of each individual vehicle within the traffic stream, and therefore a random sampling technique is used. Unfortunately, this technique does not record speeds for all vehicles, especially during high volume free-flow conditions. The difference in sample size may lead to minor differences between the two speeds recorded at one location. One additional finding is the impact of weather. On several instances, no field data are able to be collected during periods with rain. In general, the overall findings suggest that the spot speeds sampled during this study are valid data inputs for the travel time algorithm.

5.3 Evaluation of Bluetooth and Floating Car Methods

The second source for recording vehicle speed is the use of floating car probe data, with a relatively new technique using Bluetooth device matches. For the majority of the data collection, floating car and Bluetooth data are collected at the same time. In this study, three floating car vehicles are used for data collection, with the exception of SR-49. In the case of SR-49, due to the travel time segment length and the anticipated low traffic volumes, an additional fourth vehicle is used in the floating car data collection. After the data collection, the results from each method are compared against each other. The ultimate goal is highly correlated average speeds between both methods. In this study, field data are collected on three high volume access-controlled interstate highways, I-70, I-75 and I-675, an urban arterial highway, US-35, and two state highways SR-4 and SR-49.

5.3.1 High Volume Access-Controlled Interstate Highways

The first series of roads are high volume access-controlled interstate highways. For these roads there are several key variables required for an implementable data collection plan. In this study, the majority of the data are collected during the morning and afternoon rush hour periods. These periods are selected based on the increased traffic volume, which may lead to more dynamic changes to the highway in question. In general, there are several findings within this class of highway. The first finding is developed for periods when vehicles are operating under free-flow conditions. When the vehicles are travelling under free-flow conditions, the Bluetooth devices may have a tendency to record slightly faster speeds in comparison to the floating car data. The main explanation for this is the drivers of the floating cars are instructed to maintain "normal" speeds close to the posted speed limit, while there are no limitations placed on the Bluetooth data. These results are easily remedied by placing a capped or maximum speed on the Bluetooth data. In both cases, the two methods are highly correlated and show free-flow activity on the travel time segments.

A second set of results shows there are significantly higher numbers of data points for the Bluetooth devices in comparison to the floating car data. The increased number of points may not be of great significance under free-flow conditions, but is extremely effective in describing periods of high variability, for example Figure 4.6. The higher number of points also provides a greater confidence in estimating the actual speed along a segment of highway. The third finding of significance is the impact of the segment length. In the case of the floating car data, the travel time length is not a limiting factor. The drivers are instructed to begin and end their individual runs at fixed points. The Bluetooth devices are not independent of segment length. As the segment length increases the number of potential Bluetooth matches decreases. An example of the decrease in matches is shown in comparing an average data collection period on I-75, relatively short segment lengths, with I-675, relatively long 12 to 13 mile (19.3 to 20.9 km) segment lengths. The number of observations is more than half the I-75 data. In comparison to floating car data, the Bluetooth method for high volume access-controlled highways provides significantly more data points and increases the overall resolution of the traffic stream.

5.3.2 Arterial Highways

The second class of roadways sampled in this study is arterial highways. In these samples, the results between the two methods vary. In most cases, the reported speeds remain consistent and well correlated. There are, however, several limitations associated with the use of

Bluetooth data. Unlike the previous class of highways, the total volume of vehicles with Bluetooth devices decreases significantly for vehicles that travel on arterial highways between the beginning and ending travel time segment mile points. As a result of the lower volumes of traffic, the number of Bluetooth matches is highly influenced by the length and the accessibility of the arterial highway. For example there are two, one northbound and one southbound, nine mile (14.5 km) travel time segments on SR-49. This segment length, in association with areas with commercial activity, surpasses the capabilities of the Bluetooth data collection. In this example, there are more data points from the four floating cars than Bluetooth matches. In order to improve the efficiency and capabilities of the Bluetooth devices, it is recommended that either the number of travel time segments is increased, lowering the length between end points, or additional Bluetooth readers should be included throughout the studied segments.

5.4 The Statistical Evaluation of ODOT Travel Times and Speeds with Field Reference Data

The third set of conclusions are based on the statistical evaluation of the reported ODOT travel time algorithms and the field reference data provided by the floating car and the Bluetooth method. In this evaluation, findings are calculated for both the average travel times and speeds during the entire data collection as well as the individual sample comparisons. There are six conclusions discussed in this section: free-flow conditions, congestion, data resolution using Bluetooth methods, the underreporting of travel times especially on arterial highways, the influence of rounding travel times to the nearest minute on short segment lengths and unexplained differences in reported travel times.

5.4.1 Free-flow Conditions

The first evaluation of the ODOT travel time algorithm is developed under free-flow conditions. During this study, between 53% and 62% of the samples are collected during free-flow conditions. In these cases, the overall findings between the reference data and the ODOT travel time algorithm show slightly faster travel times and speeds for the reference data when compared with the ODOT travel times. The differences are explained by the capped speeds and the rounding of the travel times. Even though there are some differences between the methods, the overall results and conclusions show a nice correlation between the two methods. One potential recommendation is to define the capped speeds based on segment links in-lieu of spot locations.

5.4.2 Periods of Congestion

The second evaluation of the ODOT travel time algorithm is developed under periods of congestion. In this study, the majority of the congestion is associated with morning and afternoon rush hour and is the direct result of construction related work zones along I-75 near mile marker 54.4. In this case, there are several conclusions that are made. In general, the overall trend in terms of longer travel times and slower speeds is consistent between the ODOT travel time algorithm and the reference data, as shown by Figures 4.16 and 4.17. The ODOT travel time algorithm under congestion in most cases overestimates the actual speeds, which in turn lowers the corresponding travel time per segment. In most cases, the difference between the ODOT travel time algorithm and the reference data is between one to three minutes per segment. This estimate is reasonable under the high variability associated with congestion.

5.4.3 Data Resolution using Bluetooth Method in Addition to the Floating Car Method

The third evaluation of the ODOT travel time algorithm is the impact of data resolution between the Bluetooth and the floating car methods. In this set of results, especially for the high volume limited access-controlled interstate highways, there are substantially more Bluetooth values than floating car data. The improved resolution is particularly significant during periods of variability and the use of Bluetooth data is highly recommended.

5.4.4 The Underreporting of Travel Times, Especially on Arterial Highways

The fourth evaluation of the ODOT travel time algorithm is the underreporting of travel times on arterial highways. In this set of results, the overall trends are the same between the reference data and the ODOT travel time algorithm. The main difference is the consistent under estimation of travel times using the ODOT travel time algorithm. One potential recommendation for these results is the re-calibration of the ODOT travel time algorithm. In most cases, the difference between the two methods is between one and two minutes, and the re-calibration should be developed specifically for the arterial highways.

5.4.5 Rounding Travel Times to the Nearest Minute on Short Segment Lengths

The fifth evaluation of the ODOT travel time algorithm is the impact of rounding the travel times to the nearest minute. The rounding of the travel times is one of the variables used to calculate the average speed across a travel time segment over time. Although from a motorist point of view there probably is no noticeable difference, there is a significant impact on the estimation of speeds. In addition to the rounding of the travel times, there are significant differences with estimated speeds under both free-flow and congestion conditions. For example, Segment 16, Figures 4.24 and 4.25, the average travel times range between two and three minutes under free-flow conditions. The rounding of the travel times under these conditions creates a speed range between 42 and 62 miles per hour (67.6 and 99.8 km/h), a 20 mile per hour (32.2 km/h) difference. Under a second hypothetical set of conditions, there is congestion on this same segment and the travel time is now oscillating between five and six minutes. Although the net difference remains one minute in travel time, the average change in speed between the two travel times is less than 5 miles per hour (8.0 km/h). In conclusion, the rounding of the travel times, especially on shorter travel time segments under free flow conditions, produces a significant change in the average vehicle speeds over the duration of the segment.

One potential recommendation is the development of a calculation procedure for the minimum route travel times to avoid high equivalent speeds. Several route segments report travel times with equivalent speeds faster than the posted speed limit and in some cases, the equivalent speeds are nearly 80 miles per hour (128.7 km/h). The research team believes these high equivalent speeds may occur because the minimum travel times are calculated at the link level then rounded at the route segment level. In some cases, rounding differences appear to be causing this high equivalent speed. Similarly, the travel time rounding associated with short route segments exaggerates speed changes.

5.4.6 Unexplained Differences in Reported Travel Times

The sixth evalutaion of the ODOT travel time algorithm and the reference data is based on unexplained differences in reported travel times. In these cases, there are no clear reasons why the travel times and speeds are significantly different. The first general recommendation is further analysis of the fixed-point sensor data and the posted travel times. Additional insight may provide reasons why there are large travel time errors on several routes. For example, there are large unexplained errors on Segments 27 and 28 during nighttime data collection. A second recommendation is the review of archived travel times to reveal how often these extreme fluctuations occur in low-volume traffic conditions. Another recommendation is based on a cursory analysis of rainfall data and fixed-point sensor data. Preliminary results do not reveal an obvious connection between heavy rainfall and significant speed errors, however, more samples should be collected to evaluate the performance of Doppler radar sensor performance under adverse weather.

5.5 Conclusion Summary

In conclusion, the use of Bluetooth data along with floating car data provides an effective methodology used in referencing travel times and speeds over a travel time segment. In terms of evaluation, the research team recommends the comparison of both travel times and speeds using the mean absolute difference and the mean bias difference as well as visual observations between the ODOT travel time estimates and the reference data. In general, the overall results at the system-wide level seem reasonable. The results for specific travel time segments are found in Table 4.12 and Appendices D and E of this research report.

CHAPTER VI
IMPLEMENTATION PLAN

The implementation plan developed from this research study is divided into eight sections. These sections are described in more detail in the remaining portion of this chapter. Because the products from this research proposal are clearly defined, the implementation plan is relatively straightforward. The first product from this research proposal will be an evaluation report that details whether the travel time data service provider has met the contract requirements in terms of data quality. There is a possibility that the evaluation procedures developed as part of this ODOT study could contribute to the development of a national or international standard (such as ASTM International) for the evaluation of travel time data services. This research team is currently discussing the development of a standard travel time data evaluation protocol with several other industry leaders, including both public agencies and private companies. Depending upon the outcome of these discussions over the next six months, the ODOT research project with approval from ODOT may serve as:

- A model for the standard evaluation protocol and/or
- To "pilot test" a draft version of the standard evaluation protocol.

6.1 Recommendations for Implementation

The results from this report are based on the statistical validation of travel times provided by a data service provider. The final results are shown in Table 4.12 and Appendices D and E. In general, there are two areas for the implementation of these results. The first recommendation is to develop additional specific language required by the data service vendor in terms of the data quality. The second implementation is the development of a field reference handbook based on floating car and Bluetooth data used in evaluation of travel times. The anticipated handbook will be similar in structure to the FHWA *Travel Time Handbook*.

6.2 Steps Needed to Implement Findings

The main step required to implement these findings is a continuation of discussions between the research team and the technical liaisons. These meetings will include discussions on data quality requirements as well as the potential development of a “how to” handbook used for evaluation purposes in other areas of the state.

6.3 Suggested Time Frame for Implementation

This time frame for the implementation of these results is relatively quick for the draft language. The time frame is based on the time required to adapt the findings and suggestions from this report in contractual language that will be provided in the future to data service vendors. The time frame for a draft handbook is six months. Over this time, the research team will work with the technical liaisons in crafting the appropriate guidance required for field evaluation.

6.4 Expected Benefits from Implementation

The immediate benefit of this research project is an assurance that the travel time data service does, or does not, meet contract requirements. If the travel time data service does not meet contract requirements, then Ohio Department of Transportation (ODOT) may not be legally obligated to pay the data service provider. If the travel time data service does meet contract requirements, then ODOT will be assured that state funds have been well spent in acquiring this data service. An additional short-term benefit for ODOT will be the external review of the data. This external review ensures the accuracy of the data, strengthening the initiative’s credibility with the public as well as the media. This research will allow ODOT the capability to say an external agency has reviewed and implemented quality control/quality assurance procedures on all data provided from the external vendor.

The main long-term benefit is that ODOT may save money and provide this service much sooner than otherwise possible by purchasing this real-time traffic information service from a private company instead of installing and maintaining a state-owned traffic sensor network. The overall findings from the research will provide a long-term cost savings for ODOT whether the vendor’s travel time data is accurate or inaccurate. If the data is proven to be accurate, ODOT will be able to use this information to provide reliable travel time information both internally and externally and will lead to a cost savings. If the research proves the data provided by the vendor is inaccurate, ODOT will no longer use this vendor or pay for services that are invalid.

6.5 Potential Risks and Obstacles to Implementation

The current contract provision mentions the accuracy of reported link/route speeds. However, ODOT is using a modified travel time estimation algorithm based on the spot speeds provided by the vendor's sensors. Therefore, if the link/route travel times are inaccurate, the vendor may claim that the error is caused by ODOT's algorithm. If ODOT continues to use its own travel time estimation algorithm, then the contract provisions should be clarified to apply to the measurement of spot speeds. Additionally, the contract provisions should specify more details about the measurement of spot speed accuracy, for example how often, how many locations, how long for each test period.

6.6 Strategies to Overcome Potential Risks and Obstacles

The most effective strategy to overcome this risk is the development of a standard method used in referencing the accuracy of the data based on reference field data.

6.7 Potential Users and Other Organizations that May be Affected

The potential users of this information will include the ODOT Office of Traffic Engineering, data service vendors and motorists who are using the travel time information provided by the changeable message signs in the Dayton, Ohio area.

6.8 Estimated Costs of Implementation

The final cost for implementation is based on the requirements in developing a new handbook as well as additional training in the operation of the Bluetooth technologies.

CHAPTER VII
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APPENDIX A
SPOT SPEEDS

Table A.1. Raw data ID number 10681.

Location: I-70, at railroad overpass just west of Box #3. Did not shoot far right lane because lane was "Exit Only" to I-75 <Run 1, Location 1>

Date: 07/27/2009 | **Start Time:** 8:08 AM | **End Time:** 8:34 AM

Location Lat: 39.86650 | **Location Long:** -084.17338

Nearest Speed Sensor ID: 10681 | **Direction of Traffic Flow:** WB

		Lane 1	Lane 2	Lane 3
1	8:08 AM	64 62	63	
2	8:09 AM		68 69 60 71	
3	8:10 AM	65 56	69 65 69 69 71	66
4	8:11 AM	55 65 71 70 65	77 68 65 65 76 65	69 77 70
5	8:12 AM	66 68 68 72 67	65 71 71 63 73 69 66	70
6	8:13 AM	66	61 65	79 76
7	8:14 AM	68 64 70 63 63	68 73 66 67	71 70
8	8:15 AM	63 75 74 70 63	69 72 71 68 72 75 69	78 70 73 74
9	8:16 AM	62 73 72 71 64	64 62 71 68 73 71	76 74
10	8:17 AM	65 66 66 61 67 65	63 71 72 67 65	79 71
11	8:18 AM	65 60 79 66	79 70 61	72 71 82 75
12	8:19 AM	67 61 49 63	75 67 62 69 71 74	73 84
13	8:20 AM	63 74 66 61	71 65 70 74 69	73 72
14	8:21 AM	62	71 66 67 68 71 63	67
15	8:22 AM	67 70 67 70 66 64	66 65 66 59 59	70
16	8:23 AM	59 60	66 75 68	71
17	8:24 AM	75 65 71	67 80 74 65 72 74	
18	8:25 AM	59 65	71 66	68
19	8:26 AM	68 59 63 58 71 70	69 56 65 67 63 68 71	70
20	8:27 AM	61 67	65 63 63 66 67 72	73
21	8:28 AM	72 61 70	63 64 63	79 74
22	8:29 AM	61 64 66 75 64	67 69	74 68
23	8:30 AM	72 71 62 72	67 62 67 63 65	65 69 76
24	8:31 AM	72 65 65	66 73 74 60	73 79 75 72 71 62
25	8:32 AM	62 69 59 57 55	64 62 70 65	73

Table A.2. Raw data ID number 10691.

Location: I-70, West of Box #4 on overpass, Exit 32 <Run 1, Location 2>

Date: 07/27/2009 | **Start Time:** 8:45 AM | **End Time:** 9:10 AM

Location Lat: 39.86479 | **Location Long:** -084.22312

Nearest Speed Sensor ID: 10691 | **Direction of Traffic Flow:** WB

		Lane 1	Lane 2	Lane 3
1	8:45 AM		68 65 65 72	68
2	8:46 AM	67	63 61 71	75
3	8:47 AM	57	72 65 74 61 69 64 67 68 69	63 72
4	8:48 AM	69	74 64 56 68 72 59	74 72
5	8:49 AM		66 77 63 65 62 70 60 56	70 77 65
6	8:50 AM		58 66 69 66 63 65 59	70 77 65
7	8:51 AM	64 69	64 70 66 67 68 74 65	73 77
8	8:52 AM	61	67 61 65 59 65 71 62 66 62	70 69 64
9	8:53 AM		68 63 65 75 66 59 64	66 72 66
10	8:54 AM		75 71 63 61 69 65 58 65 64	
11	8:55 AM		70 70 66 63 61 64 65	71 67 67
12	8:56 AM		66 67	69 46 63
13	8:57 AM		68 63 64	
14	8:58 AM		65 74 65 57	69 71 73
15	8:59 AM		72 72 63 75 65	
16	9:00 AM		63 70 71	67 80 79
17	9:01 AM	60	67 64 71 67 58	
18	9:02 AM		64 70 74 65 69	71 69 71 70 64
19	9:03 AM		59 68 65 64 66 66 76 75 70	
20	9:04 AM		58 63 58 62 66 60 59 66	70 69 71
21	9:05 AM		69 63 67 65 65 67 57 62	66 78 73
22	9:06 AM		60 59 64 61 56	71 73 70 74
23	9:07 AM		68 64	
24	9:08 AM		64	
25	9:09 AM		62	68 77

Table A.3. Raw data ID number 10694.

Location: I-70

Date: 07/28/2009	**Start Time:** 6:01 PM	**End Time:** 6:26 PM
Location Lat: 39.85491	**Location Long:** 084.32297	
Nearest Speed Sensor ID: 10694	**Direction of Traffic Flow:** EB	

		Lane 2	Lane 1
1	6:01 PM	67 69 65 67 66 65	73 65 74
2	6:02 PM	64 59 67 66 65 65	80 64 65
3	6:03 PM	62 71 67 64	72 68
4	6:04 PM	72 65 70 67	61 68 70 65
5	6:05 PM	63 72 65 70 64 72 71	69
6	6:06 PM	64 63 65 68 65 66	64 74 66
7	6:07 PM	59 65 60 62 63 60 67	64 74 66
8	6:08 PM	67 62 61 65 68 65	62
9	6:09 PM	74 64 66 58 64	66 71 68 71 71
10	6:10 PM	69 64 73 63 65	73 70 72
11	6:11 PM	66 62 59 67 61	75 75 64
12	6:12 PM	69 65 59 64	65
13	6:13 PM	59 61 60 62 61 61	
14	6:14 PM	60 66	71 69 72 72
15	6:15 PM	69 65	75 74
16	6:16 PM	63 64 66	
17	6:17 PM	66 65 62 66 66	59 65 70 71
18	6:18 PM	70 66 66 67 74 67	69 70 71 77
19	6:19 PM	70 62 61	67 65
20	6:20 PM	72 64 68	
21	6:21 PM	64 68 62 58	62 69 62 68
22	6:22 PM	70 68 63 64 64	74 70 80
23	6:23 PM	70 70 69	75 79 71 80
24	6:24 PM	69 66 60 71 73 68 70 65 64	71 73 70
25	6:25 PM	69 65 69 63 71	68 71 74 63

Table A.4. Raw data ID number 10712.

Location: I-75 <Run 4, Location 1>

Date: 07/15/2009	**Start Time:** 4:30 PM	**End Time:** 5:00 PM
Location Lat: 39.76620	**Location Long:** -084.17338	
Nearest Speed Sensor ID: 10712	**Direction of Traffic Flow:** NB	

		Lane 1	Lane 2	Lane 3
1	4:30 PM	15 17		
2	4:31 PM	20 21 9		
3	4:32 PM	4	13	5
4	4:33 PM	12 16	10	
5	4:34 PM	14 14 15	12 11	
6	4:35 PM	17 17		21
7	4:36 PM	17	15	
8	4:37 PM		10 14	
9	4:38 PM	12 9 8	10 14 13	18 19
10	4:39 PM	22 19 18		
11	4:40 PM	18	13	
12	4:41 PM	20	16	15
13	4:42 PM	8	8	
14	4:43 PM	9		20
15	4:44 PM	14		
16	4:45 PM		13	13
17	4:46 PM	20 21	12 15	11
18	4:47 PM		19 18	21
19	4:48 PM		22	24 18 20
20	4:49 PM		19	17 20
21	4:50 PM		18	15
22	4:51 PM		9	16 12
23	4:52 PM	10		
24	4:53 PM	7		
25	4:54 PM	12		
26	4:55 PM		9	
27	4:56 PM		14	
28	4:57 PM	18		
29	4:58 PM			15
30	4:59 PM	17		

Table A.5. Raw data ID number 10854.

Location: I-75, stop and go traffic around 5:18 PM, <Run 4, Location 2>

Date: 07/15/2009 | **Start Time:** 5:06 PM | **End Time:** 5:30 PM

Location Lat: 39.77713 | **Location Long:** 084.18576

Nearest Speed Sensor ID: 10854 | **Direction of Traffic Flow:** NB

		Lane 1	Lane 2	Lane 3
1	5:06 PM	40 22	20	
2	5:07 PM	45	14 19	
3	5:08 PM	36 35	23 22 23 22	19
4	5:09 PM	32 32	29	39
5	5:10 PM	33 38	27 33 32	34 38 37
6	5:11 PM	48 43 37	38	
7	5:12 PM	38 36	38 42	38
8	5:13 PM	41 44	40	49
9	5:14 PM	49	40 47 42	43
10	5:15 PM		45 41	43
11	5:16 PM	42	31 28 25 22	
12	5:17 PM		4	
13	5:18 PM	39	23 23 30	28 51 39
14	5:19 PM	37 37	38 28 30 31	31 33
15	5:20 PM		35 33 48	29 33
16	5:21 PM	28 34 42 42	35	36 40 41
17	5:22 PM	40	32 35 33 32	30
18	5:23 PM	46	30 28 31 28	
19	5:24 PM	40	30 16 12 8 5	29 25
20	5:25 PM	41 20 23 30	10 13 23	43
21	5:26 PM	34 34 39 34 33	31 29 19 20 15	35 19 15
22	5:27 PM	25 25 37 38 39	15 20 17 22 13 13	
23	5:28 PM	23 23 21	21 21 25 28 28	30 29
24	5:29 PM	27 27	25 21	22

Table A.6. Raw data ID number 10715.

Location: I-75, <Run 4, Location 3>

Date: 07/15/2009	**Start Time:** 5:50 PM	**End Time:** 6:12 PM
Location Lat: 39.80510	**Location Long:**	
Nearest Speed Sensor ID: 10715	**Direction of Traffic Flow:** NB	

		Lane 1	Lane 2	Lane 3
1	5:50 PM	61 62 59	60 62 61	
2	5:51 PM		60 58	65 65 65 66
3	5:52 PM	56	64 63 54 60	65 63 70
4	5:53 PM	69 64	61 66	69
5	5:54 PM	58 59	63 59	64
6	5:55 PM		71 71 57 59 61 55	59 72
7	5:56 PM	56	63 54 60 55 72 59	68 66
8	5:57 PM	57 57	66 61 58 64	74 67 61
9	5:58 PM		60 61	
10	5:59 PM	65 67	72 66	65
11	6:00 PM	60 61 64 61	60 62 61 58 66 62	72 69 70
12	6:01 PM	58 64 58	61 57 63 58 65	
13	6:02 PM	53 58 58 59	71 61 59 71	65 76 64
14	6:03 PM	58 66	65 63 66 67 60	
15	6:04 PM	63 62 62 68 64	68 56 59 71 58 68 56	55 62
16	6:05 PM	58 66 64 62	64 61 62 61 62 60	66 70 74 66 68
17	6:06 PM	52 58 62	70 63 62 66 66 58	62 69
18	6:07 PM	57 59 68	68 69 52 64 59 65 63	65 69 66
19	6:08 PM	66 62 63 65 60 66	64 71 53 59	68 66 70 68 67
20	6:09 PM	67 58	60 62	65 67
21	6:10 PM	59 73 57 63	60 64 65 65	71
22	6:11 PM	69 60 59 65 55	67 66 68 59 66 64 69	69 72 66

Table A.7. Raw data ID number 10003.

Location: I-75, <Run 1, Location 1>

Date: 07/16/2009 | **Start Time:** 7:50 AM | **End Time:** 8:10 AM

Location Lat: 39.81301 | **Location Long:** 084.18909

Nearest Speed Sensor ID: 10003 | **Direction of Traffic Flow:** SB

		Lane 1	Lane 2	Lane 3
1	7:50 AM	20 15 22 16	8 8	7 15 15 13 15 21
2	7:51 AM	23 24 22 23	20 26 26 28 26 27	25 26 26 27 30
3	7:52 AM	38 32	27 29 29 28	31 28 29
4	7:53 AM	32 32 33	30 32 33 33	34 36
5	7:54 AM	33 32 31 32 32	35 34 36	36 37 37
6	7:55 AM	37 41 43	34 40 41 44	48 45
7	7:56 AM		44 48 44	48 45 44
8	7:57 AM	60 55 51 58	48 66 64	56 68 65
9	7:58 AM	64 60 68	59 62 54	72 67 61 56 57
10	7:59 AM	67 63 55	64 53	66 67 66
11	8:00 AM	62 57	46 58 60	55 58 57 64 66 59
12	8:01 AM	65 60 63	80 64 63 54 62 61	59 72 67
13	8:02 AM	68 62 54	62 55 61 50 53 54	69 73 63
14	8:03 AM	62 62	64 71 57 58	62 63 65
15	8:04 AM	68 59	67 69 62 59 66	69 55 54
16	8:05 AM	63 65 66 67	59 66 65 58 73 68	73 65
17	8:06 AM	63 57 55 57	65 59 61	62 63 61 65
18	8:07 AM	66 60	60 61 60	63 68 68
19	8:08 AM	58	61 66 68 65	65
20	8:09 AM	58 63	66 65 60 67 68	75 69 73

Table A.8. Raw data ID number 10719.

Location: I-75, <Run 1, Location 3>				
Date: 07/16/2009		**Start Time:** 8:10 AM		**End Time:** 8:31 AM
Location Lat: 39.80510			**Location Long:**	
Nearest Speed Sensor ID: 10719			**Direction of Traffic Flow:** NB	
		Lane 1	Lane 2	Lane 3
1	8:10 AM	70 57	68 62 64 65	67 67
2	8:11 AM	59	64 73	71 74
3	8:12 AM	60 55 51	63 57 62 73	63 62
4	8:13 AM	69 61	65 60 66	74 74
5	8:14 AM	72 60	72 48 69 76	68 74
6	8:15 AM	62 58	63 60	68 74 64 63
7	8:16 AM	64	60 69 65 70	67 78 66
8	8:17 AM	68 55 69 64	63 69 64	72 70 68 71
9	8:18 AM	64	67 60 66 61	67 65
10	8:19 AM	50 62	57 64 59 60 66	78
11	8:20 AM		59 68 59 59	69
12	8:21 AM	61 66 61 61	58 75	72 72
13	8:22 AM	61 60 62	64 57 58	69 67 78 70
14	8:23 AM		64 58 61 69	70 66 62 77 71
15	8:24 AM	52 59 64	59 55 68	67 67 75
16	8:25 AM		67 66 64	70 76 82
17	8:26 AM	49	71 65	73 71
18	8:27 AM		65	69 70
19	8:28 AM	68 58	59 68 66	67 70
20	8:29 AM	62 63	62	71
21	8:30 AM		63	71

Table A.9. Raw data ID number 10865.

Location: I-75, lane 1 closed at merging, lane 3 moving much faster than lane 2, <Run 1, Location 2>				
Date: 07/16/2009			**End Time:** 9:05 AM	
Location Lat: 39.79979		**Location Long:** 084.19009		
Nearest Speed Sensor ID: 10865			**Direction of Traffic Flow:** NB	
		Lane 1	Lane 2	Lane 3
1	8:41 AM		50 50 51	44 50
2	8:42 AM		22 20 19 17 16 37	24 41
3	8:43 AM		30 20 46	53 51 57 47 56
4	8:44 AM		47 47 44 37	52 56
5	8:45 AM		47 32 20 17 15	60 47
6	8:46 AM		13 15 41	43 41
7	8:47 AM		36 40 21 27	45 45
8	8:48 AM		52 51 56	42 41 31 51 54 51
9	8:49 AM		59 51	56 58
10	8:50 AM		44 46 58	53 53 56 67
11	8:51 AM		60 56 59	71 62 63 66
12	8:52 AM		54 53 58 58 53	57 69 68
13	8:53 AM		50 52 57 59 53 63	60 58
14	8:54 AM		57 58 60 57 62	60 65 66 60 61 67
15	8:55 AM		62 54 57 58 56	63 61 60
16	8:56 AM		59 59	58 66
17	8:57 AM		56 64 61 59	65 62 65 65
18	8:58 AM		51 50	62 63
19	8:59 AM		58 57 62	61 62 60
20	9:00 AM		61	59
21	9:01 AM		57 62	58 75
22	9:02 AM		49 56	53 66
23	9:03 AM		59 57	64 64 66
24	9:04 AM		52	64 54 64 66

Table A.10. Raw data ID number 9715.

Location: I-75, <Run 2, Location 1>

Date: 07/16/2009 | **Start Time:** 4:50 PM | **End Time:** 5:20 PM

Location Lat: 39.74884 | **Location Long:**

Nearest Speed Sensor ID: 9715 | **Direction of Traffic Flow:** NB

		Lane 1						Lane 2						
1	4:50 PM	48	45	47	45	48		59	69	61	46			
2	4:51 PM	50	54	46	49	46	46	60	51	44				
3	4:52 PM	45	49	54	55			46	58	59	60	62	57	61
4	4:53 PM	51	51	53				53	62	61	53			
5	4:54 PM	51	53	52	47			57	59	59	57	56	55	52
6	4:55 PM	49	54					57	57					
7	4:56 PM							58	59					
8	4:57 PM	53						51						
9	4:58 PM	55	54					64						
10	4:59 PM	46												
11	5:00 PM	47	49					49						
12	5:01 PM	66						52						
13	5:02 PM	55												
14	5:03 PM	57												
15	5:04 PM	52						53	53					
16	5:05 PM	48	44	51				55	50					
17	5:06 PM	49	44	47	40			53	59					
18	5:07 PM	49	43	46				52	55	55	52			
19	5:08 PM	55	60	58				38	60	57	62			
20	5:09 PM	52	52	51	42	38		60	60	58				
21	5:10 PM	43	50	49				56	50	48	51	50		
22	5:11 PM	46	53					54	55	56	56	59		
23	5:12 PM	46	43					62	56	51	62			
24	5:13 PM	53	38	42	39			56	52	48	43			
25	5:14 PM	35	34	33	35	28	25	40	40	33	31			
26	5:15 PM	23						27	25	26	26	23		
27	5:16 PM	33	28	28				32	31	35	34	40	35	39
28	5:17 PM	38	33	36	36	29	36	40	30	36	25			
29	5:18 PM	33	27	33	35	33	32	33	31	34	33	43	50	43
30	5:19 PM	34						49	51	45				

Table A.11. Raw data ID number 11120.

Location: I-75, shot speeds because of traffic congestion, <Run 3, Location 2>

Date: 07/16/2009 | **Start Time:** 5:32 PM | **End Time:** 6:00 PM

Location Lat: 39.72791 | **Location Long:** 084.20763

Nearest Speed Sensor ID: 11120 | **Direction of Traffic Flow:** NB

		Lane 1	Lane 2	Lane 3
1	5:32 PM	30 10	19	36 25
2	5:33 PM	17 14	21 18 24 13 12 14	26
3	5:34 PM	17 20 20 18 11	16 17 22	8
4	5:35 PM	13 15 14	6	14 9
5	5:36 PM	27	20	21 20
6	5:37 PM	19 18	19	
7	5:38 PM	17 17 17 19 12		32
8	5:39 PM	15	27 24	29 35 36
9	5:40 PM	16	27 26 23 20	
10	5:41 PM	33	30 33	35 35 37
11	5:42 PM	36 36 37	38	35 42
12	5:43 PM	19	33 30	44
13	5:44 PM	13 21 21	13	25
14	5:45 PM	22 26	17 19	24 28
15	5:46 PM	31 37	26	31
16	5:47 PM	31 25	28	
17	5:48 PM	32 24 12 7 13	12	
18	5:49 PM	16 15 10 10	14	27 23
19	5:50 PM	11 7	17 15	12 23
20	5:51 PM	15 12 14 18	9 9 11	
21	5:52 PM	15 13	21 24	23 26
22	5:53 PM	12 13 18 15	16	9 18
23	5:54 PM	23 25 25 19 26	19	28 21 22 25
24	5:55 PM	24 24	35	
25	5:56 PM	16		
26	5:57 PM	25		
27	5:58 PM	33		
28	5:59 PM	7		

Table A.12. Raw data ID number 9715.

Location: I-75, <Run 2, Location 2>					
Date: 07/16/2009		**Start Time:** 6:10 PM		**End Time:** 6:25 PM	
Location Lat: 39.68180			**Location Long:** 084.23059		
Nearest Speed Sensor ID: 9715				**Direction of Traffic Flow:** NB	
		Lane 1	Lane 2	Lane 3	
1	6:10 PM	64 60 61 57	68 64	65 71 67	
2	6:11 PM	64 68 62	72 62 61 70	66	
3	6:12 PM	64 66 63 64 63	70 69 72 69		
4	6:13 PM	58 60 60	64 64 74 68	71	
5	6:14 PM	71 67	66		
6	6:15 PM	62 62 62	60 65 64	71	
7	6:16 PM	64	62 72	66	
8	6:17 PM	60 66	64 68 54	73	
9	6:18 PM	64 53 58	65		
10	6:19 PM	58 61 60	68 66	68	
11	6:20 PM	60	69 70 65 66	69 70	
12	6:21 PM	58	70 65 66 65 64		
13	6:22 PM	50 63	69 73 60		
14	6:23 PM	66 66	65 65		
15	6:24 PM	57	60 66 73 65	69	

Table A.13. Raw data ID number 11121.

Location: I-75, <Run 3, Location 1>														
Date: 07/17/2009		**Start Time:** 7:25 AM						**End Time:** 7:55 AM						
Location Lat: 39.79356								**Location Long:** 084.18689						
Nearest Speed Sensor ID: 11121								**Direction of Traffic Flow:** NB						
		Lane 1						Lane 2						
1	7:25 AM	41	43	47				50	43					
2	7:26 AM	50	49	58				47	49					
3	7:27 AM	59	52	48	52			54	52	44	51	55		
4	7:28 AM	55	61	57	58	61		52	61					
5	7:29 AM	56						57	54	57	57			
6	7:30 AM	47	57	57	63			54						
7	7:31 AM	66	51	47	45			55	54	64				
8	7:32 AM	54	49	46				50	62	54	59			
9	7:33 AM	55	51	54				57	63	66				
10	7:34 AM	46	50	52	53	57	50	59	53	51	53	54		
11	7:35 AM	50	39	42	48			62	55	42	44			
12	7:36 AM	46	48	51				51	43	41				
13	7:37 AM	50	49	46	41			47	49	59	58			
14	7:38 AM	48	44	42	46	46		51	54	51	56			
15	7:39 AM	60	59	45	50	48	51	50	53	54	47	49	48	50
16	7:40 AM	45	56					50	48	50	54			
17	7:41 AM	48	50	57				51	53	56	55			
18	7:42 AM	50	59	58	50	49		56	55	52				
19	7:43 AM	55	54	50	55	52	50	49	45	46	50	57		
20	7:44 AM	53	50	51	57	55	49	53	52	52	46	66	58	
21	7:45 AM	53	49	50	48			56	54	50	48			
22	7:46 AM	57	50	51				55	53	53	58	64	48	
23	7:47 AM	49	49					44	47	49	49	51	48	
24	7:48 AM	47	47	49				51	50					
25	7:49 AM	48	51					51	53	56	42	45		
26	7:50 AM	62						51						
27	7:51 AM	65	52					53						
28	7:52 AM	57						56	55					
29	7:53 AM													
30	7:54 AM	54												

Table A.14. Raw data ID number 10709.

Location: I-75, <Run 3, Location 2>			
Date: 07/17/2009	**Start Time:** 8:15 AM		**End Time:** 8:35 AM
Location Lat: 39.74149		**Location Long:** 084.20469	
Nearest Speed Sensor ID: 10709			**Direction of Traffic Flow:** NB

		Lane 1	Lane 2	Lane 3
1	8:15 AM	59	53	65
2	8:16 AM	59 57 45	51 61 53	
3	8:17 AM		56 61 64	70 64 69
4	8:18 AM	52	63	69
5	8:19 AM	62 62	66	
6	8:20 AM	60	61 66	67
7	8:21 AM	61	49	66 65 68
8	8:22 AM	63	56	63 65
9	8:23 AM	54 63	40 43 50 56	54 62
10	8:24 AM	48 44 62	62 60 55 52 56	67 66 63
11	8:25 AM	56 54 63	60 60 66	60 67
12	8:26 AM	65 56 55	60 62 63	74 72 58
13	8:27 AM	58 64	68 66	
14	8:28 AM	68 64	55	66
15	8:29 AM	56 61 54 49 60	59 41 59 59	53
16	8:30 AM	64 62	60 51 52 60	52 60
17	8:31 AM	54	63 61	68 63 65
18	8:32 AM	56 58 54	57 58 53	62
19	8:33 AM	55	71 53 49 50 56	74 70 66
20	8:34 AM	67 63	52 56	58 55 63
21	8:35 AM		60 41	

Table A.15. Raw data ID number 11120.

Location: I-75, Construction Zone <Run 1, Location 1>																	
Date: 07/28/2009						**Start Time:** 7:24 AM							**End Time:** 7:55 AM				
Location Lat: 39.79042								**Location Long:** 084.18496									
Nearest Speed Sensor ID: 11120										**Direction of Traffic Flow:** SB							
		Lane 1								Lane 2							
24	7:24 AM	44	44	48	44	45	44	46		46	49						
25	7:25 AM	47	46	43	56					48	47	48	46	45			
26	7:26 AM	41	44	42	42					51	51	47	45	42			
27	7:27 AM	37	42	41	42	45	37			48	49	43	46				
28	7:28 AM	40	37	47						44	44	44	39	47	40	49	
29	7:29 AM	42	44	42	43					51	44						
30	7:30 AM	40	39	38	45	39	42			40	43	40					
31	7:31 AM	49	39	37	43	40	46	36		49	48	43	41	46	45		
32	7:32 AM	42	37	38	37	42	40			45	48	48	51	43			
33	7:33 AM	41	34							40	44	41	46	46	40		
34	7:34 AM	35	38	51	37					48	40	46	48	46			
35	7:35 AM	39	44	42	38					44							
36	7:36 AM																
37	7:37 AM																
38	7:38 AM																
39	7:39 AM																
40	7:40 AM																
41	7:41 AM																
42	7:42 AM	43	44	41	38	43	48	47	37	43	52	46					
43	7:43 AM	46	40	39						47	41	45					
44	7:44 AM	41	39	39	37					39	41	45	39	43	51		
45	7:45 AM	39	41	39	39					45	41	43	44	45			
46	7:46 AM	45	45	44	42					46							
47	7:47 AM	42								37							
48	7:48 AM	40	42	39	37	39				40	39	41	40				
49	7:49 AM	37	39	44	36	36	31	45		39	41						
50	7:50 AM	38	44	40	41	38				43	38	39	45				
51	7:51 AM	35	36	43	34	37	39			45	44	41	43	47			
52	7:52 AM	36	42	43	40					42	46	46	41	45	44		
53	7:53 AM	36	39	36	40	42	35	34		48	47	41					
54	7:54 AM	38	27							37							

Table A.16. Raw data ID number 10710.

Location: I-75, Just North of Exit 51 <Run 1, Location 2>

Date: 07/28/2009 | **Start Time:** 8:24 AM | **End Time:** 8:49 AM

Location Lat: 39.73777 | **Location Long:** 084.20499

Nearest Speed Sensor ID: 10710 | **Direction of Traffic Flow:** SB

		Lane 3	Lane 2	Lane 1
24	8:49 AM	61 61	51	66
25	8:50 AM	62 58 60 59 65	57 57 62 60 61 45	67 43 45
26	8:51 AM	64 57 62 57 58 63 60	62 57 69 58 63 60	69 68 68 69
27	8:52 AM	64 58 56 58 54 62	60 58	66 67 66 65
28	8:53 AM	59	61 65 55 55 69 60	66 69
29	8:54 AM	61 54 54	55 61	63 59 74 53 66
30	8:55 AM	67	61 6 65 65 58 54 60 57	64 67 65
31	8:56 AM	59 59 55 58	65 67 58 60 62 59	68
32	8:57 AM	56 64 60 54	66	76 67 64
33	8:58 AM	55 55 57	55 63 63 56	62 59
34	8:59 AM	51	65 69 57 65	68 62 77
35	9:00 AM	61 57 56 61 60	50 60 59	72 69 72
36	9:01 AM	59 60 38 35 60	46 66	57 67 69 69 66
37	9:02 AM	62 61 60 56	72 71 56 63 61	64 58
38	9:03 AM	56 56 61 61 54 59 57 62	48	64
39	9:04 AM	60	57 65	60
40	9:05 AM	65 58 54 58 63	62 65 60 65 58	61 71 66
41	9:06 AM	61 54	56	64 65 63 67 63
42	9:07 AM	55 62 58	60 57 58 68	66 73 75 71
43	9:08 AM	64 55 57 56	60 59 62 61 58	66 67
44	9:09 AM	55 63 66	57 64	60 69
45	9:10 AM	52 65 52 57	66 57 64 62	64 63 65
46	9:11 AM	50 61 50 63 55	64 54 60 56	68 64
47	9:12 AM	53 59 62	62 62 54 57 60 54 59	68 69
48	9:13 AM	63 61 56 56	64 63	63 64 73 58

Table A.17. Raw data ID number 10791.

Location: I-75

Date: 08/17/2009	**Start Time:** 8:25 AM	**End Time:** 8:50 AM

Location Lat: 39.77002	**Location Long:** 084.08743

Nearest Speed Sensor ID: 10791	**Direction of Traffic Flow:** SB

		Lane 1	Lane 2	Lane 3
31	8:25 AM	64 67 67	68 64 66 71 66	73 72
32	8:26 AM	73	67 69 73	73 73
33	8:27 AM	65 65 67	76 72 63 69	75 74
34	8:28 AM	71 67	65 67 62	75
35	8:29 AM	66 67	69 71	77 77
36	8:30 AM	65 75	69 77 66 75 69 66	78 69
37	8:31 AM	69 75	72 73 69 76 72	78 74
38	8:32 AM	61	67 65 73	71 69 65
39	8:33 AM	66 64 66	78 68 66 66 72 71 77	68 72 76
40	8:34 AM	71	75 68 65 77 62 68	69
41	8:35 AM	67 73	70 75 67 65 69 75	
42	8:36 AM	71 71	72 55	70 70 76
43	8:37 AM		68 69 67	68 65 74 71
44	8:38 AM	67 54 67	69 72 73 66 70 68	74 71
45	8:39 AM	66 62 67	63 64	76 77
46	8:40 AM	68 60	69 69 71 67	83 74
47	8:41 AM	67	66 74 68 70 65	74
48	8:42 AM	64 63 73	63 65 65 70	75 72 67 66
49	8:43 AM	57 70	73 68 67 73	70 66 73
50	8:44 AM	67 76	74 73	77 72 75
51	8:45 AM		60 66	
52	8:46 AM	60	68 63 69	71 74
53	8:47 AM	65	65 67 62 61	76 72
54	8:48 AM	64 54 71	65 68 69 67 66	70 76
55	8:49 AM	69 68 69 66	62 69 65 70 65	74 69

Table A.18. Raw data ID number 10929.

Location: I-75 <Run 1, Location 1>

Date: 07/29/2009	**Start Time:** 8:37 AM	**End Time:** 9:02 AM
Location Lat: 39.58713	**Location Long:** 084.24232	
Nearest Speed Sensor ID: 10929	**Direction of Traffic Flow:** NB	

		Lane 1	Lane 2	Lane 3
37	8:37 PM	53 63 60 61	67 60 60 59	75 69 65
38	8:38 PM	65 62 61 59	67 65 63 63	67 73 72
39	8:39 PM	62 64 55 64 60	62 61	69
40	8:40 PM	57	61 65 60	72 70 70
41	8:41 PM	64	55 65 70	78 64
42	8:42 PM		67	
43	8:43 PM	61 56	62 57 67 61 64	73 78 68 73 71
44	8:44 PM	67 59 62 63	69 64 60 58 69 60	74
45	8:45 PM	66 60 63	60 64 64 67	65 61 69 63 67
46	8:46 PM	62	61 62 58 62 65 59 66	73 72 64 64
47	8:47 PM	61 58 55	60 74	73 66
48	8:48 PM	60 54 59	61 59 66	75 62 70 73
49	8:49 PM	60 60 57	62 55 65 59 57 59	68 64 65
50	8:50 PM	56 61 57 55 60	68 53 60 62 61	62 62
51	8:51 PM	59 62 62	62 60 58 60 59	60 70 68 69
52	8:52 PM	68 59 60	57 59 56 61 57 60 70	68
53	8:53 PM	60 59	66 59 65 63 61	73
54	8:54 PM	60 58	62 65 64	65 71 68
55	8:55 PM	68 59 57	61 59 65 59	74
56	8:56 PM	64 59 67	58 67 72 69 63 76 74	72
57	8:57 PM	59 57 56		
58	8:58 PM	55 59 56	56 56 55 62 58 61 70	66
59	8:59 PM	63 60	72 64 58 58	61 65
60	9:00 PM	63 64	65 55 70 61	65 61
61	9:01 PM	60 58 59	55 62 61 60 62 58 59 54	65 68

Table A.19. Raw data ID number 10869.

Location: I-75

Date: 07/29/2009 | **Start Time:** 9:11 AM | **End Time:** 9:36 AM

Location Lat: 39.63386 | **Location Long:** 084.23014

Nearest Speed Sensor ID: 10869 | **Direction of Traffic Flow:** NB

		Lane 1	Lane 2	Lane 3
11	9:11 AM	56	66 63 61 66	67
12	9:12 AM	59 61 58	55 70	63 67 67
13	9:13 AM	69 68 59 61	63 64 67 58	68
14	9:14 AM	60 57 58 70 59 61	64 63 64 67	66
15	9:15 AM	60 64	68 59 67 65 61 62	71 73
16	9:16 AM	63 57 55 62	67 64 64	72
17	9:17 AM	35 60	67 64 64	66
18	9:18 AM	56 60 56 57 53 55	69 68 64 71	67 72
19	9:19 AM	52 59	57 60	67
20	9:20 AM	64 60 62 61	65	
21	9:21 AM	61 58 64 57	66	73 73
22	9:22 AM	61 69	68 68 69	64 74
23	9:23 AM	65 58	61 61 70 68 66	69 70
24	9:24 AM	63 48 64	63 64 60	72 69
25	9:25 AM	61 63 68 60 62 61	64	70 77
26	9:26 AM	58	64 66	
27	9:27 AM	60 54 64	65 67 60	67 67
28	9:28 AM	60 59 57 56	57 53 65 64 70 58	65 75
29	9:29 AM	60	63 64 67 71 58 68 67	71
30	9:30 AM	59 64 58	70 69	70 71 79 70
31	9:31 AM	60 58 55 66	63 68	76 63
32	9:32 AM	64	65 63 65 66	
33	9:33 AM	62	61 64 68 57 64	70
34	9:34 AM	57 65	65 60 70 61 61 64	72 63 70
35	9:35 AM	61 56 51	64 66 72	72 64 68 66

Table A.20. Raw data ID number 10782.

Location: I-75 <Run 1>			
Date: 08/17/2009	**Start Time:** 9:16 AM		**End Time:** 9:40 AM
Location Lat: 39.77313		**Location Long:** 084.06874	
Nearest Speed Sensor ID: 10782		**Direction of Traffic Flow:** NB	

		Lane 1	Lane 2	Lane 3
1	9:40 AM	67 63	60	67 64 68
2	9:41 AM	66 68	65 67	64
3	9:42 AM	60 64 68	59 65 69 68	69 78 69 64
4	9:43 AM	60 60	69	71 71 67
5	9:44 AM	64 61 77	65 64 73 65	70 74
6	9:45 AM	68 74 70 65	70 62 74	61 62
7	9:46 AM	69 68 59 60	71 57 62	67 73 70
8	9:47 AM	60 75	71 57 62	64 69 54 62 63
9	9:48 AM	58 65 69	60 65	61 66 68 72 72
10	9:49 AM	69 62 60	67 66	65 66 59 75
11	9:50 AM	68 63 67 62 67	71 68	70
12	9:51 AM	64 64 67 60 67	68 67	71 72 75 65 61 69
13	9:52 AM	59 64	66 86 70	62 71 65
14	9:53 AM	61 58 71 62 62	68 66 70 56 68	62 67 63 69 65
15	9:54 AM	65 64 56	67 65 57 68	68 70 67 65
16	9:55 AM	70 65 58 62 64	71 65	67 68 65
17	9:56 AM	60 61 80 66 63 64	57 64 65 62 62	69 69 65
18	9:57 AM	60 64 61 58 66	64 66 61	69 66 69 71 67 79
19	9:58 AM	64 65 64	63 65 62 69	64 65 63
20	9:59 AM	54 61 64 65	68 69 64 69	61 71 67 66 67
21	10:00 AM	71 66	69 63	65 66 66 69 66 74
22	10:01 AM	59 63 61 67 59 59	65 65 70 66 63	64
23	10:02 AM	63 58 67 65	69 69 63 66 67 69	69 72 64 61 79
24	10:03 AM	57 65 63 64	68 65 68 64	69 74 58 66 73 60
25	10:04 AM	67 61 62 64	68 61 69	71 70 65 73

Table A.21. Raw data ID number 10758.

Location: I-75 <Run 2, Location 1>

Date: 07/28/2009	**Start Time:** 5:17 PM	**End Time:** 5:42 PM
Location Lat: 39.82857	**Location Long:** 084.18916	
Nearest Speed Sensor ID: 10758	**Direction of Traffic Flow:** NB	

		Lane 1	Lane 2	Lane 3
17	5:17 PM	57 64	71	
18	5:18 PM	63 59 54	61 67 66 65 70	72 72
19	5:19 PM	62 54 59 55	74 60 62 66	79 71
20	5:20 PM	65 69	67 66 67 69 66 61 68 66	78 71
21	5:21 PM	54 74 73 61 59	65 69 63 64 68 64	72 71
22	5:22 PM	58 61 62 66	62 61 66 65	69 68 69
23	5:23 PM	58 63 57 51 54	60 61	74 71
24	5:24 PM	56 60a66 61 67	60 61 52	74 71
25	5:25 PM	65 58 56 64	64 60 72	71 75
26	5:26 PM	68 58 69	65 68	70
27	5:27 PM	48 53 50	65 68	69
28	5:28 PM	62 56 62	63	67
29	5:29 PM	59 65 60 62	69 64	74
30	5:30 PM	66 67 63 62 56	67 64	
31	5:31 PM	66 71 65 59 59	72 65 61	70
32	5:32 PM	63 62 54 60 57 63	68 69	
33	5:33 PM	56 61	62 72	79 75
34	5:34 PM	66 59 54 51 63 61 59	63 65 58	68
35	5:35 PM	59 62 67 63 63		72 70
36	5:36 PM	57 63	68 68 61 69	73 70
37	5:37 PM	65 62 58 58	61 52 61 56	73 75
38	5:38 PM	59 65 57 62 53 65	68 75 69	73 71
39	5:39 PM	67 57 64	70 67 62 79	
40	5:40 PM	62 62 59 65	57 63 54	74 70
41	5:41 PM	66 68 56 55 63	62 67 70	80 76 71

Table A.22. Raw data ID number 10766.

Location: I-75, Near milepost 9.1

Date: 08/17/2009	**Start Time:** 5:20 PM	**End Time:** 5:45 PM
Location Lat: 39.67804	**Location Long:** -084.09991	
Nearest Speed Sensor ID: 10766	**Direction of Traffic Flow:** SB	

		Lane 1	Lane 2	Lane 3
1	5:20 PM	61 64 63 64 66 63	64 65 66	75 71
2	5:21 PM	64 70 66 68 65	72 65	71 67 71
3	5:22 PM	67 70 64 65 63	67 73 61 67	74 76 71
4	5:23 PM	65 72 68	72 66 73	68 73 69
5	5:24 PM	70 80 71 72	63 72 65 73	70 80 71 72
6	5:25 PM	64 64 69	66 64	72 66 71
7	5:26 PM	70 66	67 69	78
8	5:27 PM	66 65 72 67 65	71 71 64 67	70 74 71 73
9	5:28 PM	53 68 76	73 68 72 71	72 77
10	5:29 PM	63 69 64 69 79 69	68 69	71 77 72 80
11	5:30 PM	66 62 69	74 69 69 78	63
12	5:31 PM	67 64 67	70 73 67	73 68 72 78
13	5:32 PM	62 60 70 68 70	62 63	71 70 70
14	5:33 PM	71 69 64 64 66 61	70 69 65	76 71
15	5:34 PM	75 62	69 71 74	74 72 74
16	5:35 PM	62 66 73 65 65	65 78 69	70 68 75
17	5:36 PM	74 68 72 60	70 64 71 67 74	75 81
18	5:37 PM	67 71 71	60 70	75 74
19	5:38 PM	60 64 66	69 72 69	69
20	5:39 PM	67 67 63 69 56	71 73	77 76
21	5:40 PM	67 67 71	62	79 80
22	5:41 PM	71 67 72	68 70	76 68 75
23	5:42 PM	74 64 75 72 66 64 69	68 70 66	73
24	5:43 PM	71 65 68	71 66 70 68	70 73 77
25	5:44 PM	68 64 66 69 67 67	69 72 73	70 73 78 70

Table A.23. Raw data ID number 10870.

Location: I-75		
Date: 07/29/2009	**Start Time:** 5:23 PM	**End Time:** 5:48 PM
Location Lat: 39.63165	**Location Long:** 084.23081	
Nearest Speed Sensor ID: 10870	**Direction of Traffic Flow:** SB	

		Lane 1	Lane 2	Lane 3
23	5:23 PM	48 39 53 43 46 40	66	64 70
24	5:24 PM	44 57 56 62 59	47 66 63	72 70 76
25	5:25 PM	59 43	57 66 65 65 60 67 70 65	71 68
26	5:26 PM	56 66 67 66	68 68 66 66 69	73 73 74
27	5:27 PM	56 59 62 53 60		76 68 70
28	5:28 PM			
29	5:29 PM			
30	5:30 PM			
31	5:31 PM	37 70 44 53 49	40 40	49 49
32	5:32 PM	41 44 39 53 40	50 49 51	51 59
33	5:33 PM	39 37 41 40 56 35	56 57 53 51 57	63 62 58 66
34	5:34 PM	63 56 56 64 43 55	58 43 61 67 61	67 65 69 67
35	5:35 PM	58 54 49 64 51 59	62 64 63 62 42	53 70 61 65
36	5:36 PM	57 60	57 54 60 52 60 61 52 71	72 67 70
37	5:37 PM	55 41 59 53 46	51 50 48	61 62 69 63 58 62 65
38	5:38 PM	44 49 62 56 55 69 50 61	64 62	71 61 69 69 69
39	5:39 PM	62 58 56 69	66 60 61 60 65	70 67 71 75 64
40	5:40 PM	61 67 57 59 59	54 65	61 71 73 66 77 67 71
41	5:41 PM	48 59 34 42 45 36	56 61 56	64 62 60
42	5:42 PM	36 40 44 38 42 43	51 53 57 47 52 51	61 65
43	5:43 PM	34 39 36 34	52 39 48 55 56 41 51	60 61 53 49 51
44	5:44 PM	43 46 56 36 59 34	54 48 57 49	58 58 57 59
45	5:45 PM	61 47 63 44 42	67 65 65 62 67	71 67 67 63 37 67
46	5:46 PM	64 54 43 58 61	52 63 61	76 70 68
47	5:47 PM	54 65 60 52	63 62 63 67	75 72 66

Table A.24. Raw data ID number 10777.

Location: I-75, Mile mark 3.5

Date: 08/17/2009	**Start Time:** 6:10 PM	**End Time:** 6:34 PM
Location Lat: 39.63600	**Location Long:** 084.17700	
Nearest Speed Sensor ID: 10777	**Direction of Traffic Flow:** NB	

		Lane 1	Lane 2	Lane 3
1	6:10 PM	71 64 68 69 64	66 65 68 74	71 78
2	6:11 PM	65 60 69 66	70 72 70 69	
3	6:12 PM	65 65 65 61	69 71 72 66 70 71	71 69 71
4	6:13 PM	65 62 58 65 60	64 69 62 67 63	75 75 71
5	6:14 PM	59 61 64 70 69 72	72 68 76	72
6	6:15 PM	64 73 71 64 65	67 68 68 72 77	74 75 72
7	6:16 PM	65 71 67	70 68 77 71 63 67	70 75
8	6:17 PM	63 56 67	72 64 66 68	
9	6:18 PM	64 66 64 67 68	64 63 68 68 65	72
10	6:19 PM	57 67 66	70 67 72	68
11	6:20 PM	70 68 69 58 62	70 67 72	
12	6:21 PM	59 66 62	63 69 68	
13	6:22 PM	68 66 69 74 60 71 72	63 67 62 59 69 69	66
14	6:23 PM	61 63 64 63	66 66 70 64	69
15	6:24 PM	56 53 68 65 62	64 67 64	67 71
16	6:25 PM	60 61 68 63 68 66 63	68 69 68 69	71 72
17	6:26 PM	66 64 58 60 70	78 73 69 64 65 62 71	68 81
18	6:27 PM	67 61 71 67 60	69 74 62 64 70 67	76 74 74
19	6:28 PM	64 69 62 62 73 69 67	66 76 80	78
20	6:29 PM	58 69 68 65 66 67	70 68 69 65 73	73
21	6:30 PM	68 60 69 65 66 6	68 74 64	69 74
22	6:31 PM	63 69 71 39 61	67 66 66 68 69 67 71 68	
23	6:32 PM	70 72 61 64 61 70	73 80 69	68
24	6:33 PM	rain		
25	6:34 PM			

Table A.25. Raw data ID number 10934.

Location: I-75

Date: 07/29/2009	**Start Time:** 6:31 PM	**End Time:** 6:56 PM
Location Lat: 39.60934	**Location Long:** 084.23469	
Nearest Speed Sensor ID: 10934	**Direction of Traffic Flow:** SB	

		Lane 1	Lane 2	Lane 3
31	6:31 PM	59 70 66	72 73 80 64	73 69
32	6:32 PM	65 57	70 64 66 69 71 73 70	73 71 76 70
33	6:33 PM	62 64	67 65	77 75 70 78
34	6:34 PM	60 76	64 61 71	77 73
35	6:35 PM	65	65 61 66 68 71	80
36	6:36 PM	60 72	72 64 74 66 64 65 62 70	69
37	6:37 PM	63 68	64 62	67 71
38	6:38 PM	61	64 71 59	72 72 74 75 78 46
39	6:39 PM	65	71 64 64 68 62	
40	6:40 PM	59 66	64 65 67	71
41	6:41 PM			
42	6:42 PM	91 94 96	63	68 82
43	6:43 PM	57	61 61 58 61 66 57 70 61	69 79 72
44	6:44 PM		72 67 69	
45	6:45 PM	66 62	68 75 77 64	73
46	6:46 PM	60	64 64 68 64 64 67 65 68	73 73
47	6:47 PM	60	62 65 63 67 66	78 76
48	6:48 PM		69 70 64 68	67
49	6:49 PM	63 66 34	63	73 66
50	6:50 PM	53	64 69 62 66 62	74
51	6:51 PM	59	68 64	70
52	6:52 PM	62 65	63	
53	6:53 PM	60	61 65	71 71
54	6:54 PM	62	71 66 67	74 76
55	6:55 PM	61	63 67 63 60 63 63	83

Table A.26. Raw data ID number 10788.

Location: I-675, MM 1.6

Date: 08/20/2009 | **Start Time:** 8:32 AM | **End Time:** 8:57 AM

Location Lat: 39.62966 | **Location Long:** 084.21108

Nearest Speed Sensor ID: 10788 | **Direction of Traffic Flow:** NB

		Lane 1										Lane 2			
1	8:32 AM	63	68	61	58	68	72	69	68	73	65	68	72	70	71
2	8:33 AM	74	63	61	61	62	62	59	72			74	74	64	
3	8:34 AM	62	70	62	64	72	61	70				69	60		
4	8:35 AM	68	65	67	66	64	64	61	69			68	70	68	71
5	8:36 AM	57	61	59	70	66	66					66	65	71	71
6	8:37 AM	71	64	62								74	70	70	66
7	8:38 AM	59	59	63	65	67						71	70		
8	8:39 AM	67	73	68	65	69						67	76	71	
9	8:40 AM	64	63	73	65	62	68	62				67	66	71	
10	8:41 AM	67	74	65	58	68	63	60				73	69	70	
11	8:42 AM	65	69	62	71	64	62	65				73	70	70	
12	8:43 AM	68	67	63	63	59						64	69		
13	8:44 AM	64	63	65								76	75	69	
14	8:45 AM	70	68	71	66	66	62	63	63			73			
15	8:46 AM	75	65	59	62	58	61	64				73			
16	8:47 AM	69	65	64	67	70	60	66				57	63	71	68
17	8:48 AM	68	66	64	63	65	61	68				69			
18	8:49 AM	59	65	68	68	69	63	72	59			69	71		
19	8:50 AM	64	60	57	65	63						66	68	75	67
20	8:51 AM	52	64	73	63	68						65	65	61	
21	8:52 AM	65	66	68	70	61	62	64				61	72		
22	8:53 AM	65	69	64	57	67	61					68	61		
23	8:54 AM	65	68	64	63	63	62	64				73	73		
24	8:55 AM	66	60	56	64	66						67	75	74	
25	8:56 AM	70	65	62	57	63	67	70				70	51	67	

Table A.27. Raw data ID number 10836.

Location: I-35, MM32.2, South/East, Traffic signal approximately 0.4 miles West, traffic is platooning

Date: 08/18/2009 | **Start Time:** 9:14 AM | **End Time:** 9:39 AM

Location Lat: 39.73720 | **Location Long:** 084.26523

Nearest Speed Sensor ID: 10836 | **Direction of Traffic Flow:** SB/EB

		Lane 1	Lane 2	Lane 3
14	9:14 AM	54 48 54	58 53 48 48	49 50
15	9:15 AM	49 45	52 54	53
16	9:16 AM	51	52 57	60
17	9:17 AM	54 51 56	56 49 47 48 58	56 50 58
18	9:18 AM	57 56 55	61 53 52	59
19	9:19 AM		49	53 46
20	9:20 AM	50	52 51 38	59 54
21	9:21 AM	51 47	49 49 47 53 49 52 50	52
22	9:22 AM	54 57 53 32	47 46 57 48 62 54 56 42	56 59
23	9:23 AM	55 57 47	54	46 53 58
24	9:24 AM	48 57 58 54	49 60 39 59 69	
25	9:25 AM	49 53 44	54 50	57
26	9:26 AM	51	50	
27	9:27 AM	56 52 42	55 49 59 43	53 51
28	9:28 AM	40	52	54 48 60
29	9:29 AM	57 53 55 47	58 60 53 72	57 53 60
30	9:30 AM	50		
31	9:31 AM	49 45 41 39	53 50	53 56 52
32	9:32 AM	51 50	44 49 53 52 47 46	53 56 52
33	9:33 AM	46 56	54 55 52 50	46 56
34	9:34 AM	52 59	58 52 51	57 56
35	9:35 AM	45 48 54 53	48 50 54 43	54
36	9:36 AM	58 49	58 55 48 56	56 55
37	9:37 AM	43	40 48 61	49 58 52
38	9:38 AM	54 52	40 45 61 59	59

Table A.28. Raw data ID number 10744.

Location: SR-4, MM 21.0, Slight rain which became moderate

Date: 08/19/2009 | **Start Time:** 8:49 AM | **End Time:** 9:14 AM

Location Lat: 39.78690 | **Location Long:** 084.14200

Nearest Speed Sensor ID: 10744 | **Direction of Traffic Flow:**

		Lane 1								Lane 2				
1	8:49 AM	58	53	57	60	57				62				
2	8:50 AM	62	50	60						64	59			
3	8:51 AM	62	66	64	58					64				
4	8:52 AM	53	55	60						60	62	65		65
5	8:53 AM	65	60	47	61	60	67	67	53	62				
6	8:54 AM	54	56	53	52	66	68	58						
7	8:55 AM	61	66	58	59					64				
8	8:56 AM	59	60	60	61	64	64			65				
9	8:57 AM	51	56	57										
10	8:58 AM	55	56	65						56				
11	8:59 AM	66	61	59	63	60	56	55	62	62	74			
12	9:00 AM	53	53	60	57					56	64	55		
13	9:01 AM	59	59	59						60	58			
14	9:02 AM	60	61	56	53	60	61			59	62	64		
15	9:03 AM	59	58		starting to rain					59				
16	9:04 AM	55	56	57	58					63	55			
17	9:05 AM	63								61				
18	9:06 AM	65	64	46						58	53			
19	9:07 AM	60								63				
20	9:08 AM	60	62	56	56									
21	9:09 AM									63				
22	9:10 AM	58	63							66				
23	9:11 AM	61	56	62	65	71	58							
24	9:12 AM	59	55	65	59	63				64	60			
25	9:13 AM	59	64	60	57	66	63			62	62			

Table A.29. Raw data ID number 10725.

Location: SR-4, Work zone down to one lane, moderate rain									
Date: 08/19/2009		**Start Time:** 10:19 AM				**End Time:** 10:44 AM			
Location Lat: 39.77110						**Location Long:** 084.18000			
Nearest Speed Sensor ID: 10725						**Direction of Traffic Flow:** SB			
		Lane 1							
19	10:19 AM	48	47	44					
20	10:20 AM	46	51	48	54				
21	10:21 AM	56	56	51	48				
22	10:22 AM	63	53	49					
23	10:23 AM	58	54						
24	10:24 AM	56	46	55	57	60	61		
25	10:25 AM	53	55	55					
26	10:26 AM	52	55	54	52	54	52	50	
27	10:27 AM	60	54	57	55	56	47	49	
28	10:28 AM	53	59	62	53	46	54		
29	10:29 AM	56	56	59	61	53	57	58	
30	10:30 AM	59							
31	10:31 AM								
32	10:32 AM	59	57	61	46	54	55		
33	10:33 AM								
34	10:34 AM	53	53	54		stopped raining			
35	10:35 AM	52	55	52	56	55			
36	10:36 AM	63	52	53	62				
37	10:37 AM	52							
38	10:38 AM	57	58	55	44	44			
39	10:39 AM	43	58	57	58				
40	10:40 AM	54	55	49	66	60	50		
41	10:41 AM	59	57	49	54	52	59	57	
42	10:42 AM	53	56	60					
43	10:43 AM	41	47	53	54	52			

APPENDIX B

HISTOGRAMS

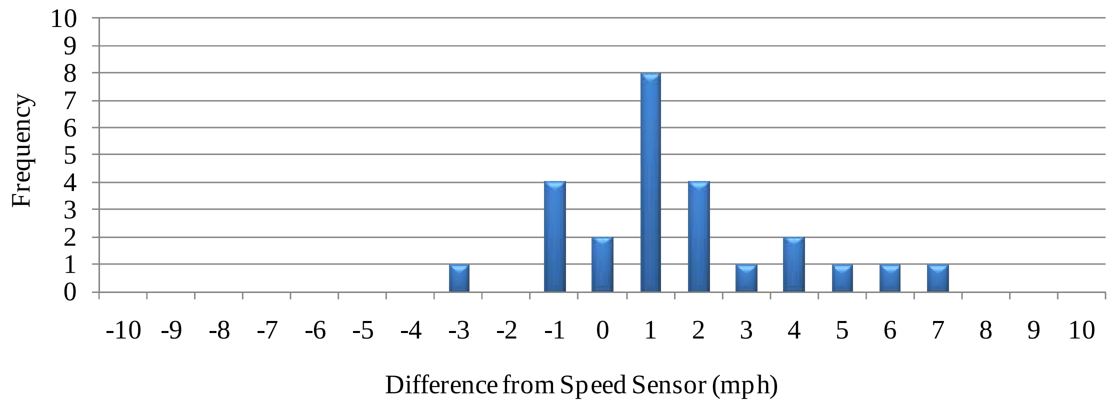


Figure B.1. Histogram for ID number 10681

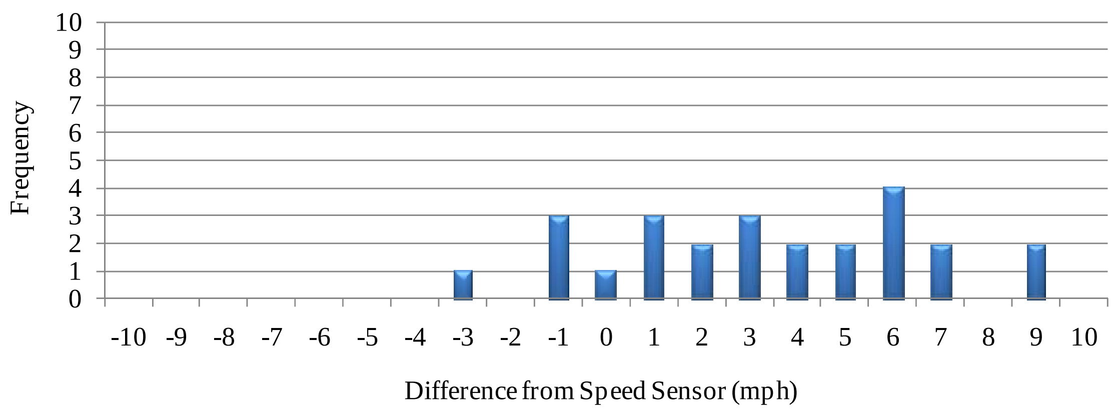


Figure B.2. Histogram for ID number 10691.

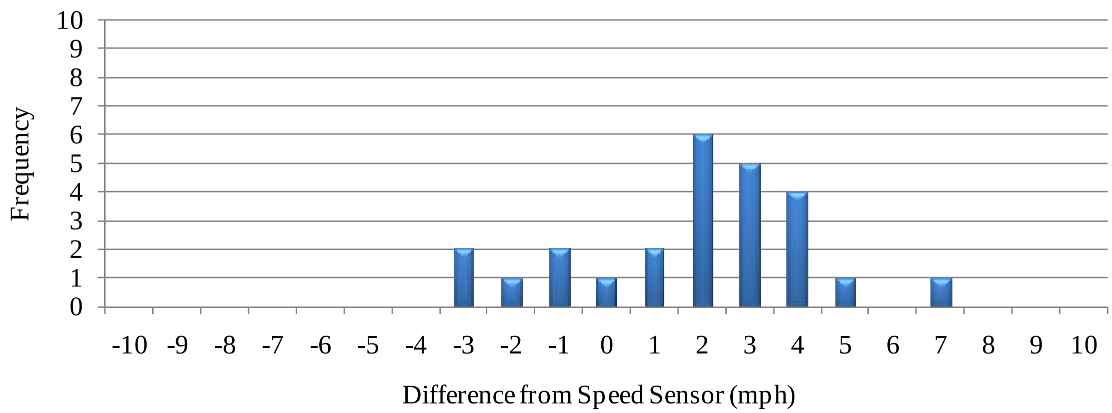


Figure B.3. Histogram for ID number 11120.

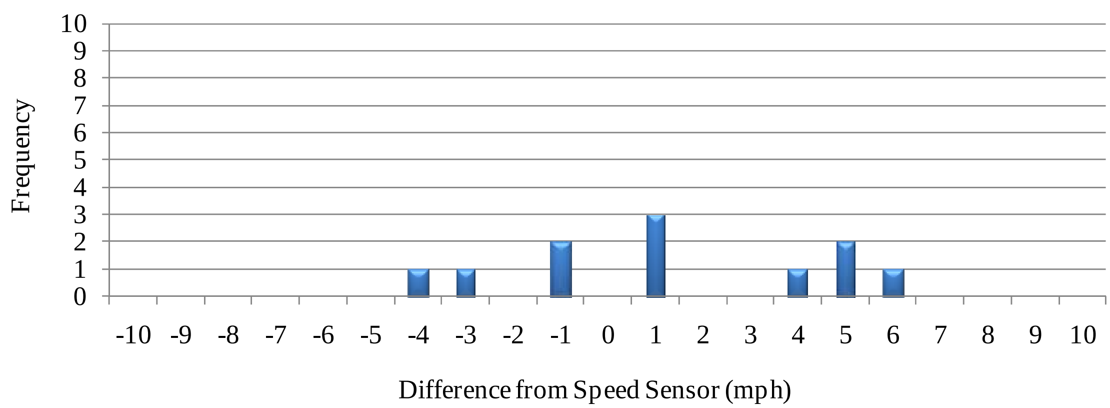


Figure B.4. Histogram for ID number 10710.

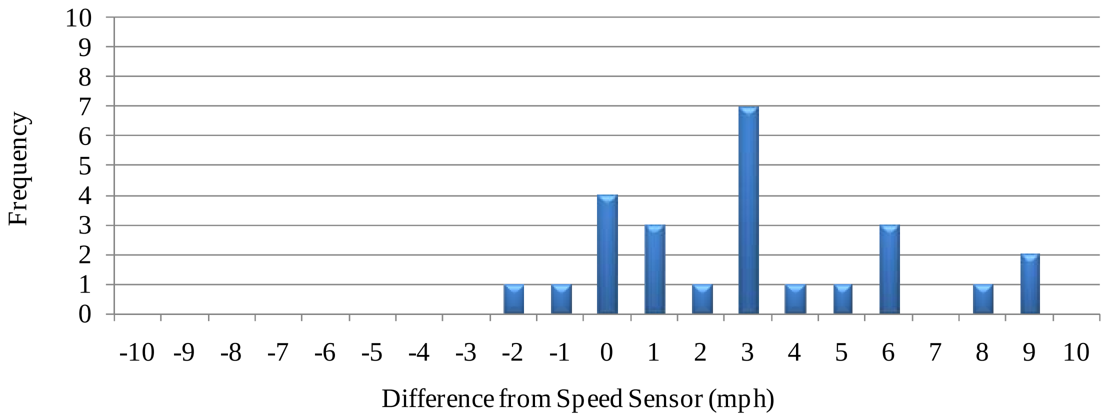


Figure B.5. Histogram for ID number 10694.

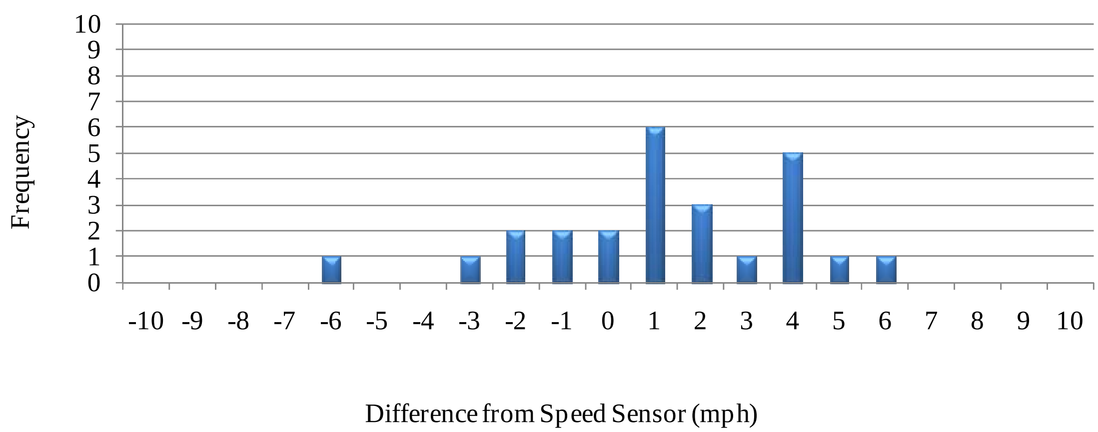


Figure B.6. Histogram for ID number 10791.

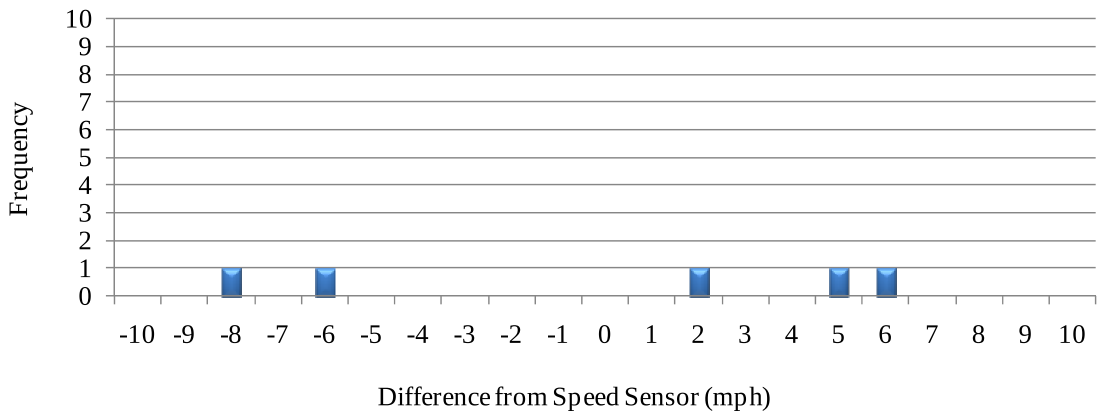


Figure B.7. Histogram for ID number 10929.

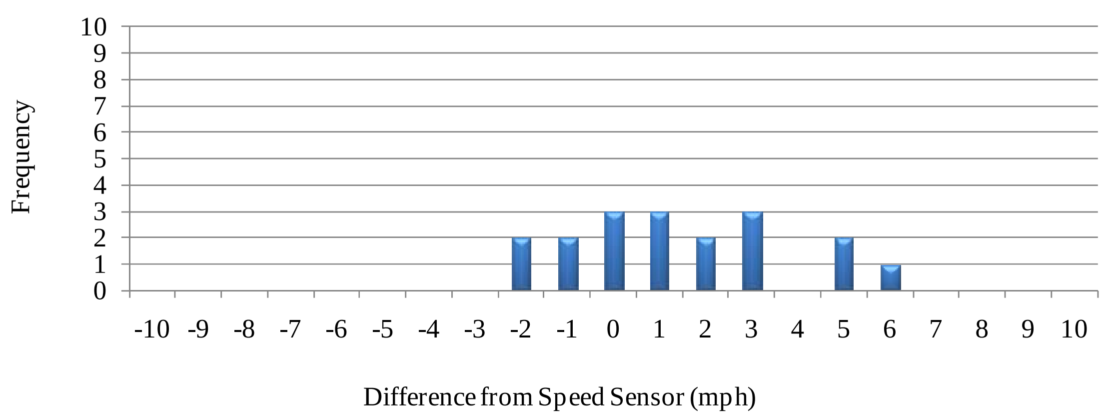


Figure B.8. Histogram for ID number 10782.

.

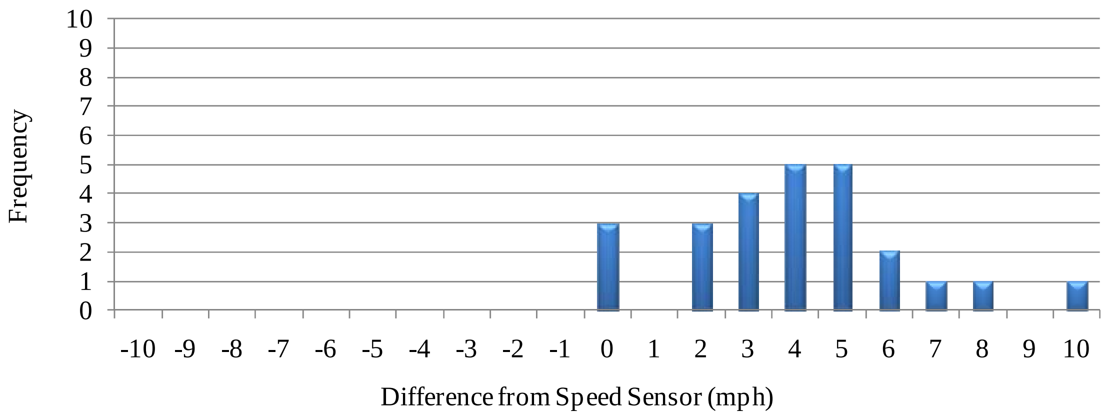


Figure B.9. Histogram for ID number 10766.

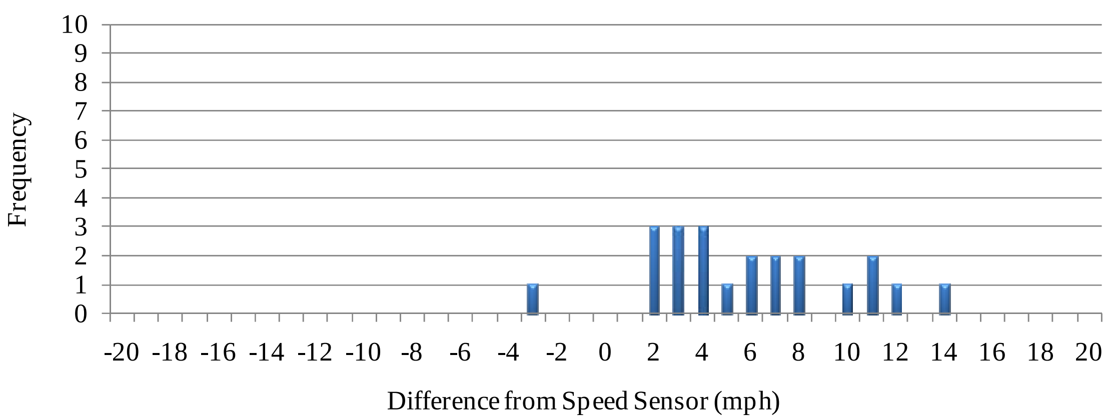


Figure B.10. Histogram for ID number 10870.

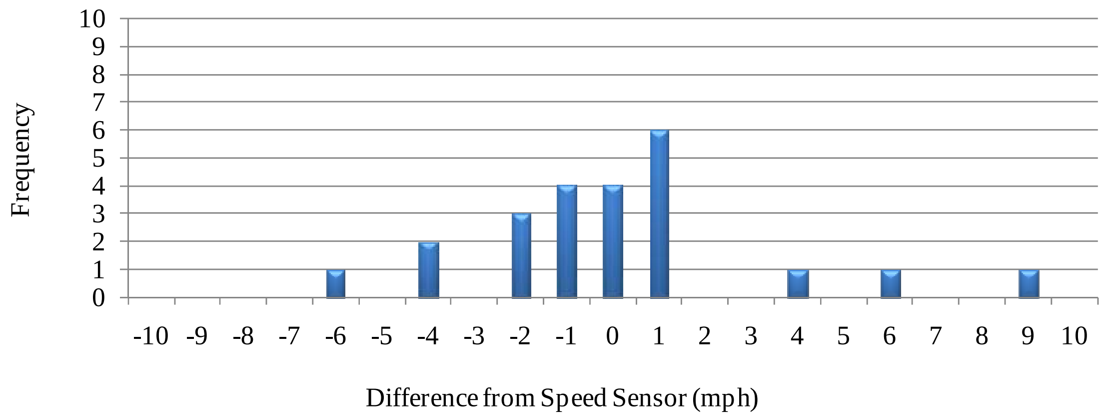


Figure B.11. Histogram for ID number 10777.

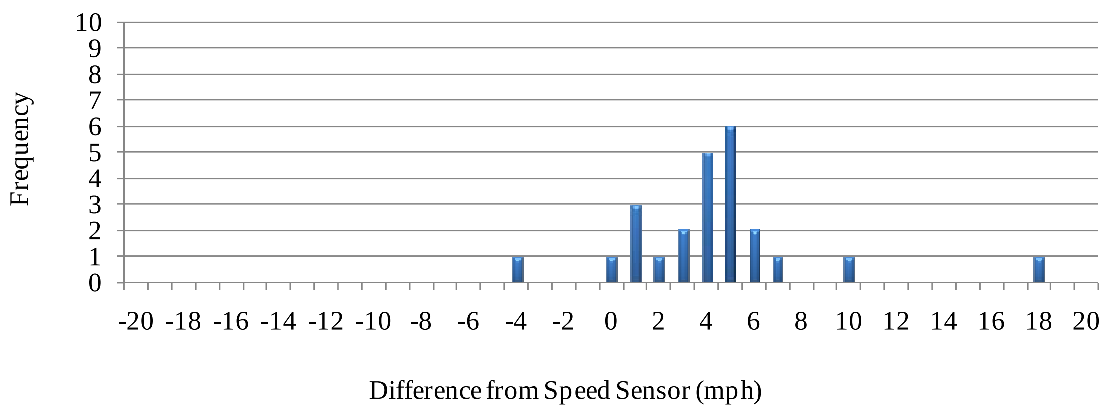


Figure B.12. Histogram for ID number 10934.

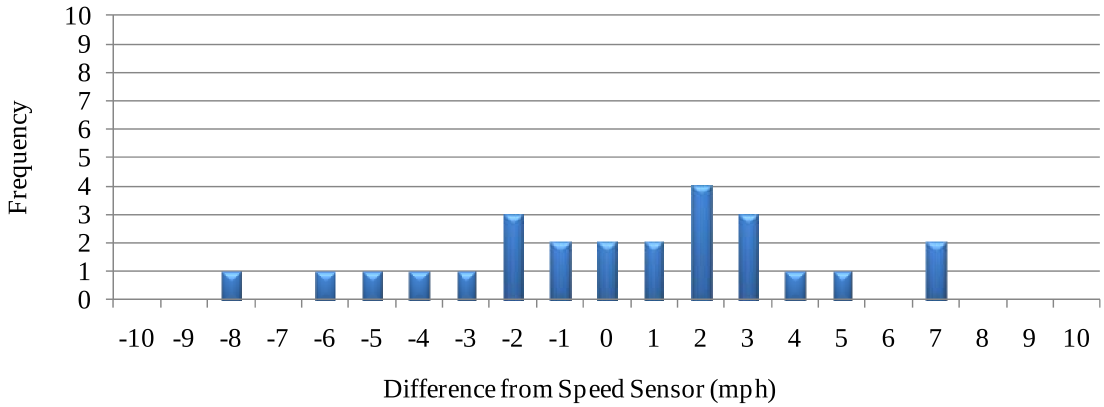


Figure B.13. Histogram for ID number 10836.

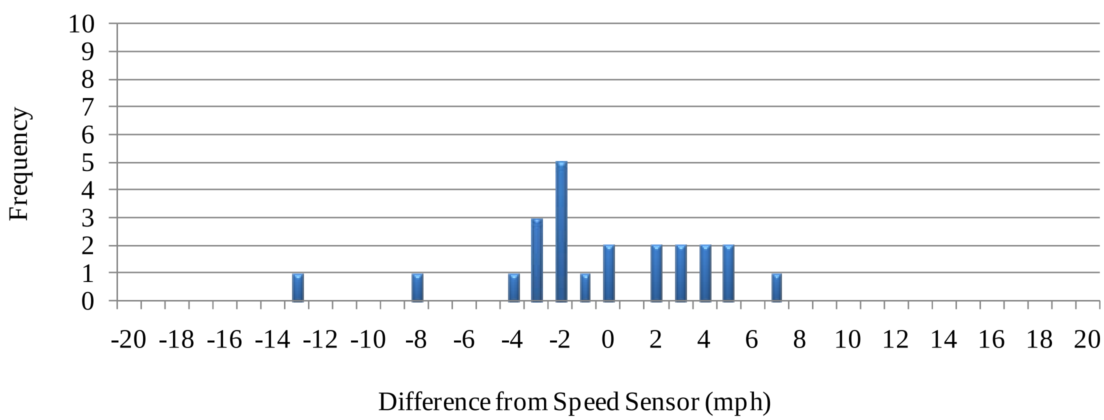


Figure B.14. Histogram for ID number 10744.

APPENDIX C

BLUETOOTH AND FLOATING CAR COMPARISON

I-70

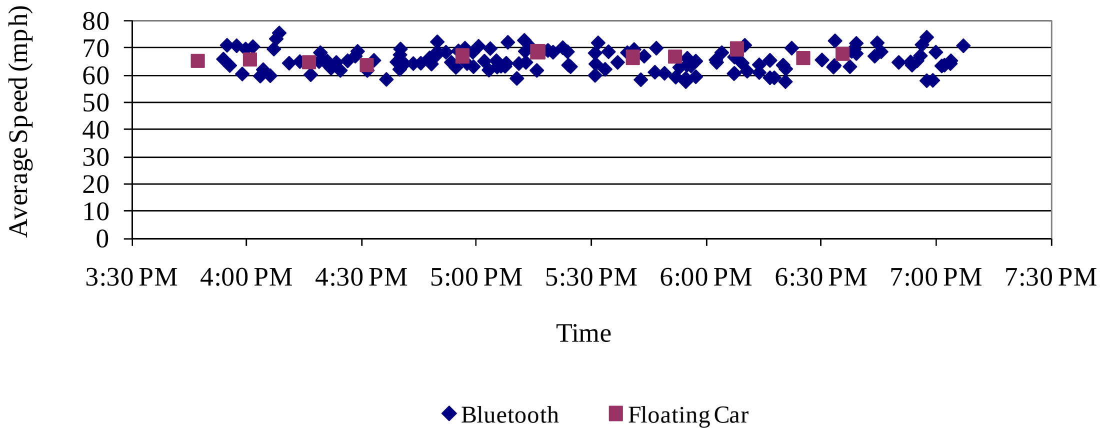


Figure C.1. Travel Time Segment ID 1, 8.0 miles (12.9 km), 7/27/2009, PM

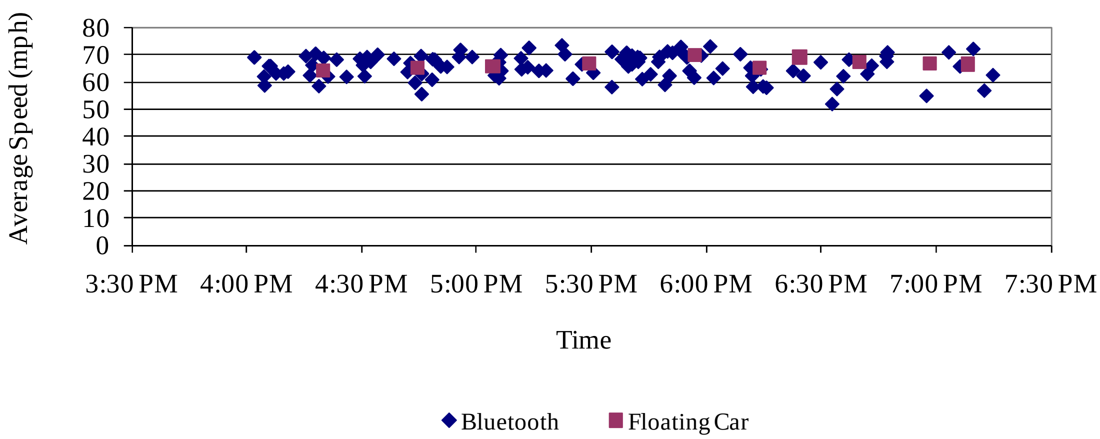


Figure C.2. Travel Time Segment ID 2, 8.0 miles (12.9 km), 7/27/2009, PM

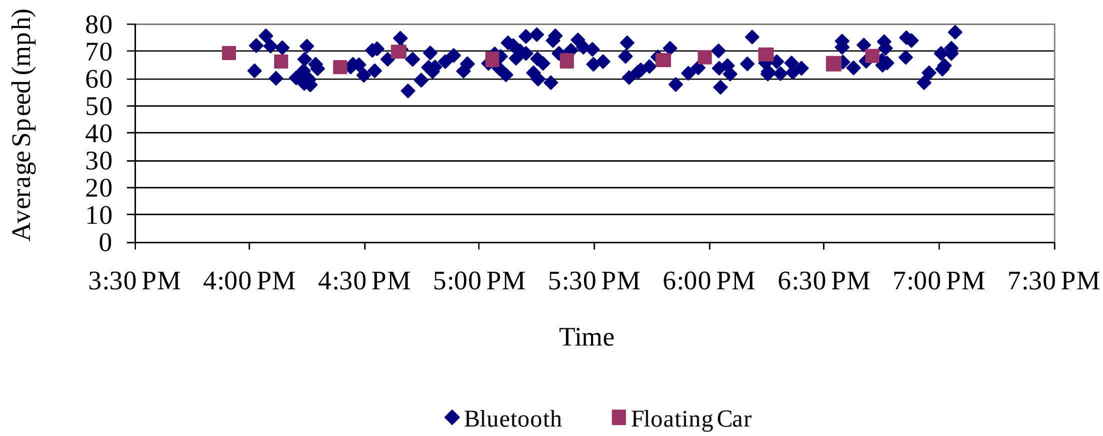


Figure C.3. Travel Time Segment ID 3, 7.2 miles (11.6 km), 7/27/2009, PM

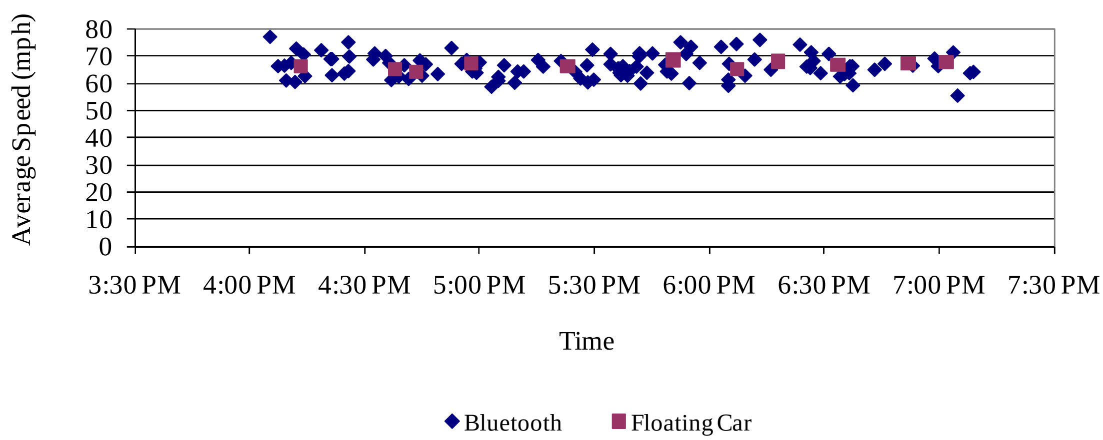


Figure C.4. Travel Time Segment ID 4, 7.2 miles (11.6 km), 7/27/2009, PM

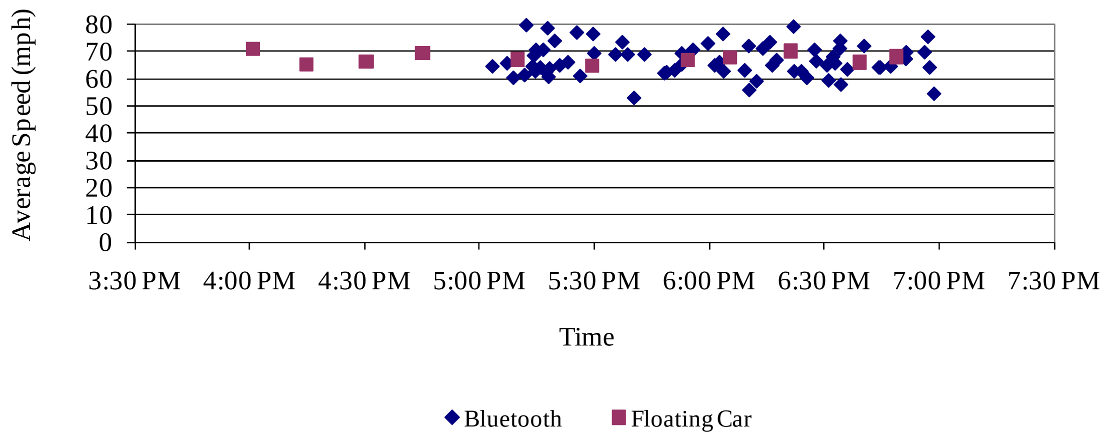


Figure C.5. Travel Time Segment ID 5, 3.2 miles (5.1 km), 7/27/2009, PM

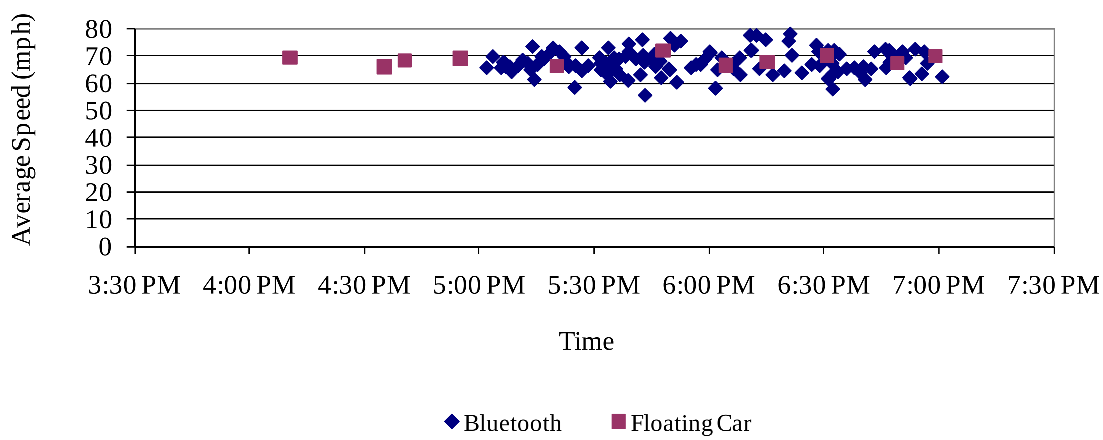


Figure C.6. Travel Time Segment ID 6, 3.2 miles (5.1 km), 7/27/2009, PM

I-75

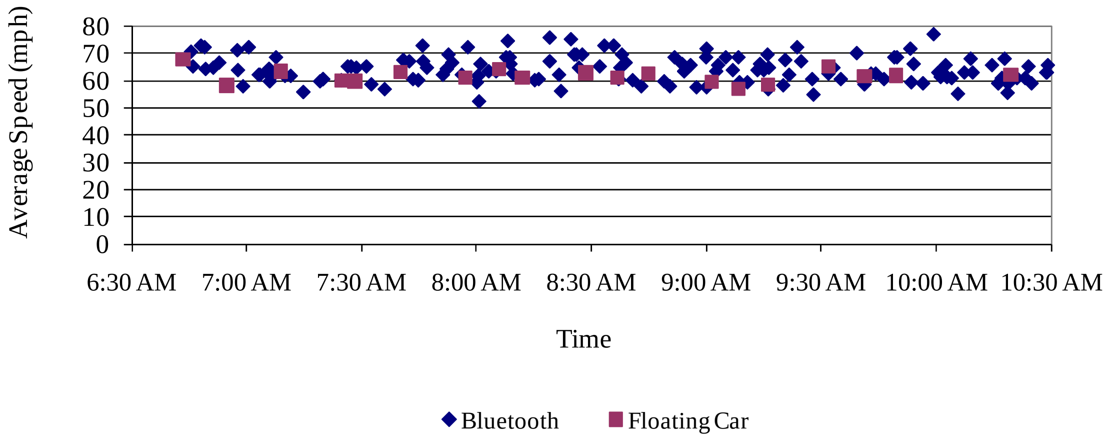


Figure C.7. Travel Time Segment ID 9, 2.6 miles (4.2 km), 7/29/2009, AM

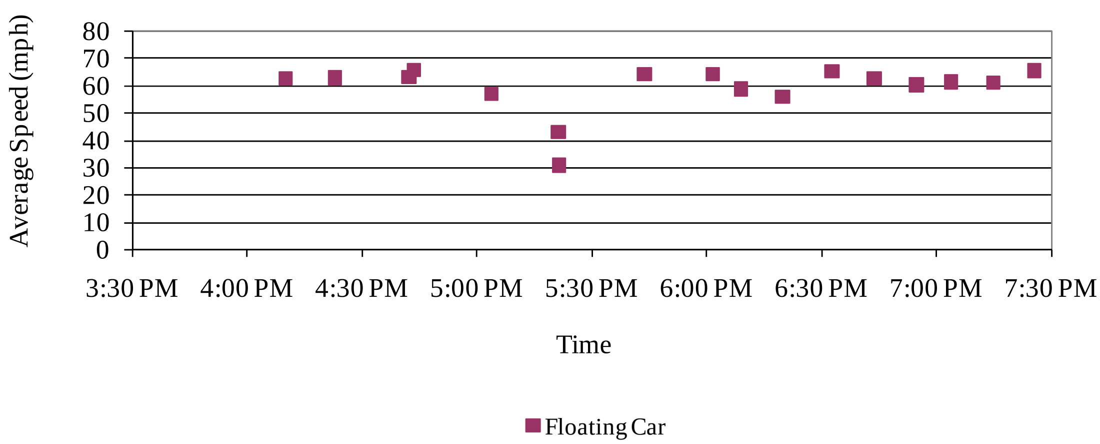


Figure C.8. Travel Time Segment ID 9, 2.6 miles (4.2 km), 7/29/2009, PM

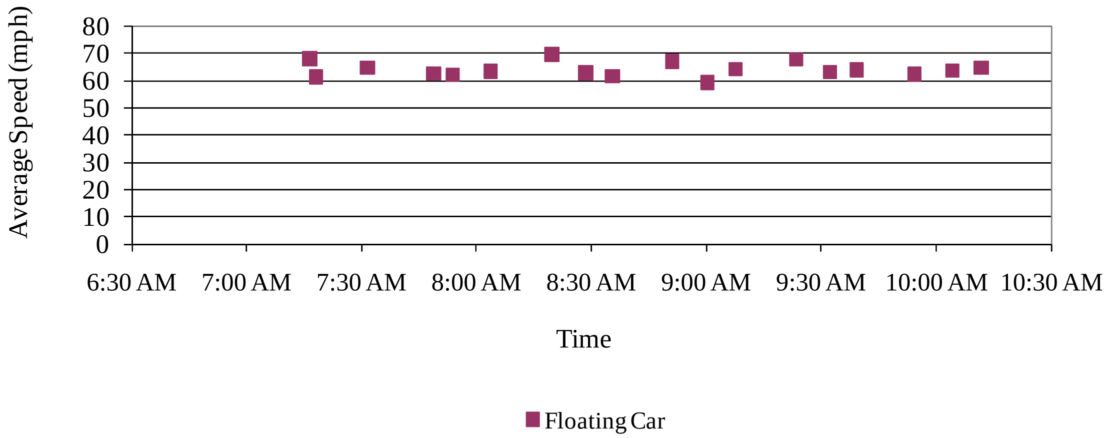


Figure C.9. Travel Time Segment ID 10, 2.6 miles (4.2 km), 7/29/2009, AM

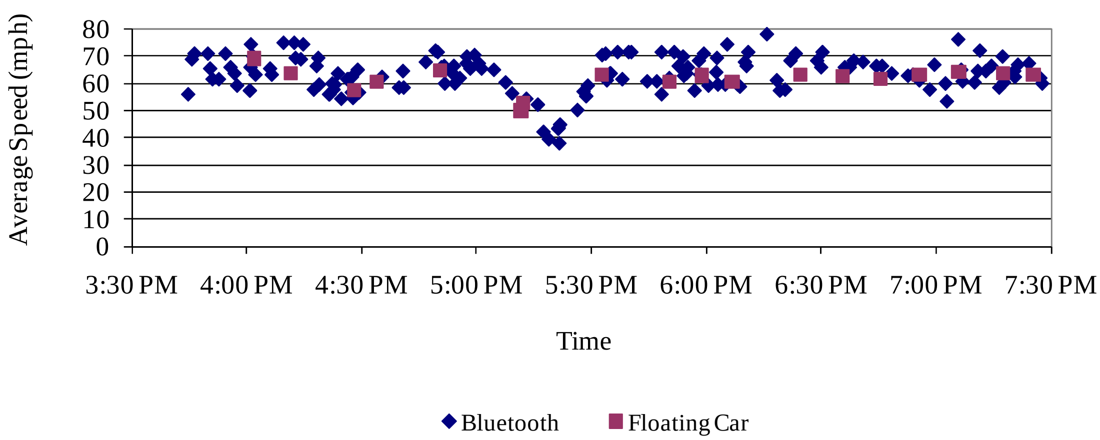


Figure C.10. Travel Time Segment ID 10, 2.6 miles (4.2 km), 7/29/2009, PM

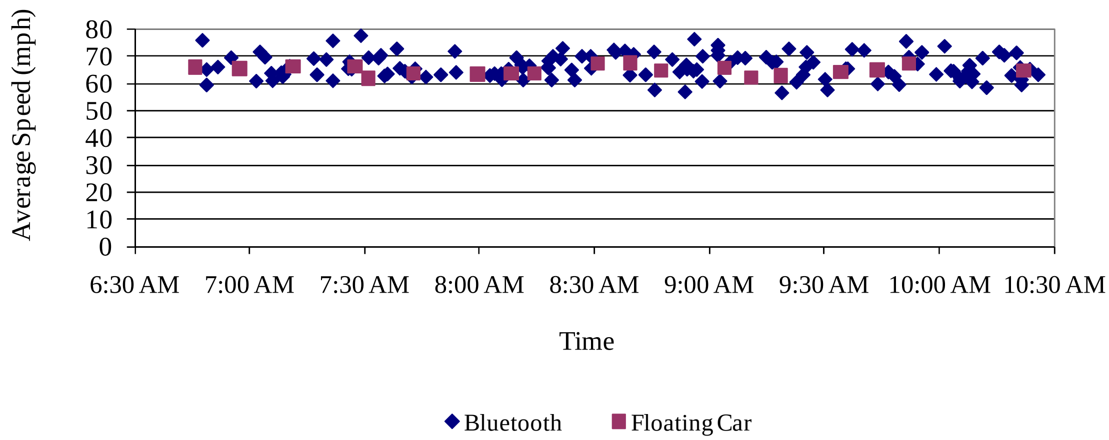


Figure C.11. Travel Time Segment ID 11, 8.3 miles (13.4 km), 7/29/2009, AM

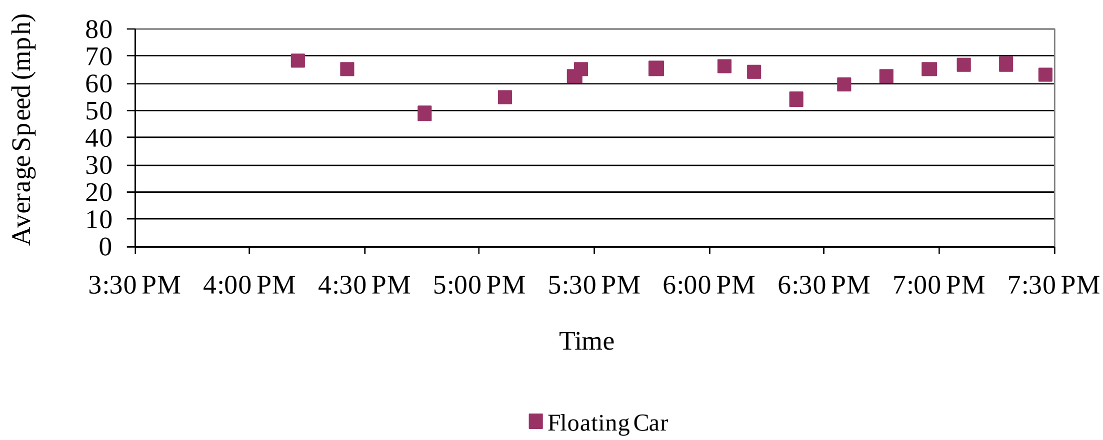


Figure C.12. Travel Time Segment ID 11, 8.3 miles (13.4 km), 7/29/2009, PM

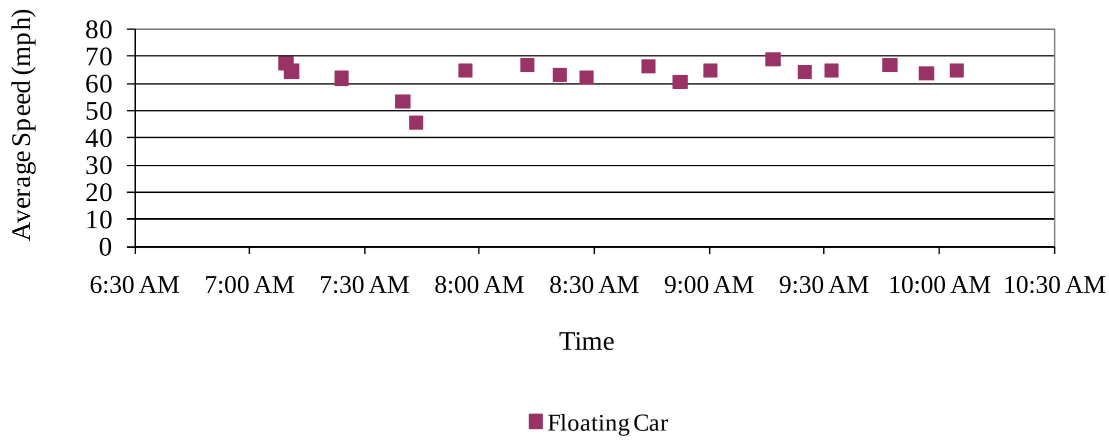


Figure C.13. Travel Time Segment ID 12, 8.3 miles (13.4 km), 7/29/2009, AM

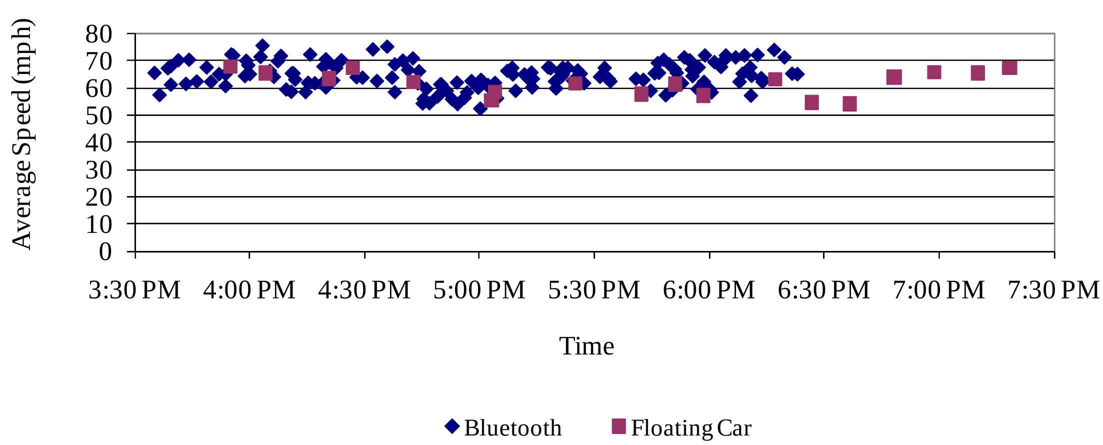


Figure C.14. Travel Time Segment ID 12, 8.3 miles (13.4 km), 7/29/2009, PM

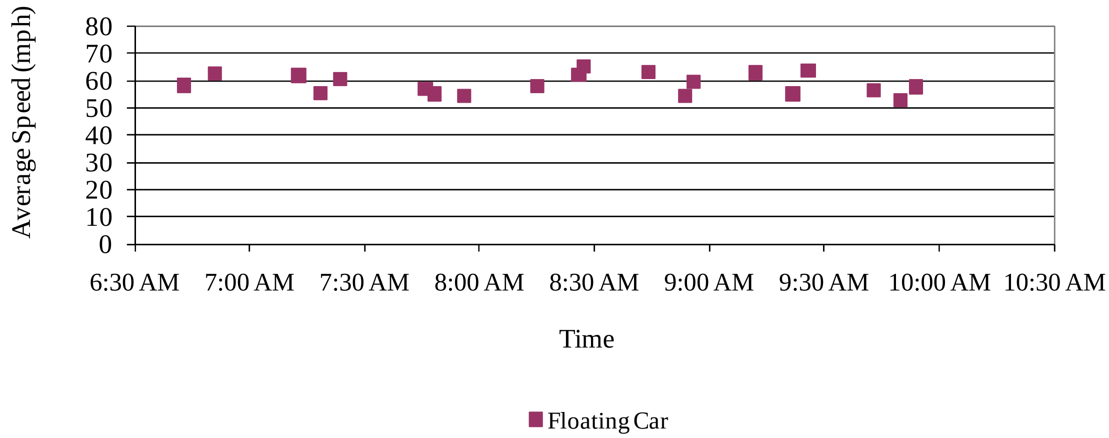


Figure C.15. Travel Time Segment ID 13, 0.9 miles (1.4 km), 7/28/2009, AM

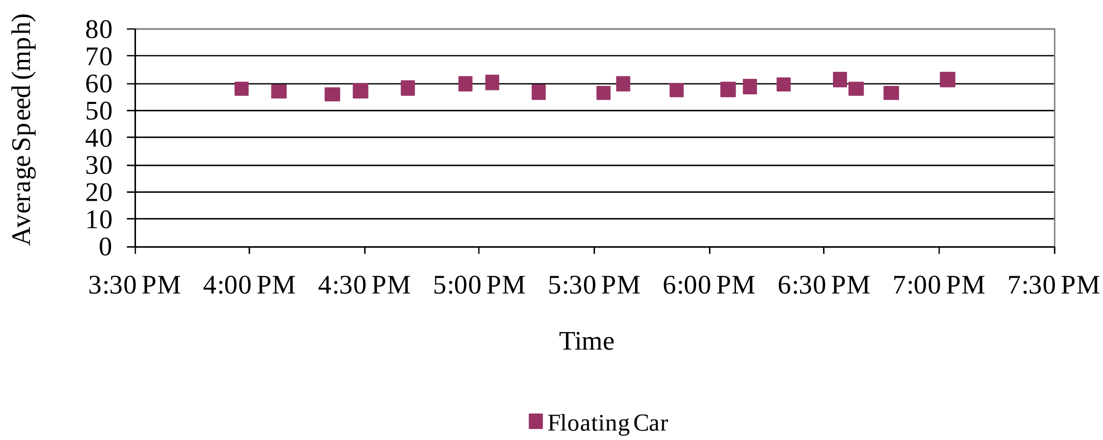


Figure C.16. Travel Time Segment ID 13, 0.9 miles (1.4 km), 7/28/2009, PM

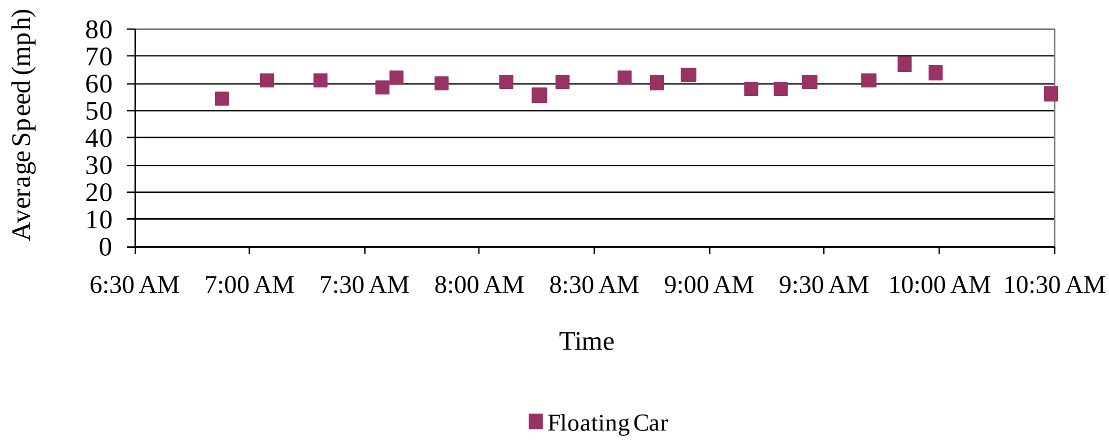


Figure C.17. Travel Time Segment ID 13, 0.9 miles (1.4 km), 7/29/2009, AM

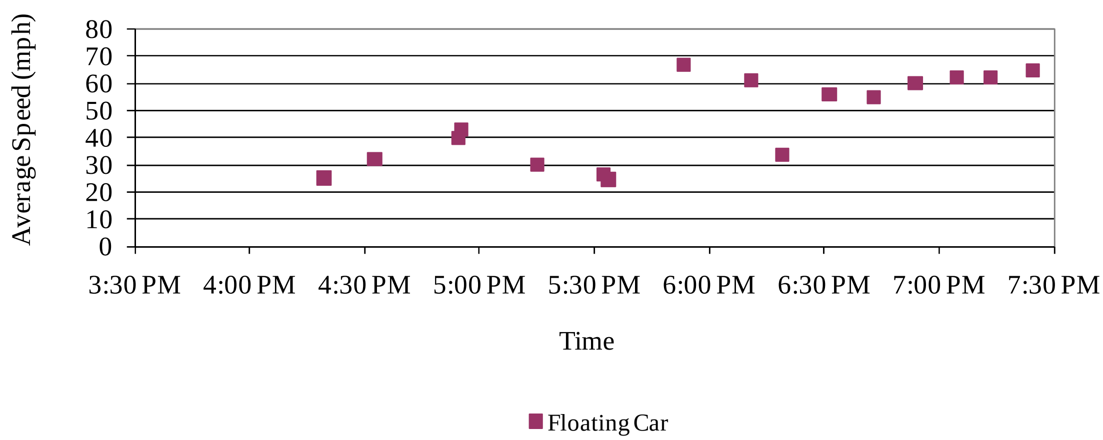


Figure C.18. Travel Time Segment ID 13, 0.9 miles (1.4 km), 7/29/2009, PM

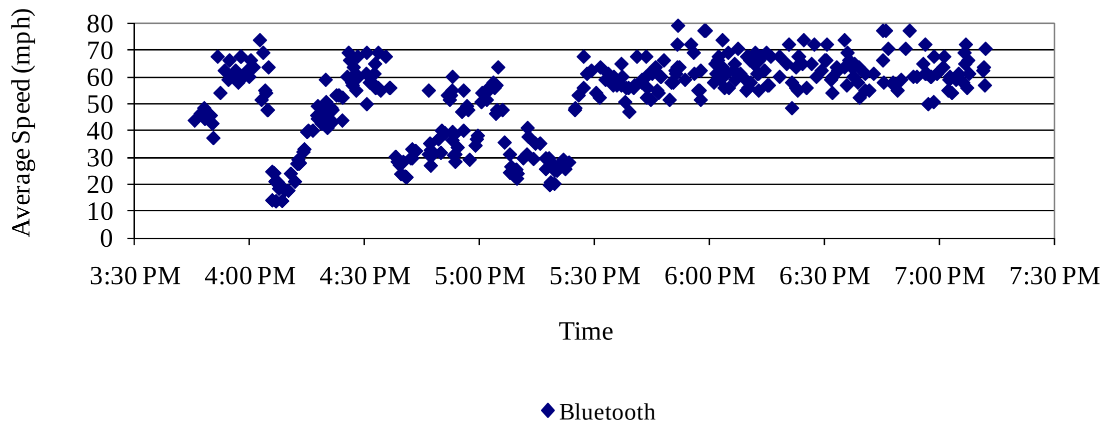


Figure C.19. Travel Time Segment ID 13, 0.9 miles (1.4 km), 9/3/2009

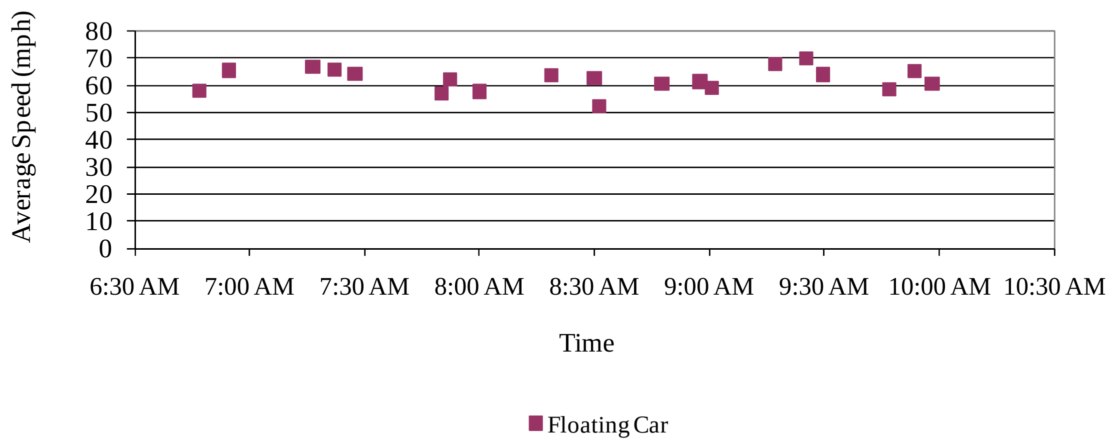


Figure C.20. Travel Time Segment ID 14, 0.9 miles (1.4 km), 7/28/2009, AM

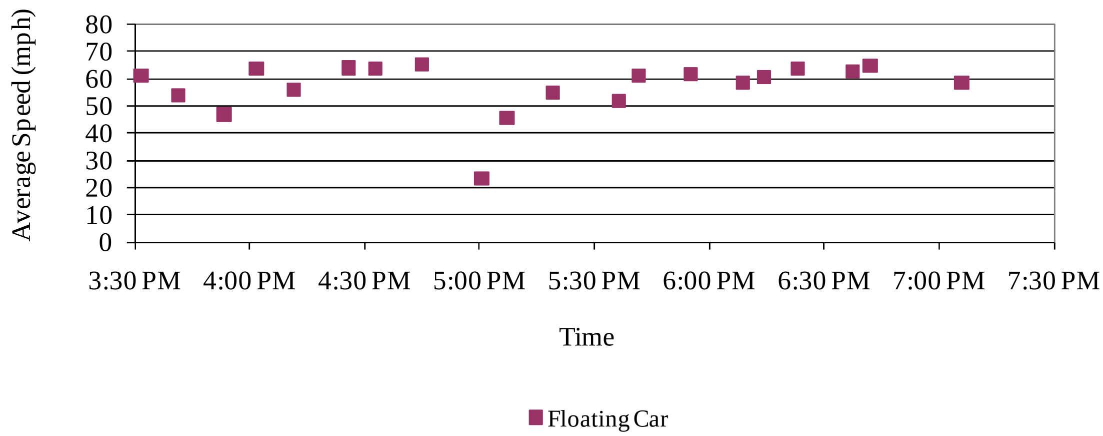


Figure C.21. Travel Time Segment ID 14, 0.9 miles (1.4 km), 7/28/2009, PM

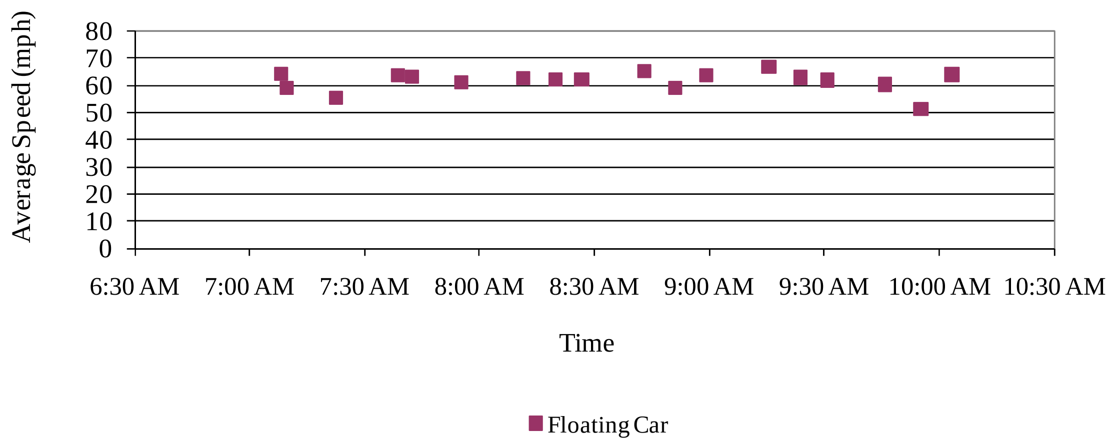


Figure C.22. Travel Time Segment ID 14, 0.9 miles (1.4 km), 7/29/2009, AM

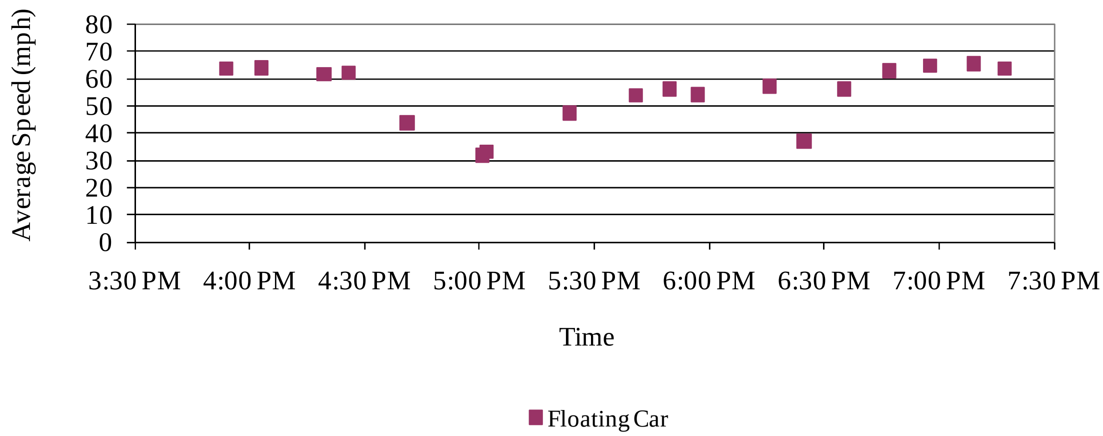


Figure C.23. Travel Time Segment ID 14, 0.9 miles (1.4 km), 7/29/2009, PM

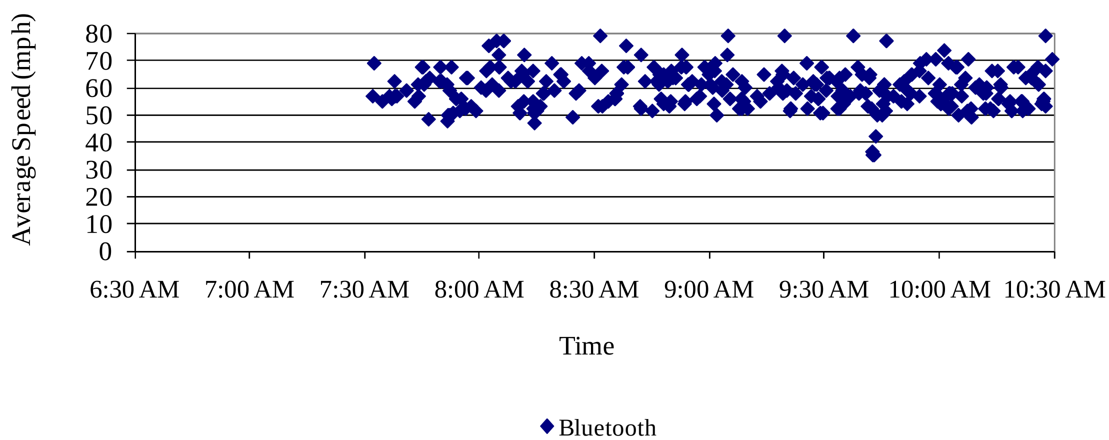


Figure C.24. Travel Time Segment ID 14, 0.9 miles (1.4 km), 9/3/2009

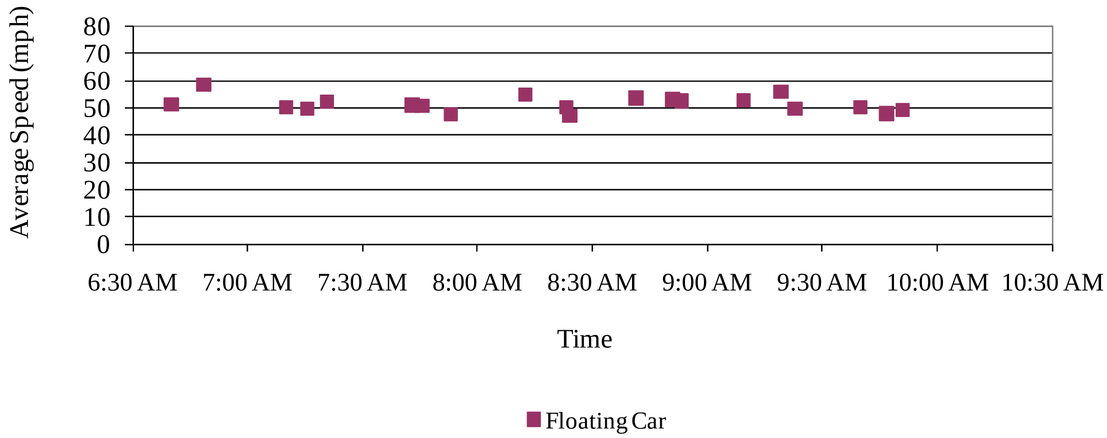


Figure C.25. Travel Time Segment ID 15, 2.1 miles (3.4 km), 7/28/2009, AM

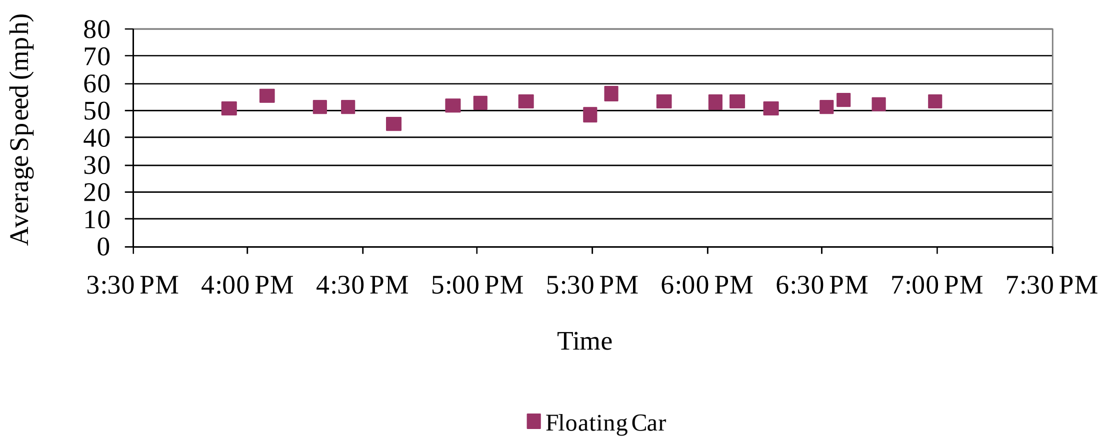


Figure C.26. Travel Time Segment ID 15, 2.1 miles (3.4 km), 7/28/2009, PM

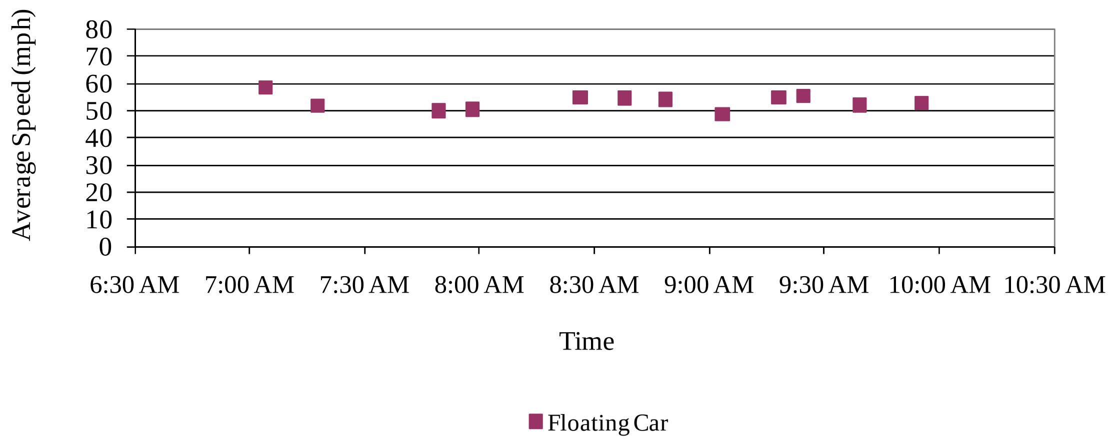


Figure C.27. Travel Time Segment ID 15, 2.1 miles (3.4 km), 7/30/2009, AM

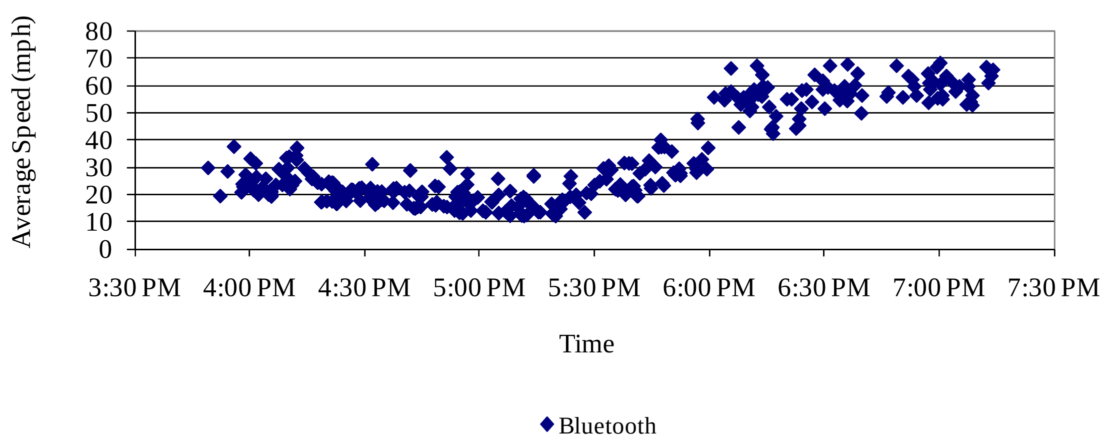


Figure C.28. Travel Time Segment ID 15, 2.1 miles (3.4 km), 9/3/2009

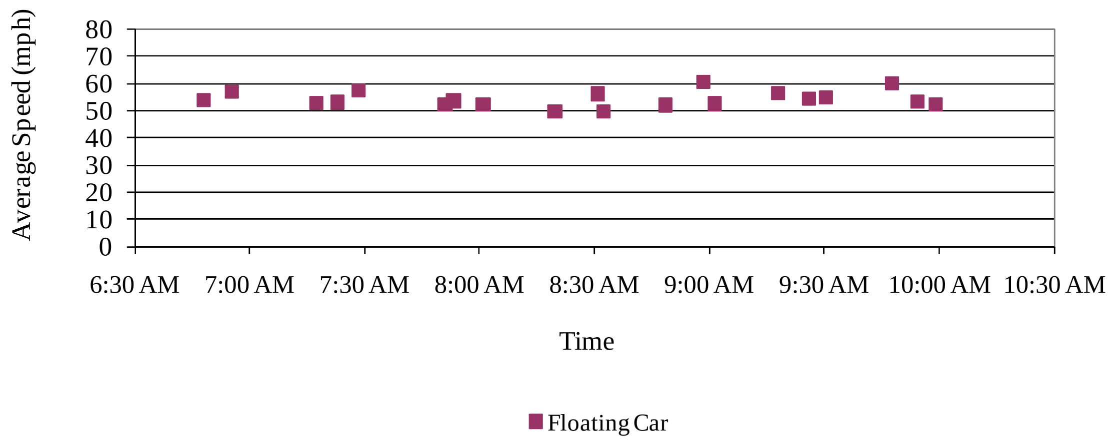


Figure C.29. Travel Time Segment ID 16, 2.1 miles (3.4 km), 7/28/2009, AM

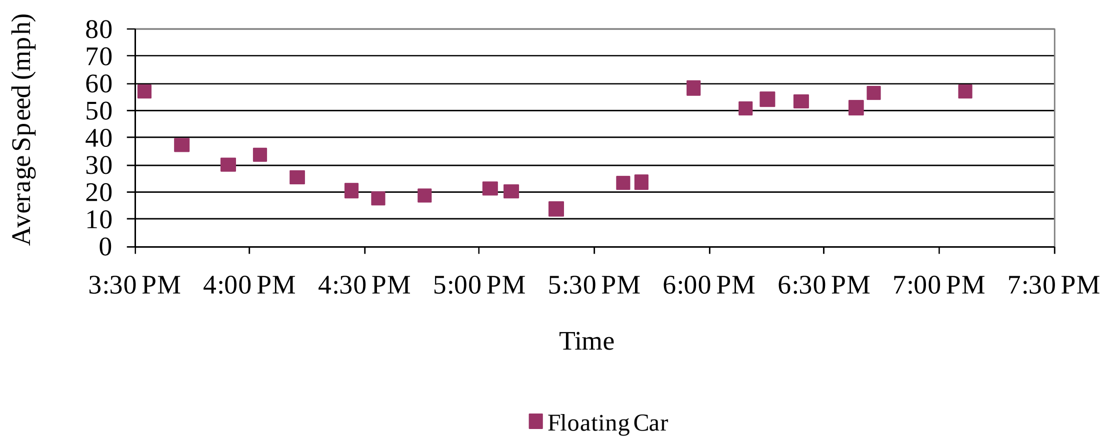


Figure C.30. Travel Time Segment ID 16, 2.1 miles (3.4 km), 7/28/2009, PM

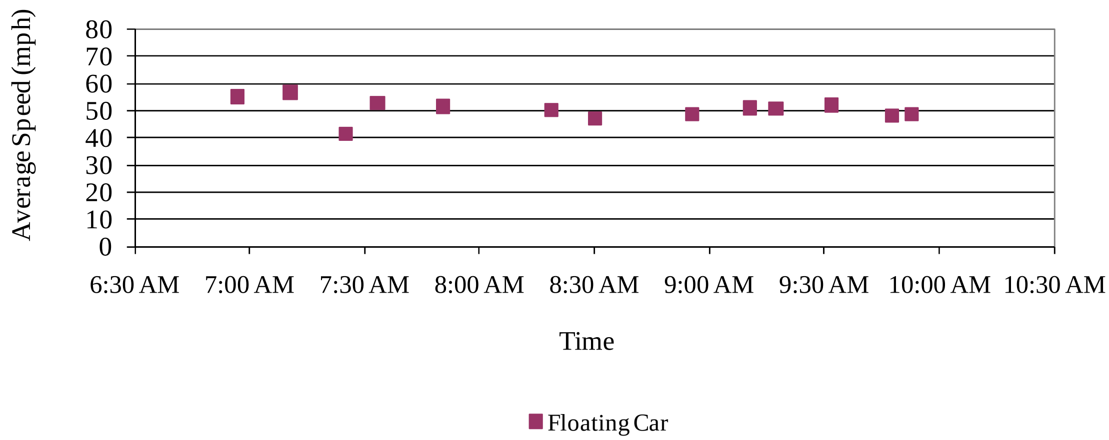


Figure C.31. Travel Time Segment ID 16, 2.1 miles (3.4 km), 7/30/2009, AM

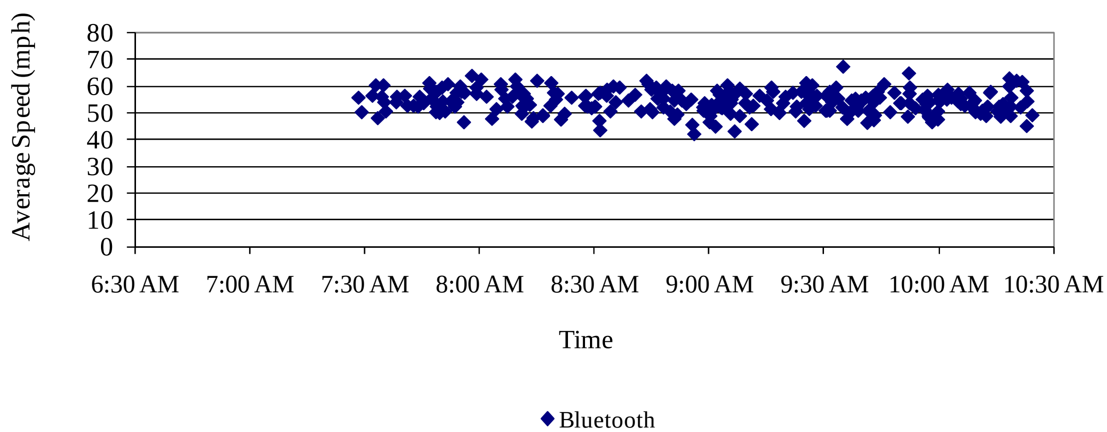


Figure C.32. Travel Time Segment ID 16, 2.1 miles (3.4 km), 9/3/2009

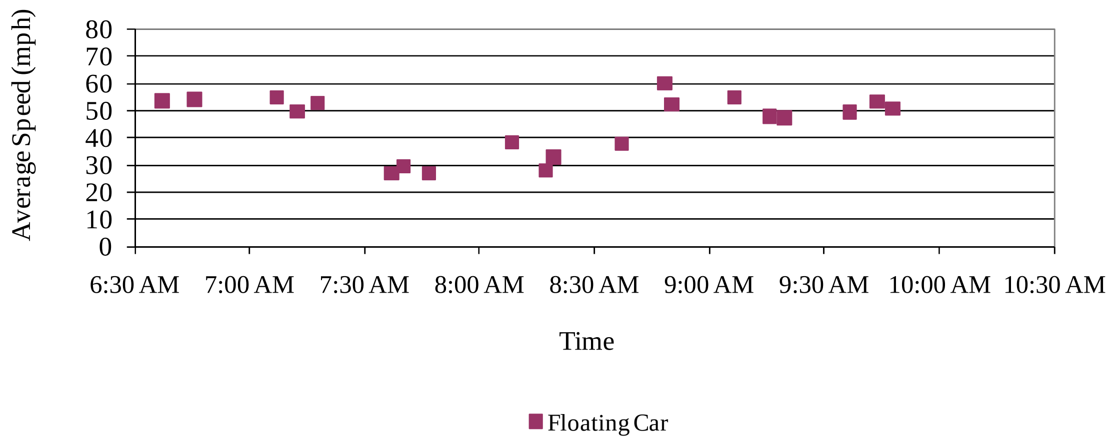


Figure C.33. Travel Time Segment ID 17, 2.9 miles (4.7 km), 7/28/2009, AM

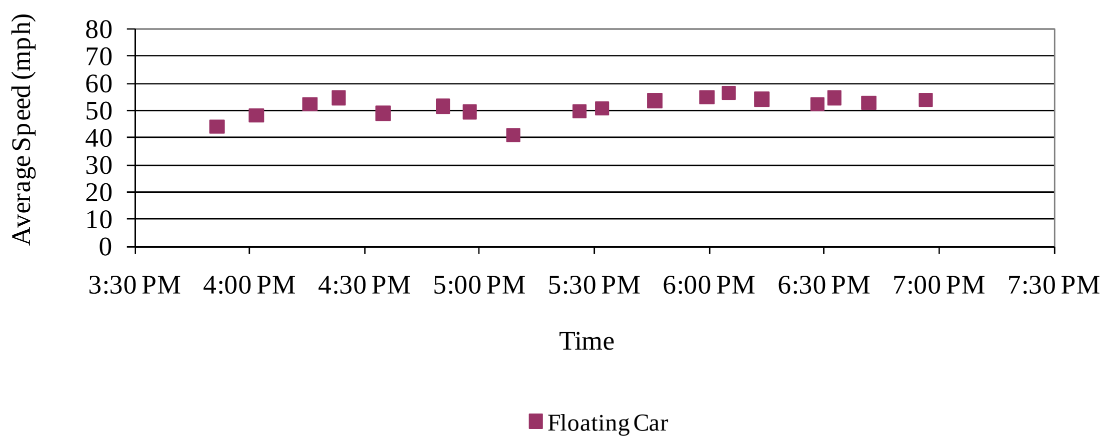


Figure C.34. Travel Time Segment ID 17, 2.9 miles (4.7 km), 7/28/2009, PM

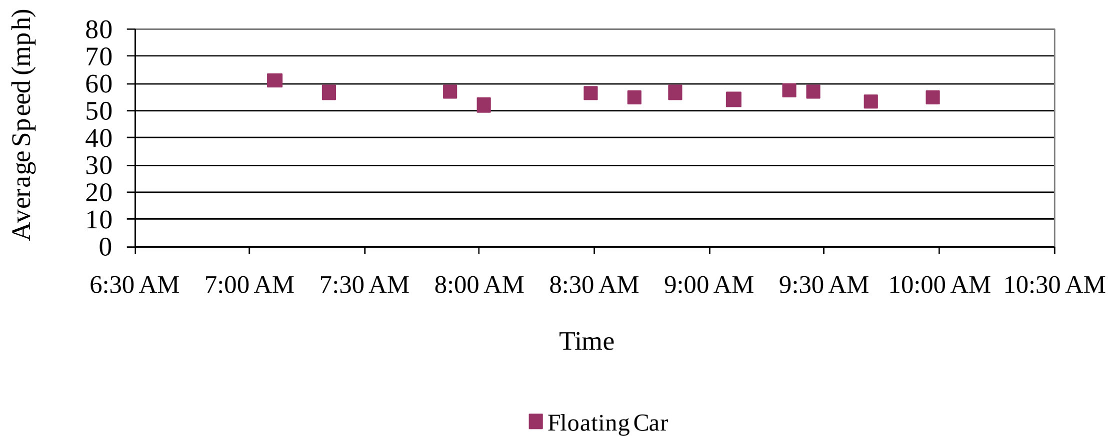


Figure C.35. Travel Time Segment ID 17, 2.9 miles (4.7 km), 7/30/2009, AM

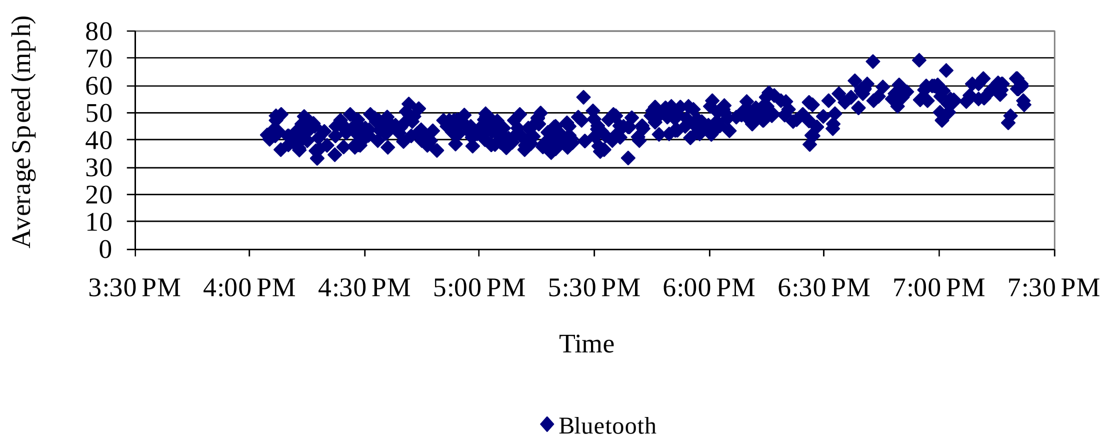


Figure C.36. Travel Time Segment ID 17, 2.9 miles (4.7 km), 9/3/2009

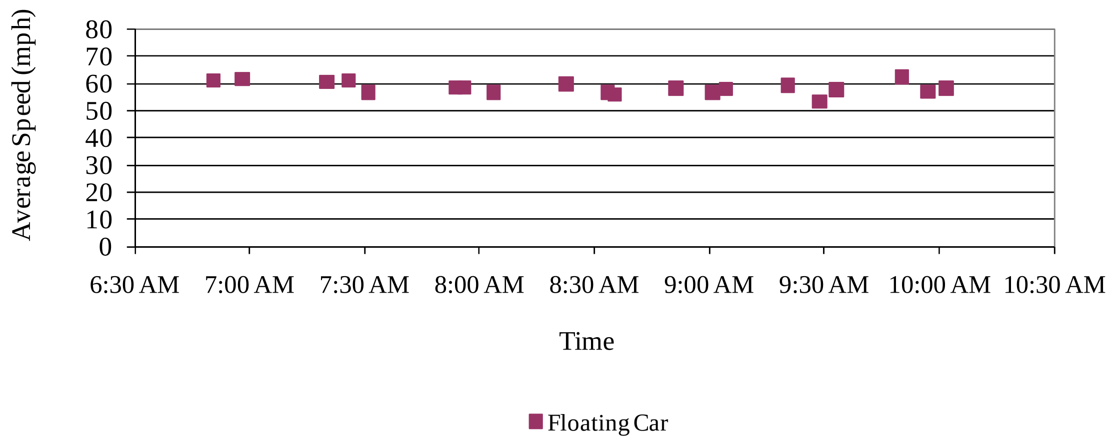


Figure C.37. Travel Time Segment ID 18, 2.9 miles (4.7 km), 7/28/2009, AM

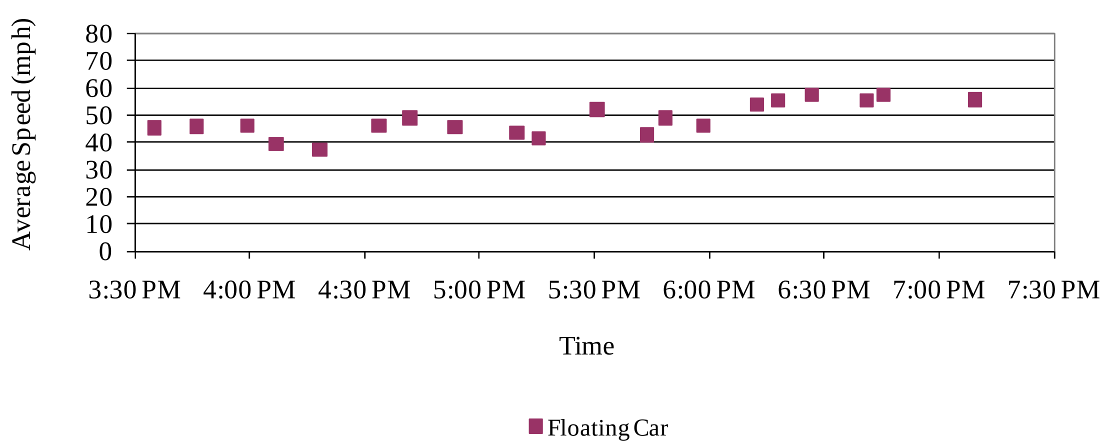


Figure C.38. Travel Time Segment ID 18, 2.9 miles (4.7 km), 7/28/2009, PM

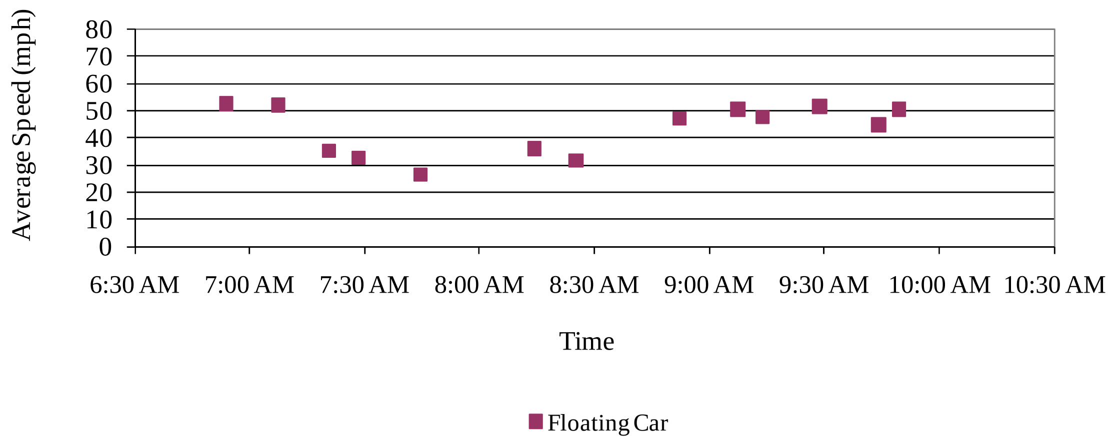


Figure C.39. Travel Time Segment ID 18, 2.9 miles (4.7 km), 7/30/2009, AM

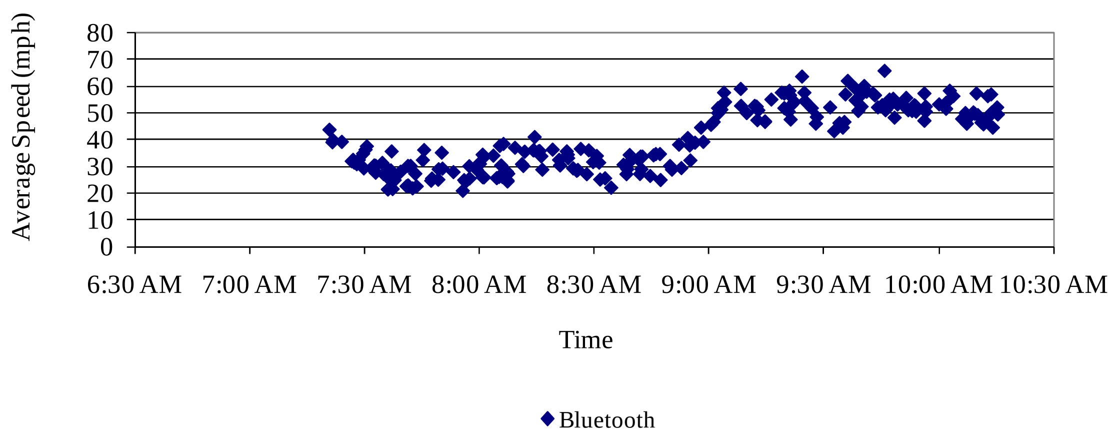


Figure C.40. Travel Time Segment ID 18, 2.9 miles (4.7 km), 9/3/2009

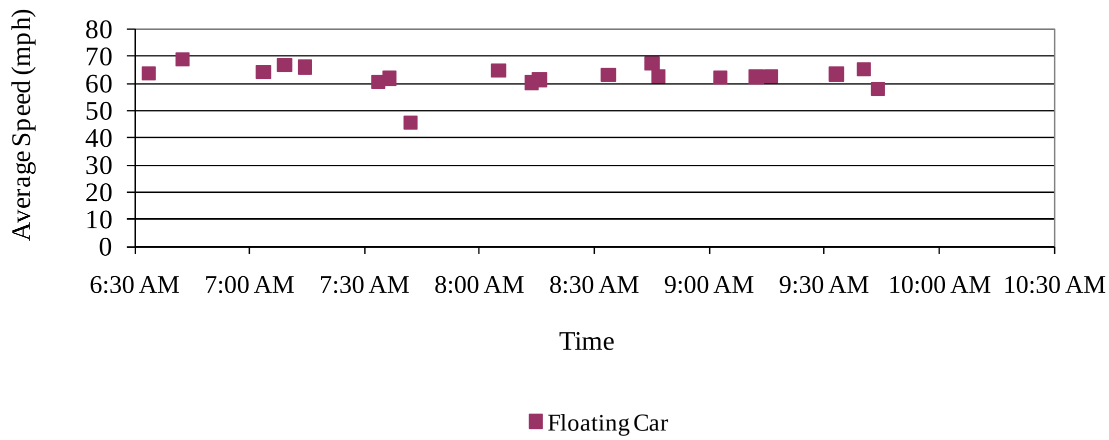


Figure C.41. Travel Time Segment ID 19, 3.7 miles (6.0 km), 7/28/2009, AM

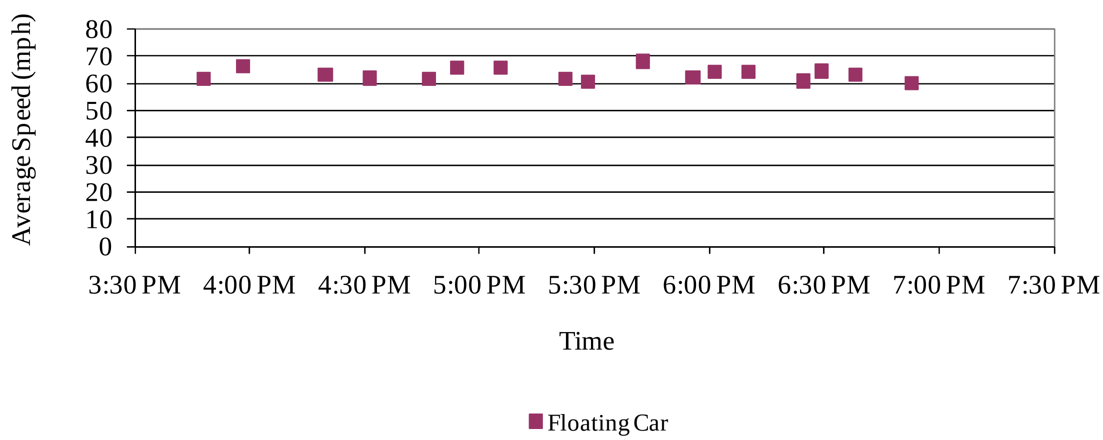


Figure C.42 Travel Time Segment ID 19, 3.7 miles (6.0 km), 7/28/2009, PM

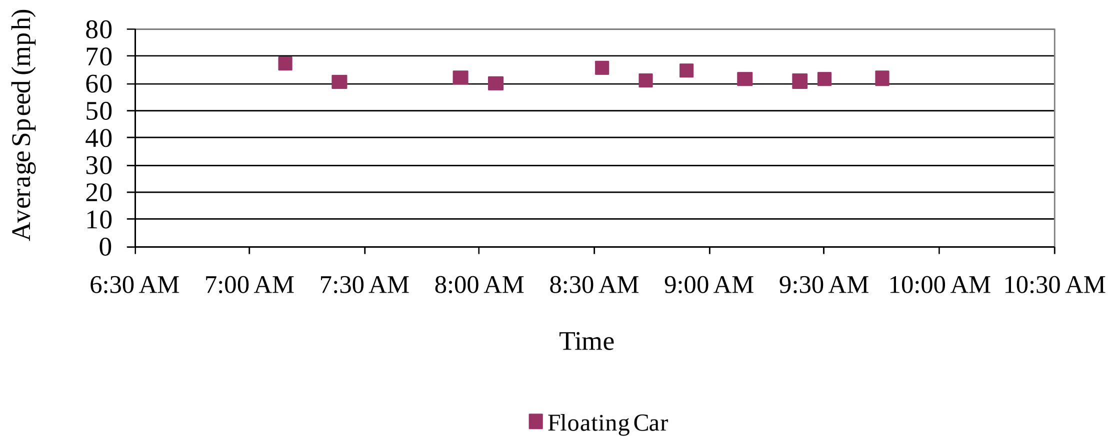


Figure C.43. Travel Time Segment ID 19, 3.7 miles (6.0 km), 7/30/2009, AM

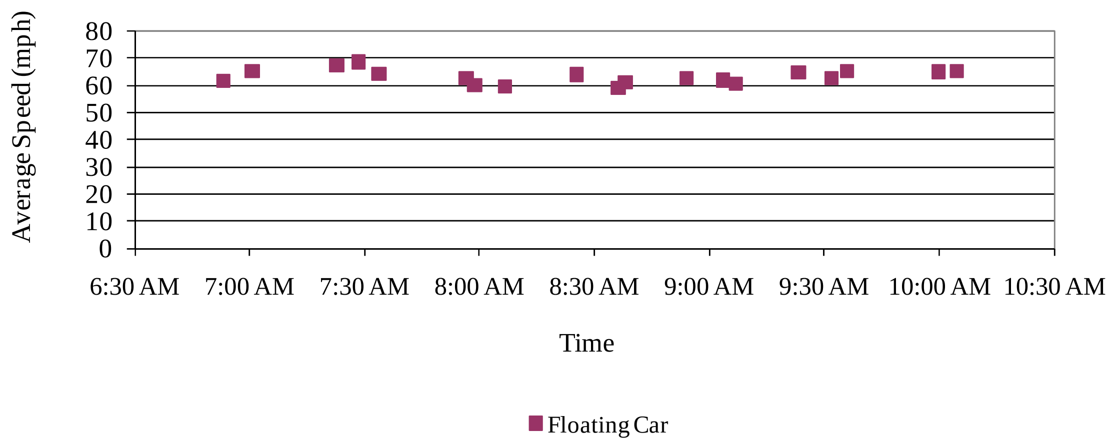


Figure C.44. Travel Time Segment ID 20, 3.7 miles (6.0 km), 7/28/2009, AM

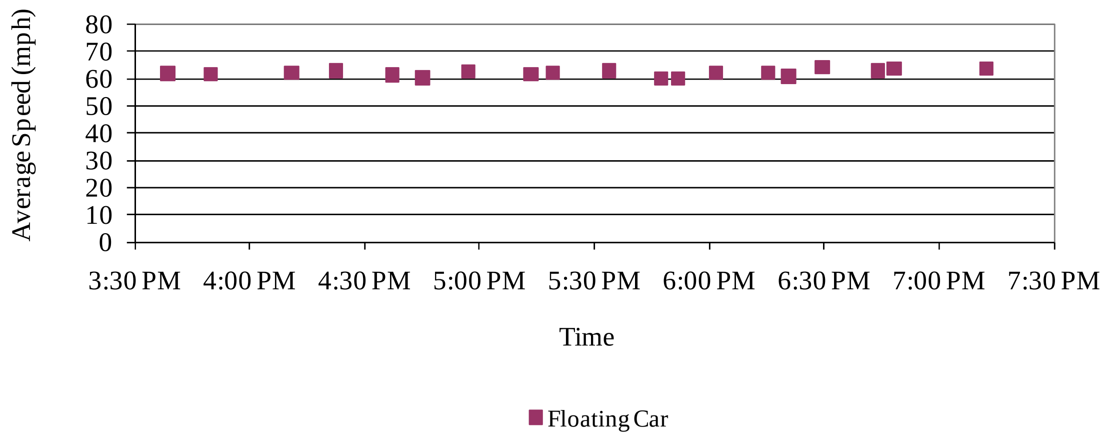


Figure C.45. Travel Time Segment ID 20, 3.7 miles (6.0 km), 7/28/2009, PM

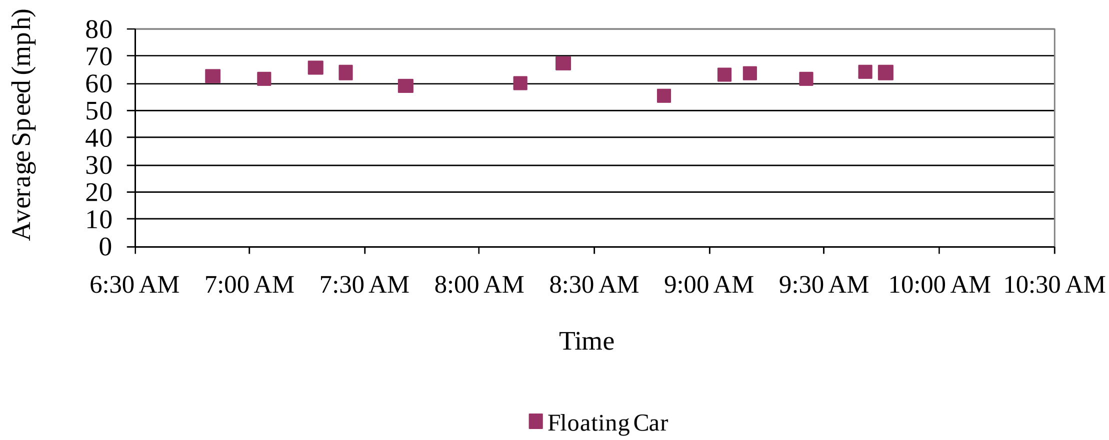


Figure C.46. Travel Time Segment ID 20, 3.7 miles (6.0 km), 7/30/2009, AM

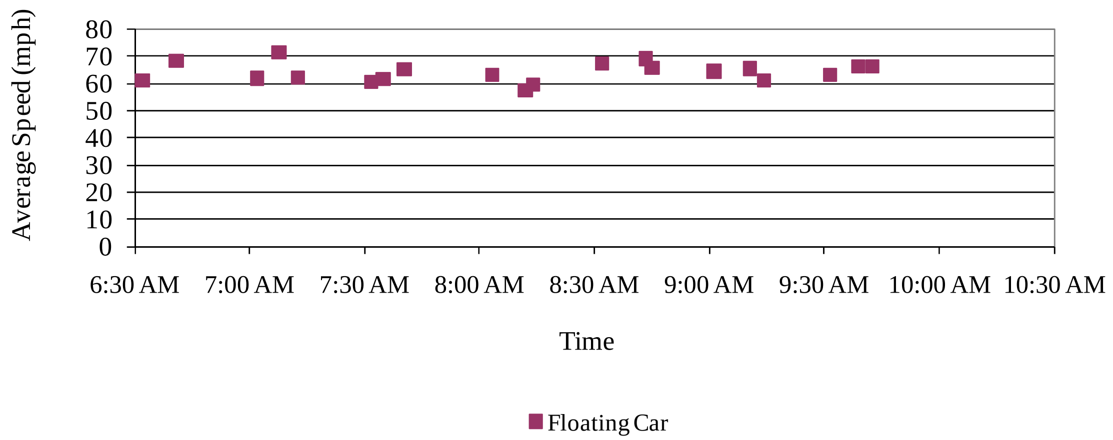


Figure C.47. Travel Time Segment ID 21, 1.8 miles (2.9 km), 7/28/2009, AM

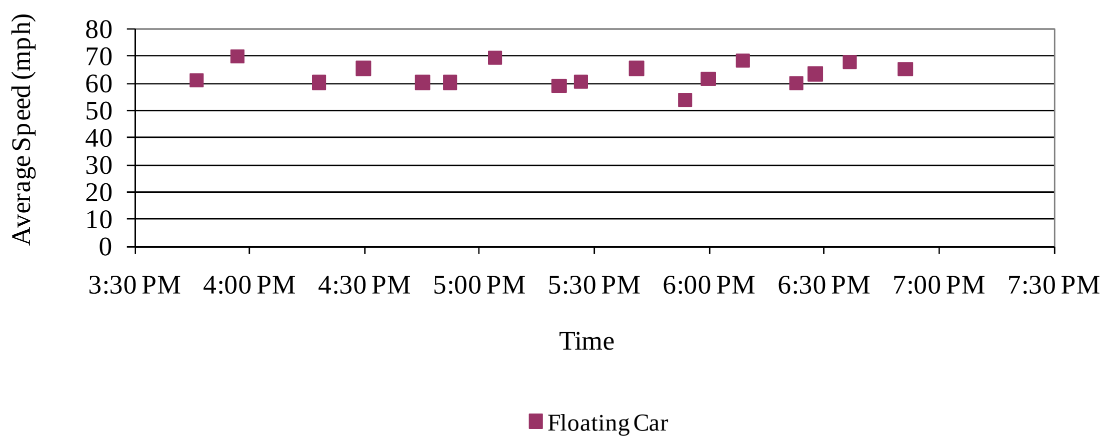


Figure C.48. Travel Time Segment ID 21, 1.8 miles (2.9 km), 7/28/2009, PM

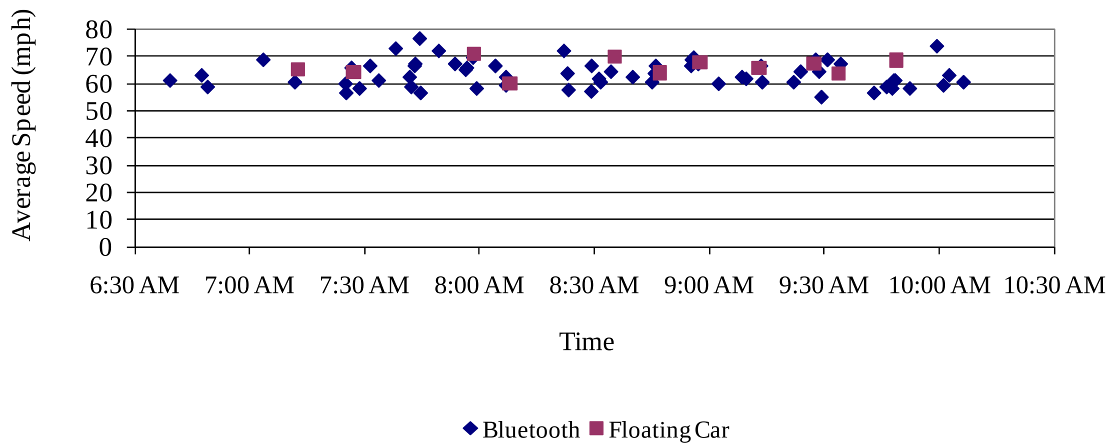


Figure C.49. Travel Time Segment ID 21, 1.8 miles (2.9 km), 7/30/2009, AM

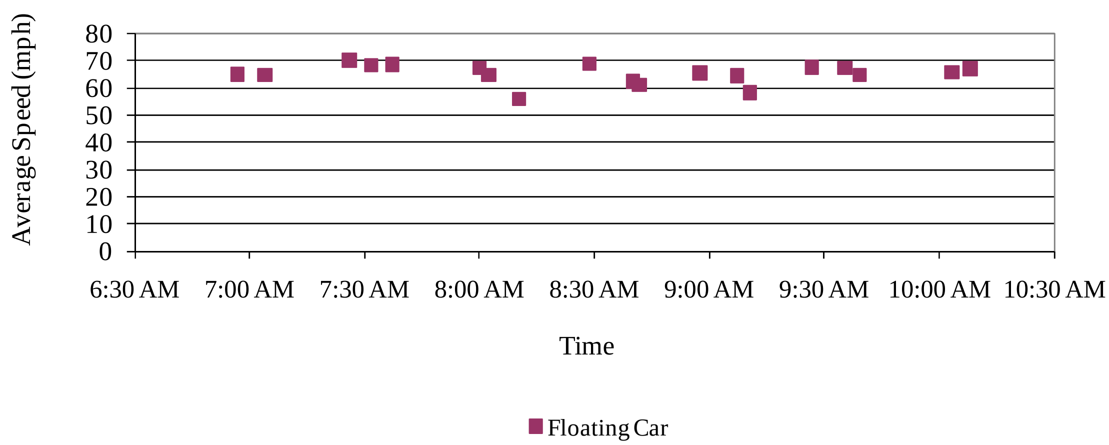


Figure C.50. Travel Time Segment ID 22, 1.8 miles (2.9 km), 7/28/2009, AM

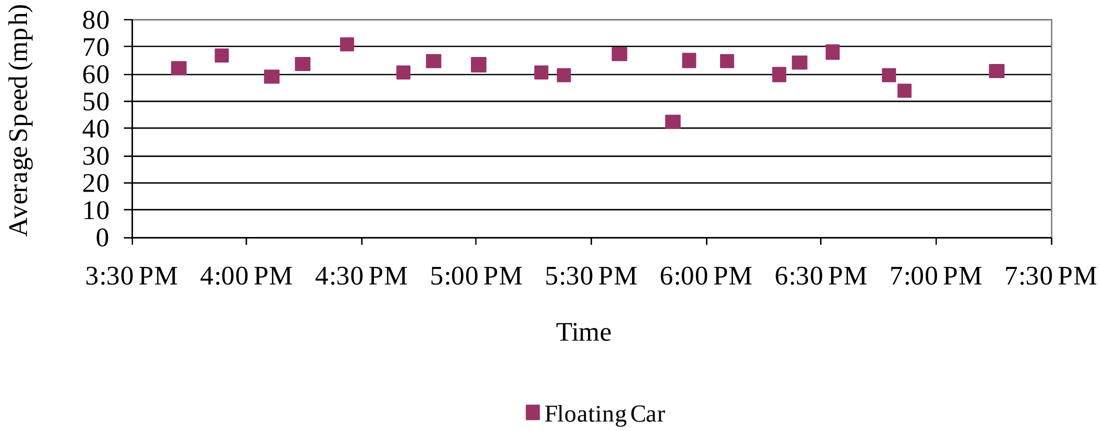


Figure C.51. Travel Time Segment ID 22, 1.8 miles (2.9 km), 7/28/2009, PM

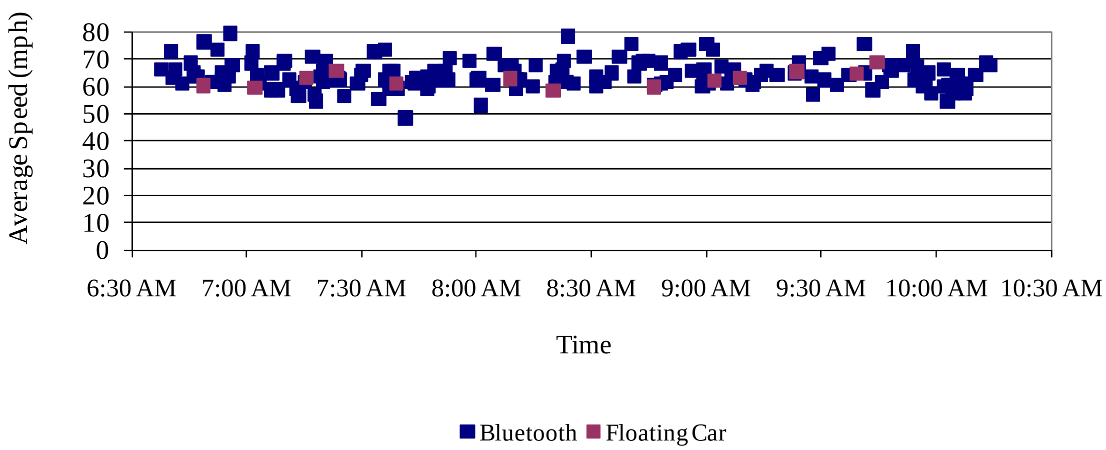


Figure C.52. Travel Time Segment ID 22, 1.8 miles (2.9 km), 7/30/2009, AM

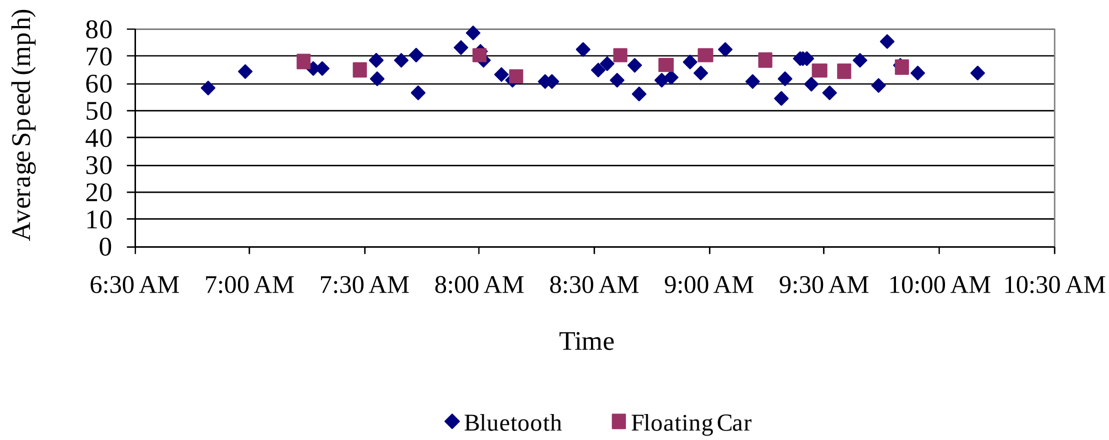


Figure C.53. Travel Time Segment ID 23, 2.1 miles (3.4 km), 7/30/2009, AM

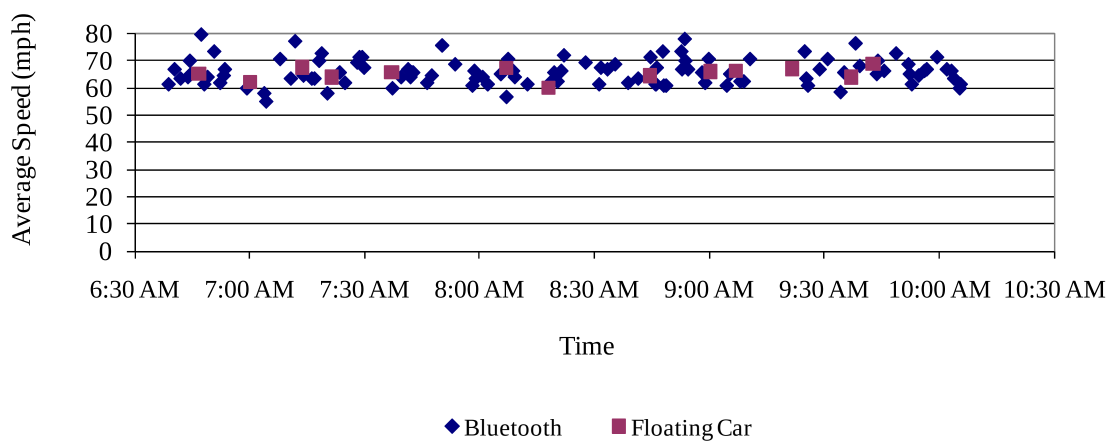


Figure C.54 Travel Time Segment ID 24, 2.1 miles (3.4 km), 7/30/2009, AM

I-675

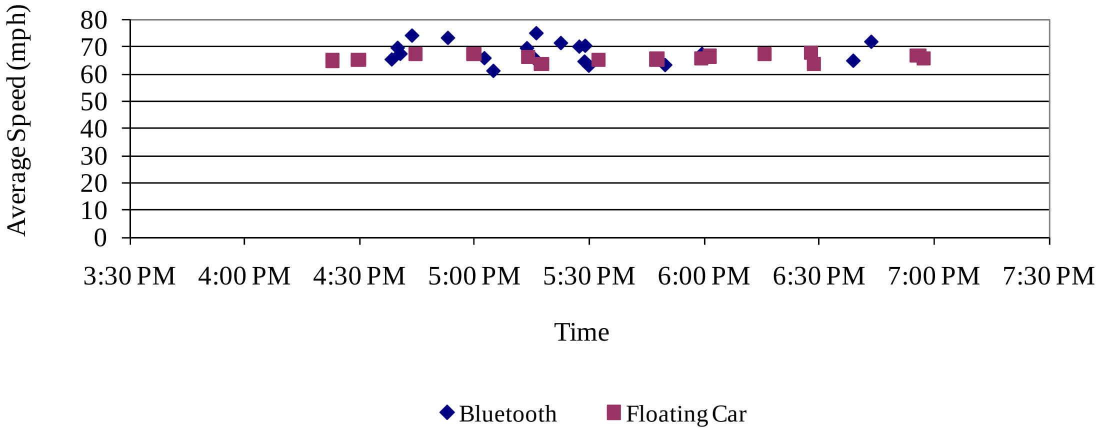


Figure C.55. Travel Time Segment ID 25, 12.7 miles (20.4 km), 8/17/2009, PM

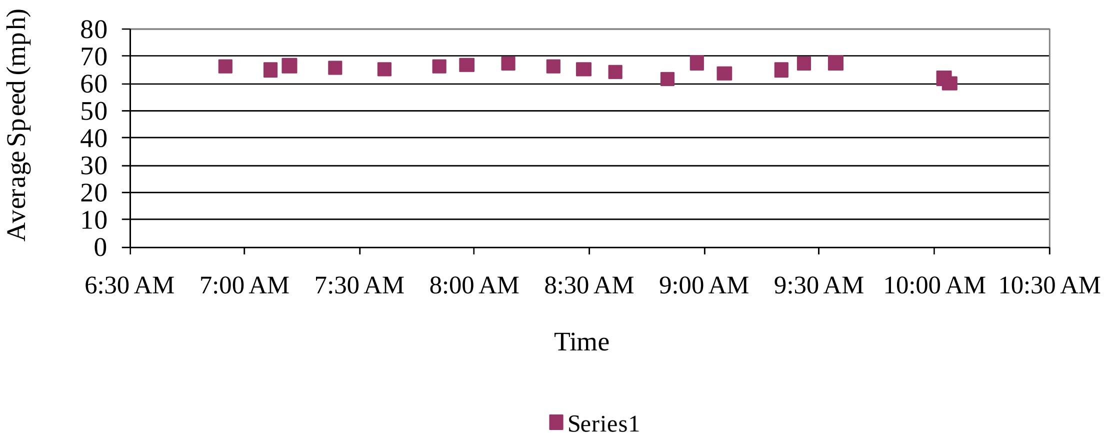


Figure C.56. Travel Time Segment ID 25, 12.7 miles (20.4 km), 8/20/2009, AM

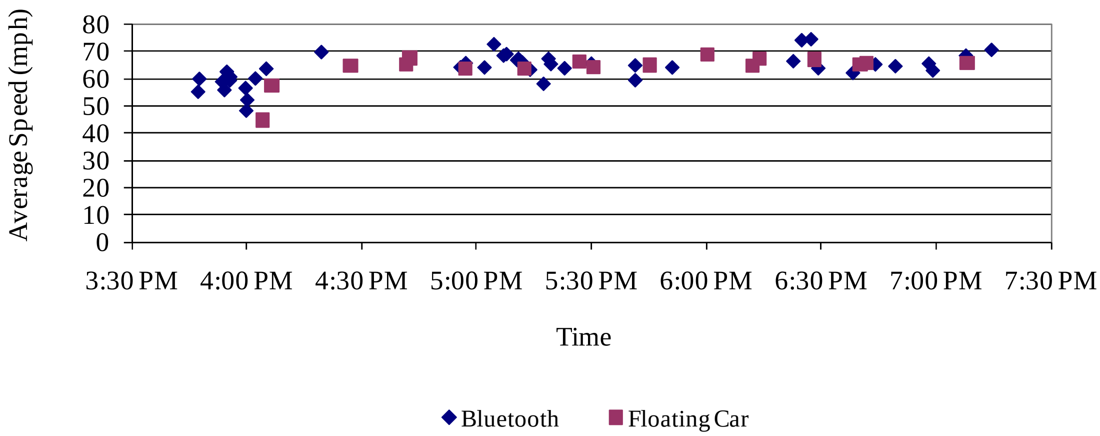


Figure C.57 Travel Time Segment ID 26, 12.7 miles (20.4 km), 8/17/2009, PM

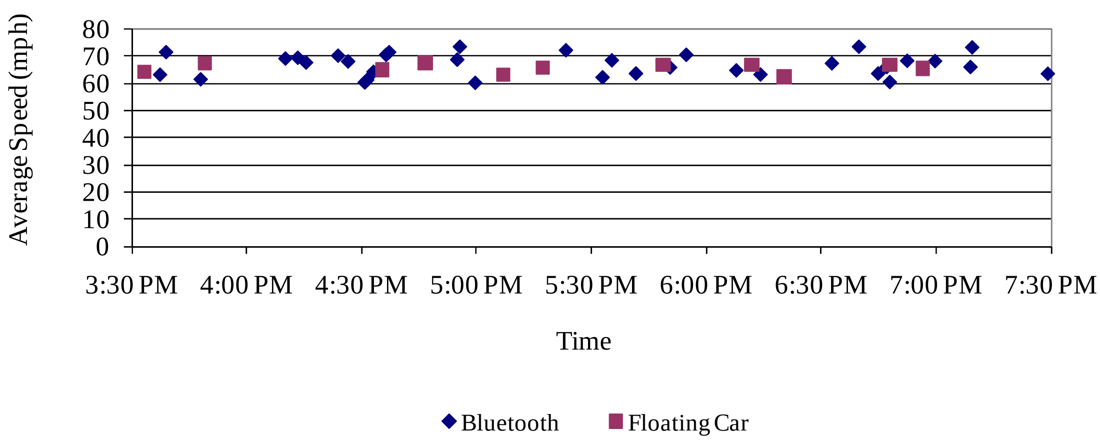


Figure C.58. Travel Time Segment ID 27, 13.2 miles (21.2 km), 8/19/2009, PM

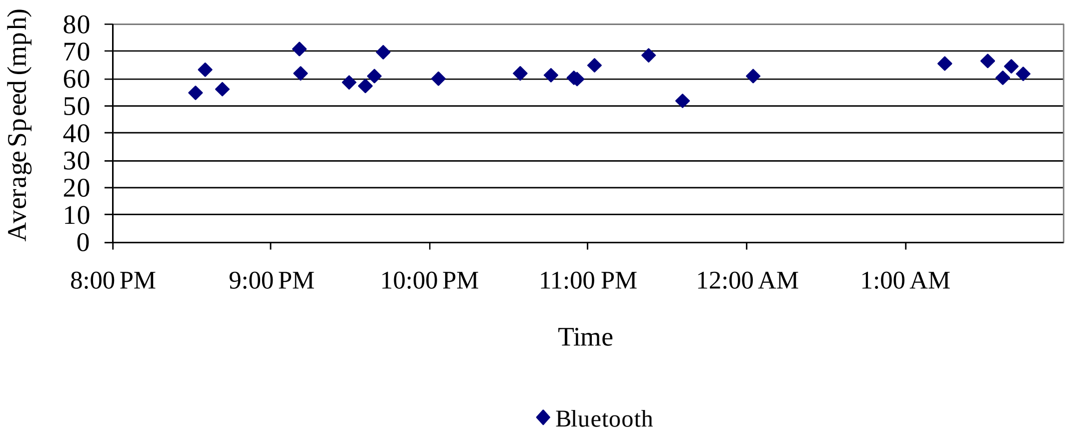


Figure C.59. Travel Time Segment ID 27, 13.2 miles (21.2 km), 8/19/2009, PM

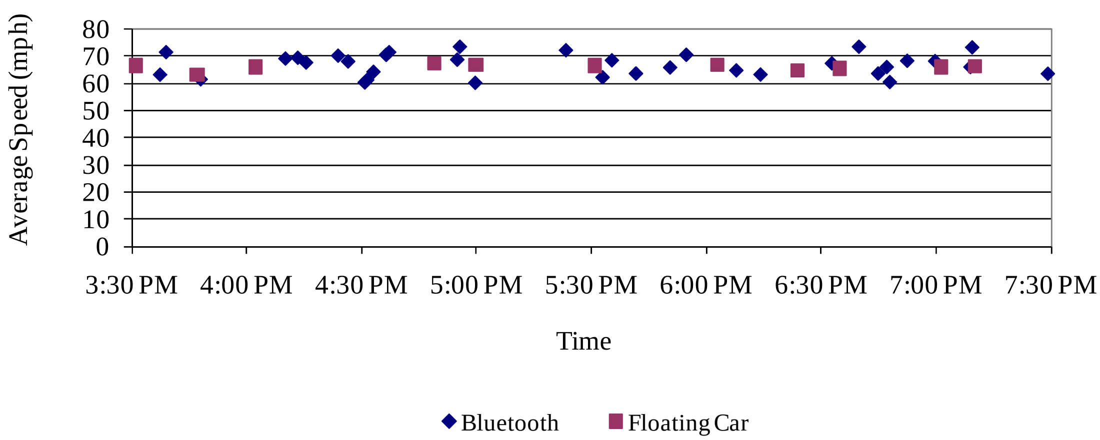


Figure C.60. Travel Time Segment ID 28, 13.2 miles (21.2 km), 8/19/2009, PM

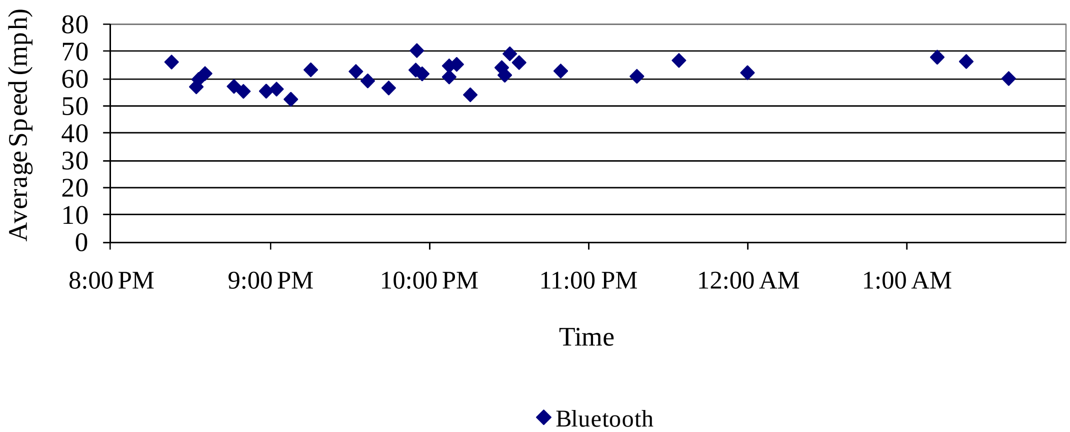


Figure C.61. Travel Time Segment ID 28, 13.2 miles (21.2 km), 8/19/2009, PM

US-35

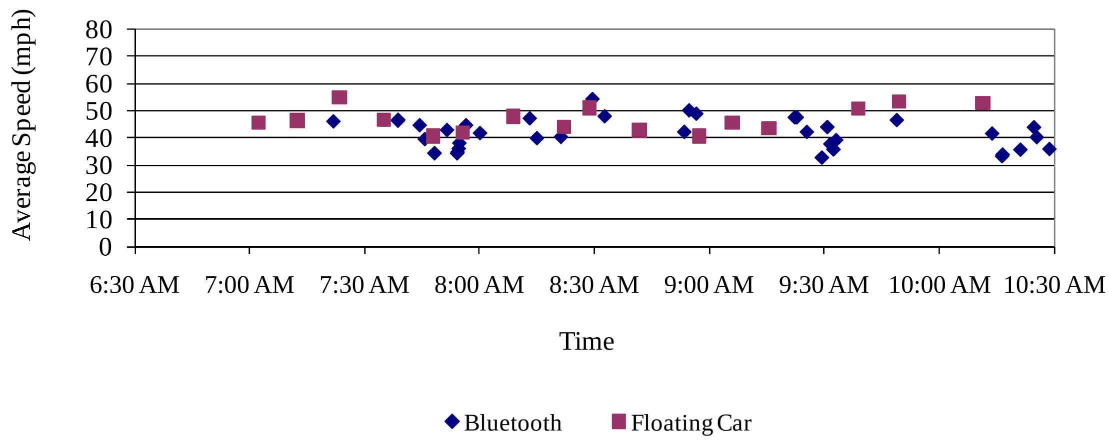


Figure C.62. Travel Time Segment ID 29, 5.1 miles (8.2 km), 8/18/2009, AM

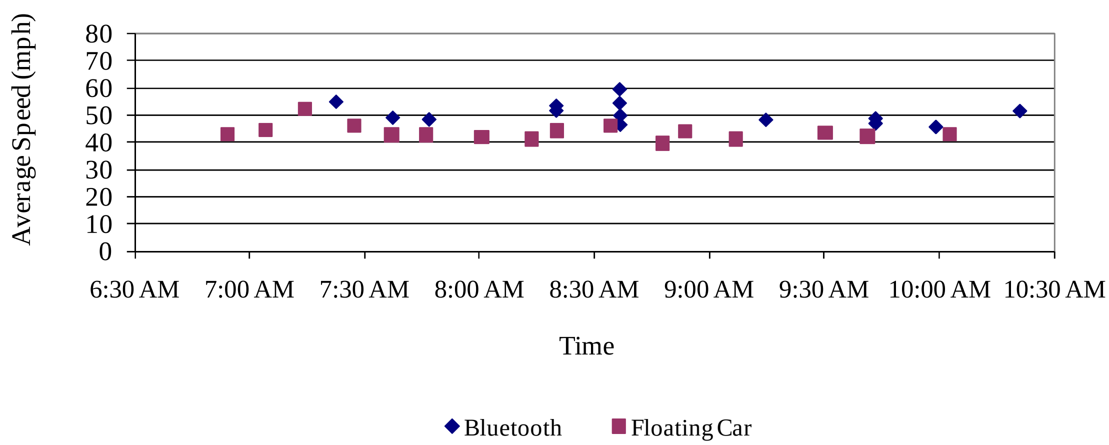


Figure C.63. Travel Time Segment ID 30, 5.1 miles (8.2 km), 8/18/2009, AM

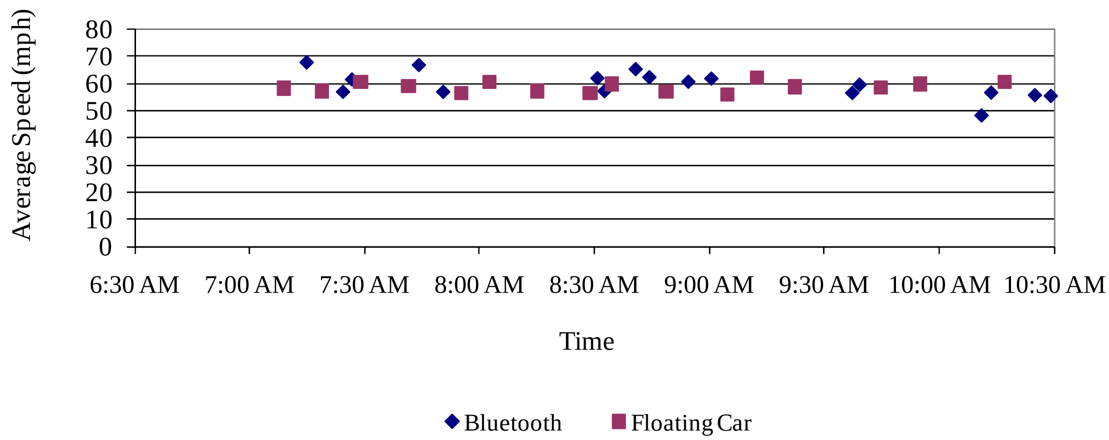


Figure C.64. Travel Time Segment ID 31, 6.4 miles (10.3 km), 8/18/2009, AM

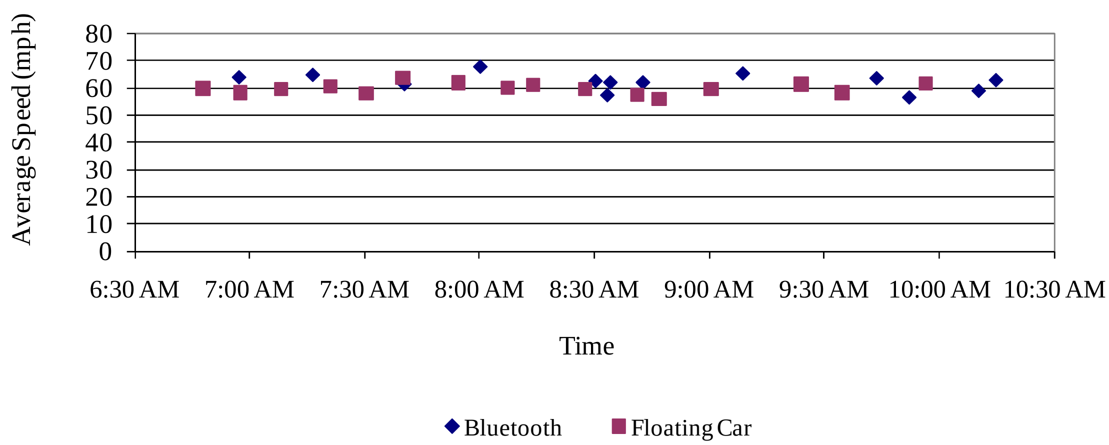


Figure C.65. Travel Time Segment ID 32, 6.4 miles (10.3 km), 8/18/2009, AM

SR-4

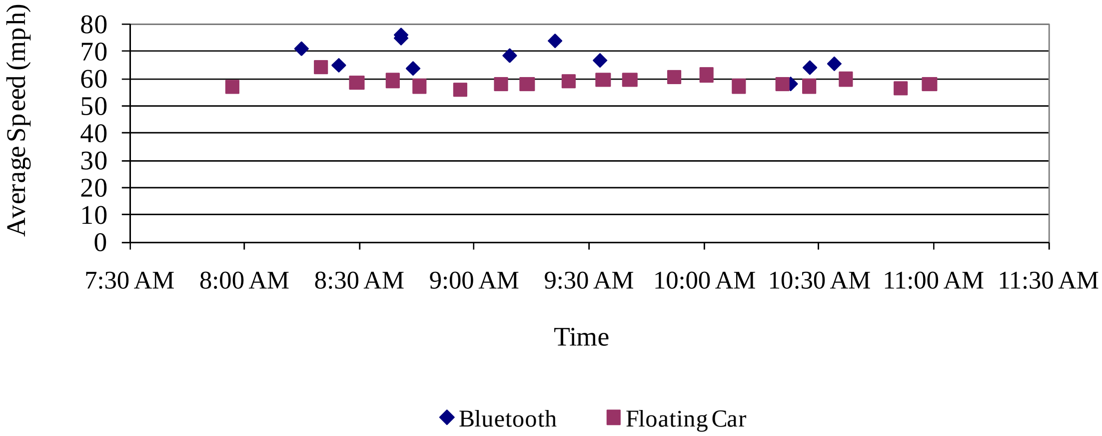


Figure C.66. Travel Time Segment ID 33, 10.7 miles (17.2 km), 8/19/2009, AM

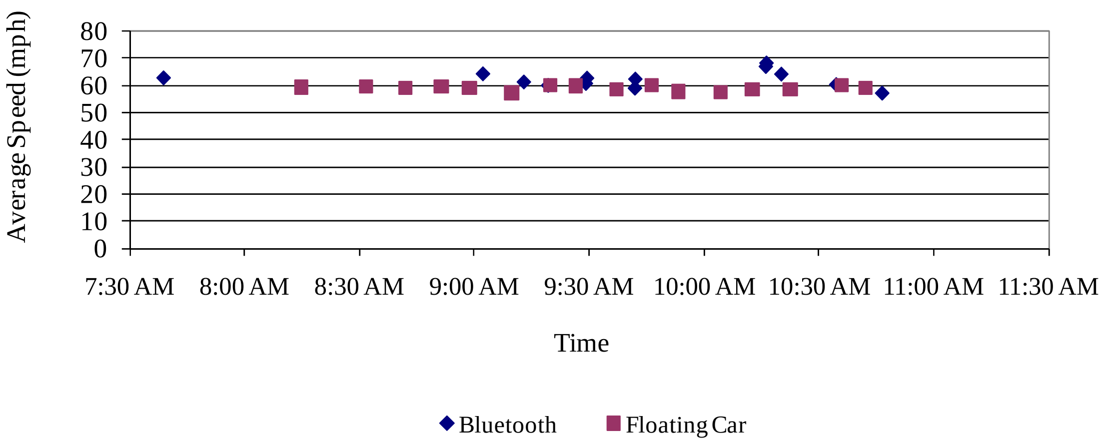


Figure C.67. Travel Time Segment ID 34, 10.7 miles (17.2 km), 8/19/2009, AM

SR-49

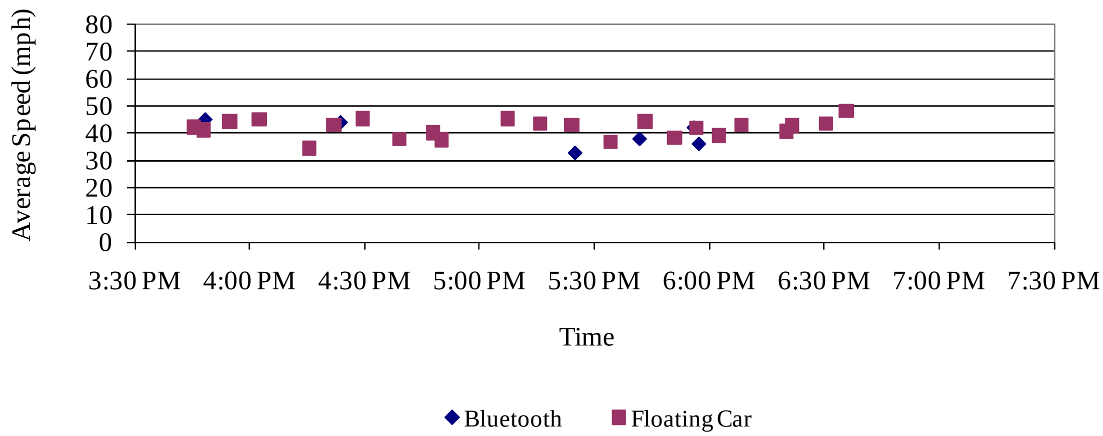


Figure C.68. Travel Time Segment ID 35, 9.0 miles (14.5 km), 8/18/2009, PM

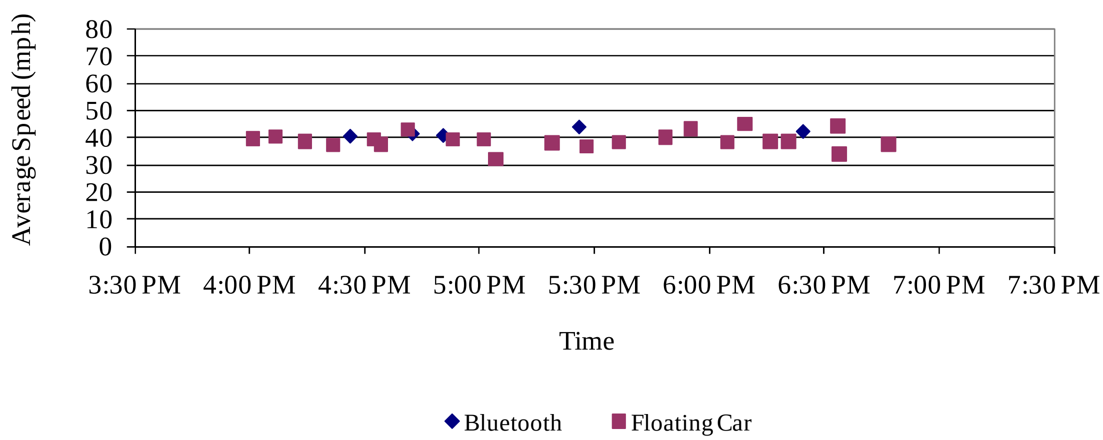


Figure C.69. Travel Time Segment ID 36, 9.0 miles (14.5 km), 8/18/2009, PM

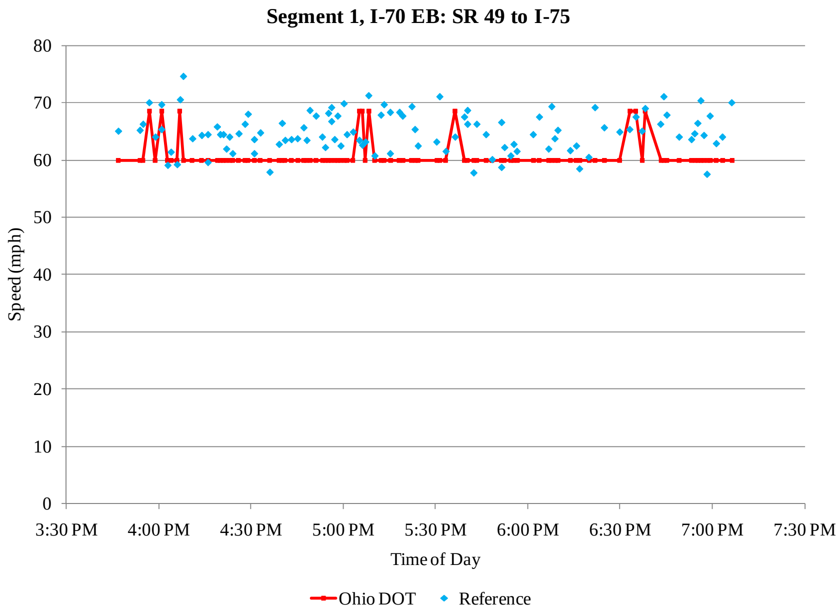
APPENDIX D

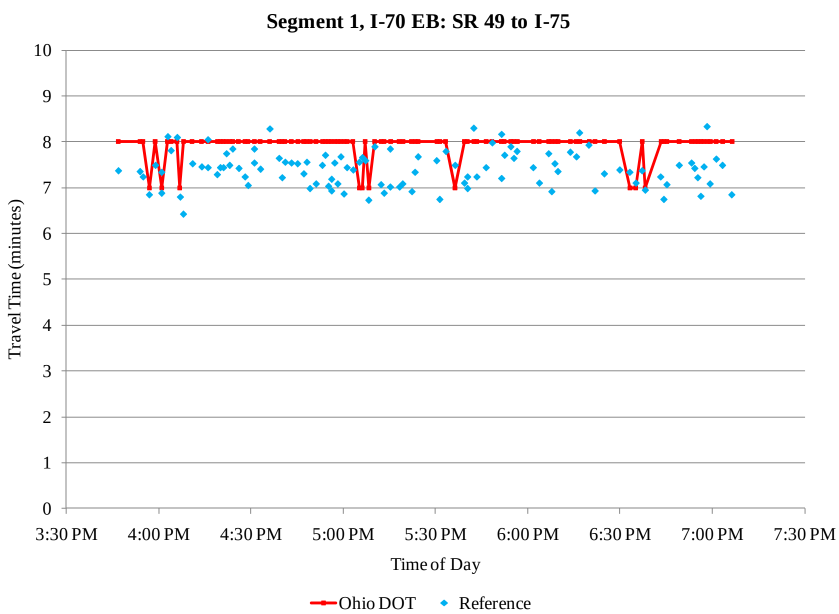
STATISTICAL EVALUATION OF ODOT TRAVEL TIMES AND REFERENCE DATA

Segment 1: I-70 EB: SR 49 to I-75

Length: 8.0 miles (12.9 km)

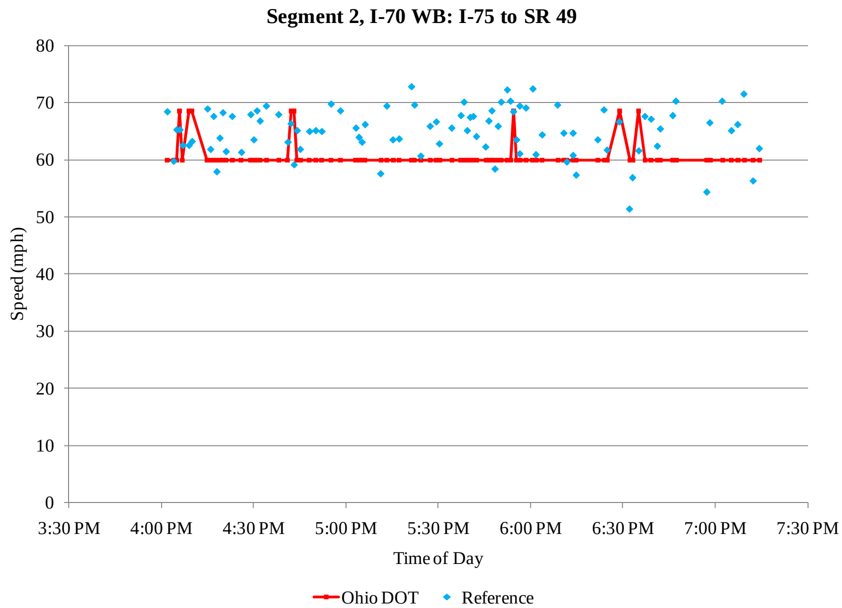
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.0	0.8	0.0	0.8	8
60+ mph	0.6	5.1	0.6	-4.1	103

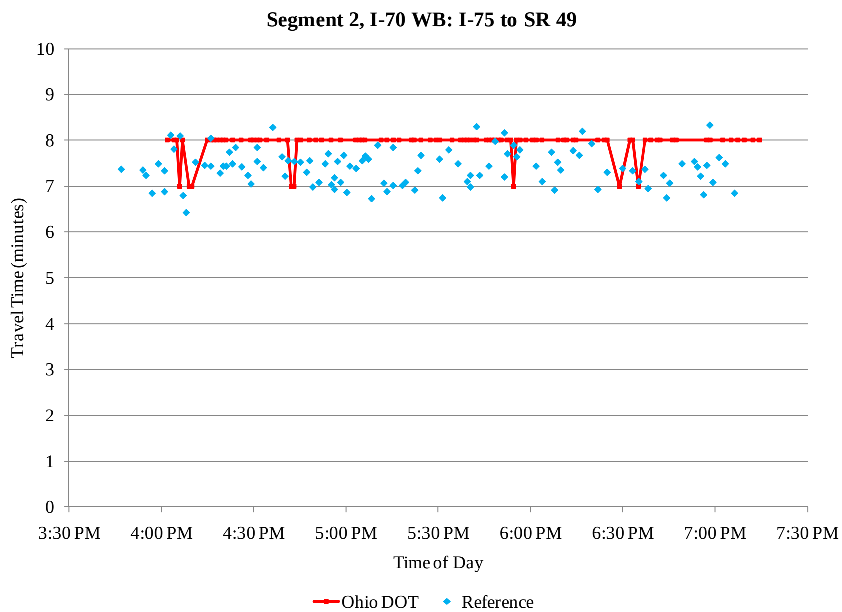




Segment 2: I-70 WB: I-75 to SR 49
Length: 8.0 miles (12.9 km)

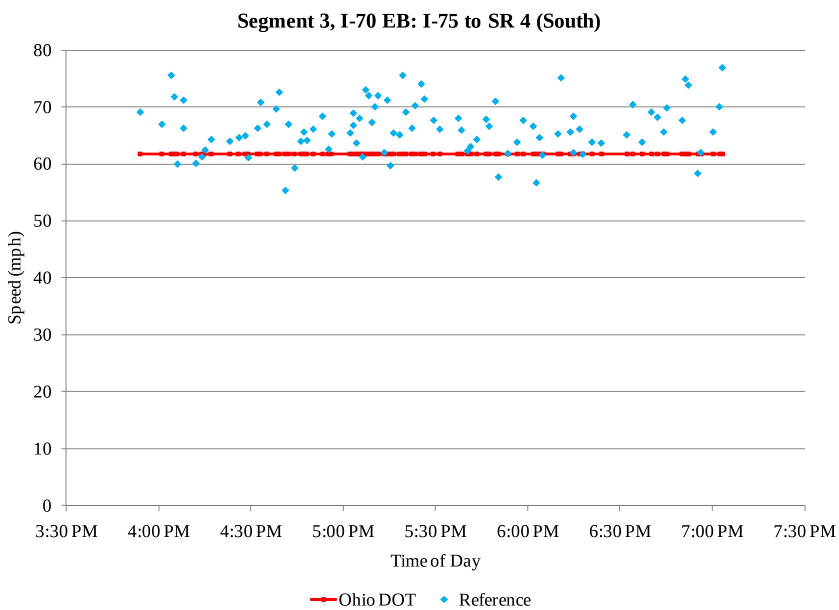
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.4	3.3	-0.4	3.3	11
60+ mph	0.7	5.6	0.6	-4.4	85

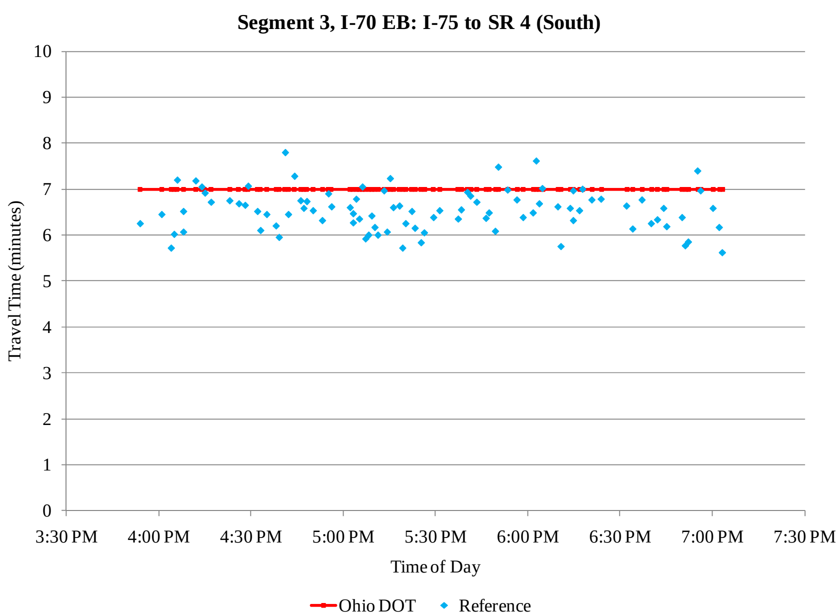




Segment 3: I-70 EB: I-75 to SR 4 (South)
Length: 7.2 miles (11.6 km)

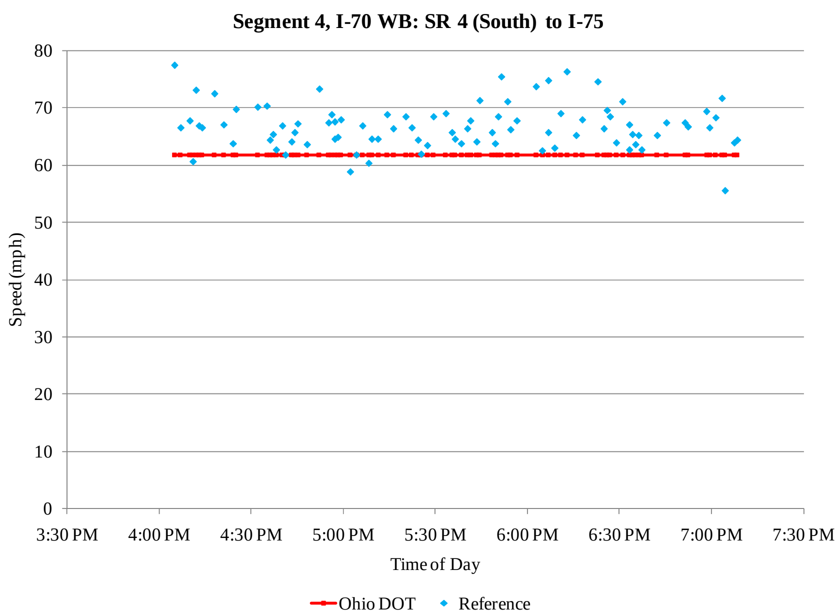
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.3	2.6	-0.3	2.6	6
60+ mph	0.5	5.0	0.5	-5.0	88

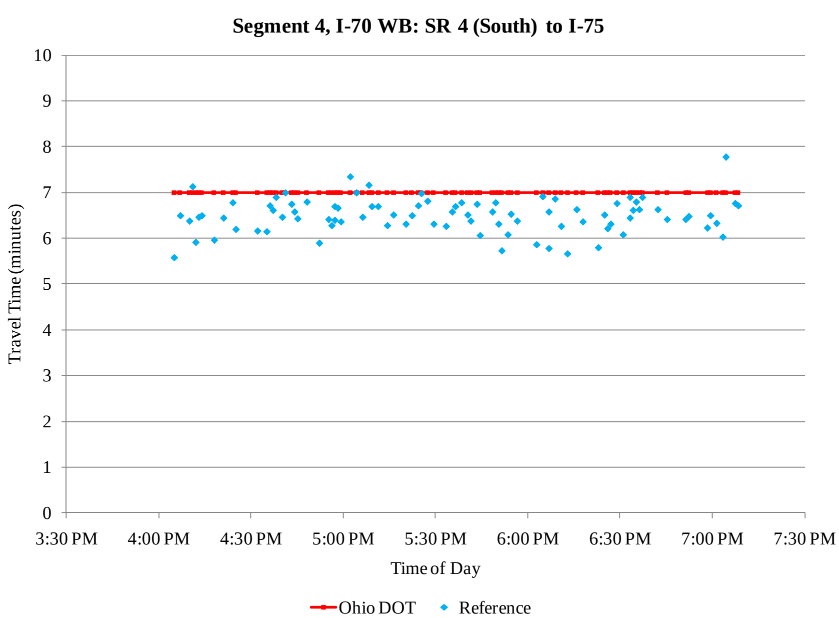




Segment 4: I-70 WB: SR 4 (South) to I-75
Length: 7.2 miles (11.6 km)

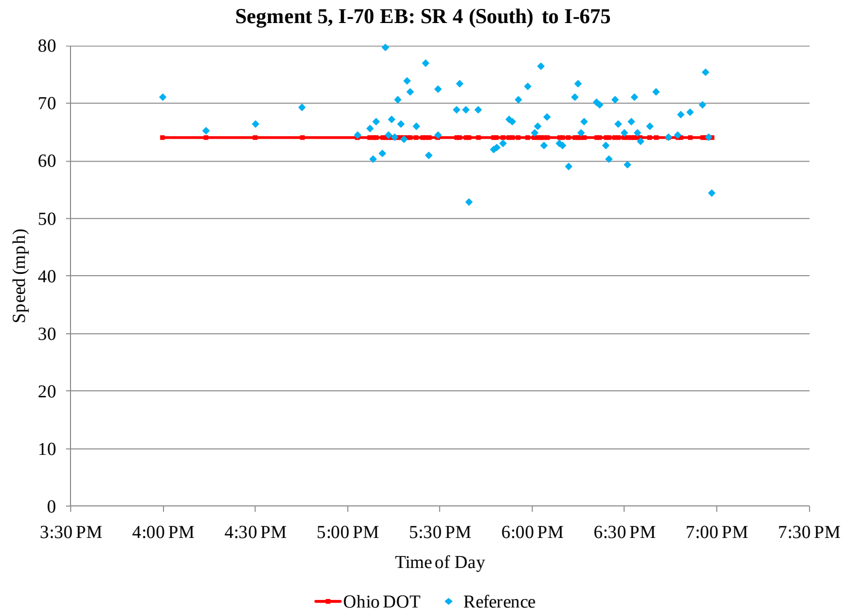
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.5	3.9	-0.5	3.9	2
60+ mph	0.5	5.0	0.5	-5.0	88

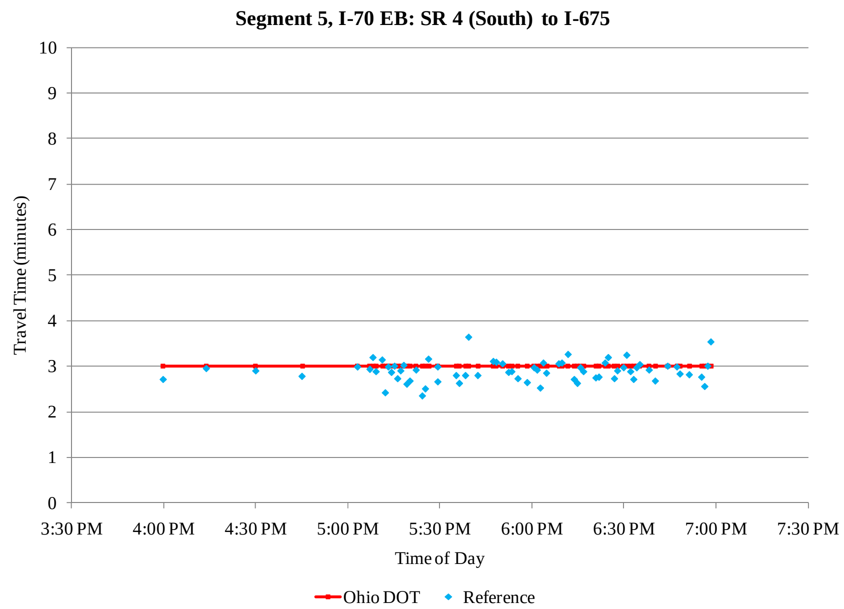




Segment 5: I-70 EB: SR 4 (South) to I-675
Length: 3.2 miles (5.1 km)

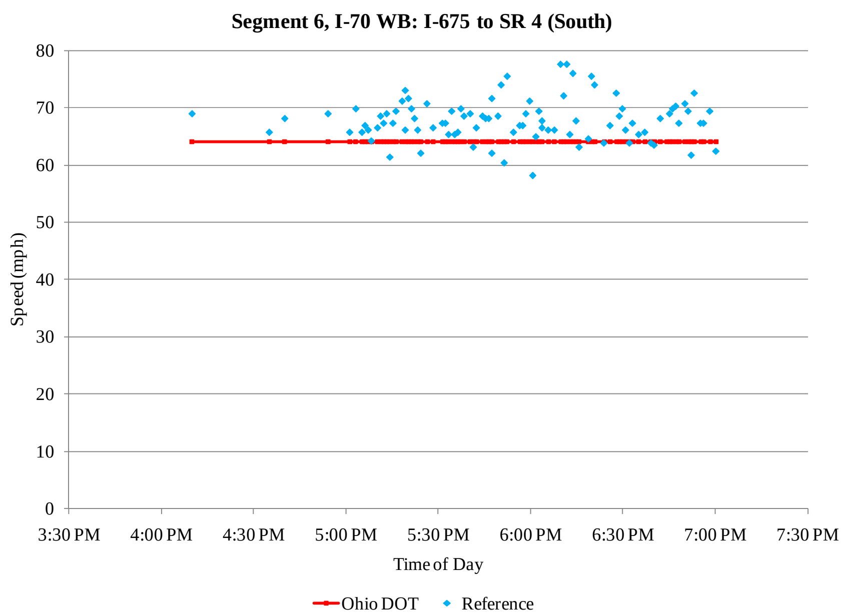
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.5	9.7	-0.5	9.7	4
60+ mph	0.0	3.2	0.0	0.6	66

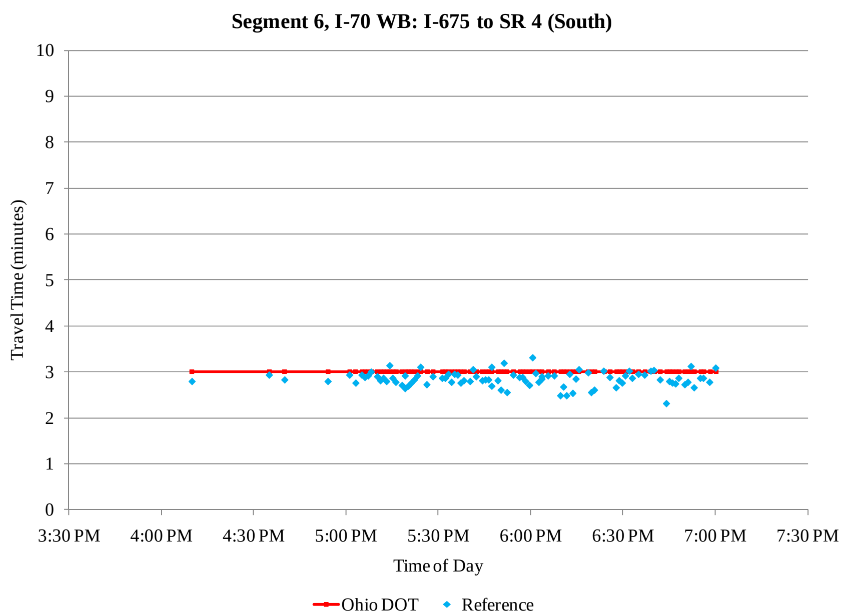




Segment 6: I-70 WB: I-675 to SR 4 (South)
Length: 3.2 miles (5.1 km)

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.0	2.0	0.0	2.0	1
60+ mph	0.0	2.9	0.0	1.0	94





Segment 7: I-70 EB: I-675 to SR 4 (Enon)

Length: 2.9 miles (4.7 km)

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	-	-	-	-	0
60+ mph	-	-	-	-	0

No Evaluation Data Available

No Evaluation Data Available

Segment 8: I-70 WB: SR 4 (Enon) to I-675

Length: 2.9 miles (4.7 km)

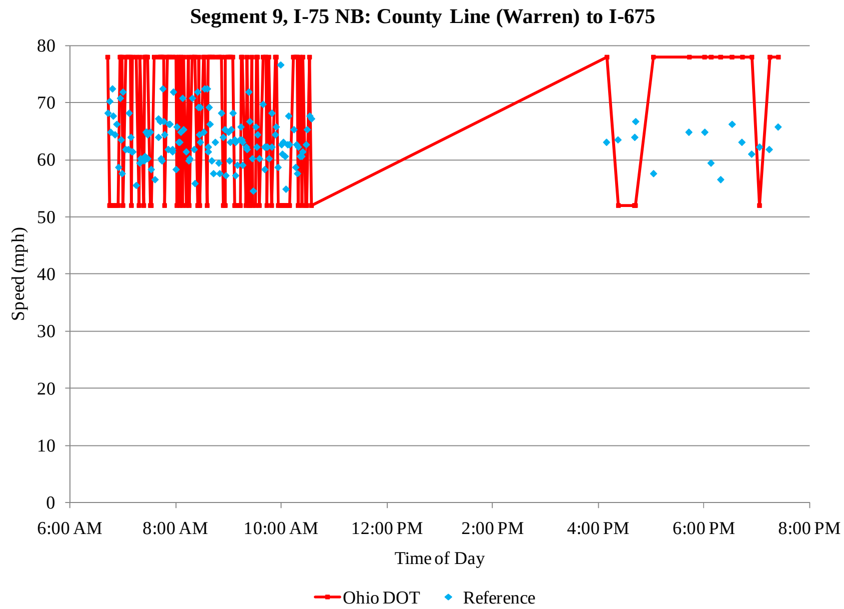
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	-	-	-	-	0
60+ mph	-	-	-	-	0

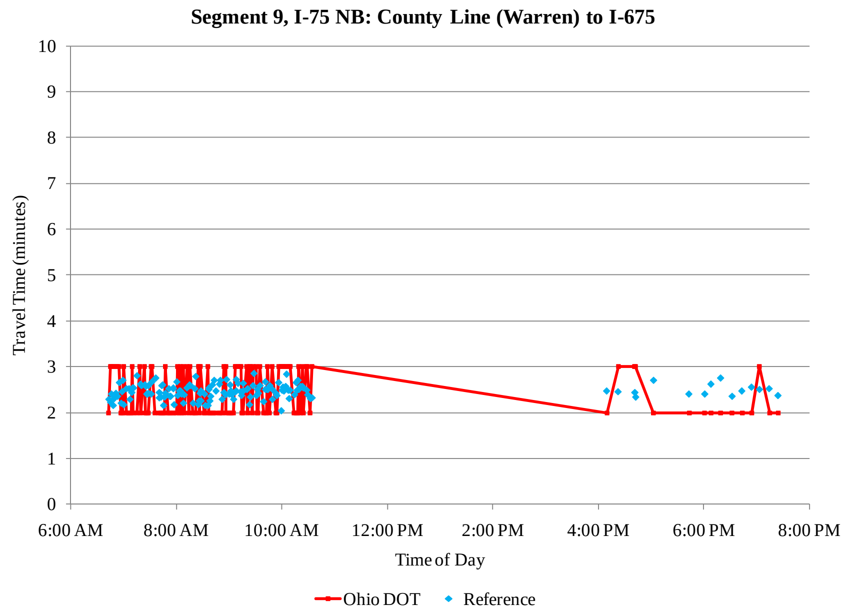
No Evaluation Data Available

No Evaluation Data Available

Segment 9: I-75 NB: County Line (Warren) to I-675
Length: 2.6 miles (4.2 km)

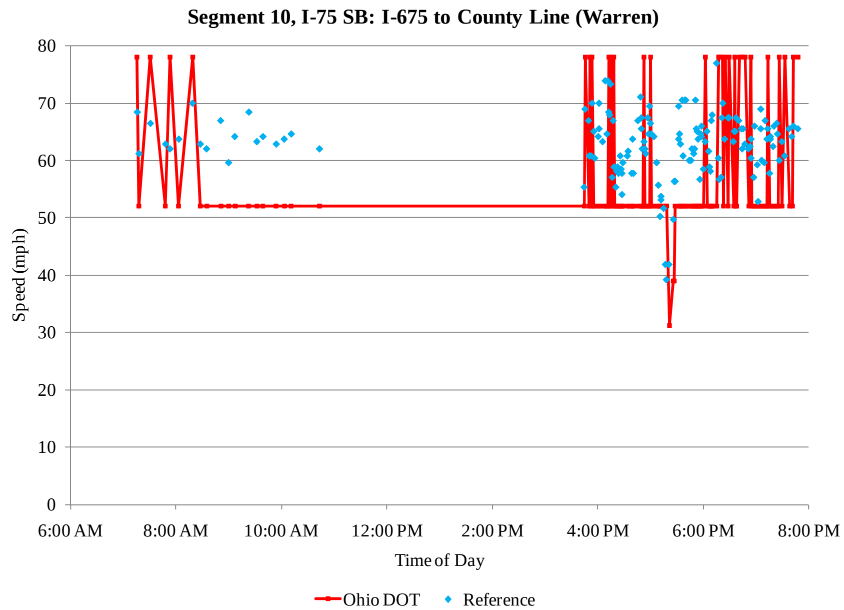
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.7	18.4	-0.7	18.4	29
60+ mph	0.5	13.6	0.1	-2.8	120

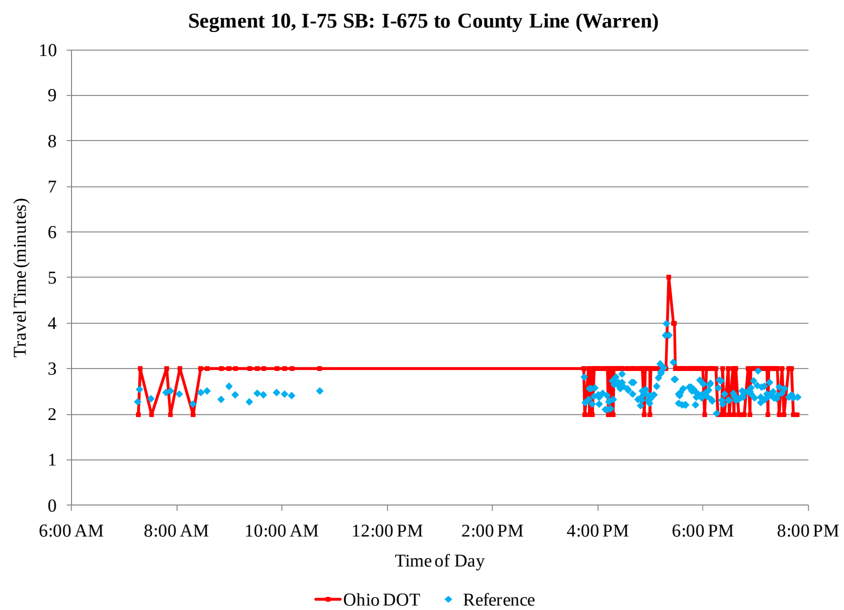




Segment 10: I-75 SB: I-675 to County Line (Warren)
Length: 2.6 miles (4.2 km)

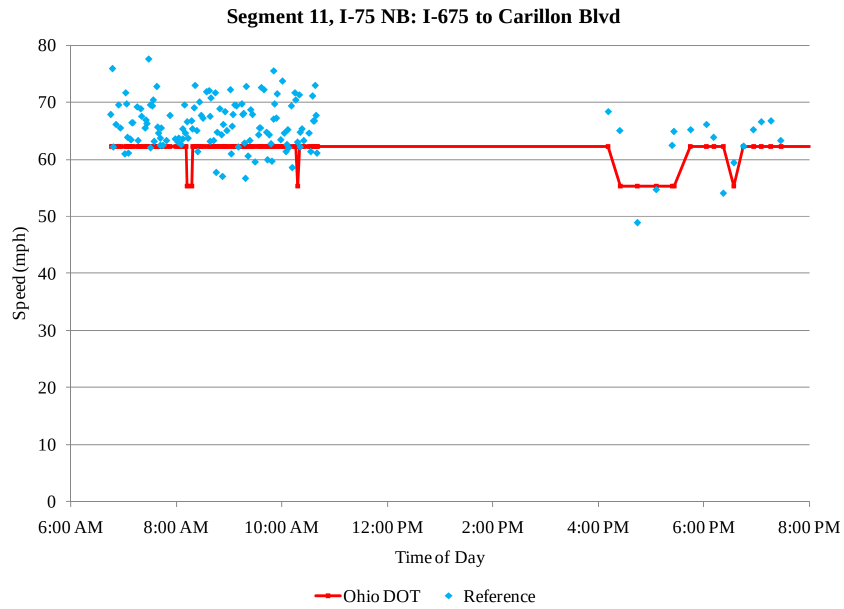
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	1.0	11.4	-0.3	6.6	3
45 to 60 mph	0.1	3.3	0.0	2.1	38
60+ mph	0.6	16.5	0.6	-13.5	115

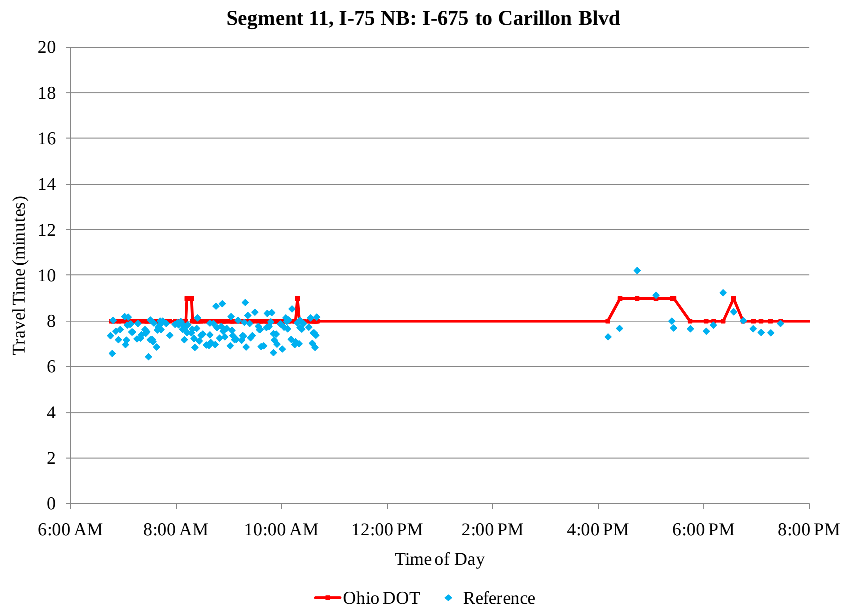




Segment 11: I-75 NB: I-675 to Carillon Blvd
Length: 8.3 miles (13.4 km)

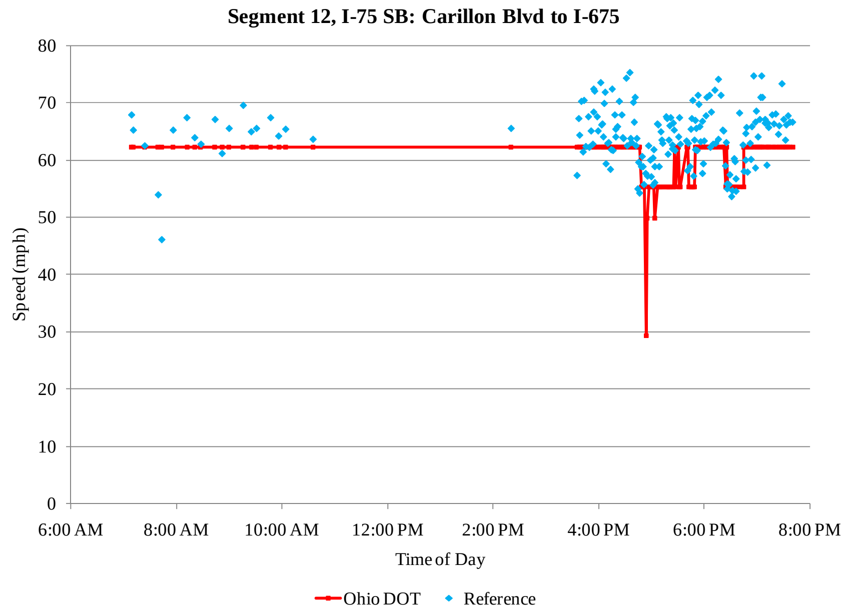
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.8	7.7	-0.6	7.2	12
60+ mph	0.5	4.3	0.5	-0.4	134

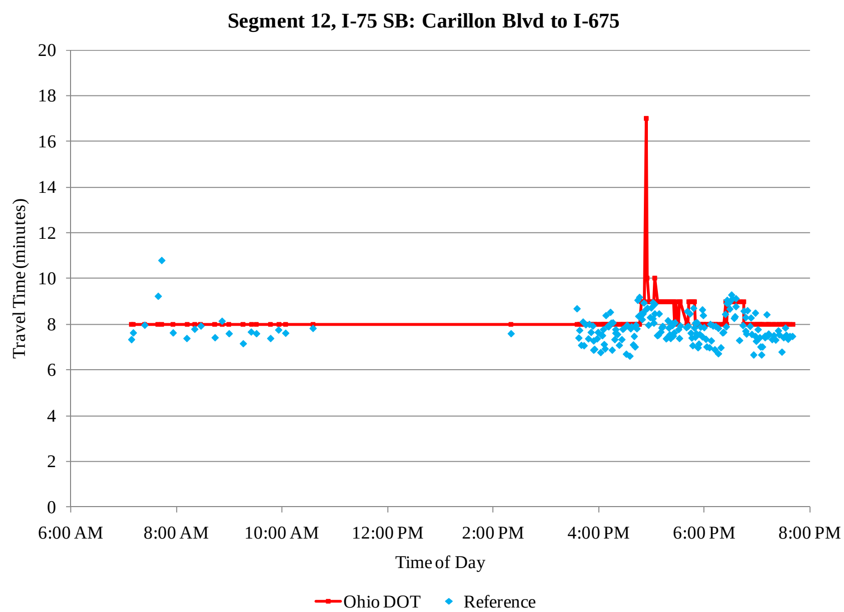




Segment 12: I-75 SB: Carillon Blvd to I-675
Length: 8.3 miles (13.4 km)

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.8	5.8	0.2	2.4	37
60+ mph	0.6	4.5	0.6	-1.9	149

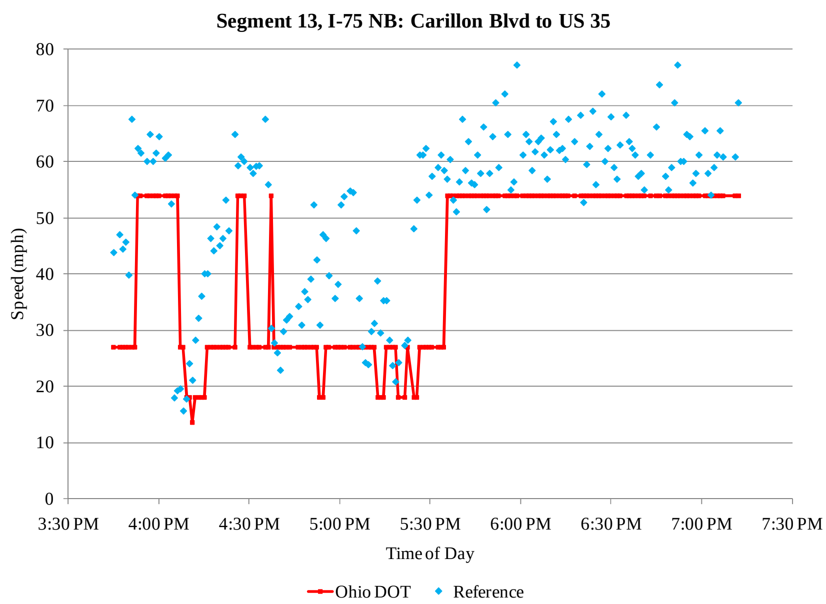


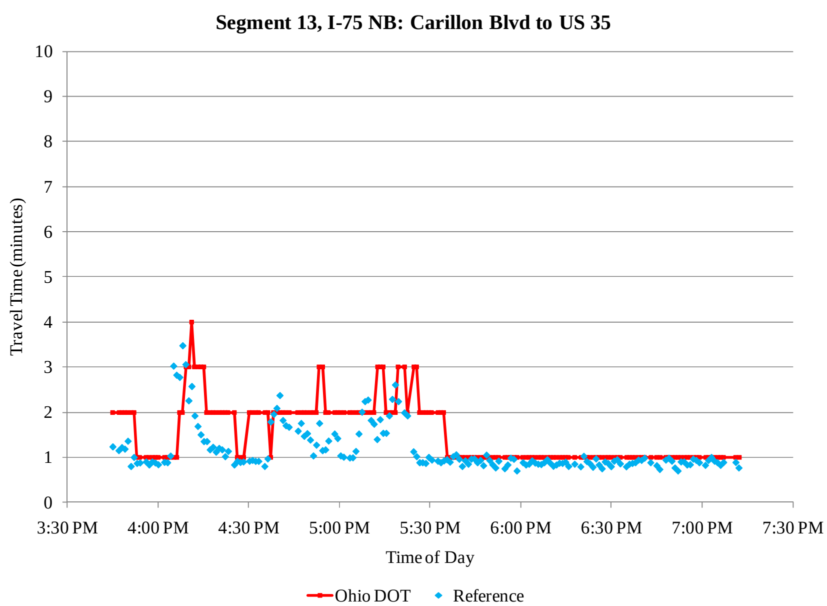


Segment 13: I-75 NB: Carillon Blvd to US 35
Length: 0.9 miles (1.4 km)

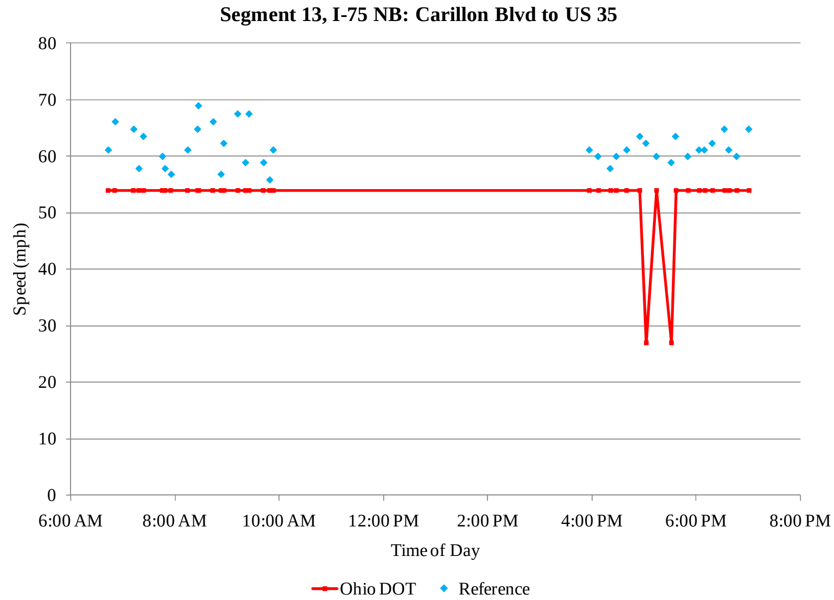
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	0.5	6.5	-0.1	3.2	30
30 to 45 mph	0.4	8.8	0.4	-7.7	50
45 to 60 mph	0.4	10.8	0.4	-10.8	75
60+ mph	0.1	2.1	0.1	-2.1	101

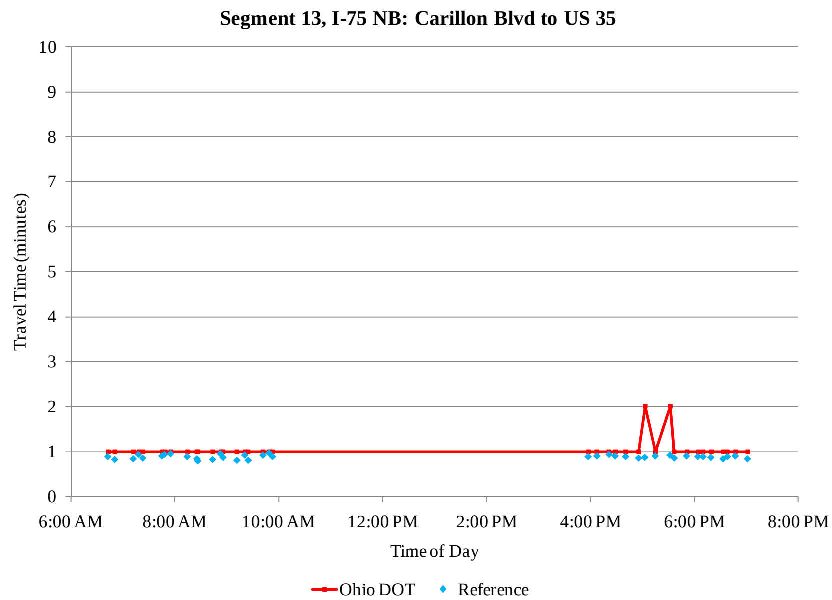
September 3 – Bluetooth only



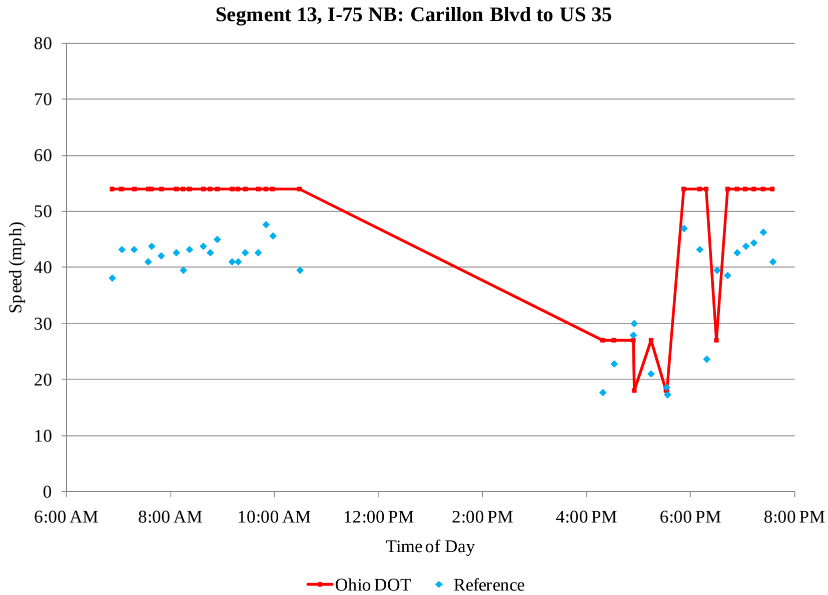


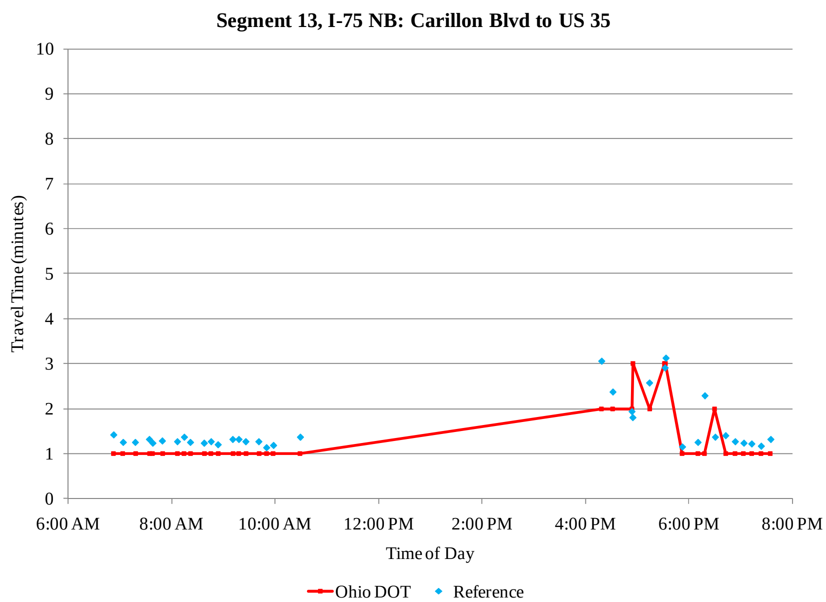
July 28 – Floating car only





July 29 – Floating car only

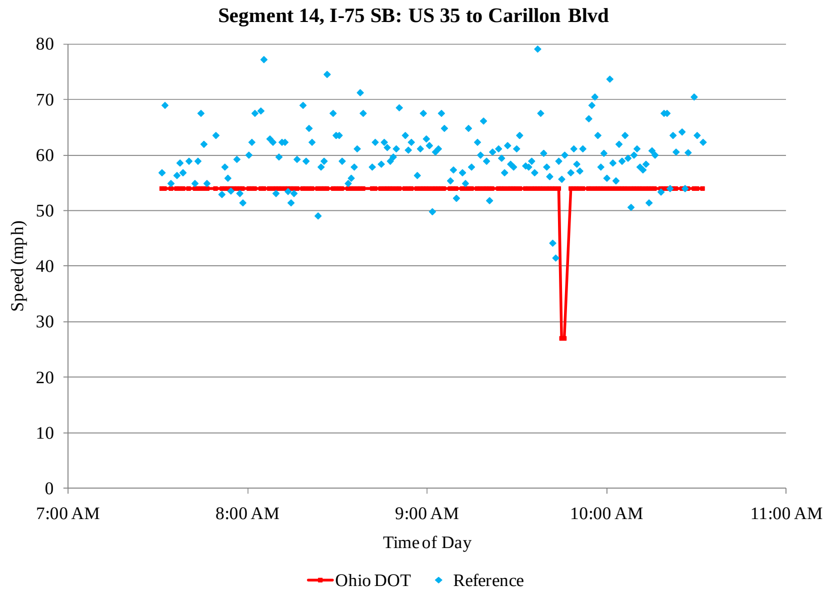


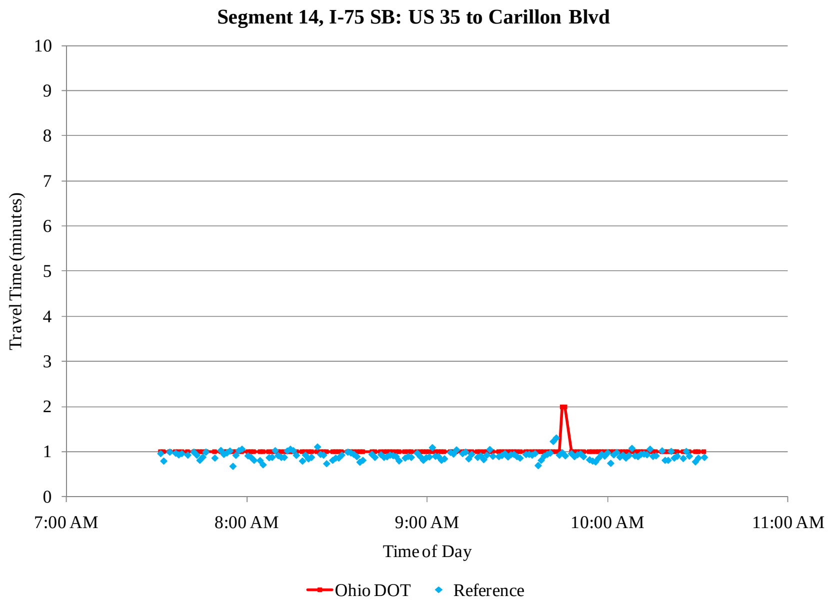


Segment 14: I-75 SB: US 35 to Carillon Blvd
Length: 0.9 miles (1.4 km)

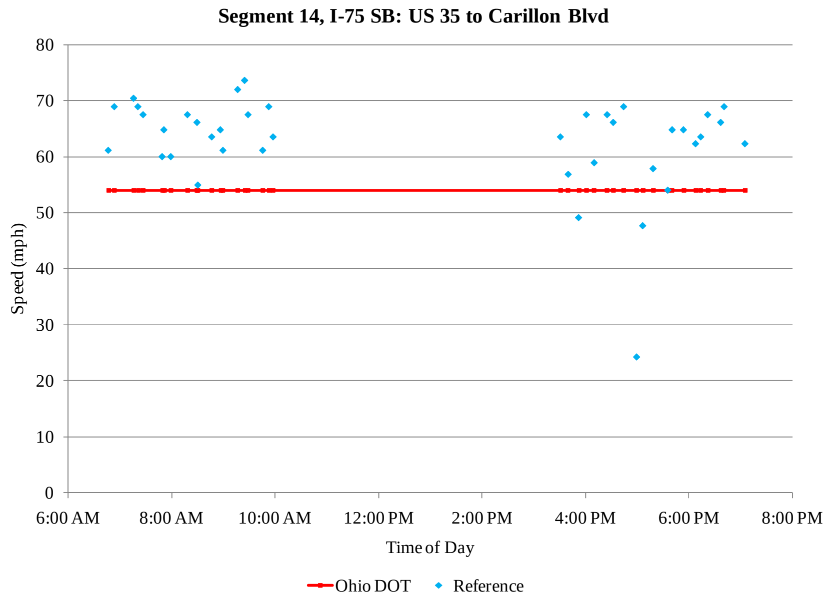
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	0.8	11.3	0.3	2.3	4
30 to 45 mph	0.1	3.7	0.0	1.2	22
45 to 60 mph	0.0	0.3	0.0	-0.3	94
60+ mph	0.0	0.3	0.0	-0.2	108

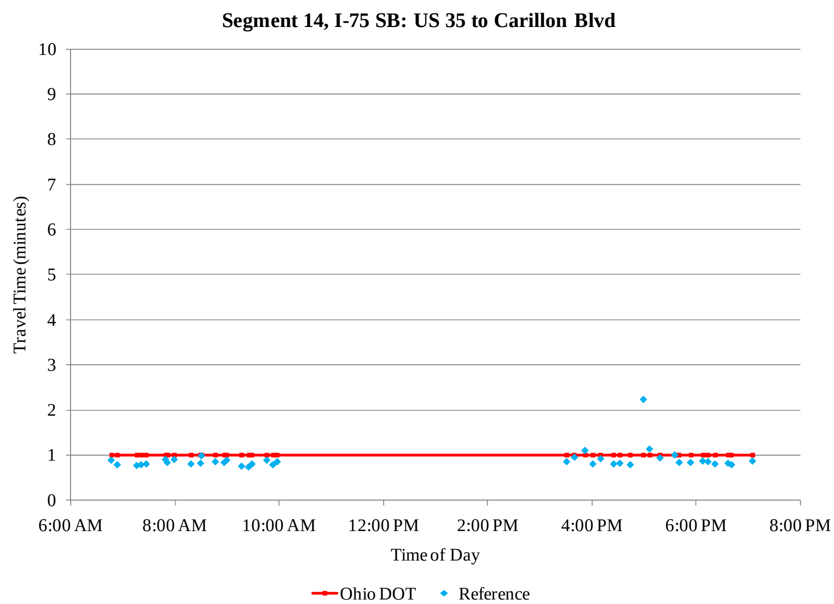
September 3 – Bluetooth only



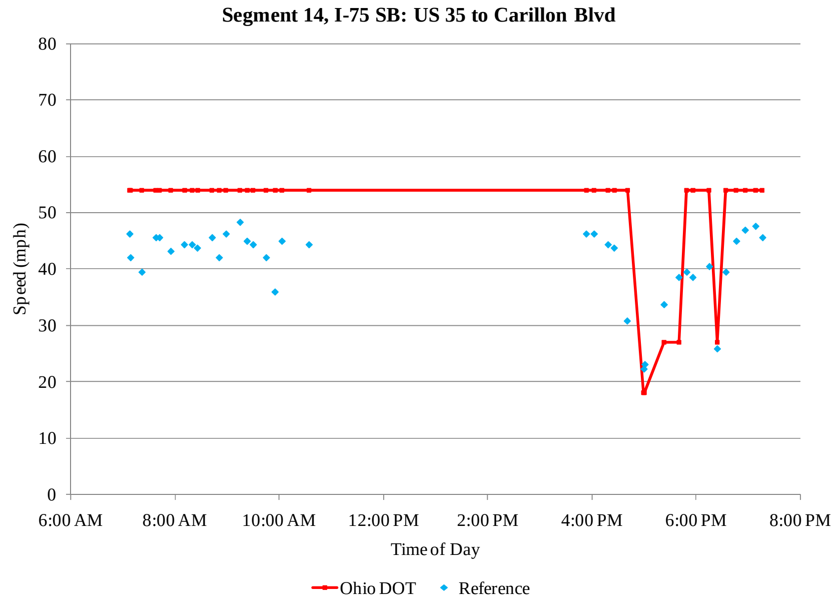


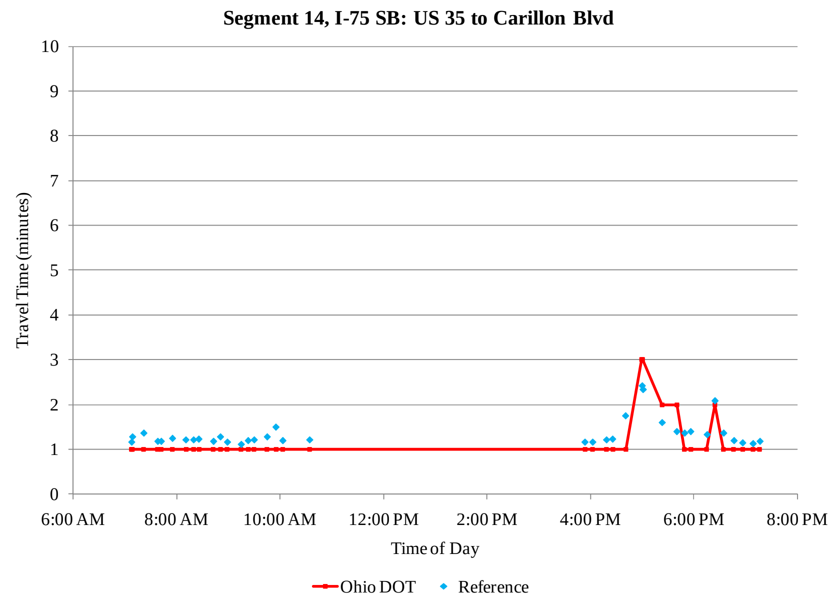
July 28 – Floating car only





July 29 – Floating car only





Segment 15: I-75 NB: US 35 to SR 4
Length: 2.1 miles (3.4 km)

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	1.3	4.7	-0.9	-1.3	105
30 to 45 mph	0.6	10.1	0.3	-8.9	15
45 to 60 mph	0.4	19.6	0.3	-18.9	69
60+ mph	0.4	20.4	0.4	-20.4	20

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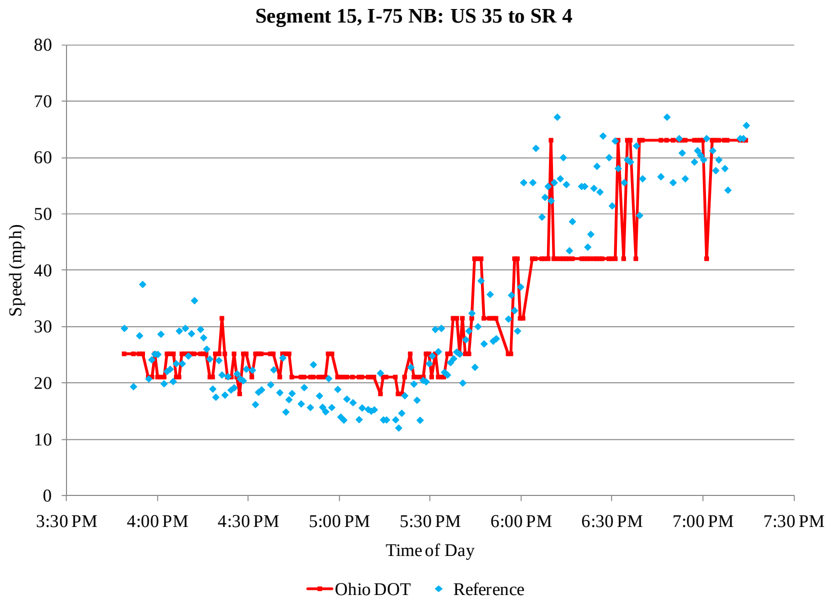
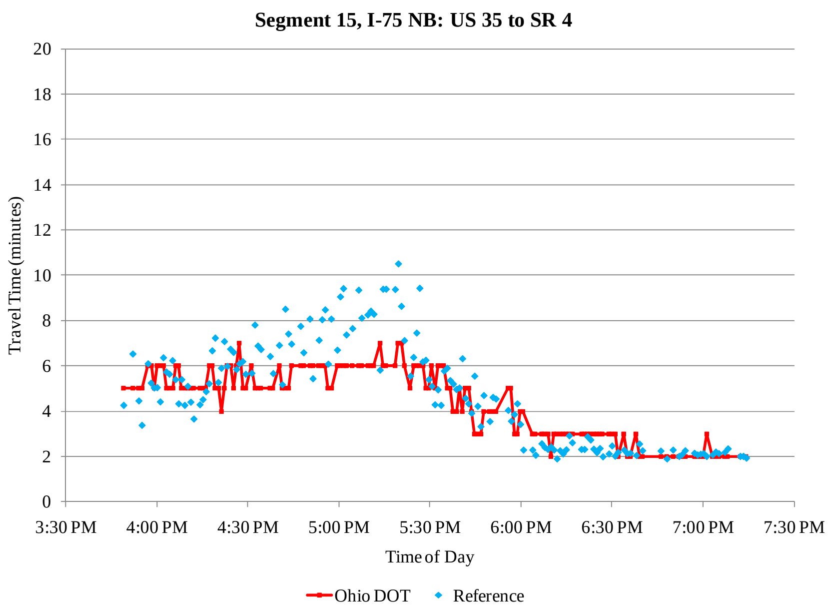
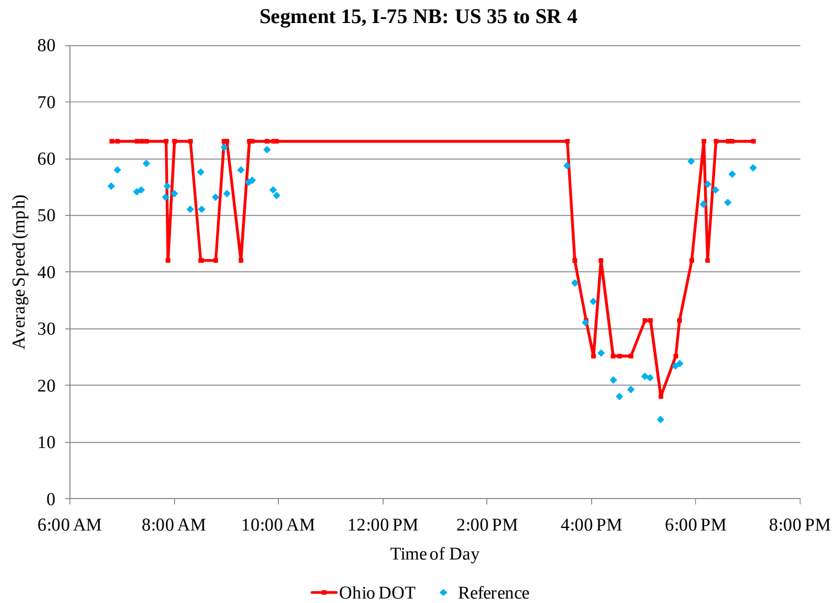
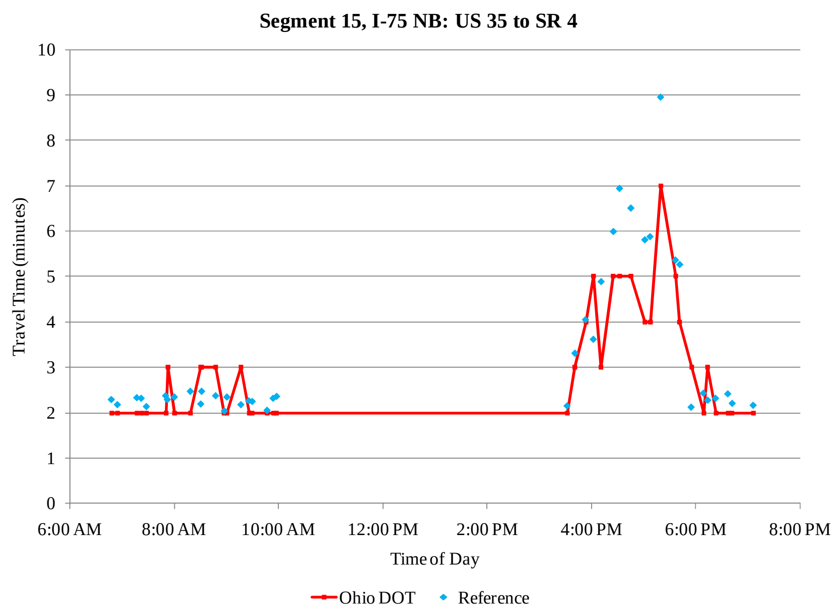


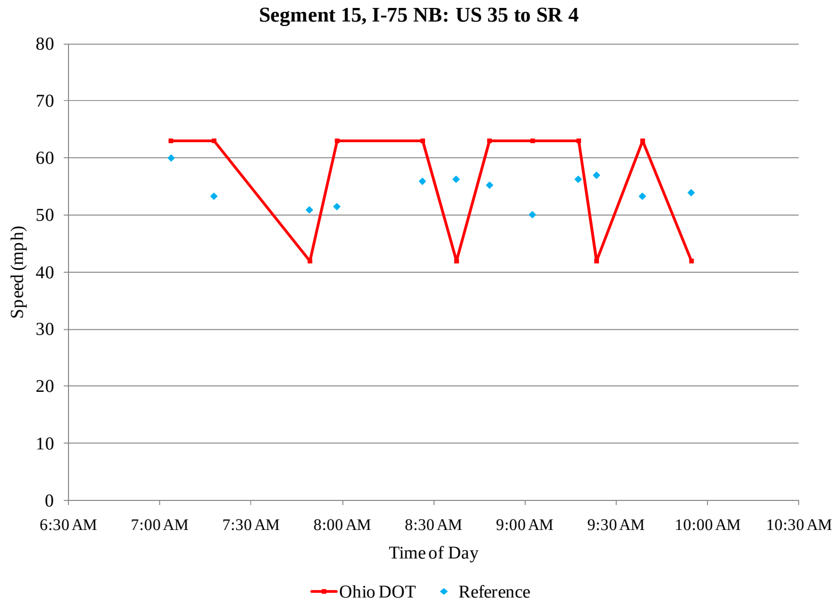


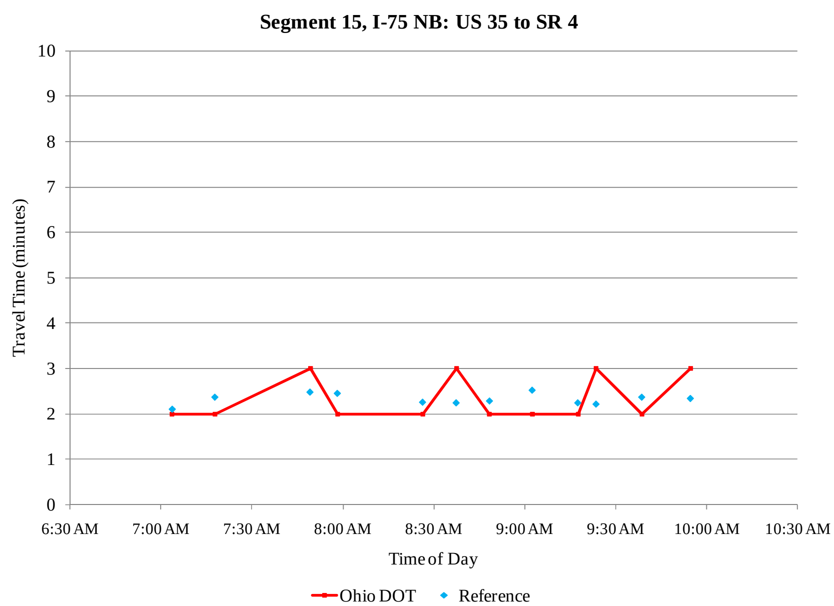
July 28 – Floating car only





July 30 – Floating car only

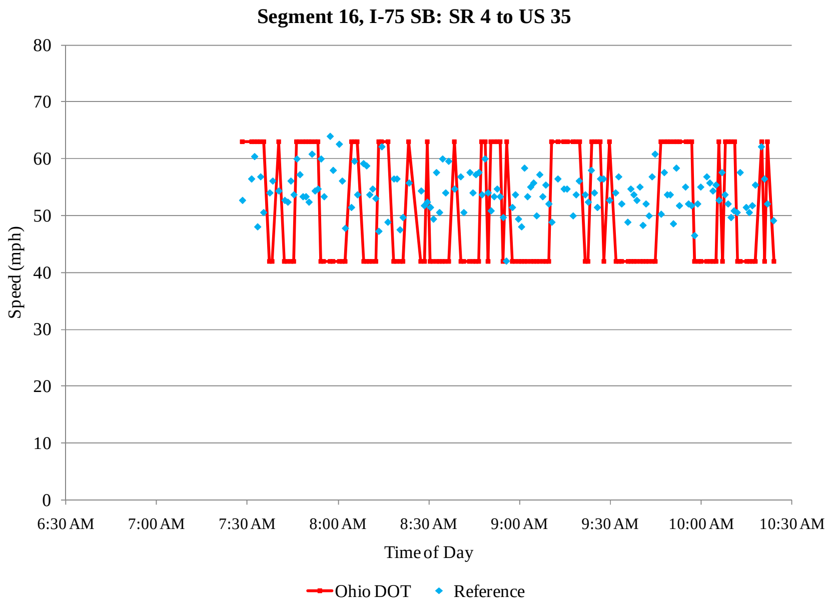


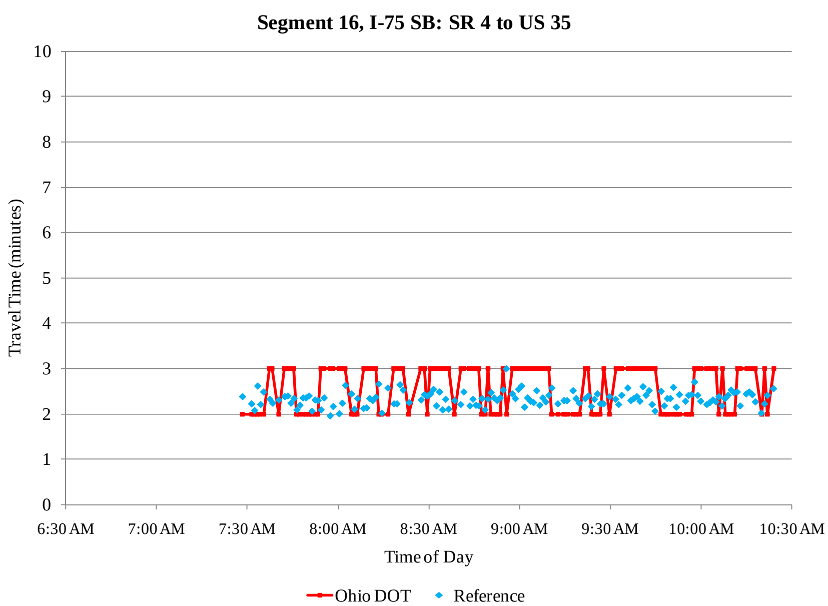


Segment 16: I-75 SB: SR 4 to US 35
Length: 2.1 miles (3.4 km)

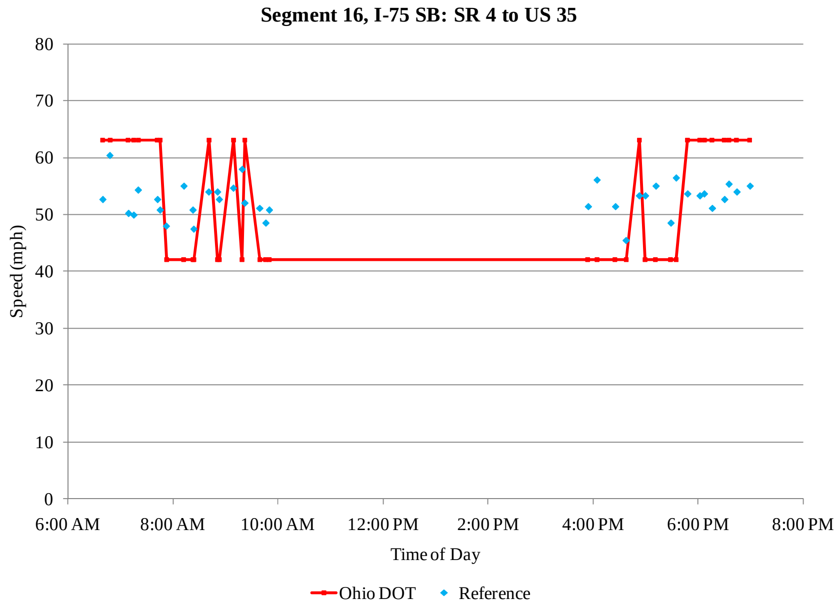
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	1.0	15.0	-1.0	15.0	1
45 to 60 mph	0.5	18.9	0.4	-17.3	180
60+ mph	0.4	17.8	0.4	-17.8	12

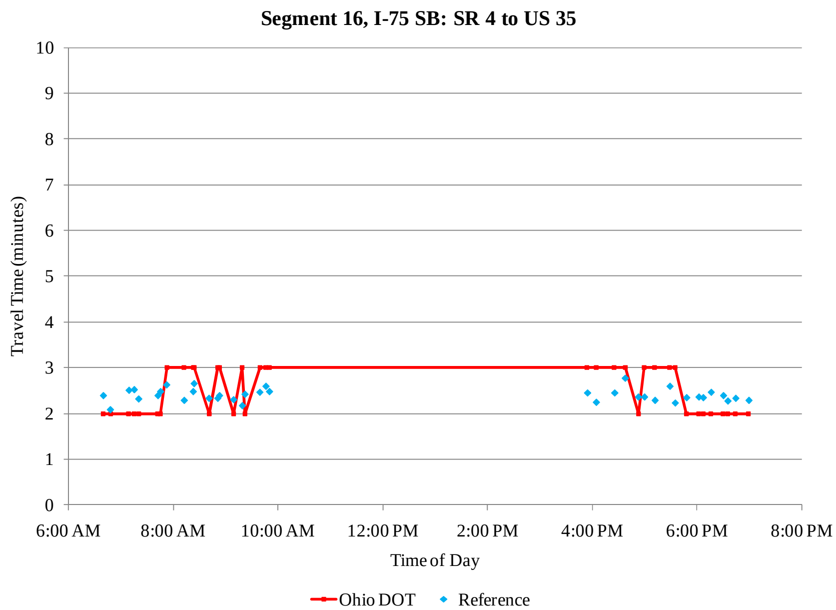
September 3 – Bluetooth only



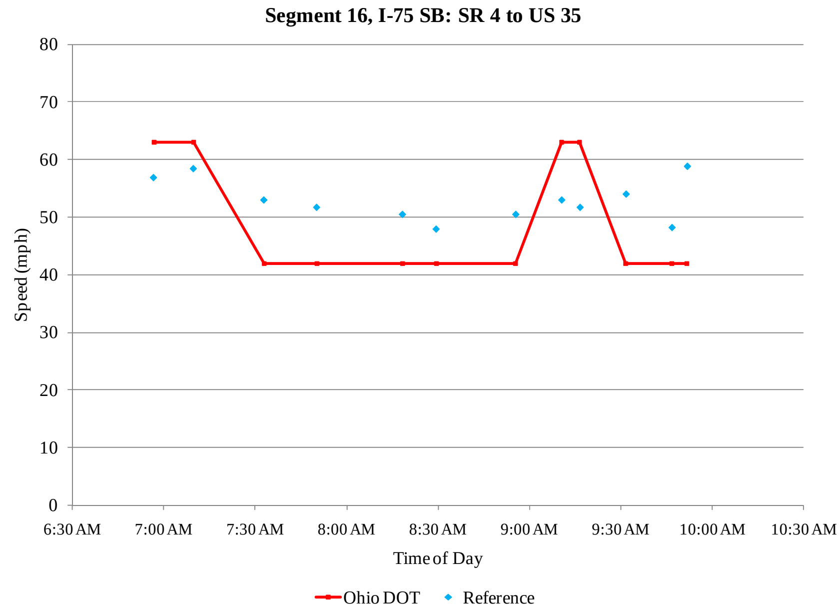


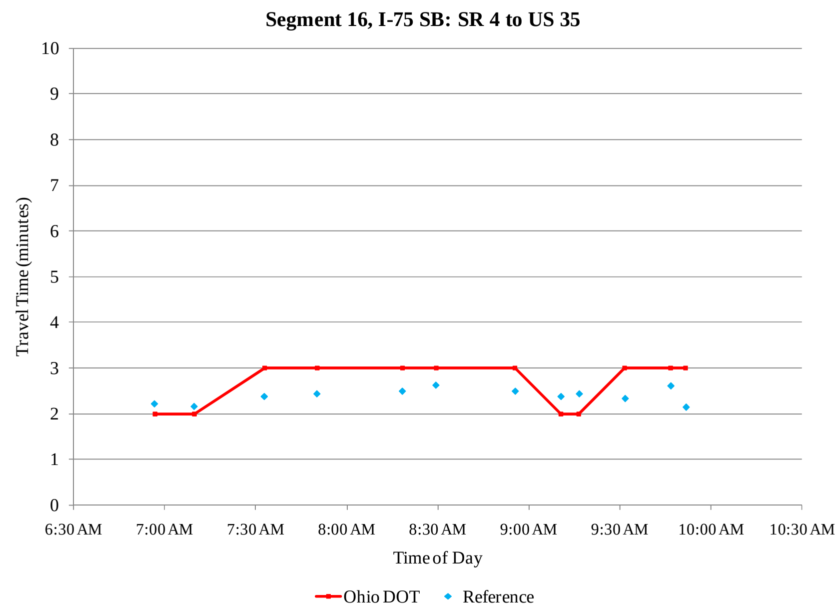
July 28 – Floating car only





July 30 – Floating car only

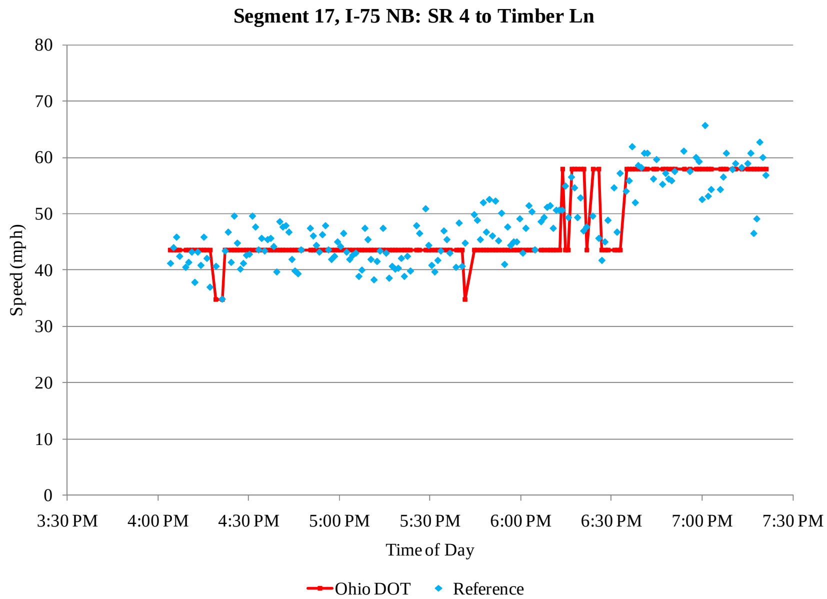


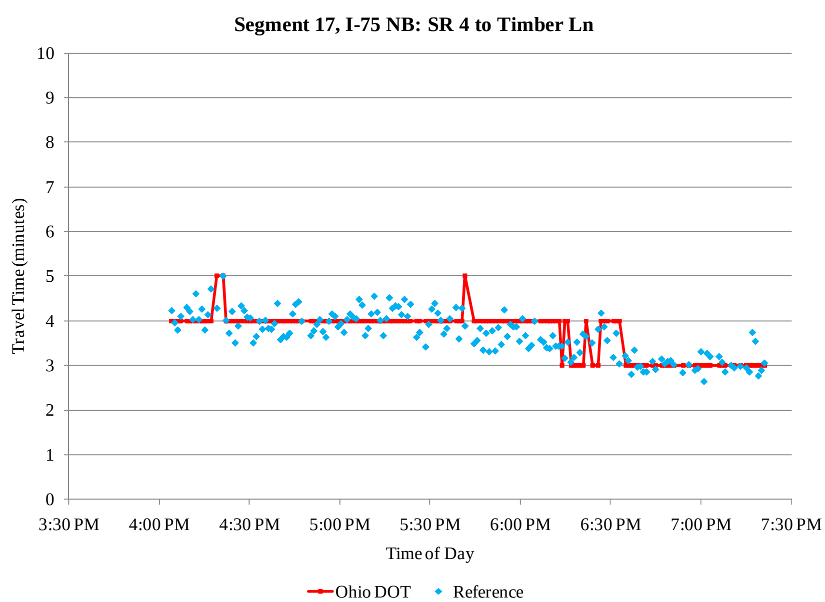


Segment 17: I-75 NB: SR 4 to Timber Ln
Length: 2.9 miles (4.7 km)

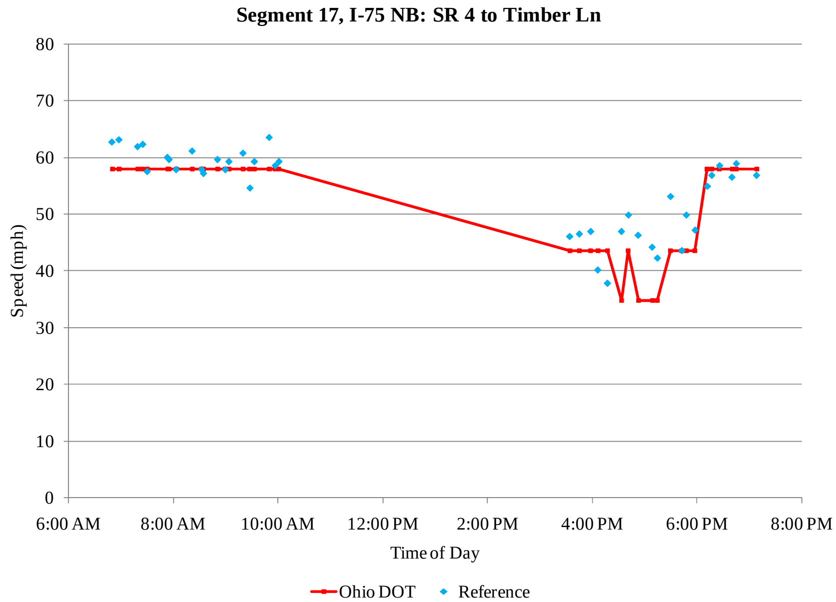
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	0.1	3.7	0.0	3.1	72
45 to 60 mph	0.2	5.2	0.1	2.1	132
60+ mph	0.0	4.0	0.0	4.0	19

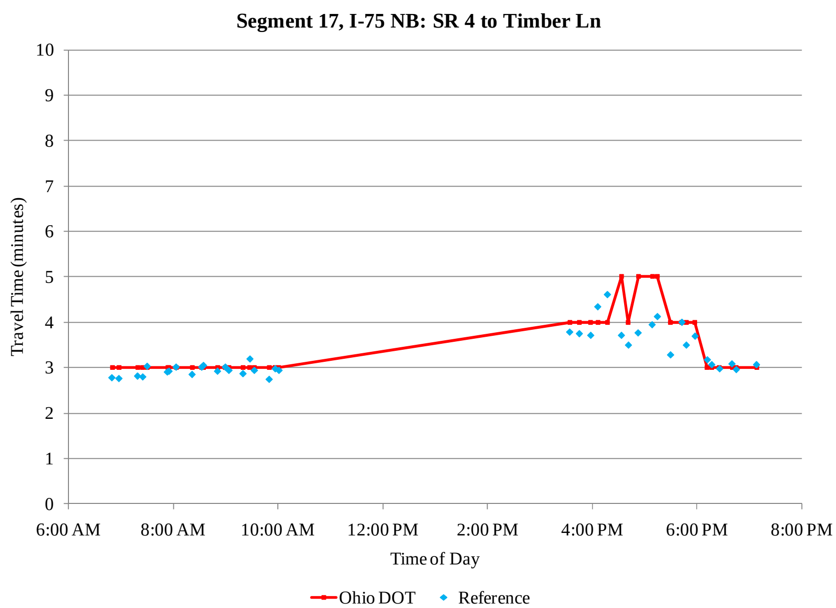
September 3 – Bluetooth only



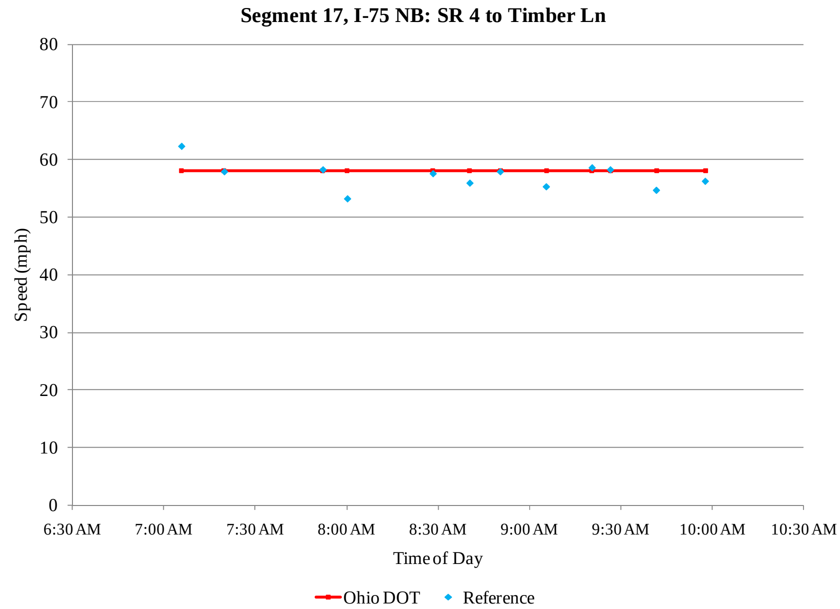


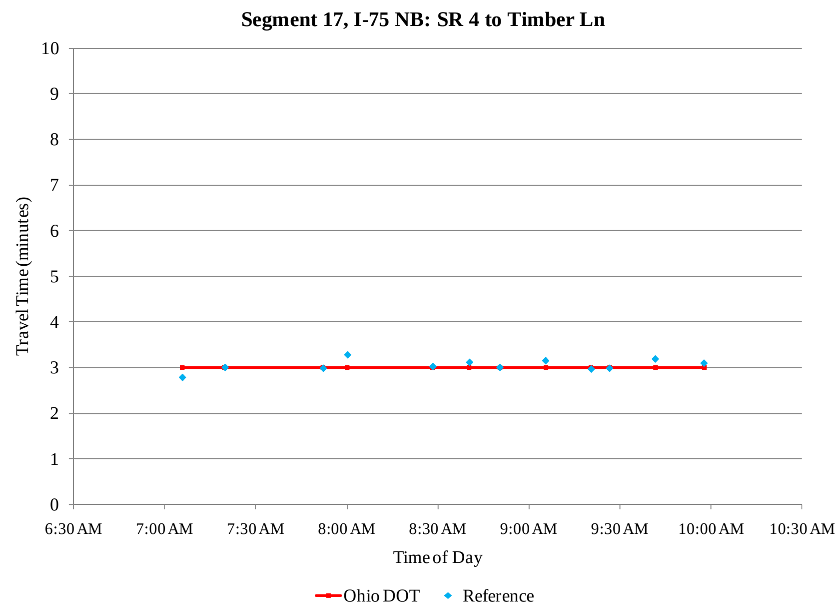
July 28 – Floating car only





July 30 – Floating car only

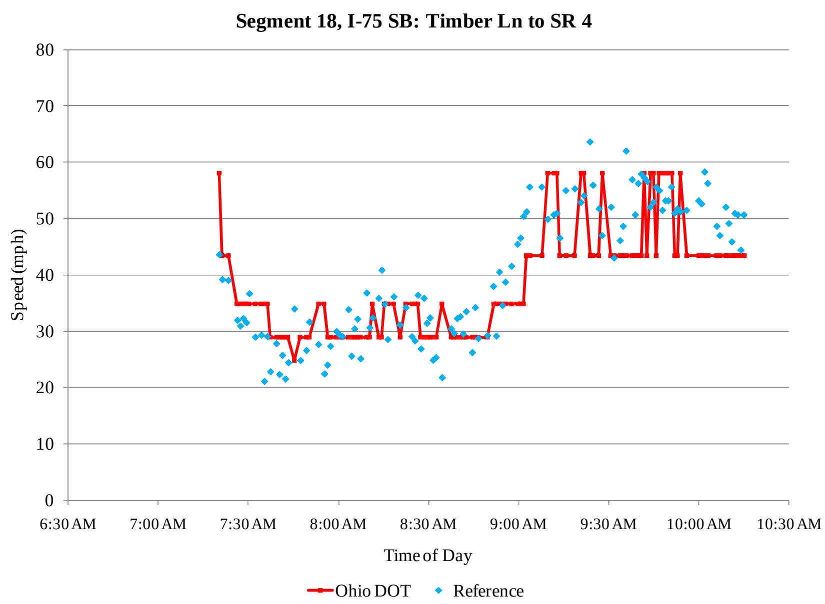


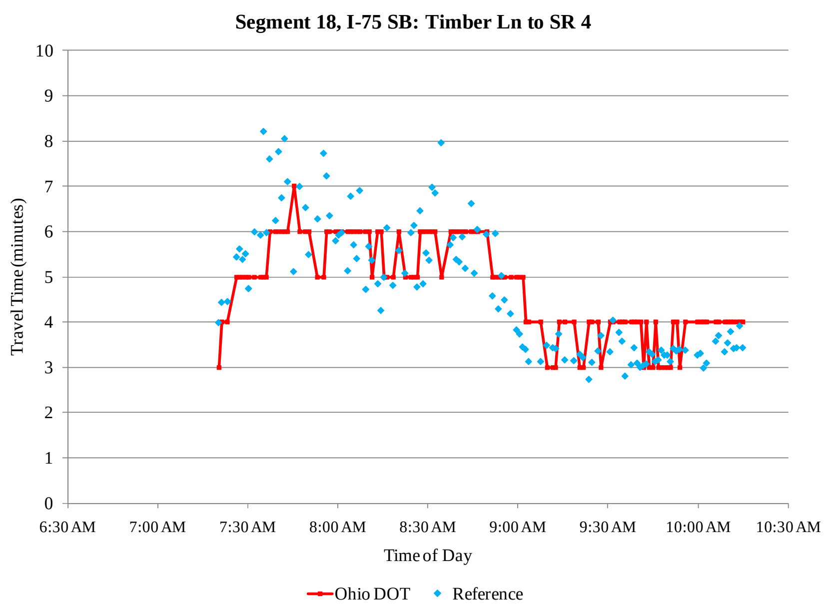


Segment 18: I-75 SB: Timber Ln to SR 4
Length: 2.9 miles (4.7 km)

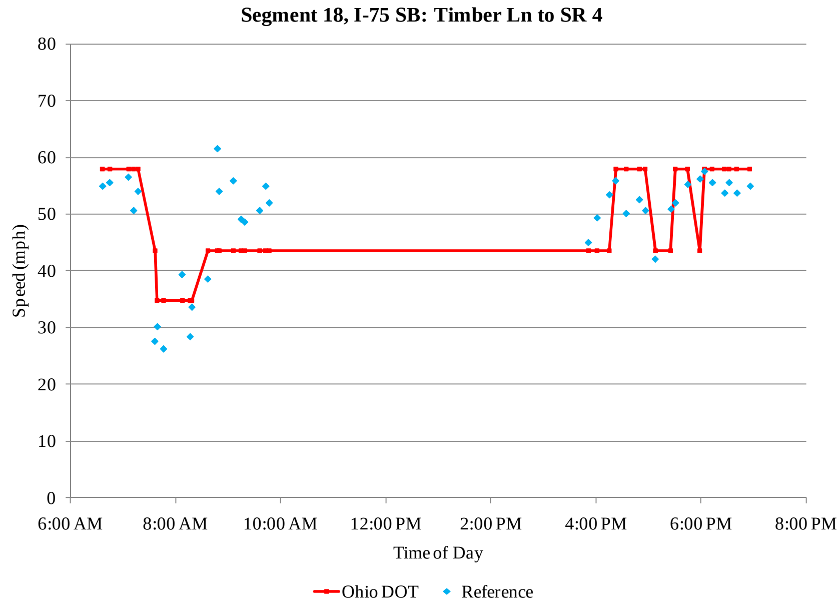
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	1.1	6.8	-1.1	6.8	37
30 to 45 mph	0.6	4.6	0.2	1.3	48
45 to 60 mph	0.5	7.1	0.4	-2.3	87
60+ mph	1.0	10.5	1.0	-10.5	3

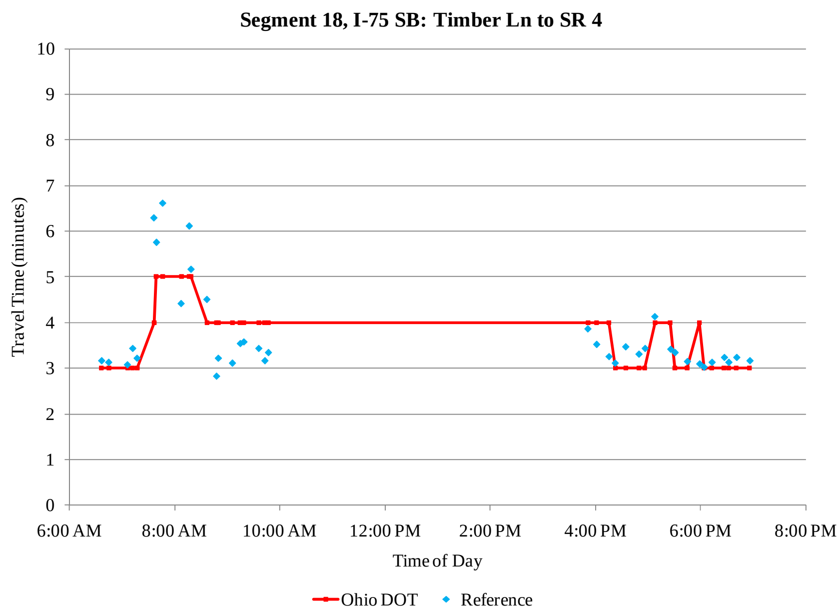
September 3 – Bluetooth only



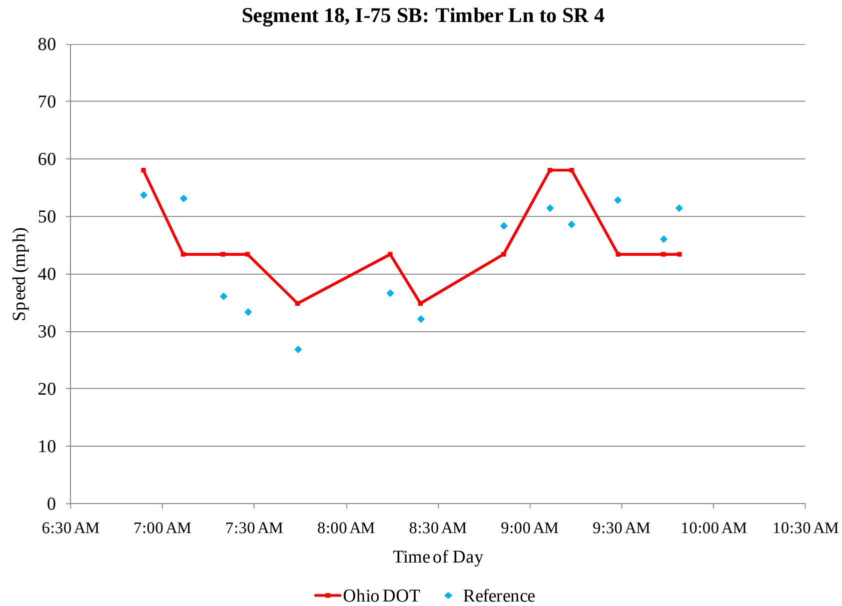


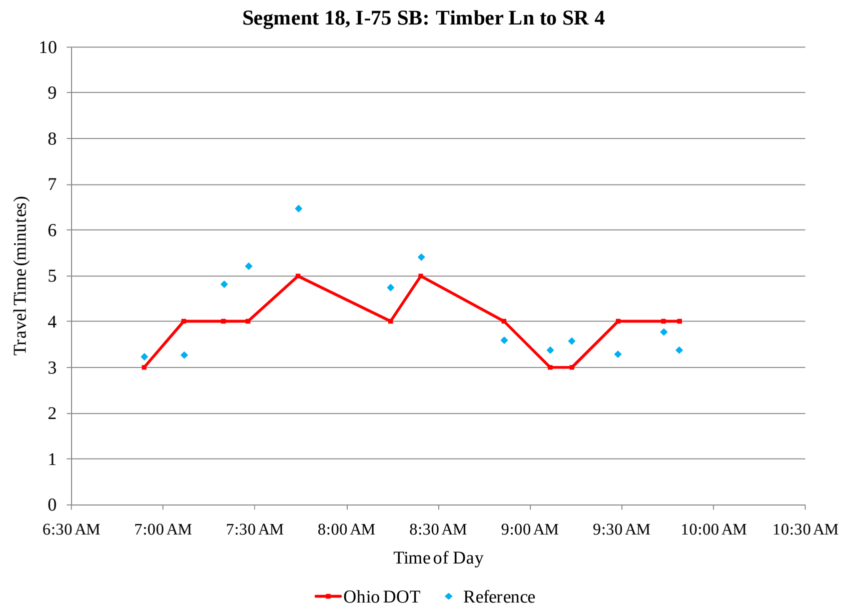
July 28 – Floating car only





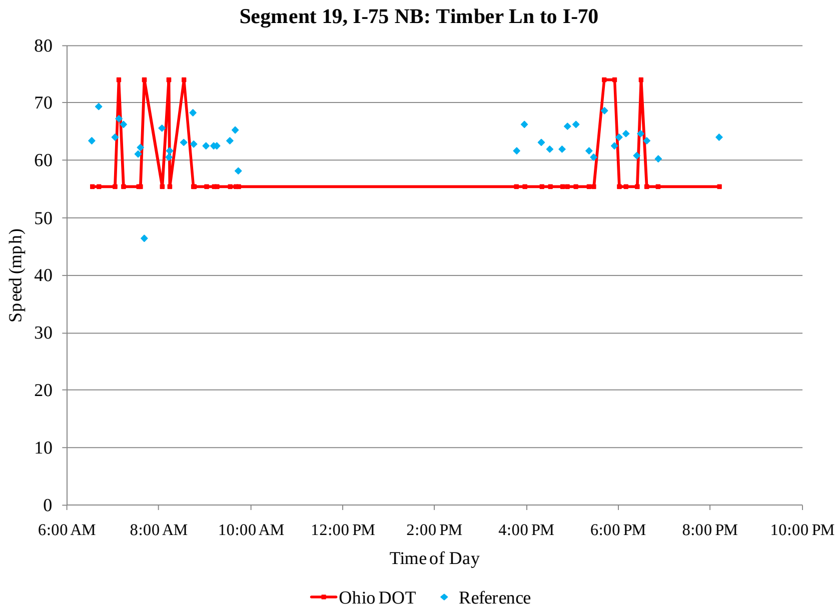
July 30 – Floating car only

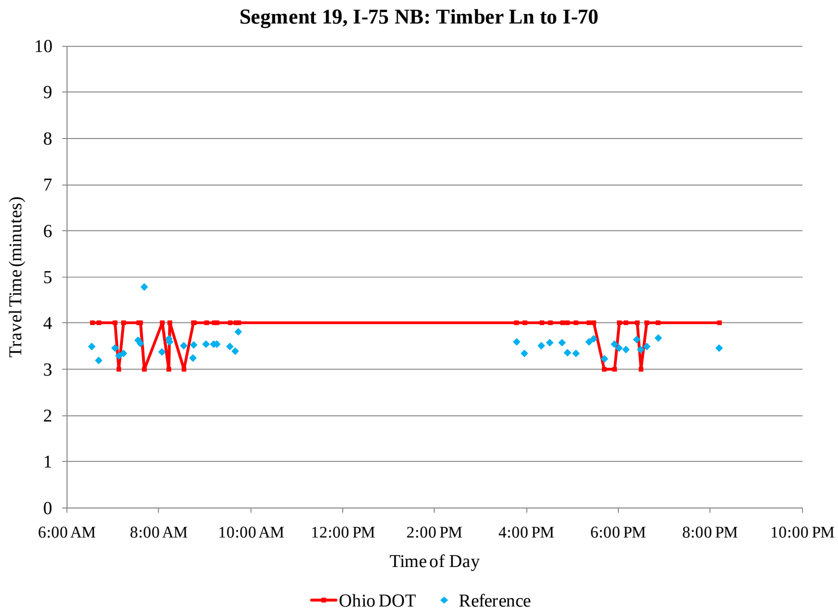




Segment 19: I-75 NB: Timber Ln to I-70
Length: 3.7 miles (6.0 km)

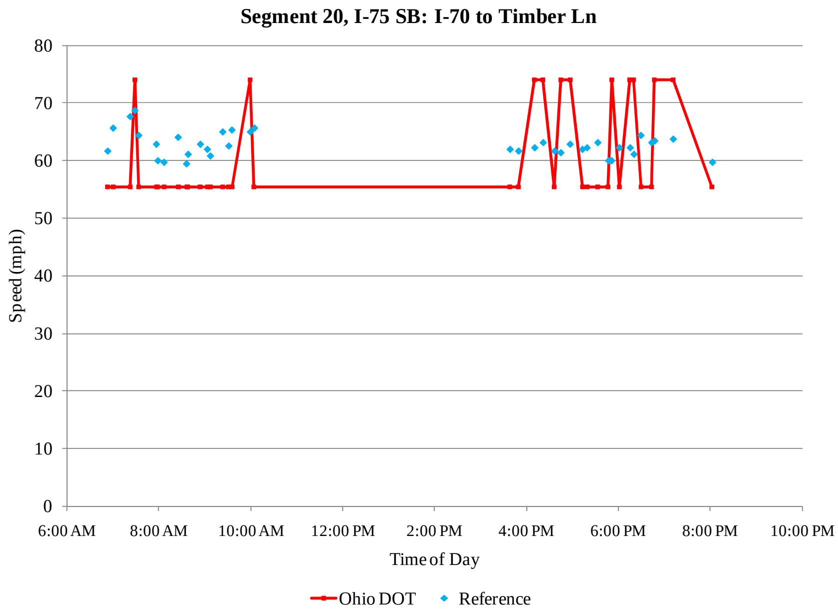
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	1.0	14.8	-1.0	14.8	2
60+ mph	0.4	6.7	0.2	-4.3	47

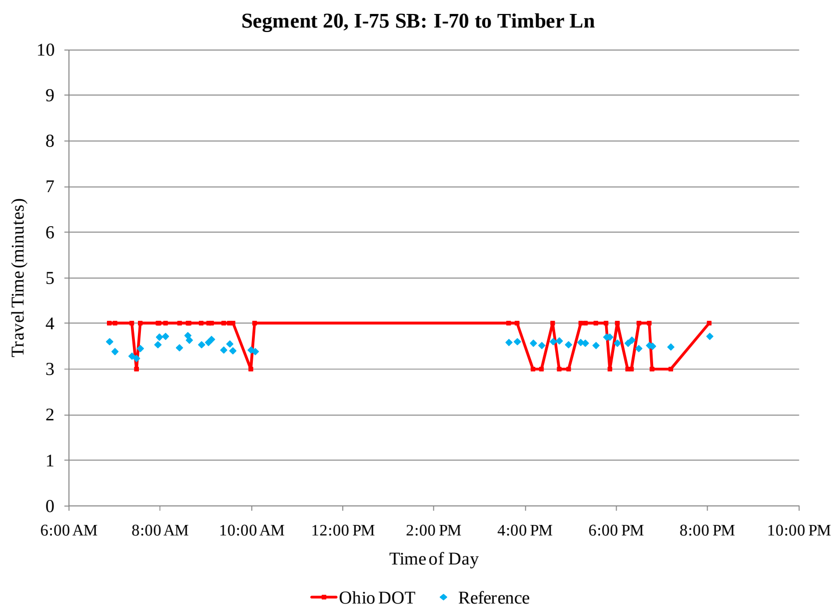




Segment 20: I-75 SB: I-70 to Timber Ln
Length: 3.7 miles (6.0 km)

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.0	0.0	0.0	0.0	5
60+ mph	0.5	9.1	0.1	-1.2	47

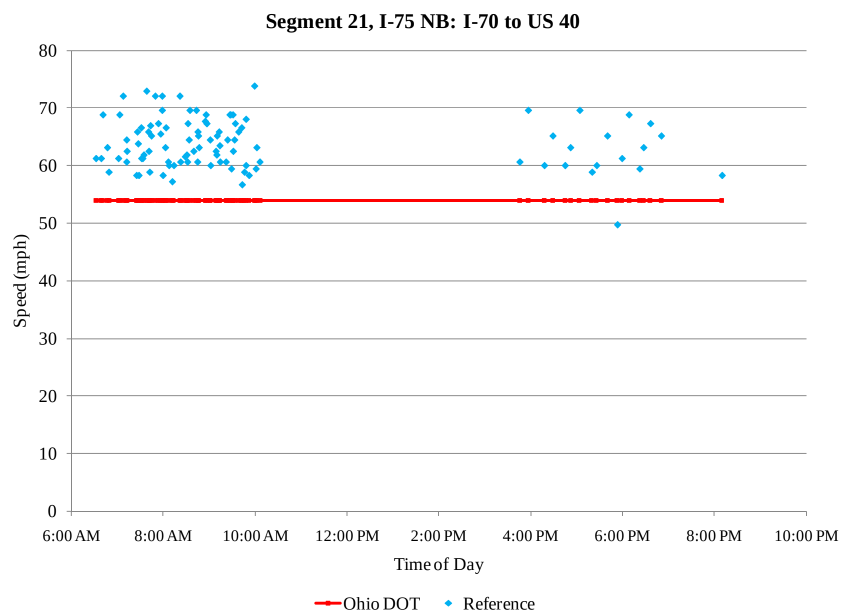


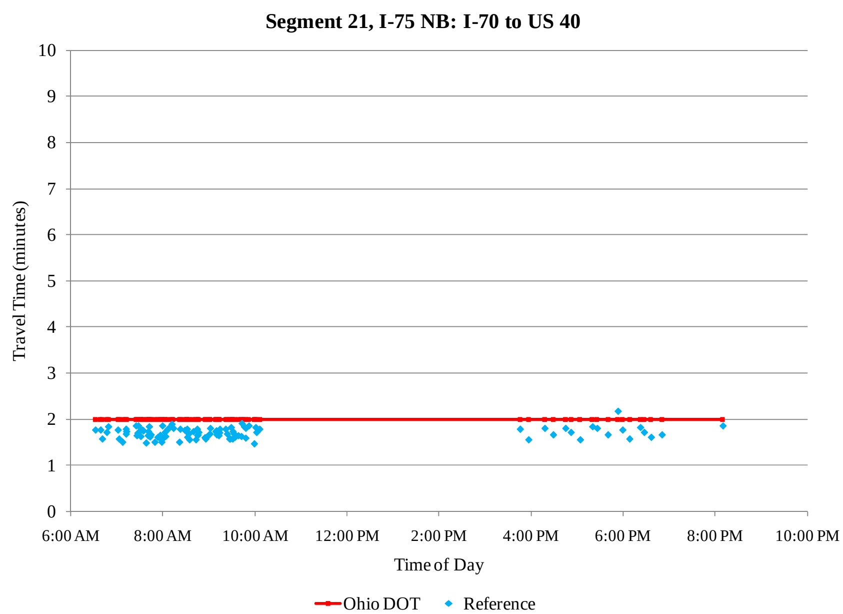


Segment 21: I-75 NB: I-70 to US 40

Length: 1.8 miles (2.9 km)

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.0	3.0	0.0	3.0	15
60+ mph	0.0	4.0	0.0	1.8	86

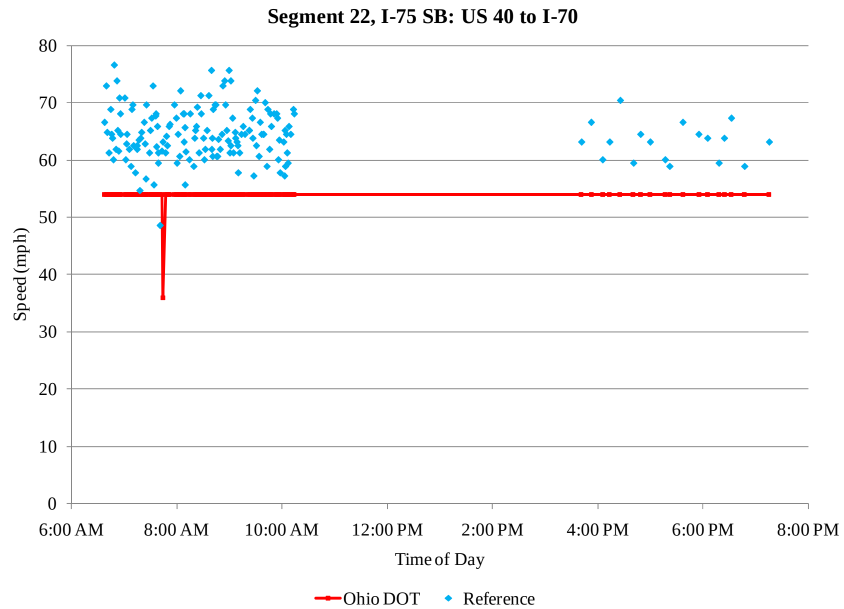


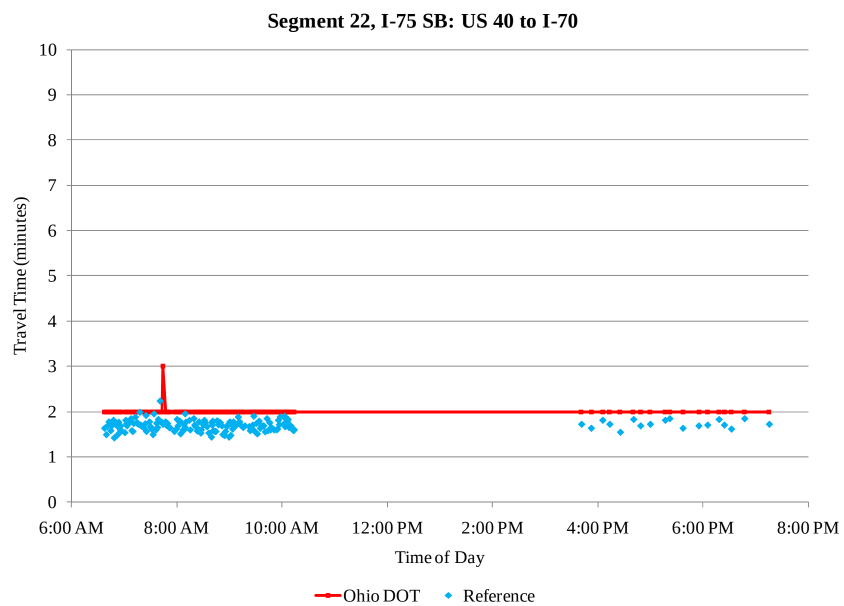


Segment 22: I-75 SB: US 40 to I-70

Length: 1.8 miles (2.9 km)

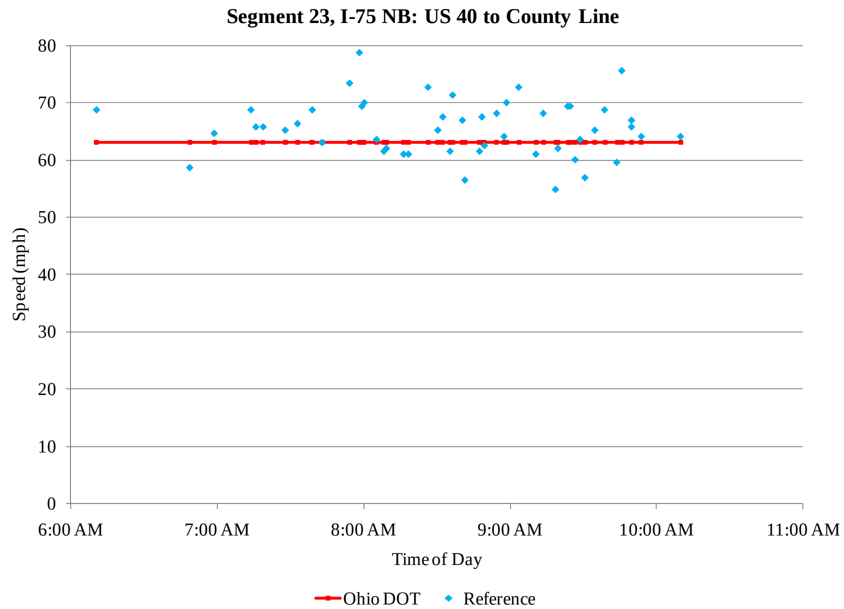
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.0	3.0	0.0	3.0	21
60+ mph	0.1	5.8	0.1	-0.2	148

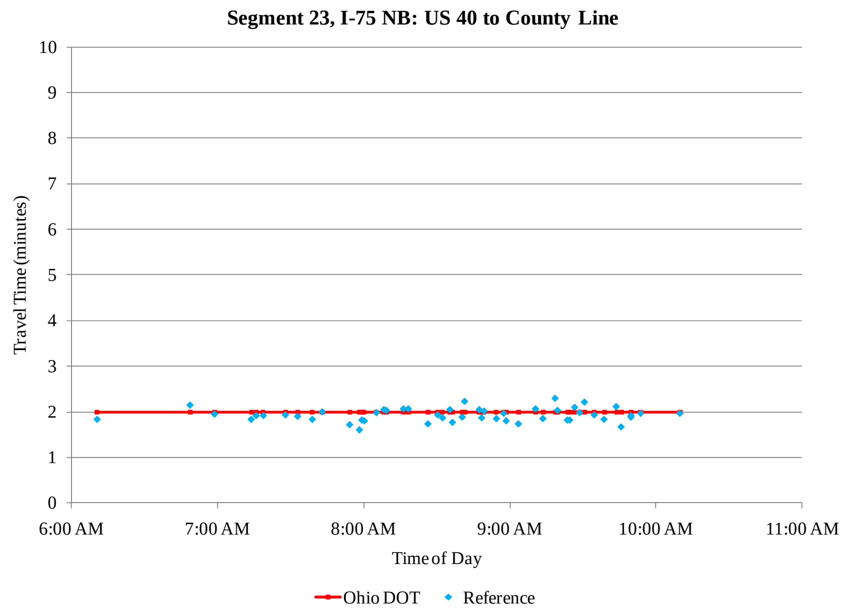




Segment 23: I-75 NB: US 40 to County Line (Miami)
Length: 2.1 miles (3.4 km)

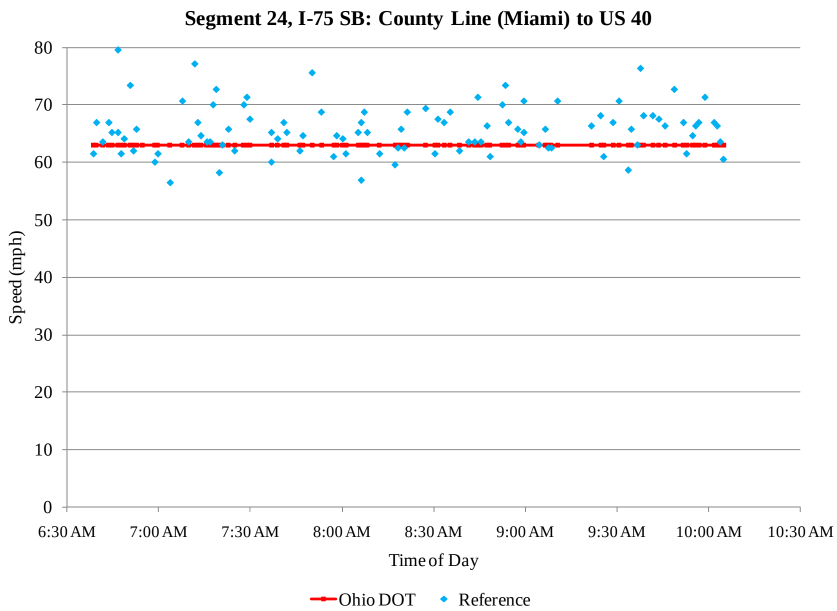
Reference Speed Bin	Mean Absolute Difference: Travel Time (minutes)	Mean Absolute Difference: Speed (mph)	Mean Difference (bias): Travel Time (minutes)	Mean Difference (bias): Speed (mph)	Comparison Samples
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.0	0.0	0.0	0.0	5
60+ mph	0.0	0.0	0.0	0.0	45

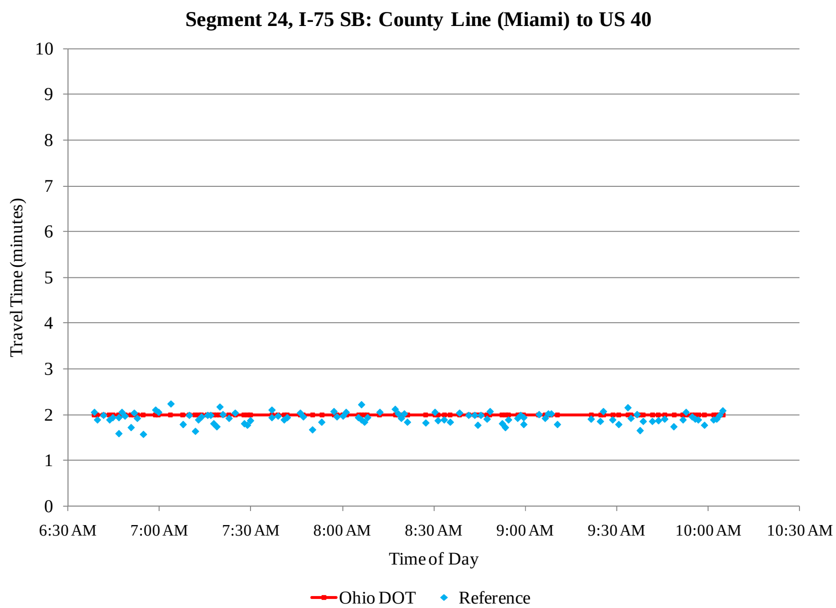




Segment 24: I-75 SB: County Line (Miami) to US 40
Length: 2.1 miles (3.4 km)

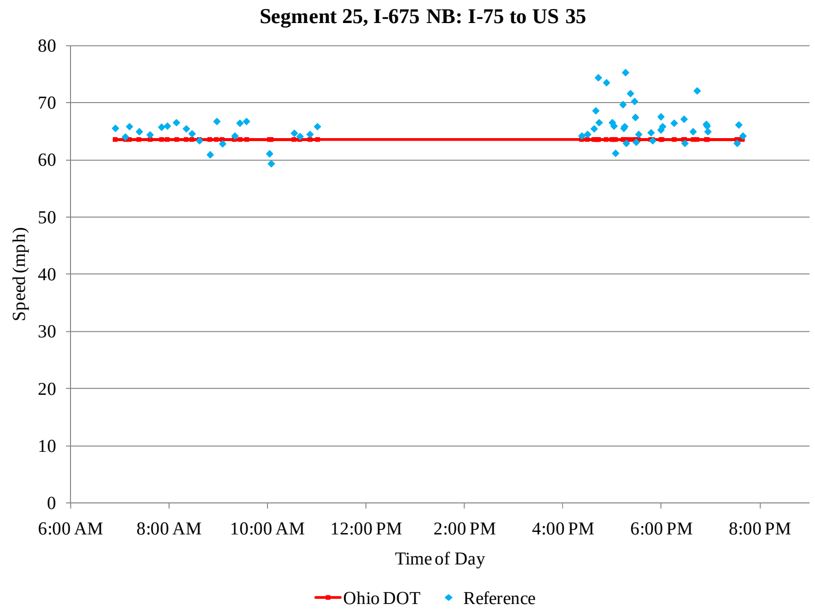
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	0.0	0.0	0.0	0.0	5
60+ mph	0.0	0.0	0.0	0.0	99

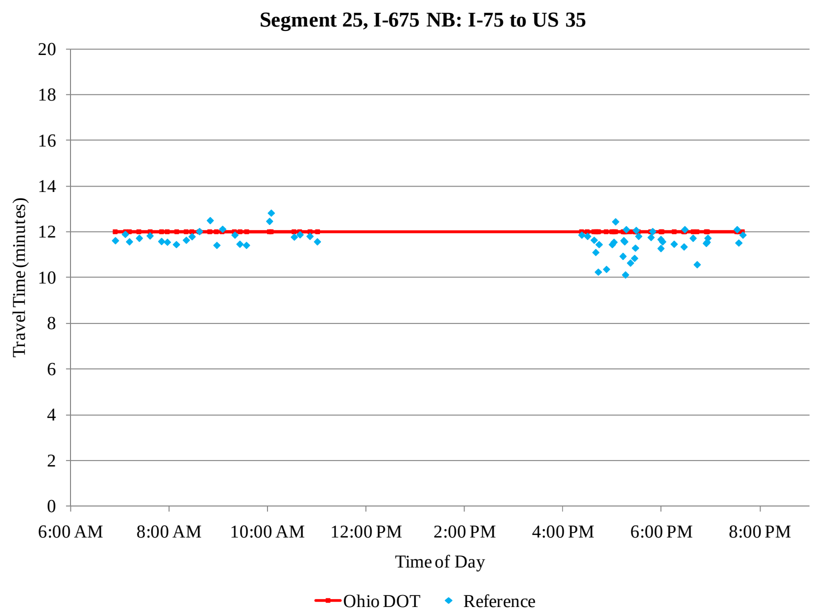




Segment 25: I-675 NB: I-75 to US 35
Length: 12.7 miles (20.4 km)

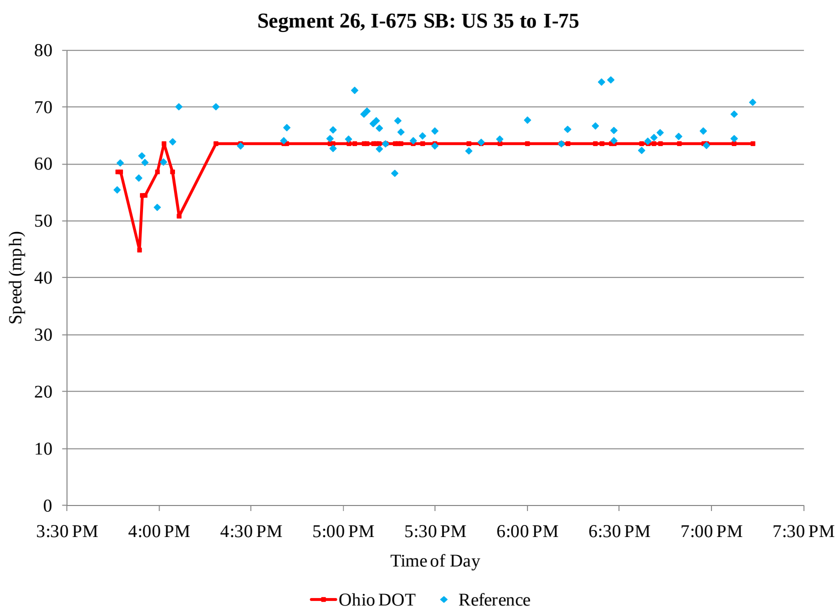
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	1.0	6.7	-1.0	6.7	1
60+ mph	0.4	2.9	0.3	0.0	58

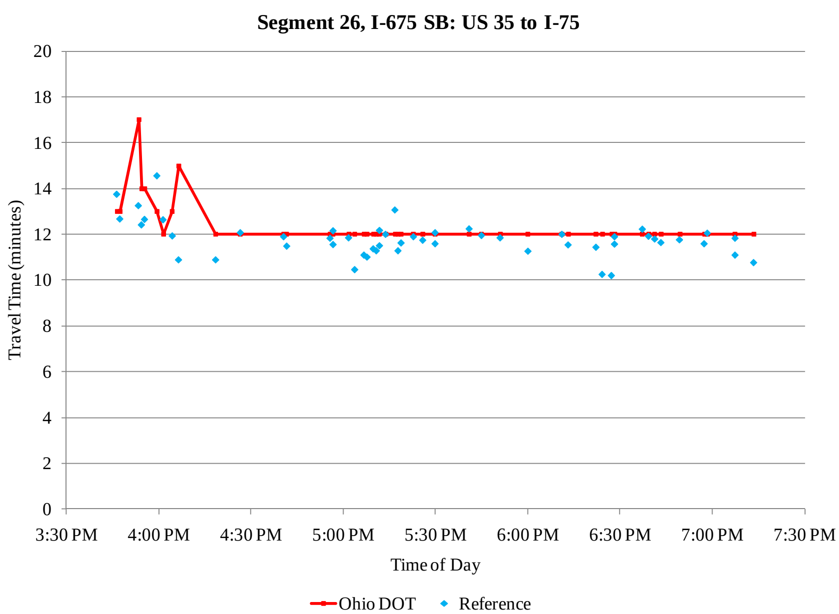




Segment 26: I-675 SB: US 35 to I-75
Length: 12.7 miles (20.4 km)

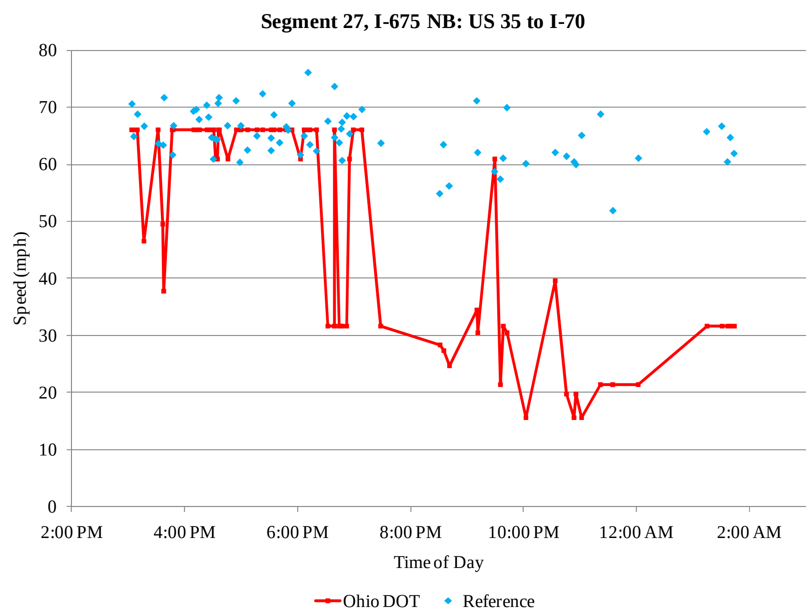
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	2.0	8.5	0.0	2.5	4
60+ mph	0.6	3.4	0.5	-0.8	49

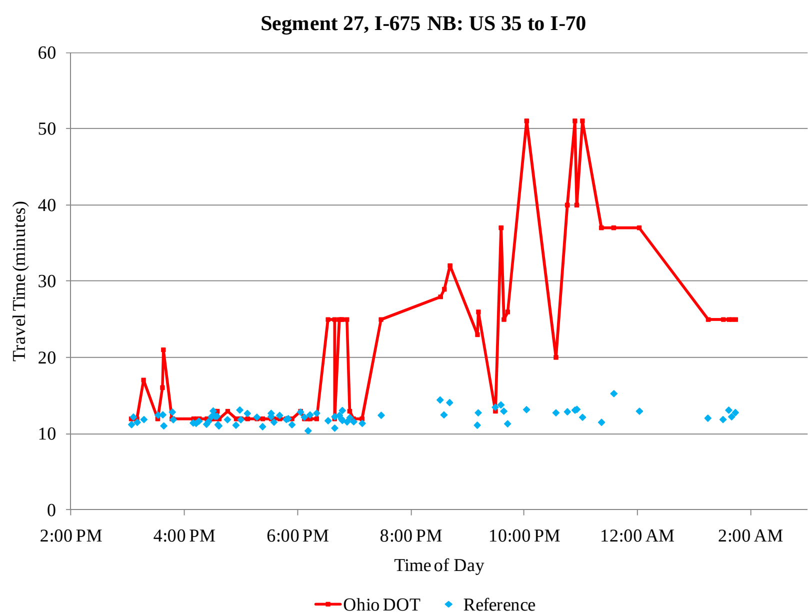




Segment 27: I-675 NB: US 35 to I-70
Length: 13.2 miles (21.2 km)

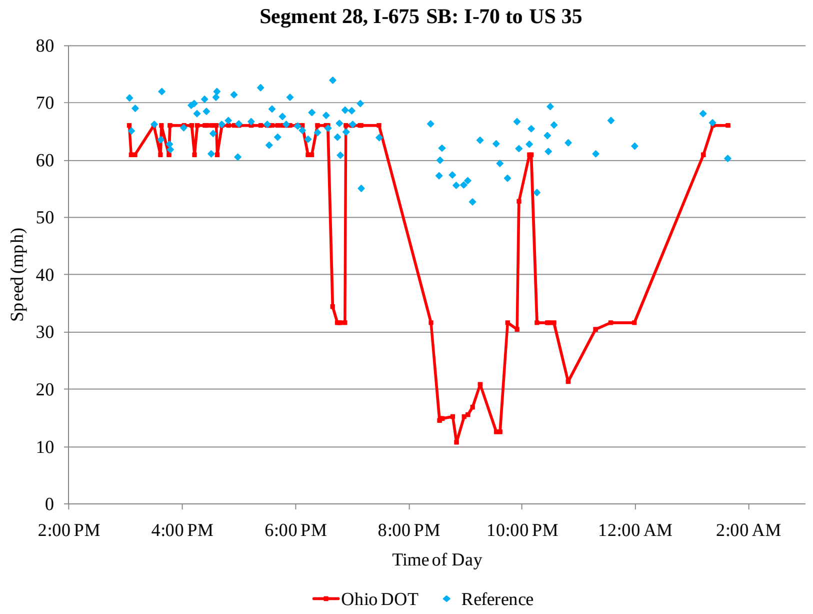
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	17.3	26.6	17.3	-25.8	6
60+ mph	7.0	15.3	6.8	-12.6	68

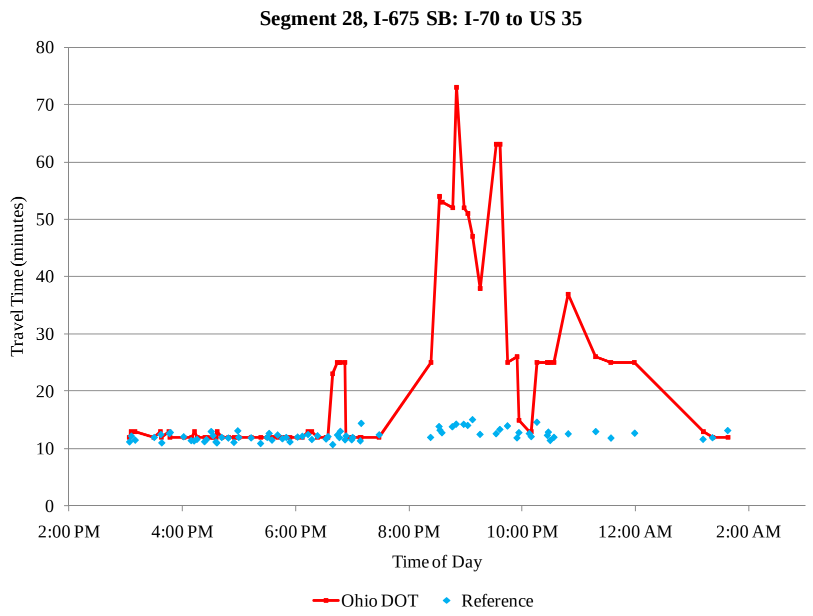




Segment 28: I-675 SB: I-70 to US 35
Length: 13.2 miles (21.2 km)

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 30 mph	-	-	-	-	0
30 to 45 mph	-	-	-	-	0
45 to 60 mph	32.5	34.5	32.1	-32.4	11
60+ mph	5.1	11.6	5.0	-8.8	68

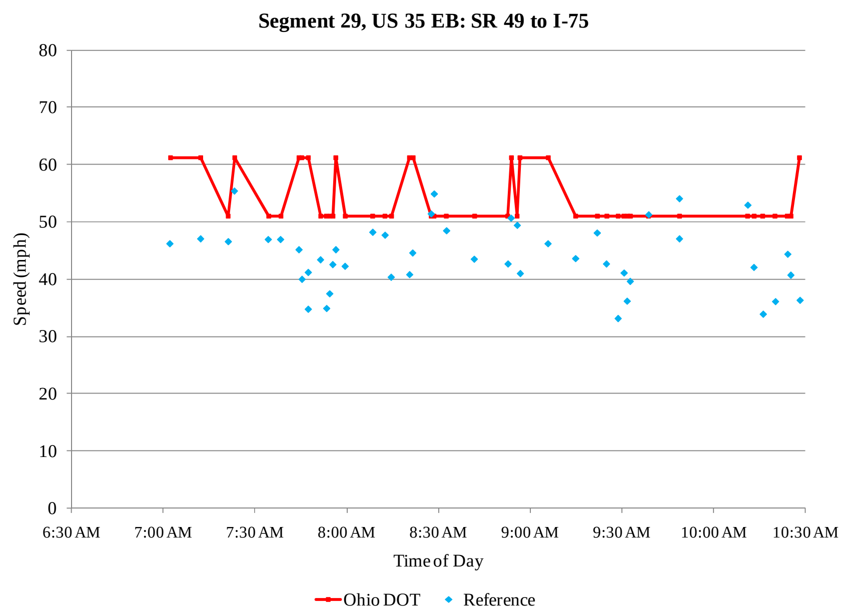


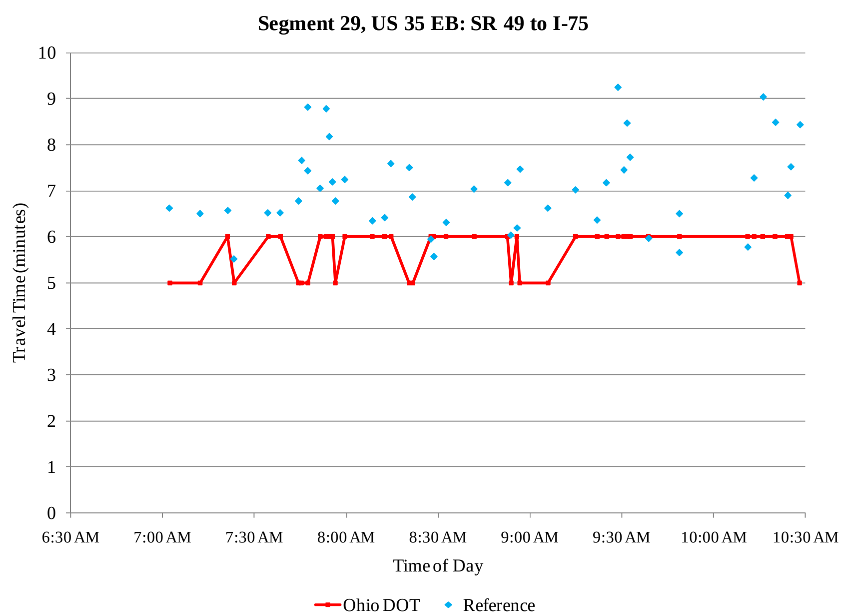


Segment 29: US 35 EB: SR 49 to I-75

Length: 5.1 miles (8.2 km)

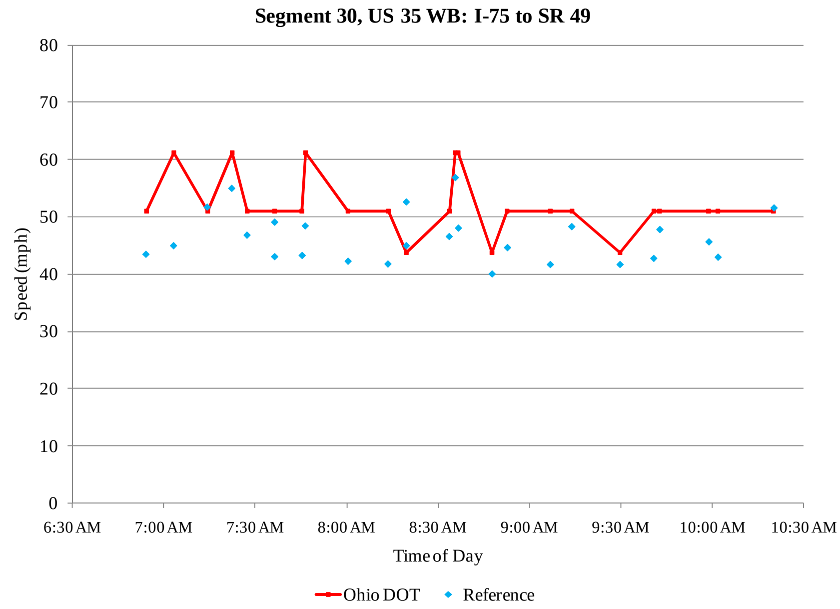
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 20 mph	-	-	-	-	0
20 to 35 mph	3.3	20.6	-3.3	20.6	4
35 to 50 mph	1.4	12.1	-1.4	12.1	36
50+ mph	0.3	4.5	-0.3	4.5	7

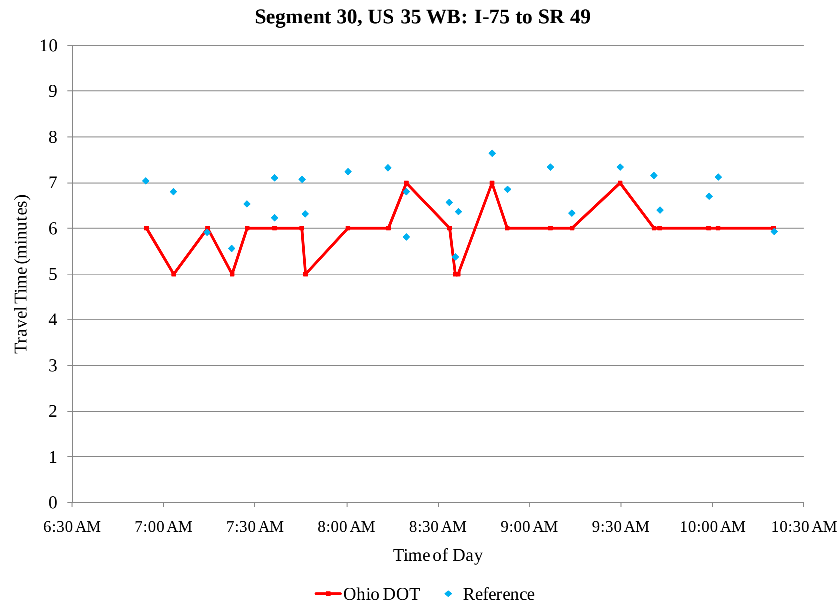




Segment 30: US 35 WB: I-75 to SR 49
Length: 5.1 miles (8.2 km)

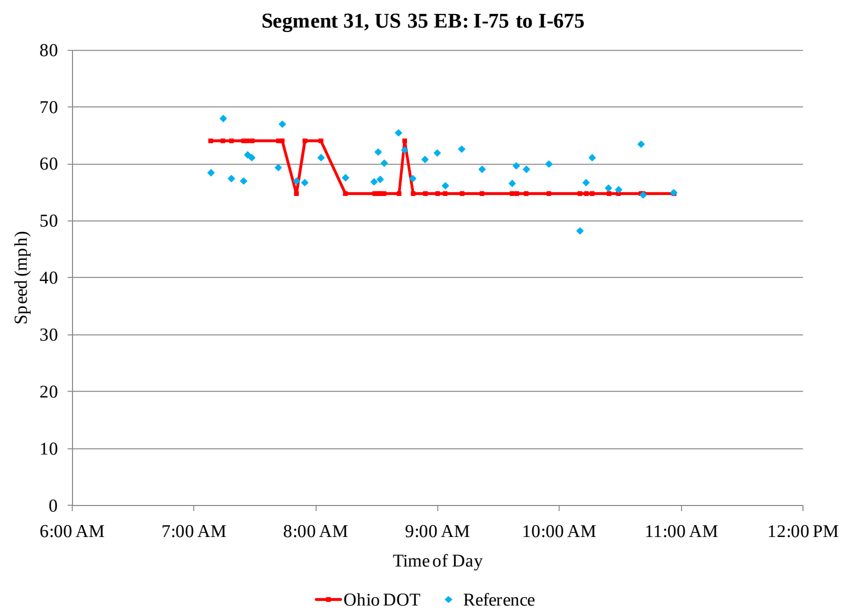
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 20 mph	-	-	-	-	0
20 to 35 mph	-	-	-	-	0
35 to 50 mph	0.8	6.3	-0.8	6.3	21
50+ mph	0.4	3.6	0.0	0.7	5

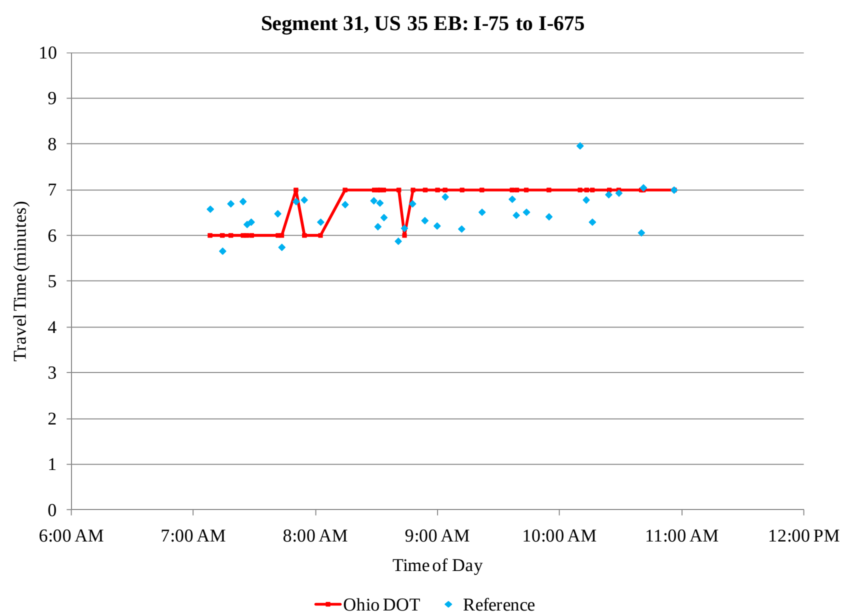




Segment 31: US 35 EB: I-75 to I-675
Length: 6.4 miles (10.3 km)

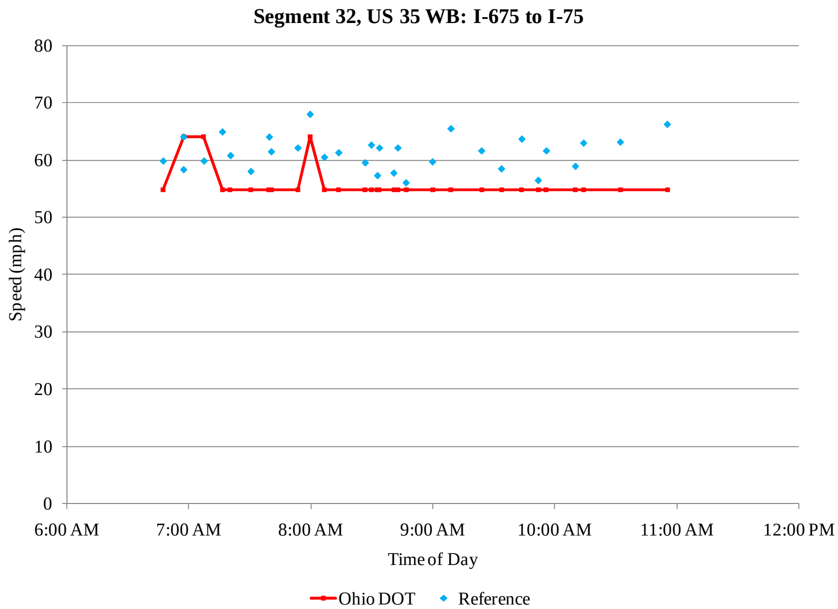
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 20 mph	-	-	-	-	0
20 to 35 mph	-	-	-	-	0
35 to 50 mph	1.0	6.9	-1.0	6.9	1
50+ mph	0.4	3.7	0.2	-1.6	35

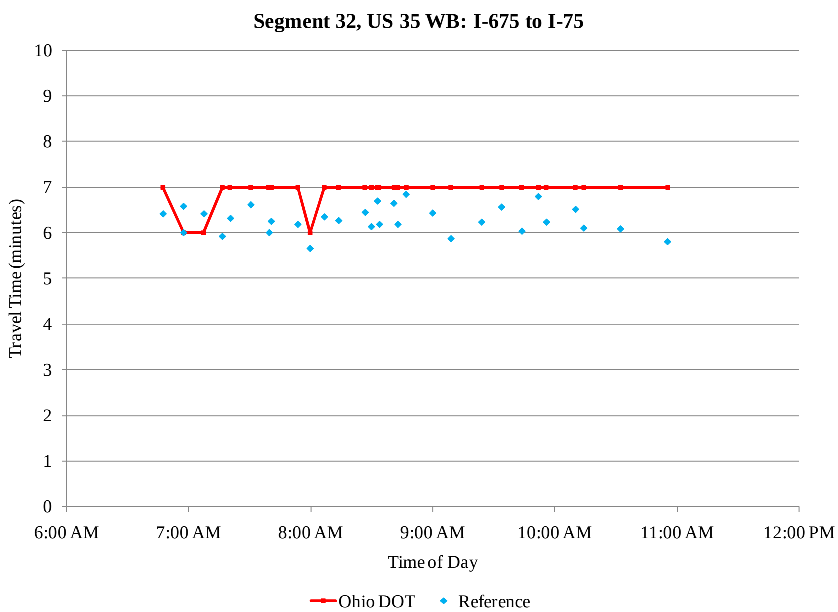




Segment 32: US 35 WB: I-675 to I-75
Length: 6.4 miles (10.3 km)

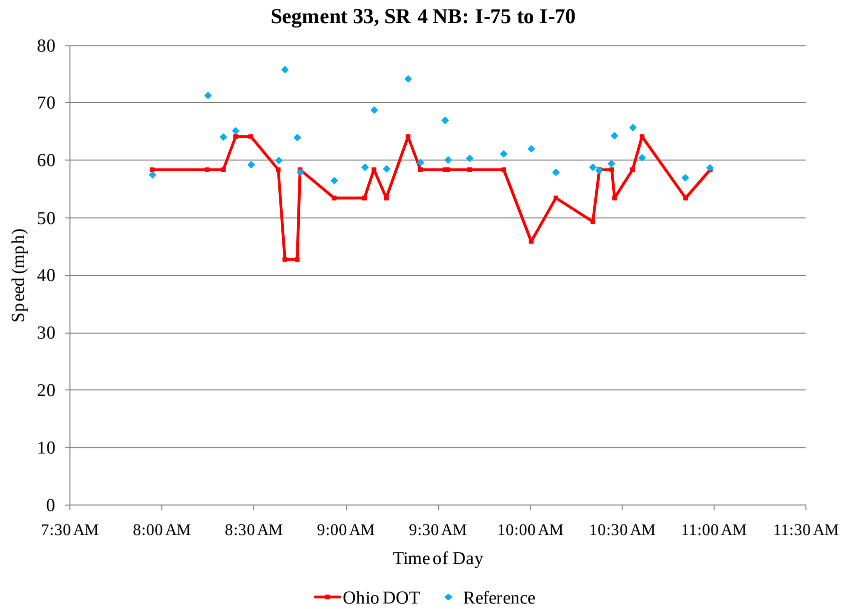
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 20 mph	-	-	-	-	0
20 to 35 mph	-	-	-	-	0
35 to 50 mph	-	-	-	-	0
50+ mph	0.7	6.2	0.6	-5.6	31

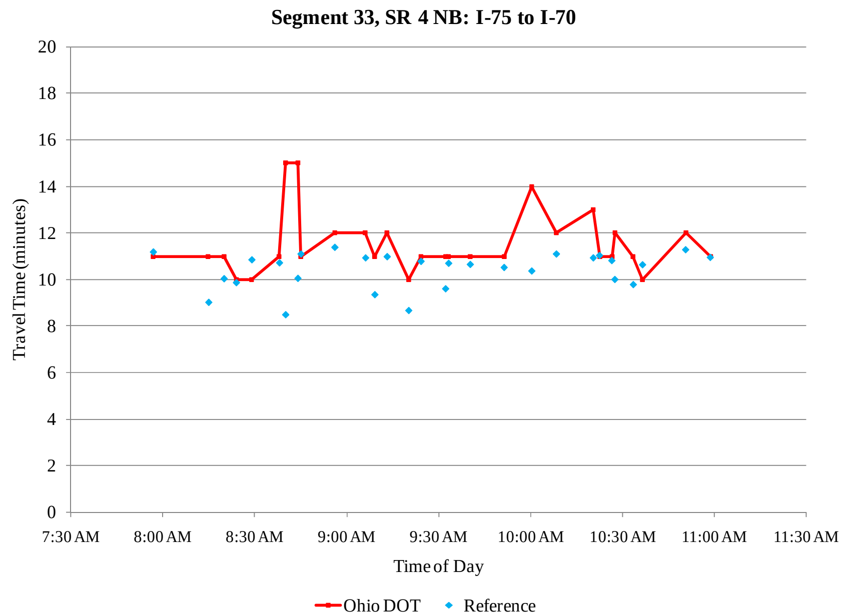




Segment 33: SR 4 NB: I-75 to I-70
Length: 10.7 miles (17.2 km)

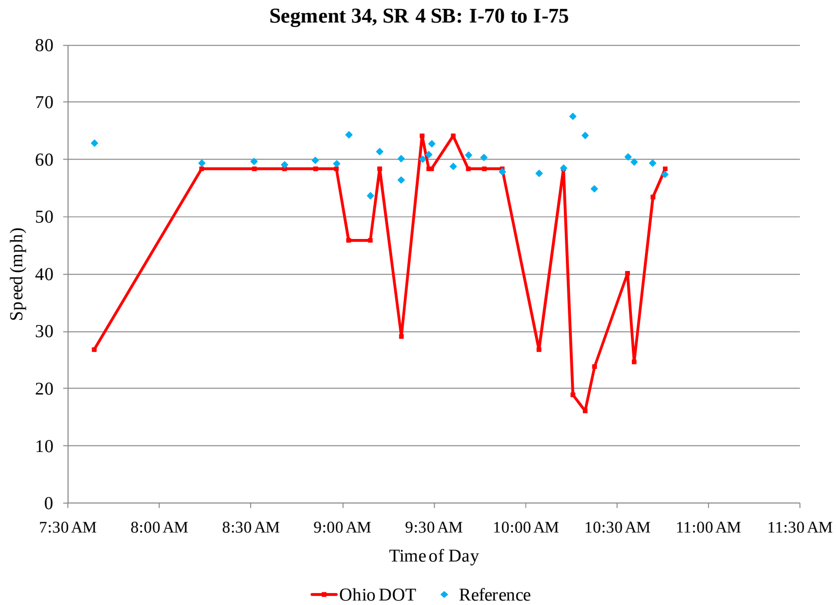
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 20 mph	-	-	-	-	0
20 to 35 mph	-	-	-	-	0
35 to 50 mph	-	-	-	-	0
50+ mph	1.2	6.3	1.1	-5.5	29

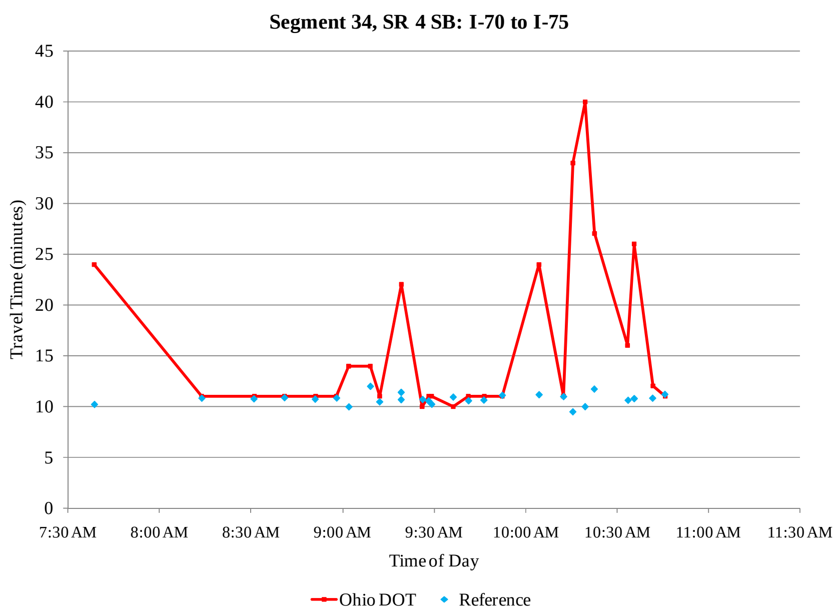




Segment 34: SR 4 SB: I-70 to I-75
Length: 10.7 miles (17.2 km)

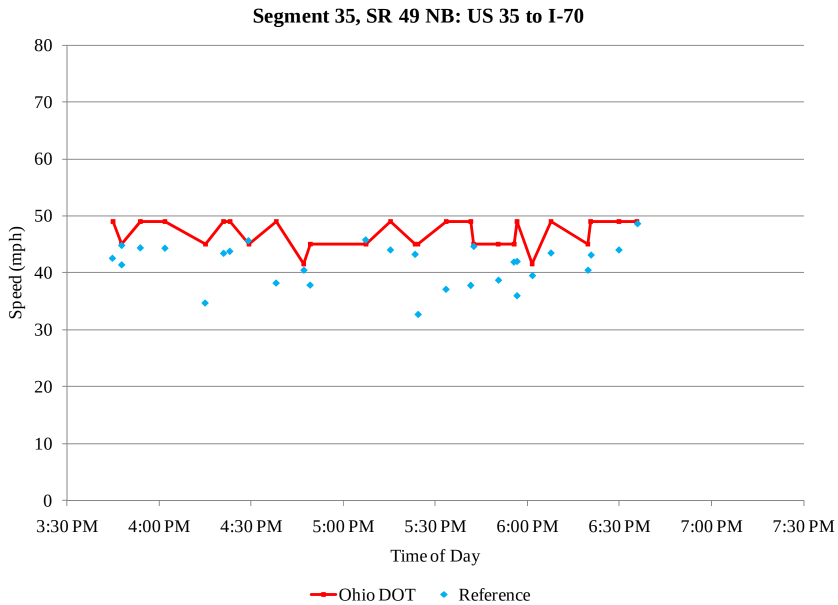
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 20 mph	-	-	-	-	0
20 to 35 mph	-	-	-	-	0
35 to 50 mph	-	-	-	-	0
50+ mph	5.5	13.0	5.4	-9.0	27

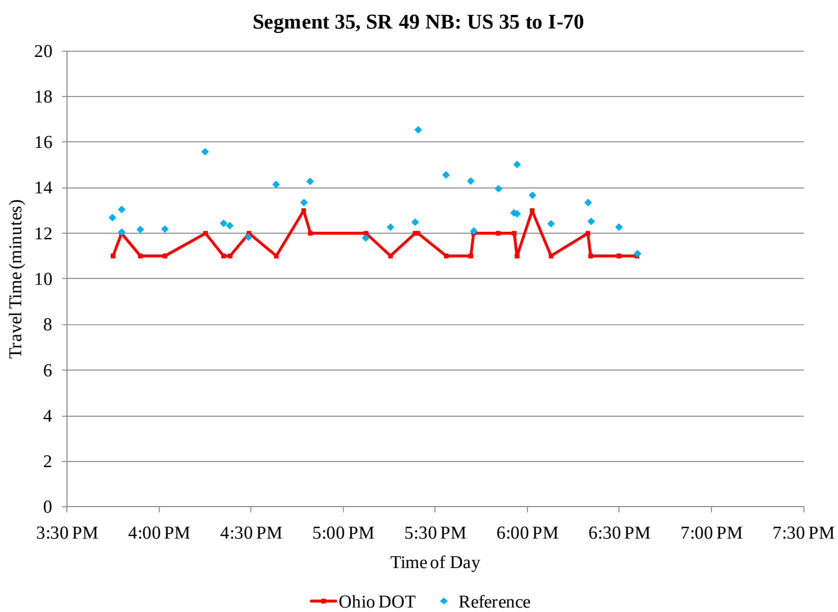




Segment 35: SR 49 NB: US 35 to I-70
Length: 9.0 miles (14.5 km)

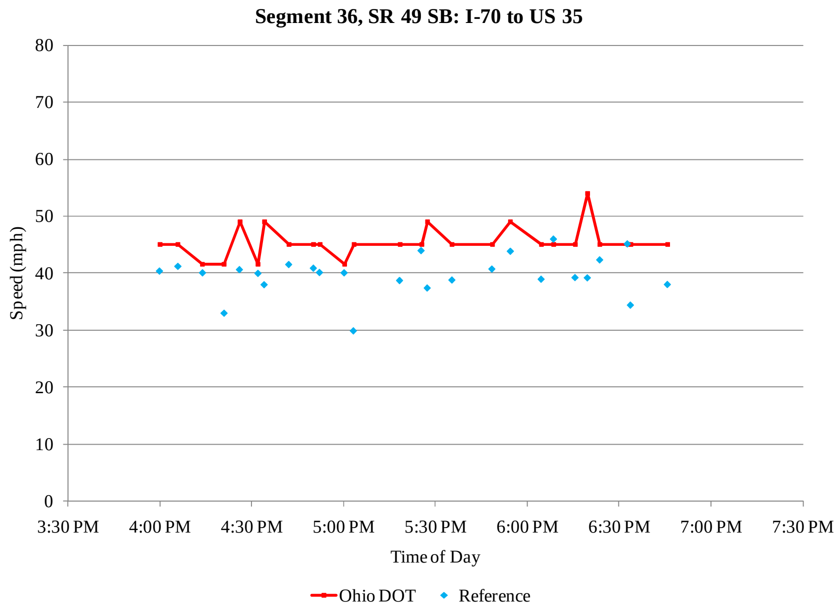
Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 20 mph	-	-	-	-	0
20 to 35 mph	4.5	12.8	-4.5	12.8	2
35 to 50 mph	1.3	5.3	-1.3	5.3	27
50+ mph	-	-	-	-	0

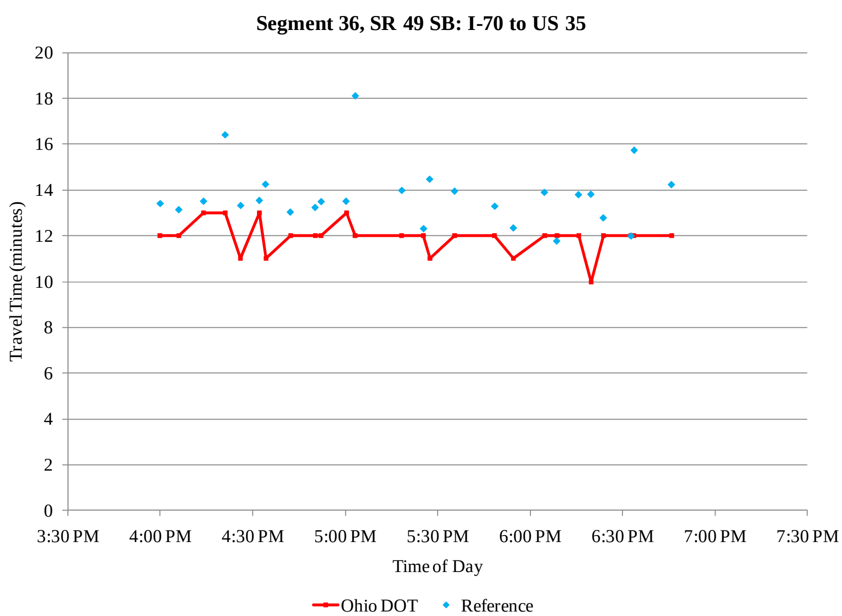




Segment 36: SR 49 SB: I-70 to US 35
Length: 9.0 miles (14.5 km)

Reference Speed Bin	Mean Absolute Difference		Mean Difference (bias)		Comparison Samples
	Travel Time (minutes)	Speed (mph)	Travel Time (minutes)	Speed (mph)	
0 to 20 mph	-	-	-	-	0
20 to 35 mph	4.3	11.7	-4.3	11.7	3
35 to 50 mph	1.4	5.4	-1.4	5.4	23
50+ mph	-	-	-	-	0

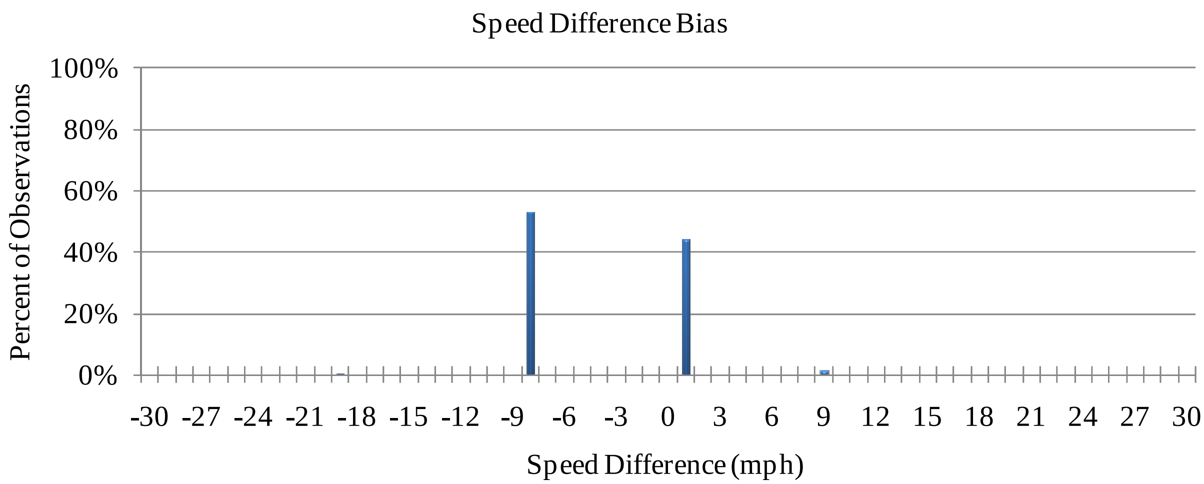


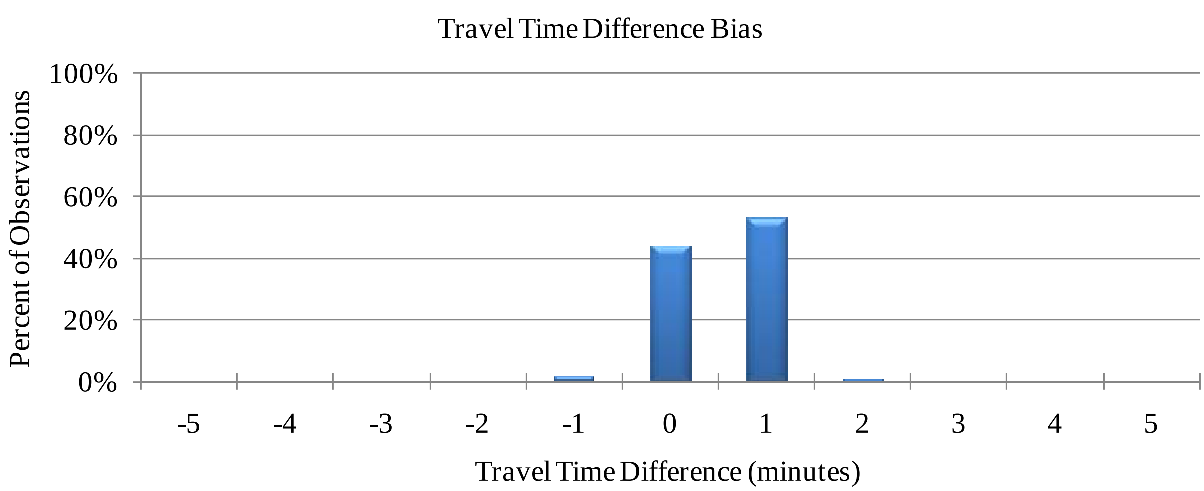


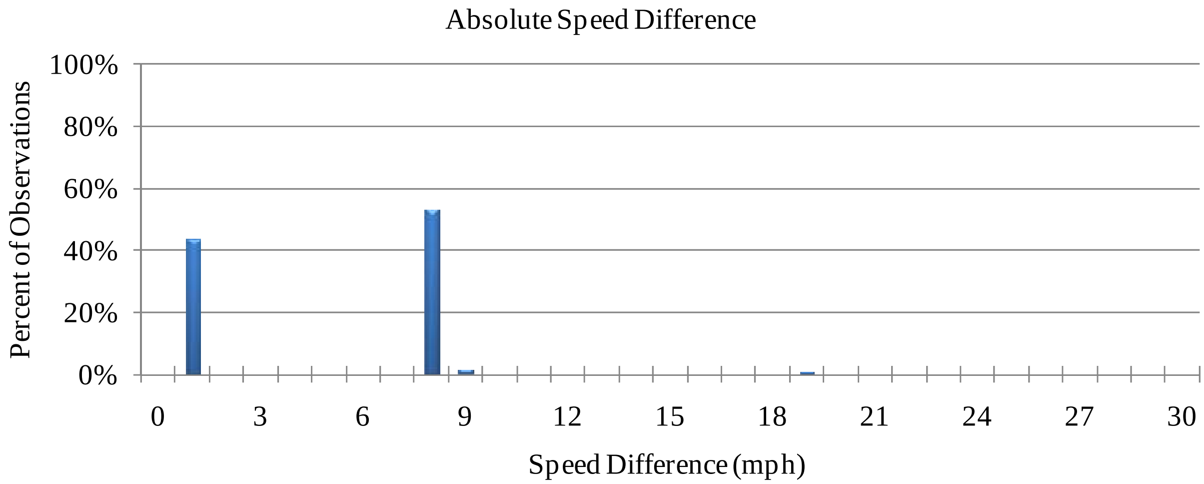
APPENDIX E

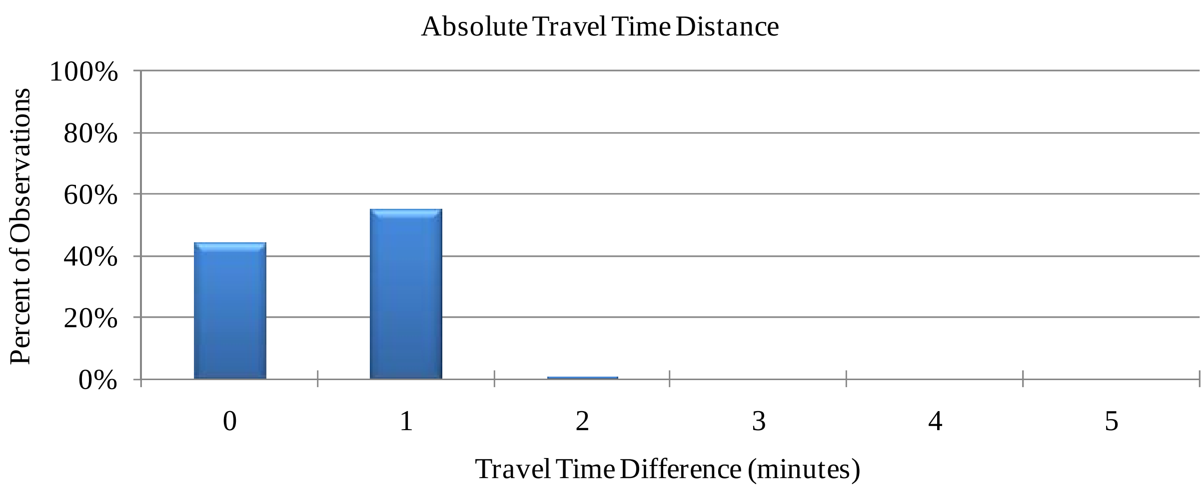
SPEED AND TRAVEL TIME DISTRIBUTION

Segment 1: I-70 EB: SR 49 to I-75
Length: 8.0 miles (12.9 km)

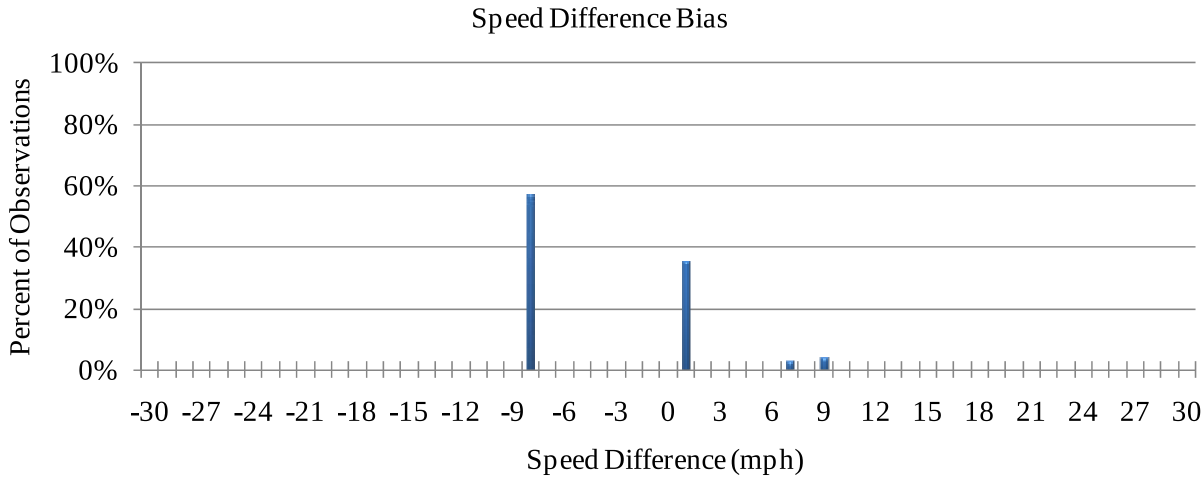


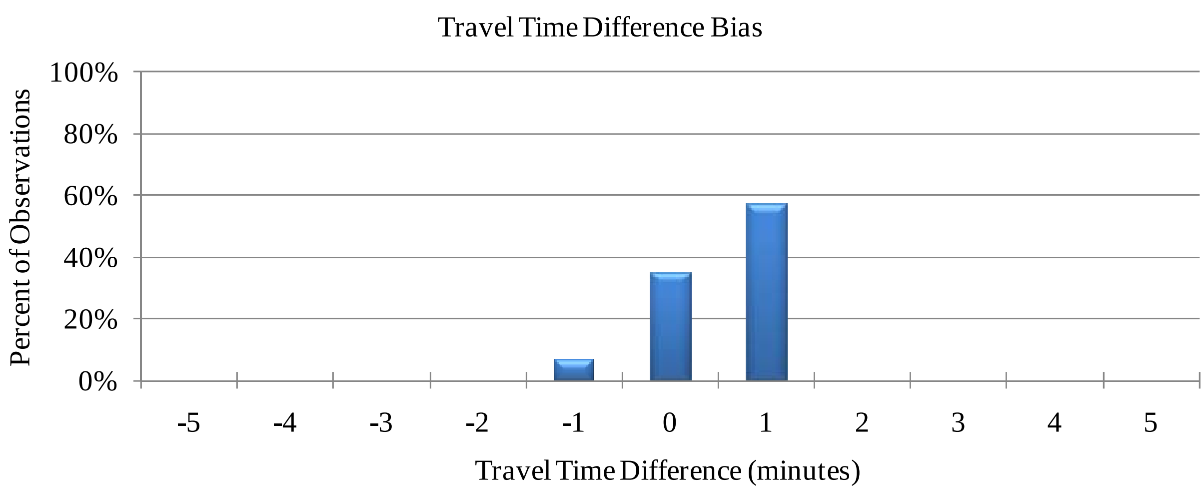


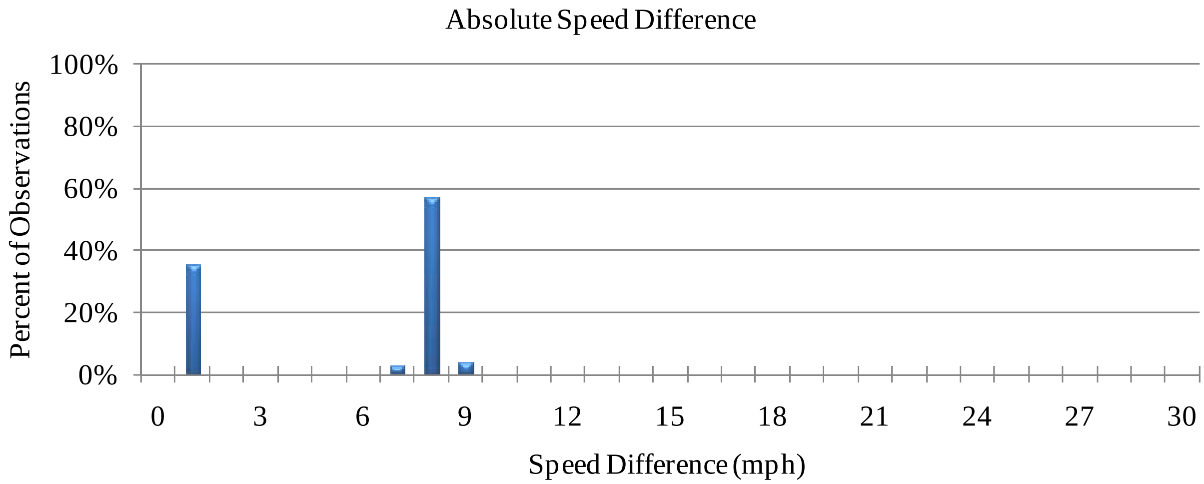

Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

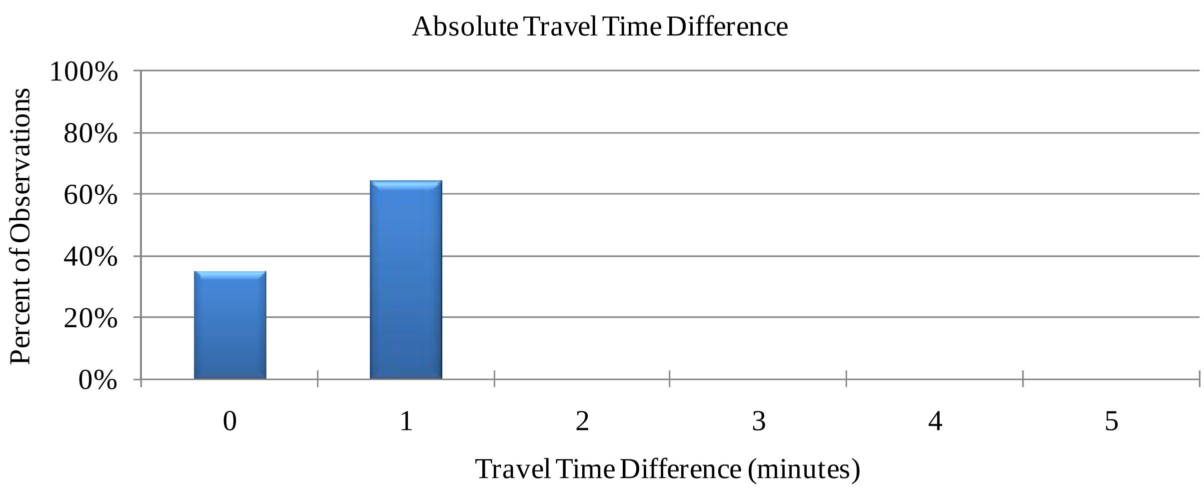

Absolute Travel Time Distance
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 2: I-70 WB: I-75 to SR 49
Length: 8.0 miles (12.9 km)

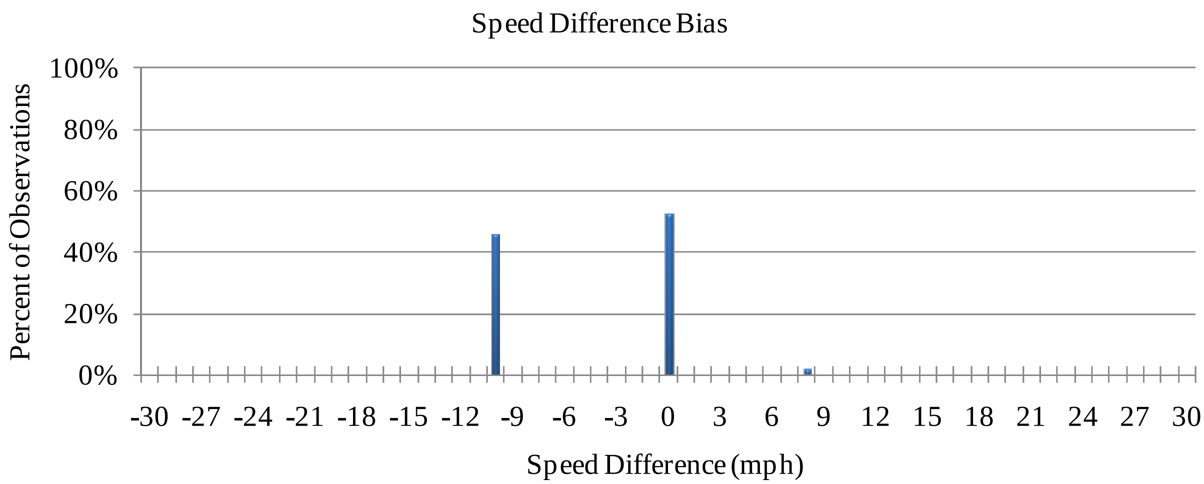


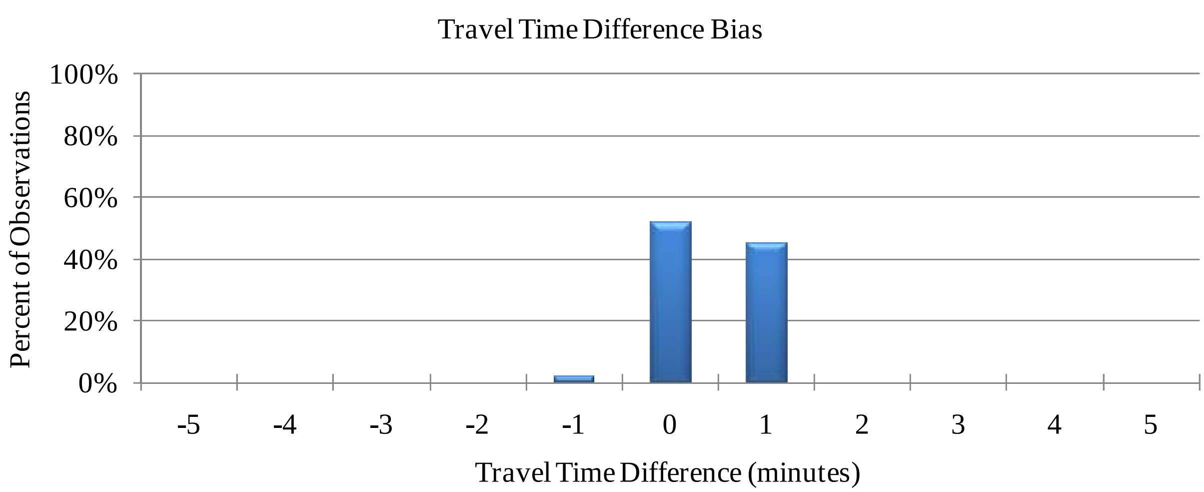


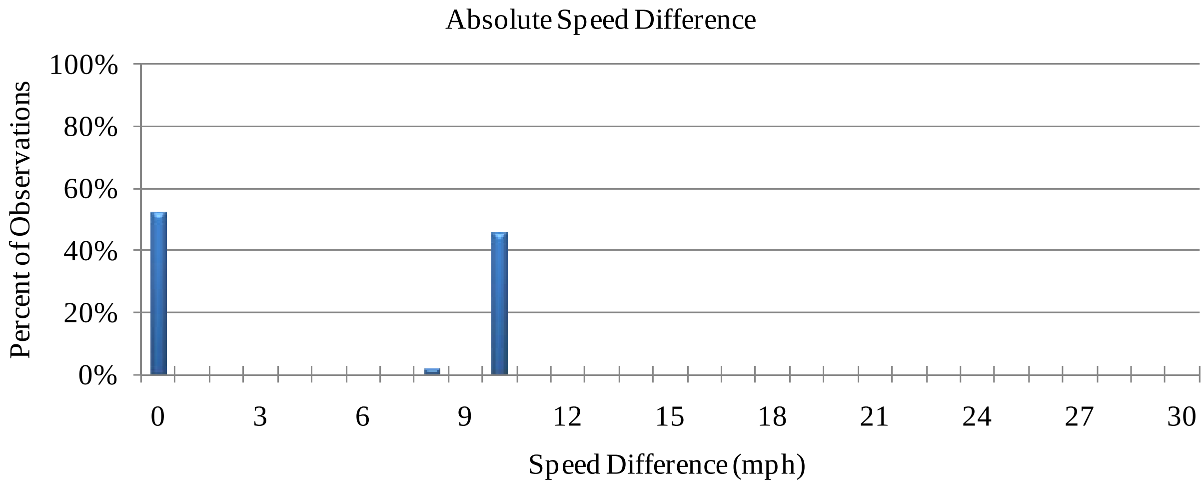

Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)


Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
Travel Time Difference (minutes)

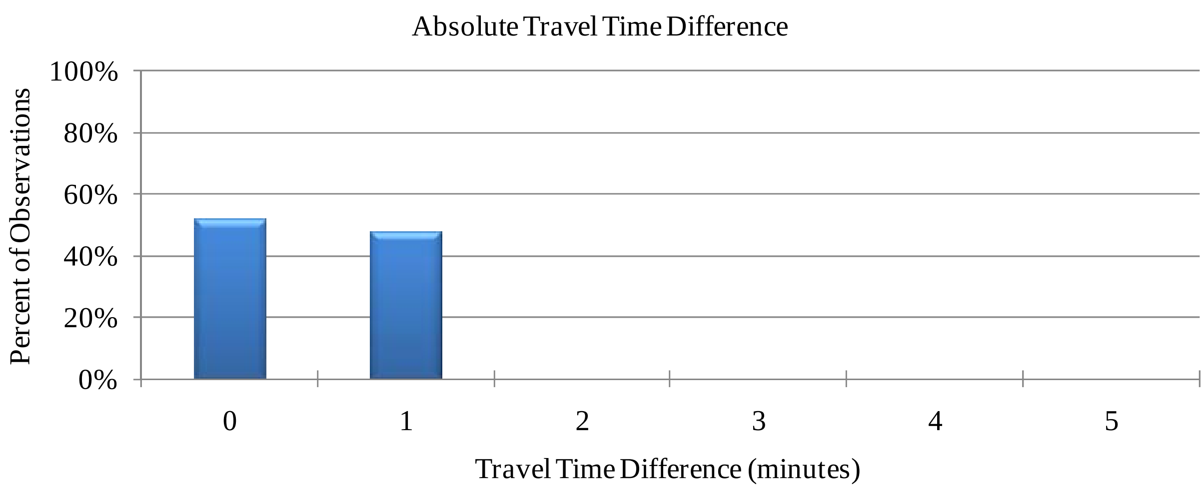
Segment 3: I-70 EB: I-75 to SR 4 (South)
Length: 7.2 miles (11.6 km)





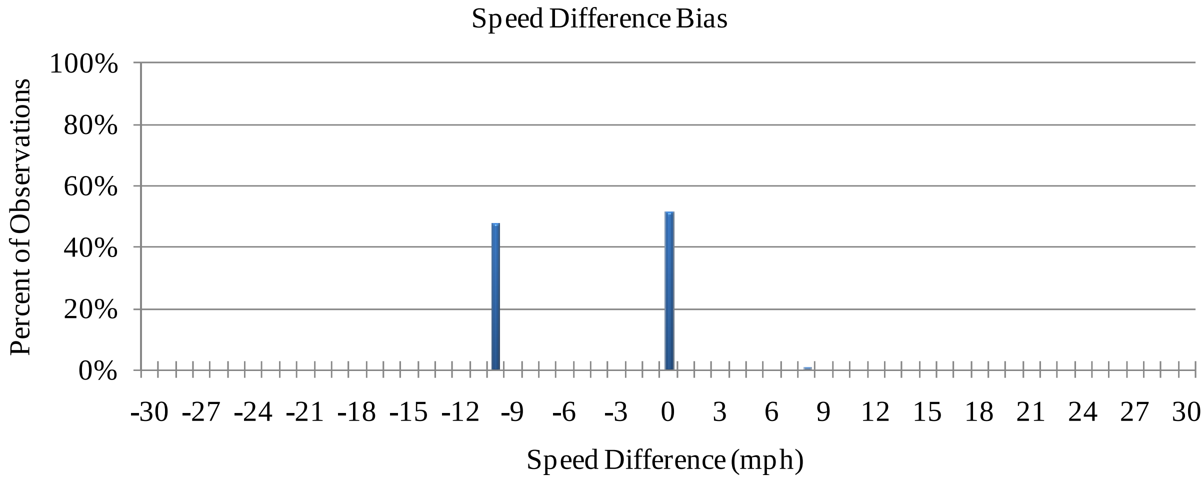


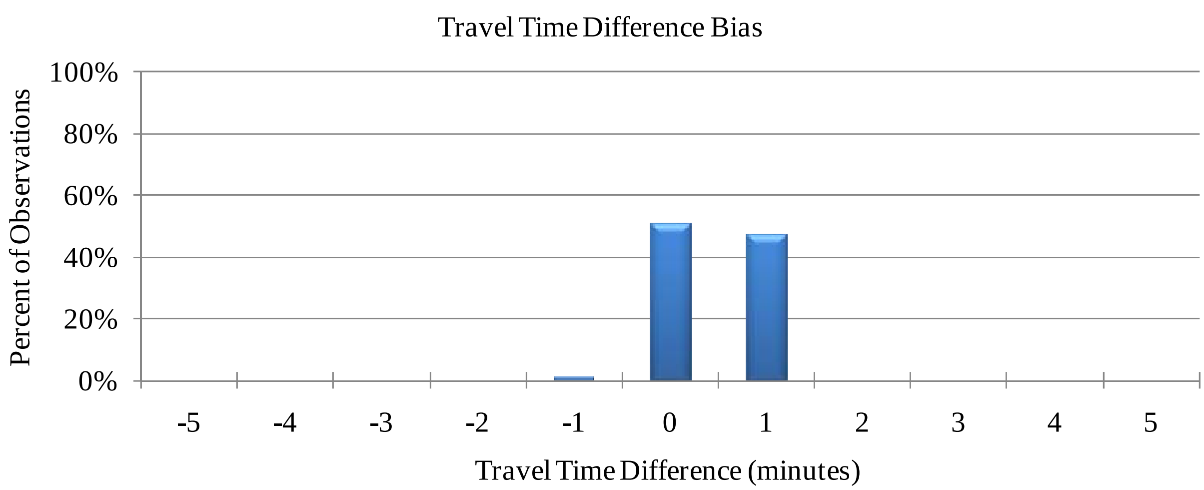
Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

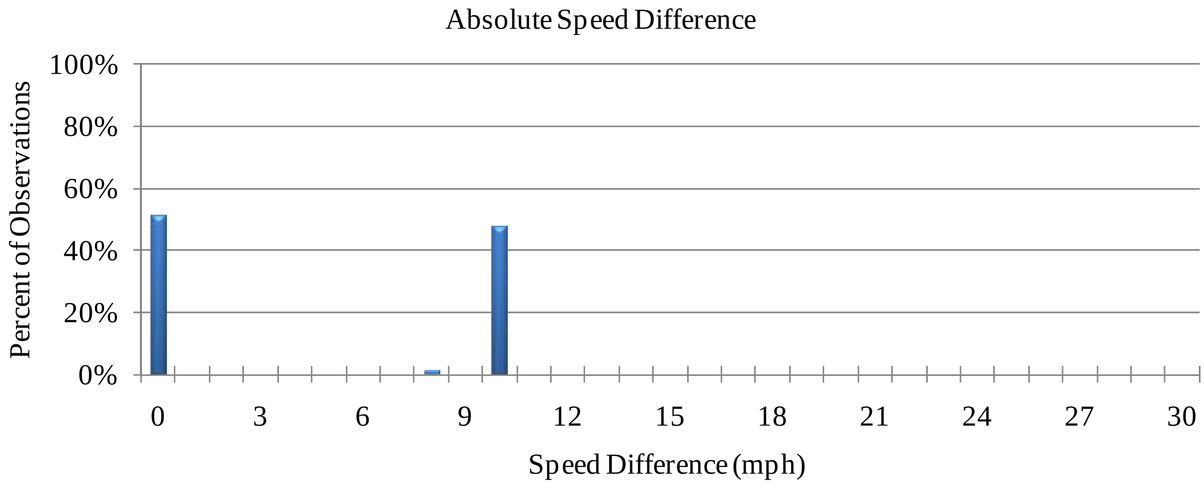


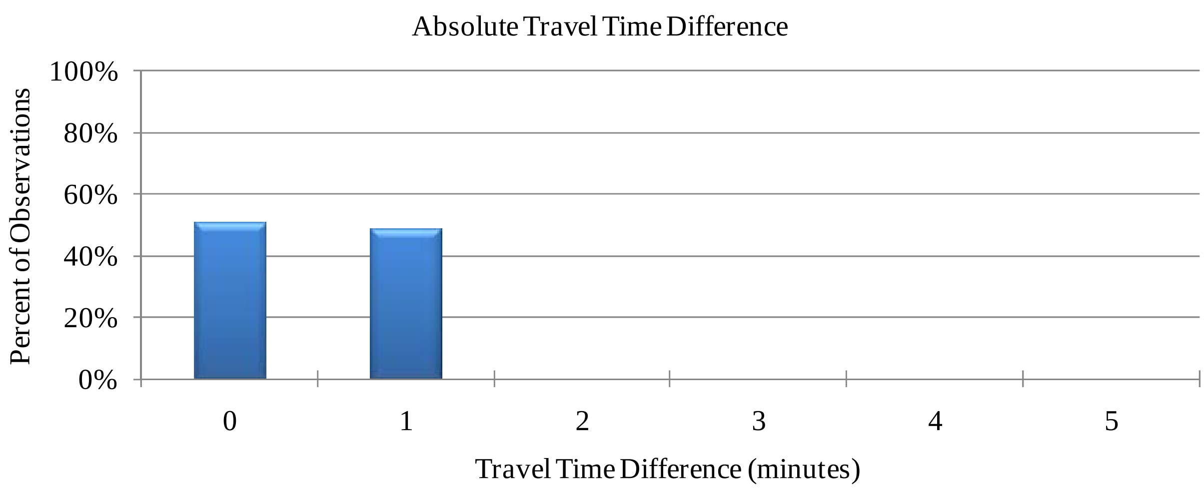
Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 4: I-70 WB: SR 4 (South) to I-75
Length: 7.2 miles (11.6 km)

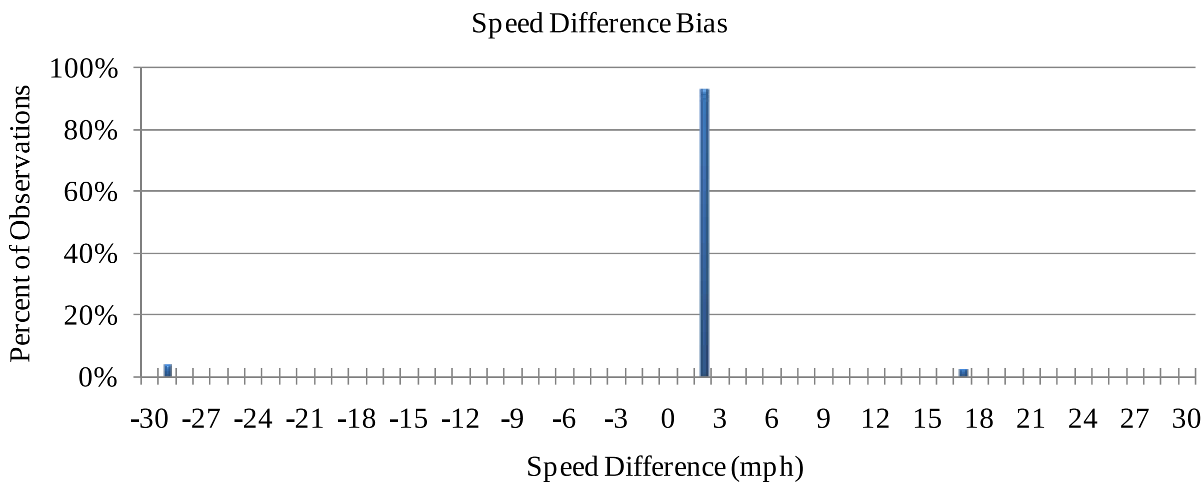


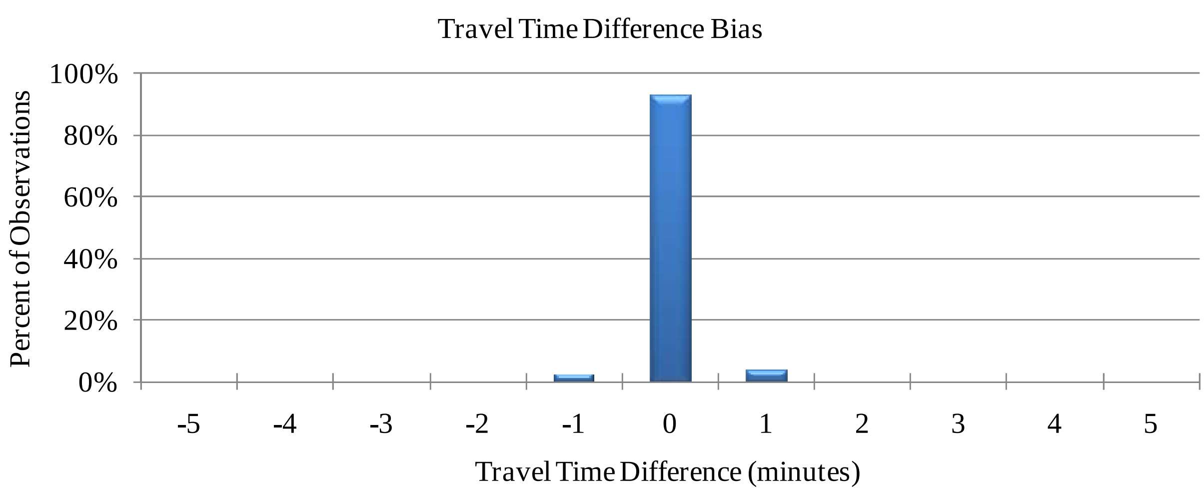


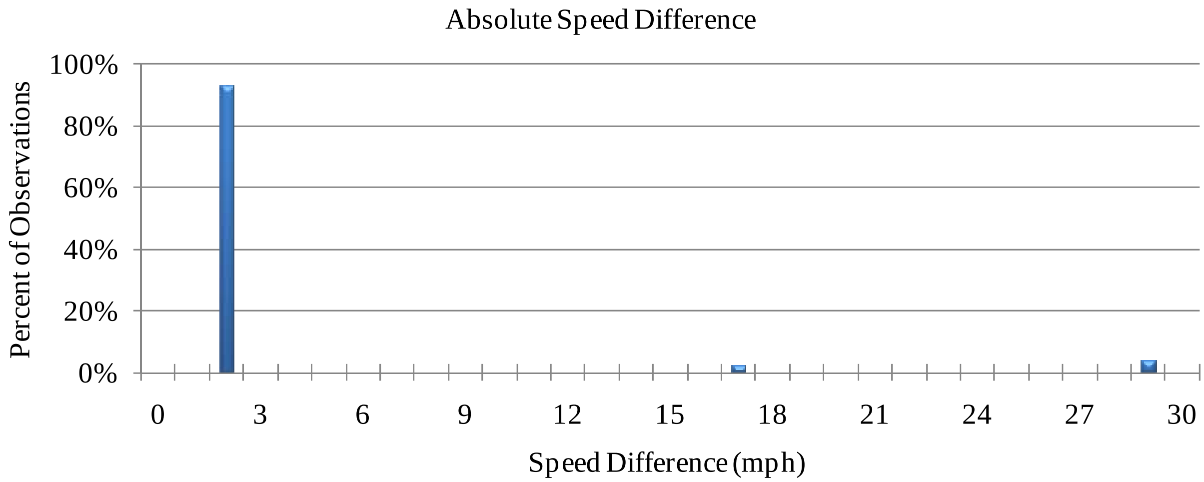

Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

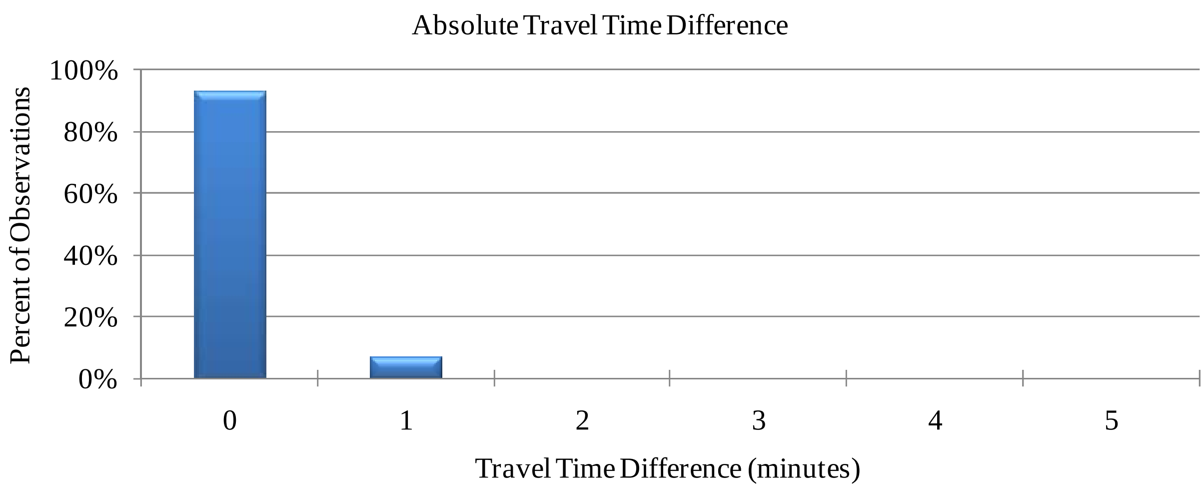

Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 5: I-70 EB: SR 4 (South) to I-675
Length: 3.2 miles (5.1 km)

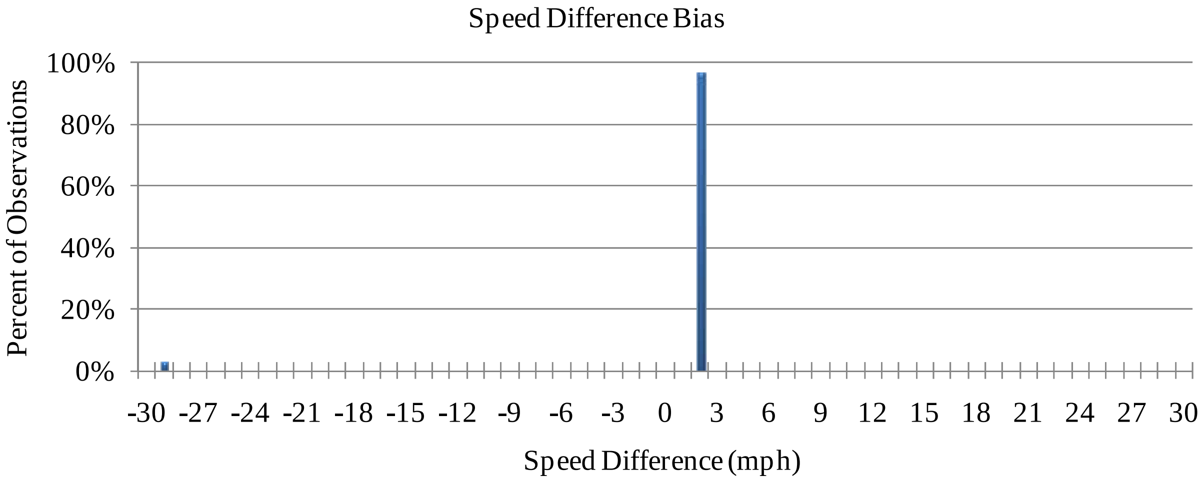


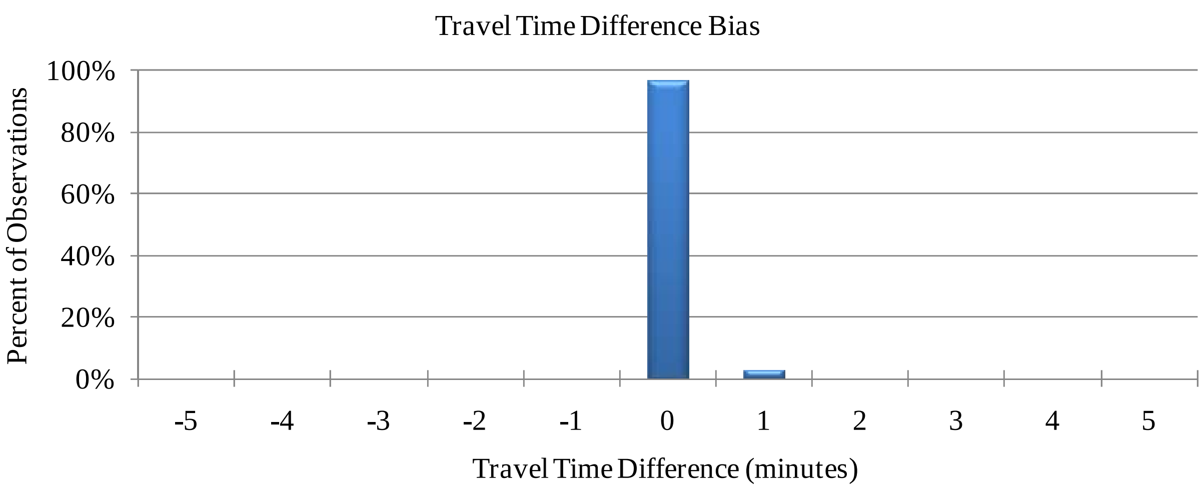


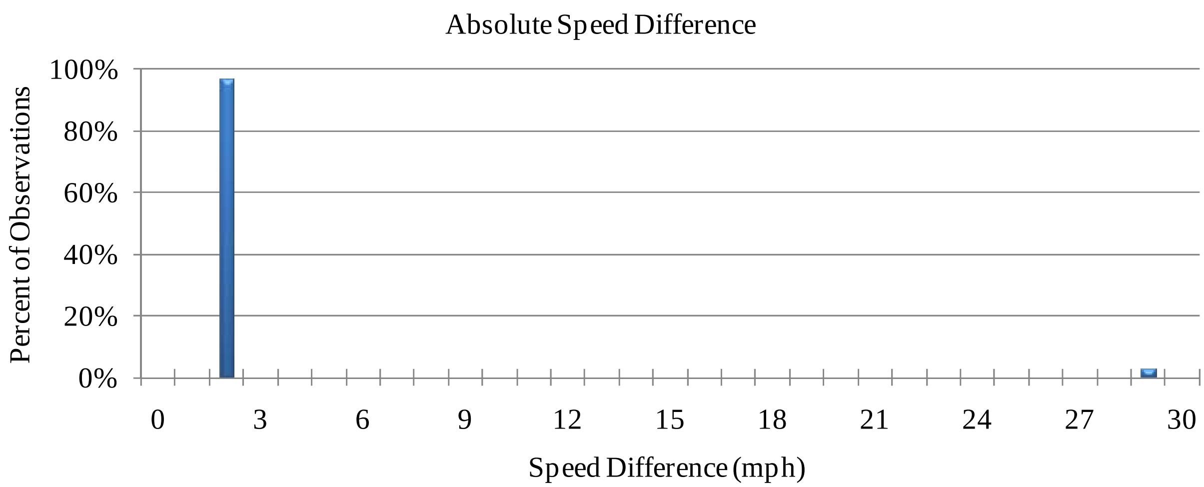

Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)


Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
Travel Time Difference (minutes)

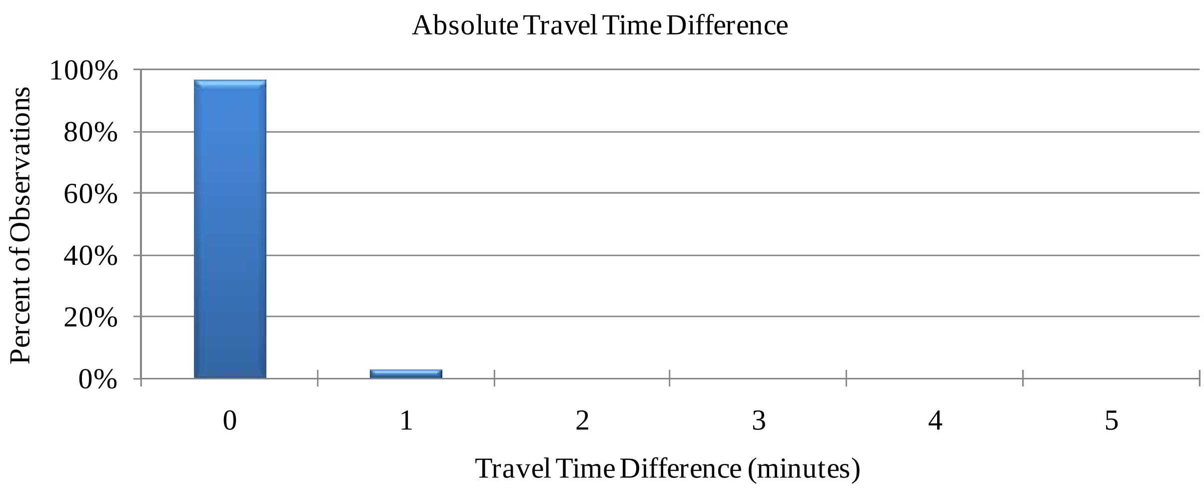
Segment 6: I-70 WB: I-675 to SR 4 (South)
Length: 3.2 miles (5.1 km)







Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)



Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 7: I-70 EB: I-675 to SR 4 (Enon)

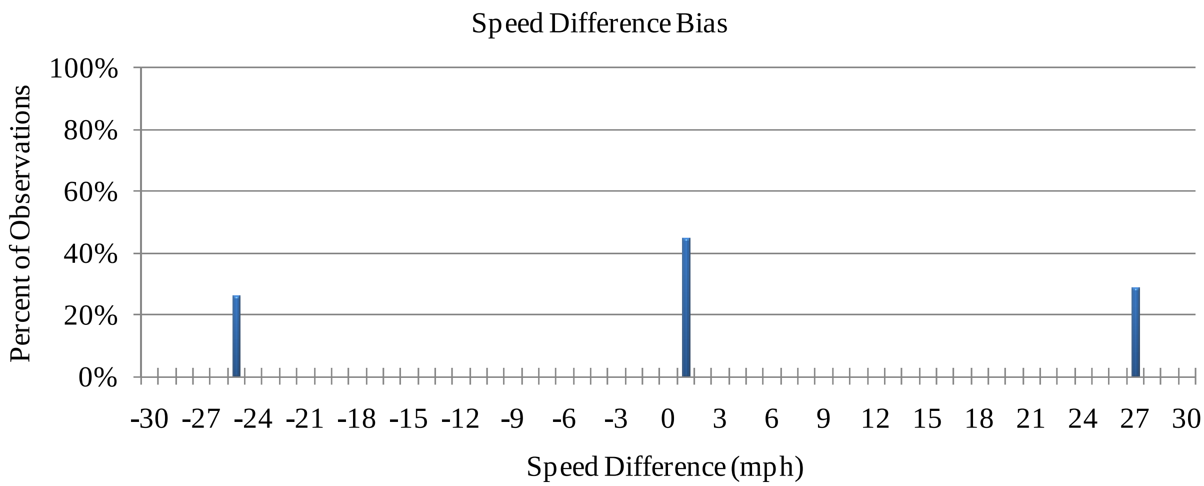
Length: 2.9 miles (4.7 km)

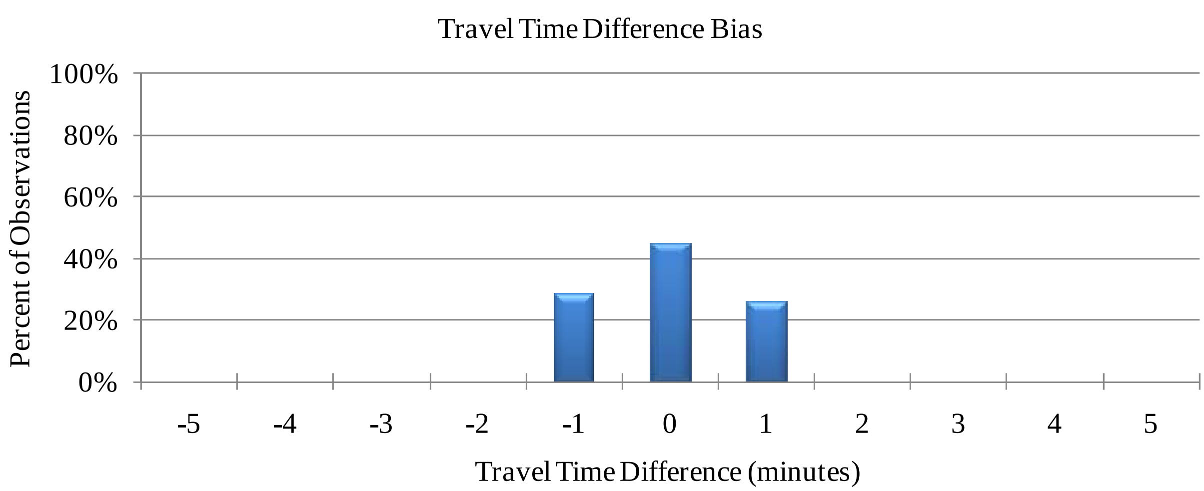
No Evaluation Data Available

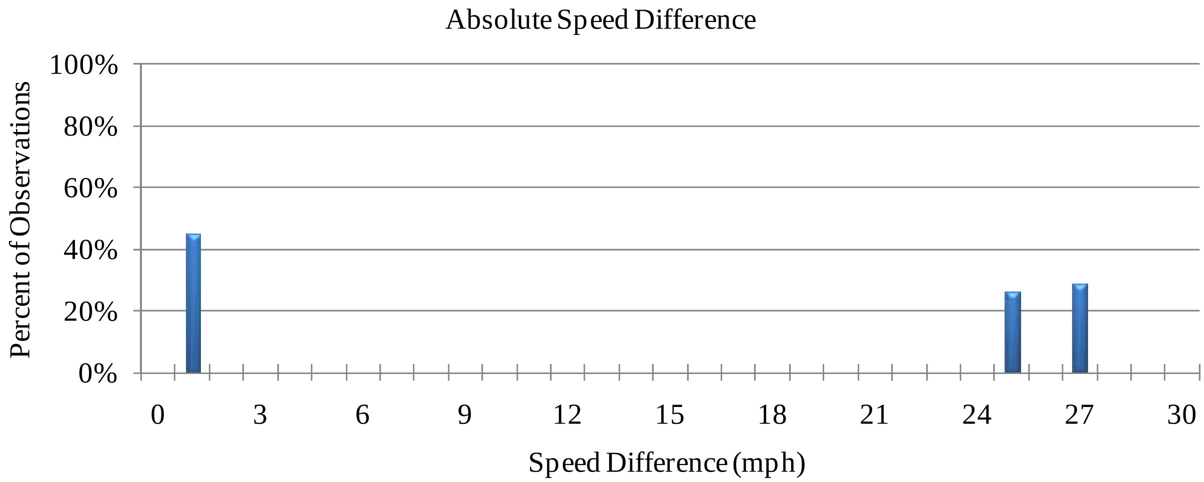
Segment 8: I-70 WB: SR 4 (Enon) to I-675
Length: 2.9 miles (4.7 km)

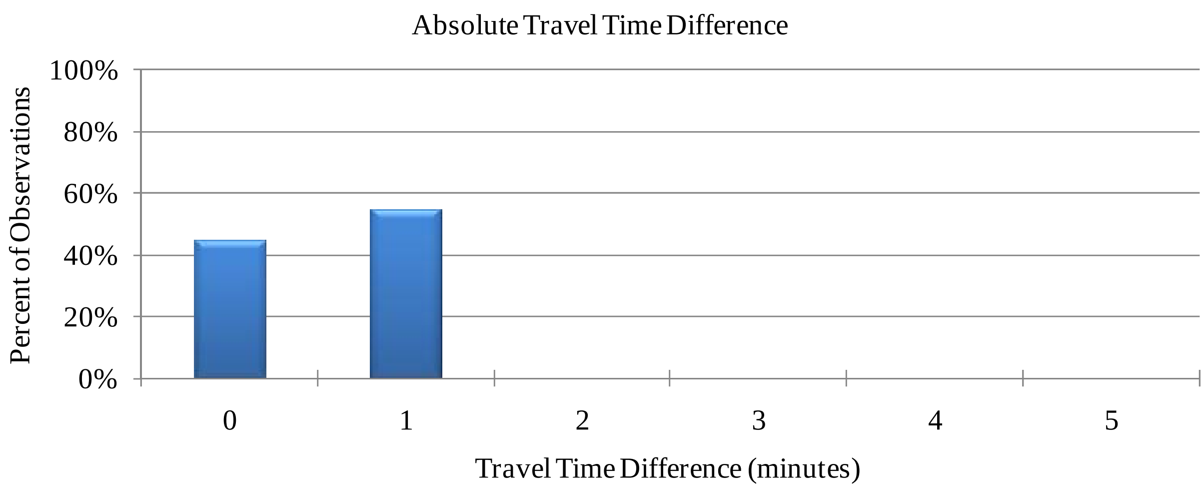
No Evaluation Data Available

Segment 9: I-75 NB: County Line (Warren) to I-675
Length: 2.6 miles (4.2 km)

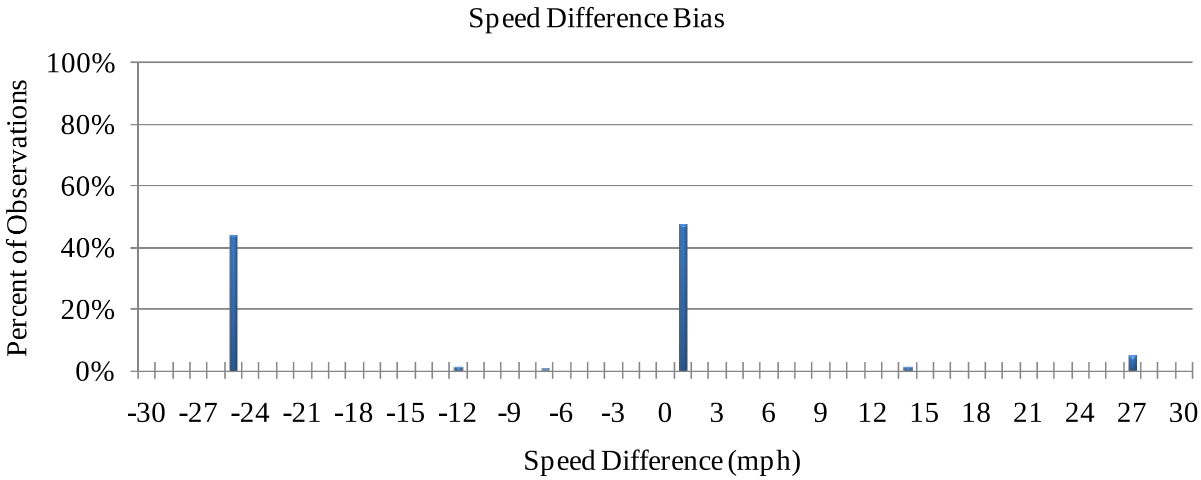


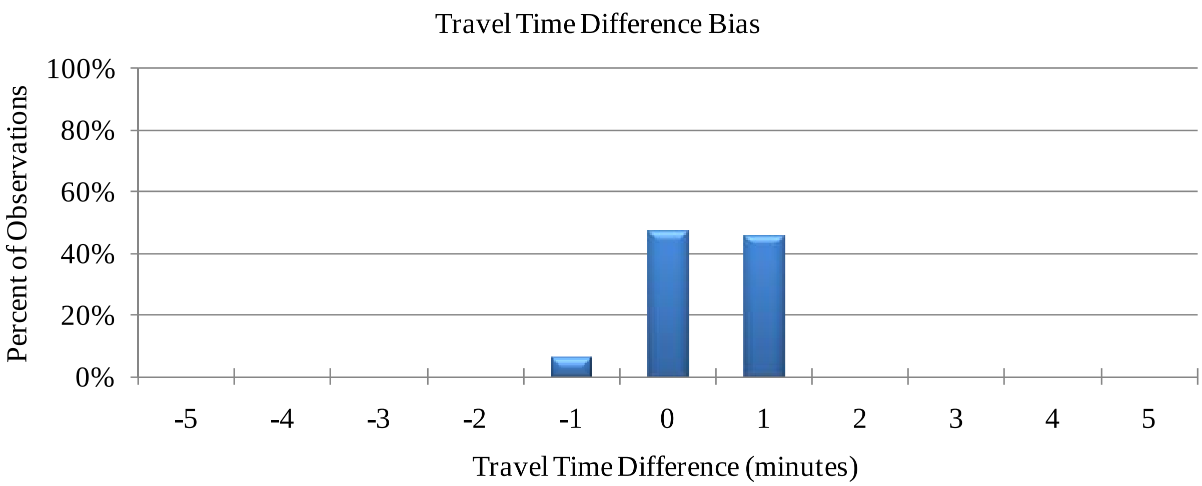


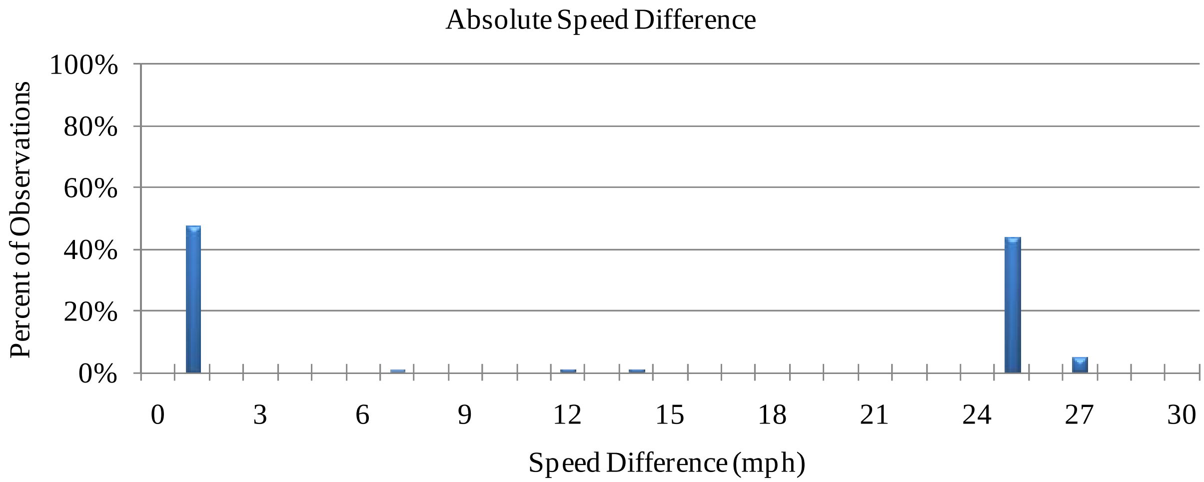

Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

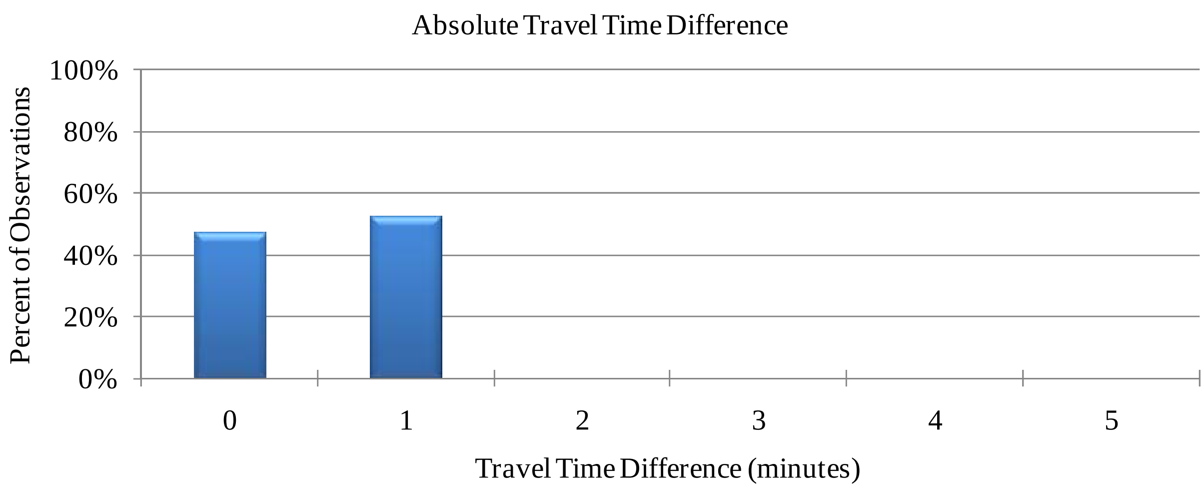

Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 10: I-75 SB: I-675 to County Line (Warren)
Length: 2.6 miles (4.2 km)

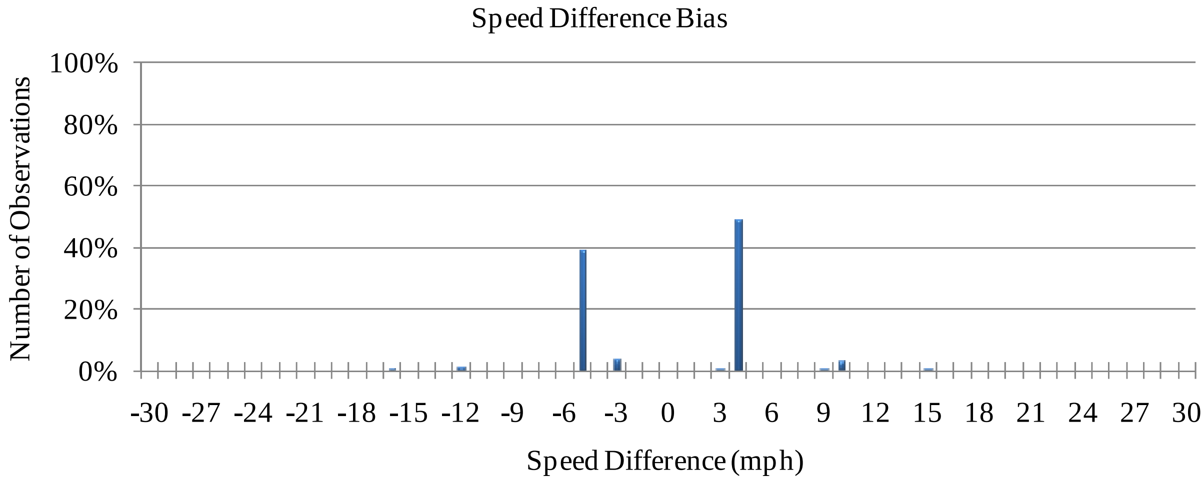


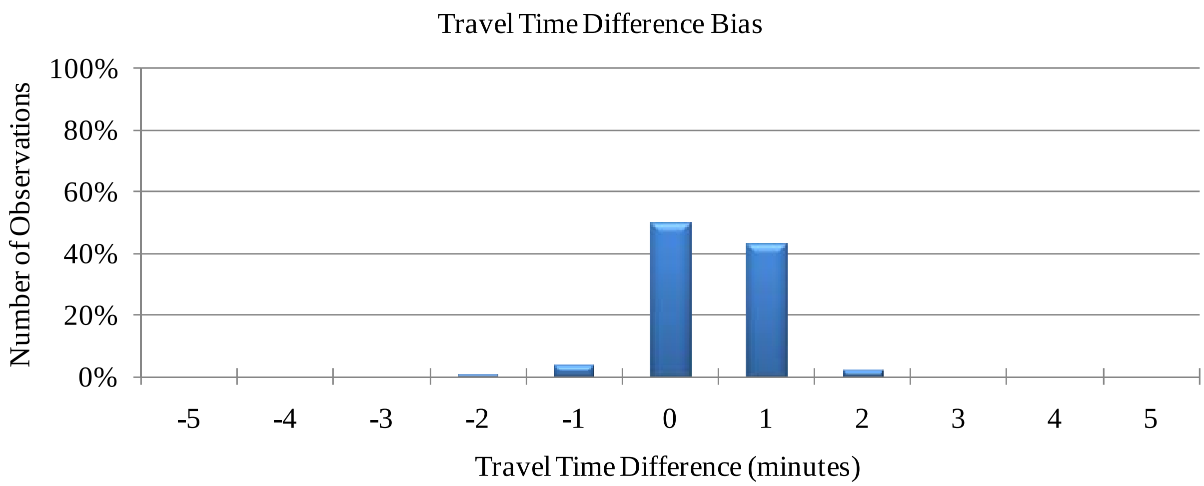


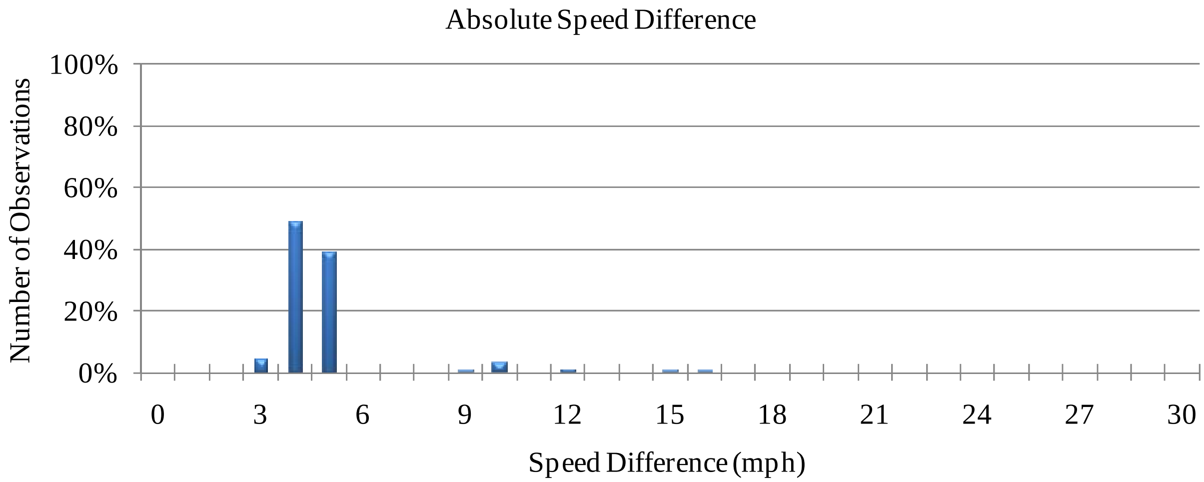

Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

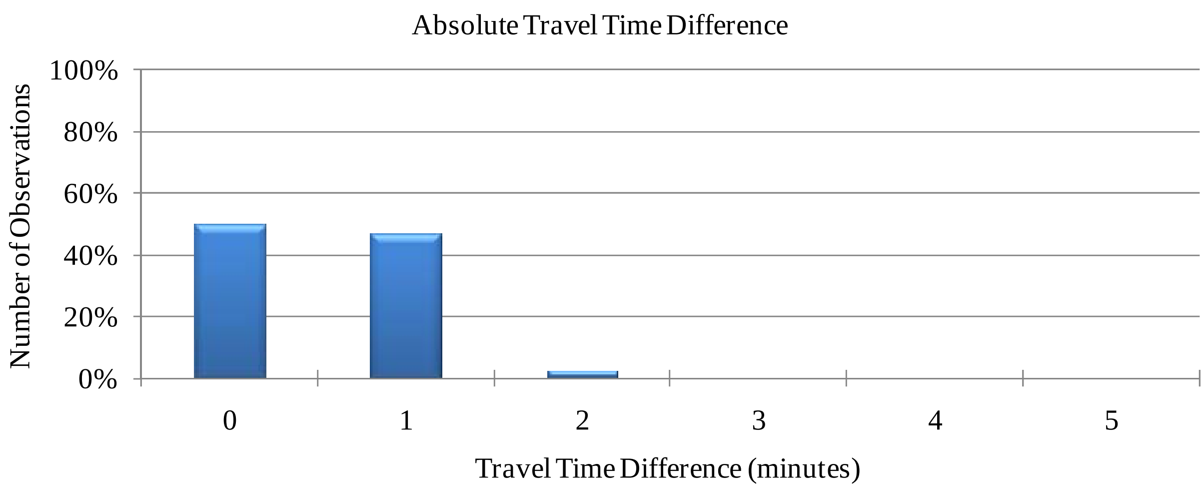

Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 11: I-75 NB: I-675 to Carillon Blvd
Length: 8.3 miles (13.4 km)

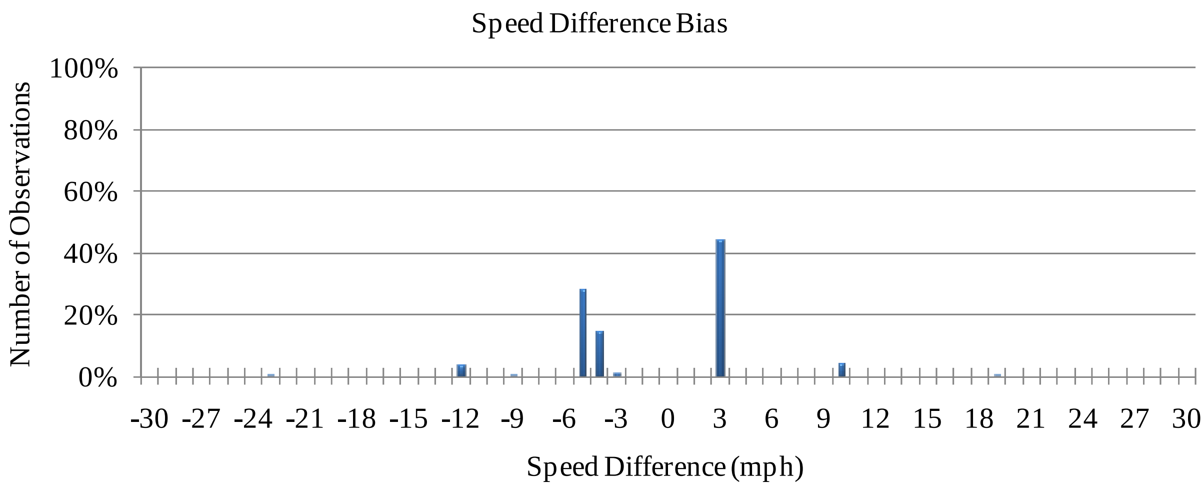


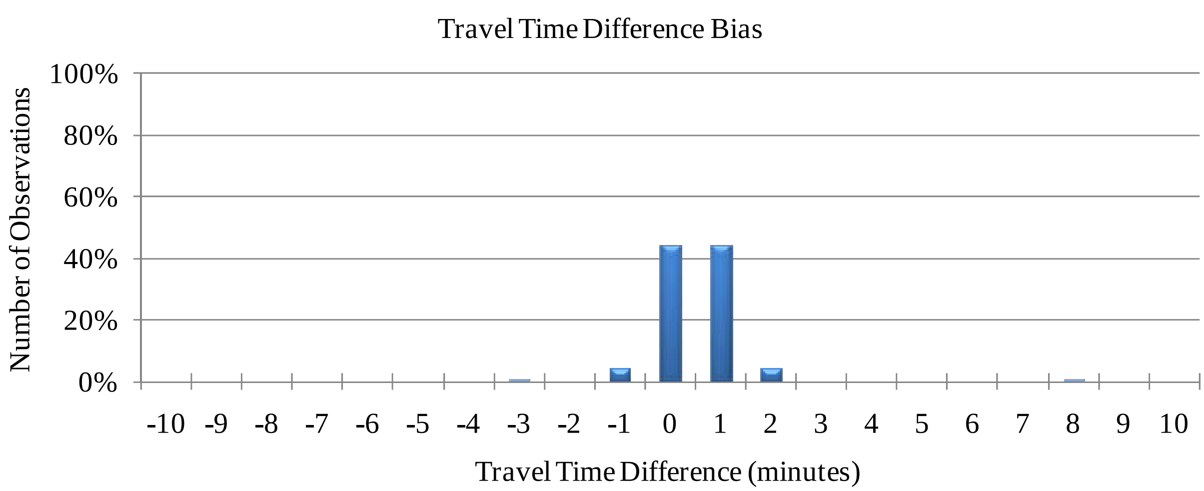


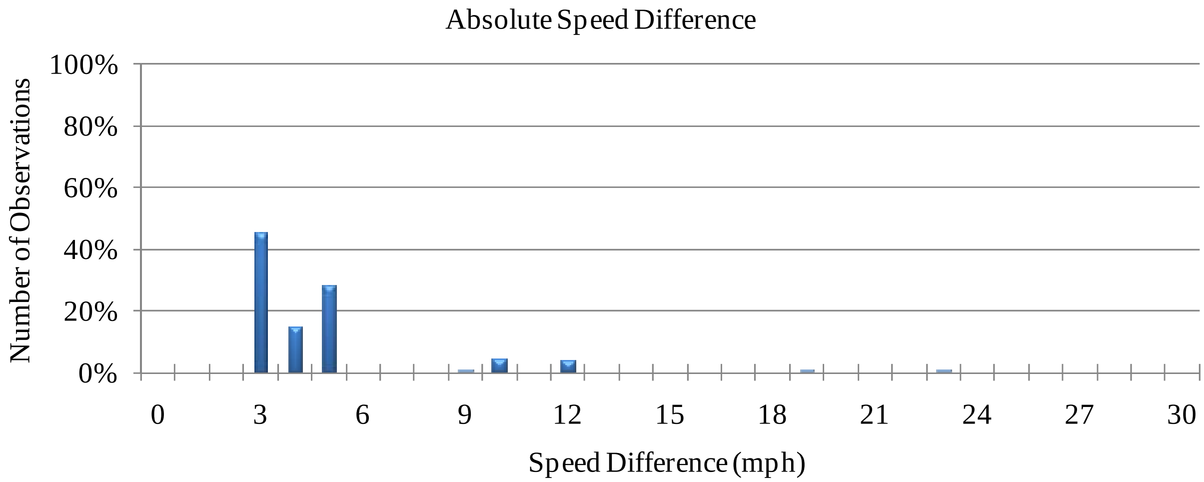

Absolute Speed Difference
Number of Observations
100%
80%
60%
40%
20%
0%
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

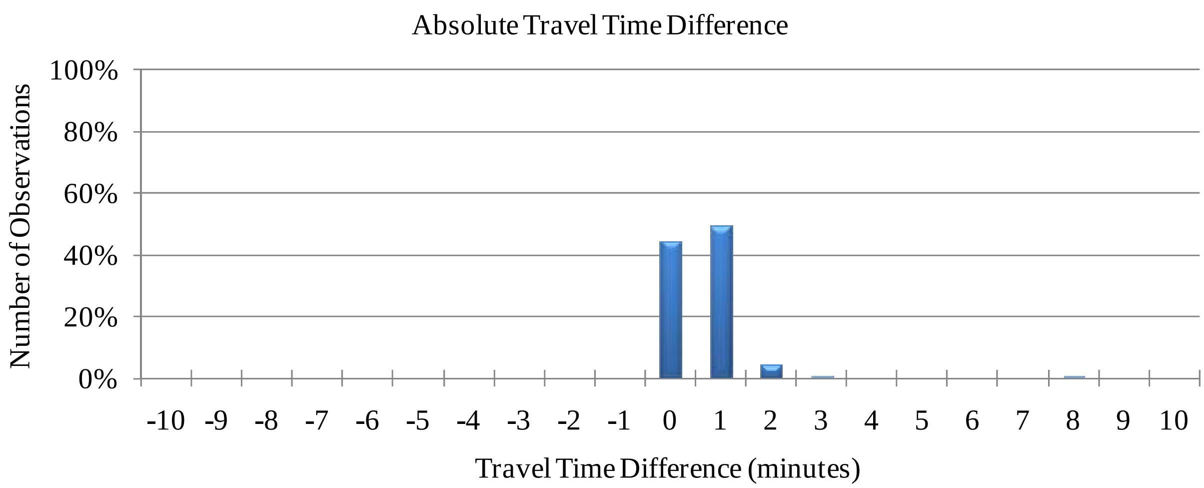

Absolute Travel Time Difference
Number of Observations
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 12: I-75 SB: Carillon Blvd to I-675
Length: 8.3 miles (13.4 km)

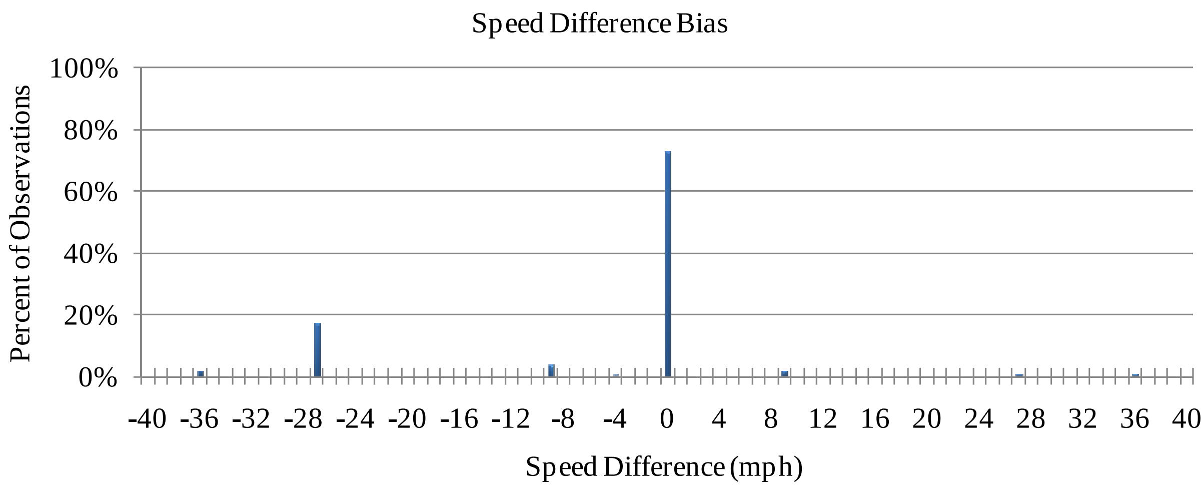


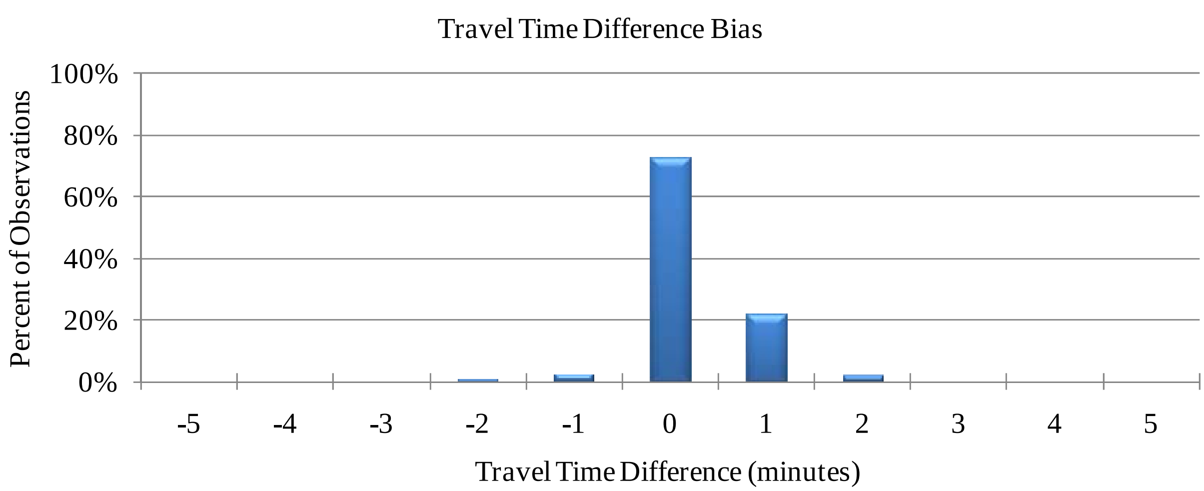


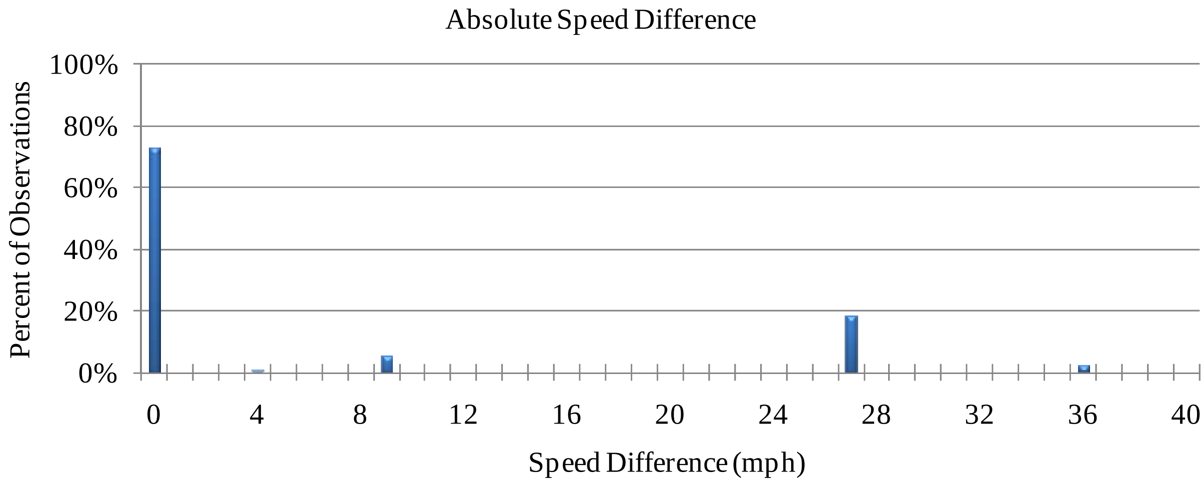

Absolute Speed Difference
Number of Observations
100%
80%
60%
40%
20%
0%
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)


Absolute Travel Time Difference
Number of Observations
100%
80%
60%
40%
20%
0%
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10
Travel Time Difference (minutes)

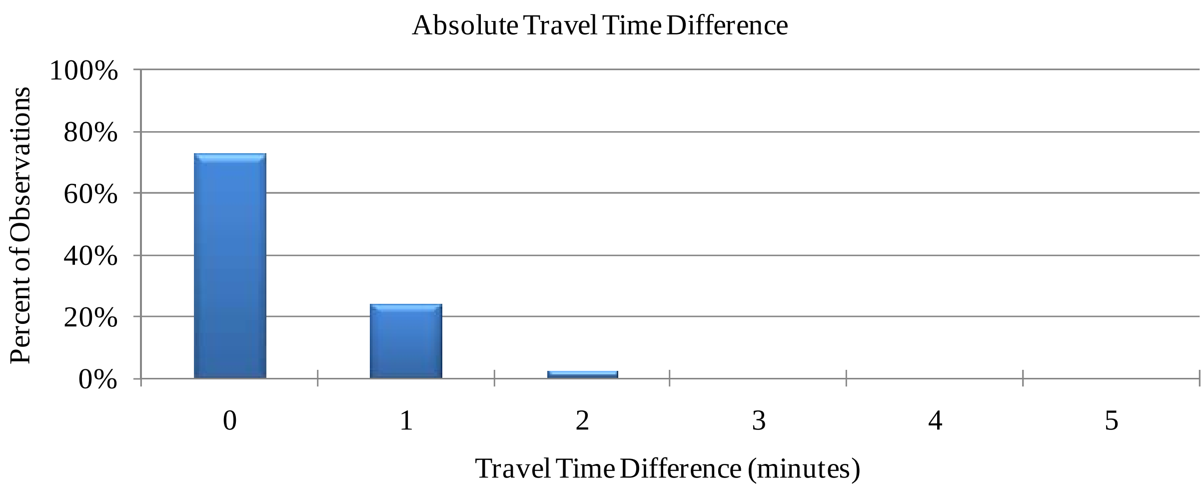
Segment 13: I-75 NB: Carillon Blvd to US 35
Length: 0.9 miles (1.4 km)





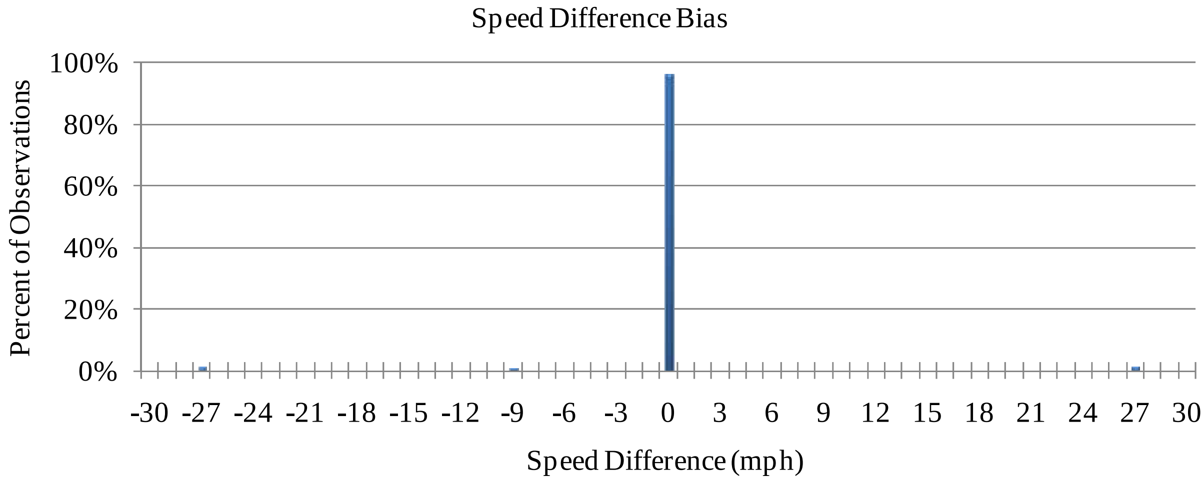


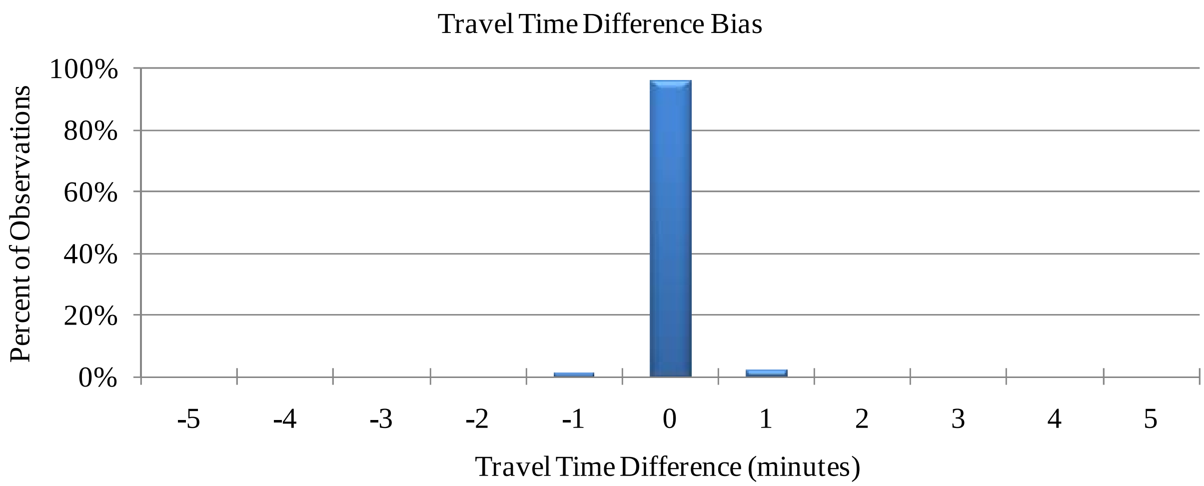
Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
4
8
12
16
20
24
28
32
36
40
Speed Difference (mph)

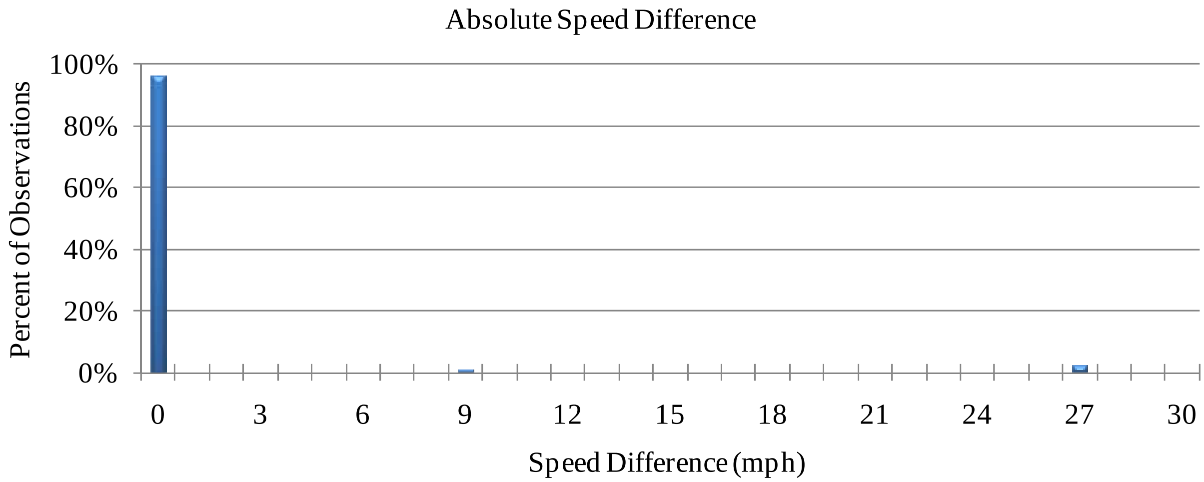


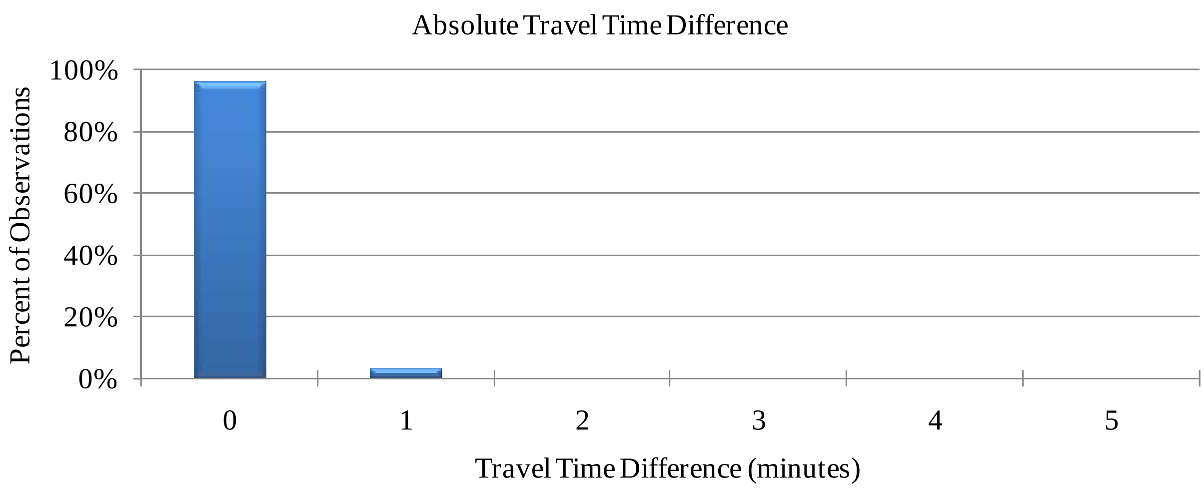
Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 14: I-75 SB: US 35 to Carillon Blvd
Length: 0.9 miles (1.4 km)

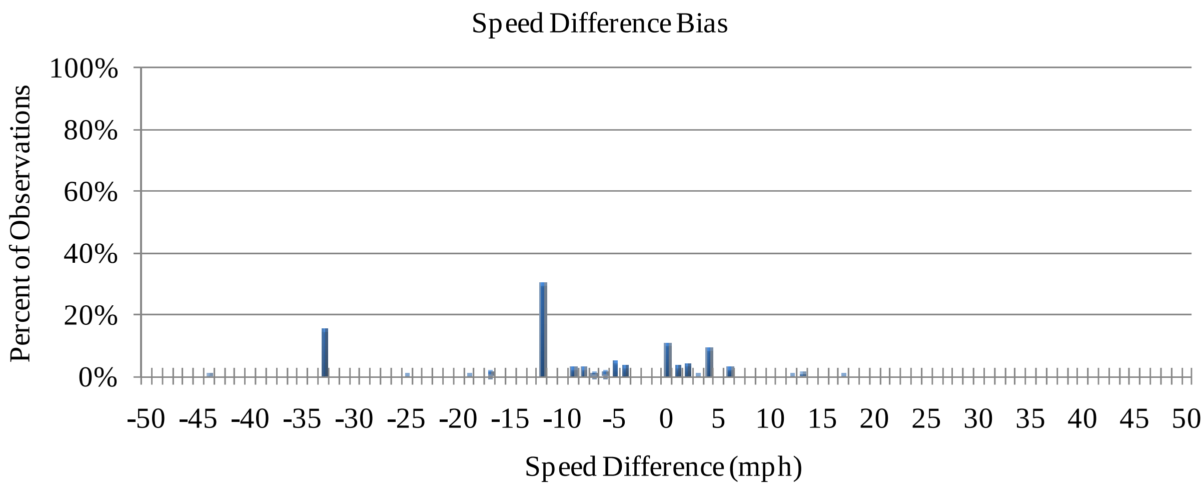


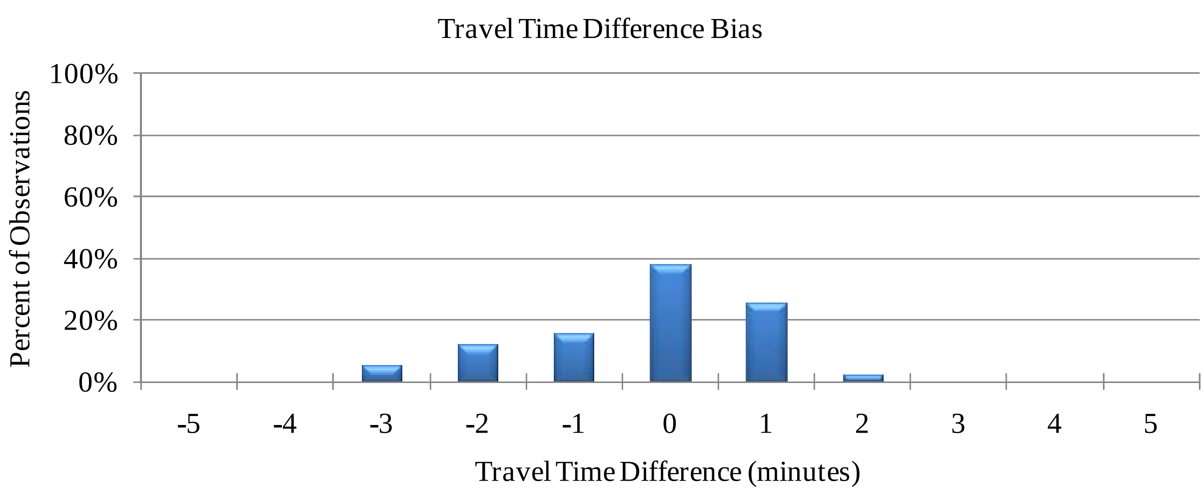


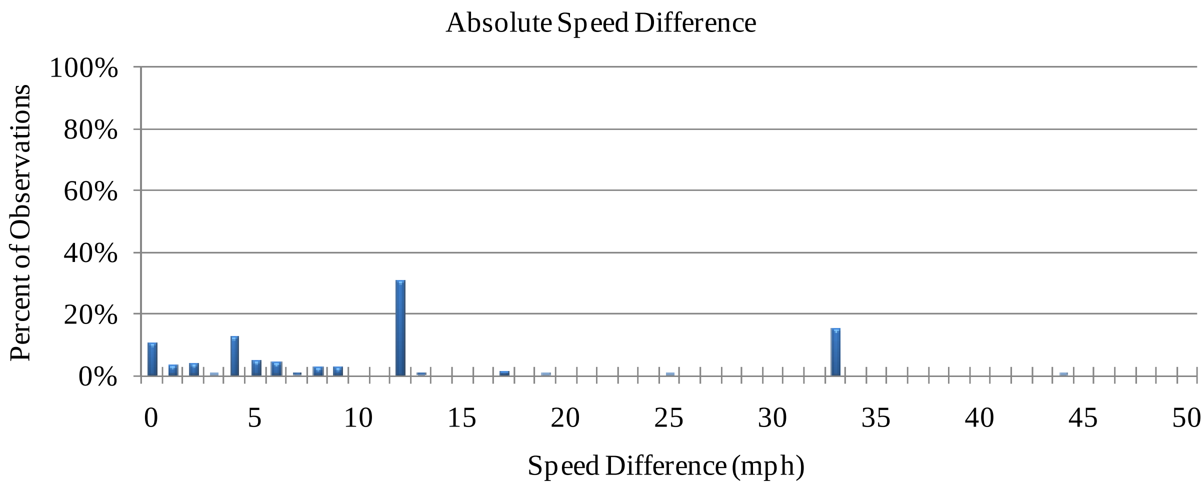

Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

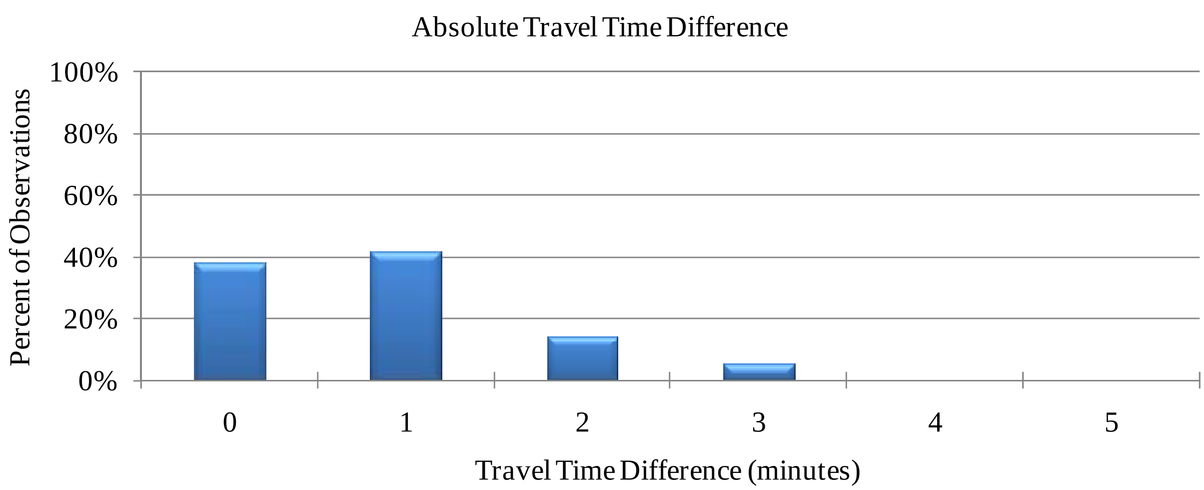

Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 15: I-75 NB: US 35 to SR 4
Length: 2.1 miles (3.4 km)

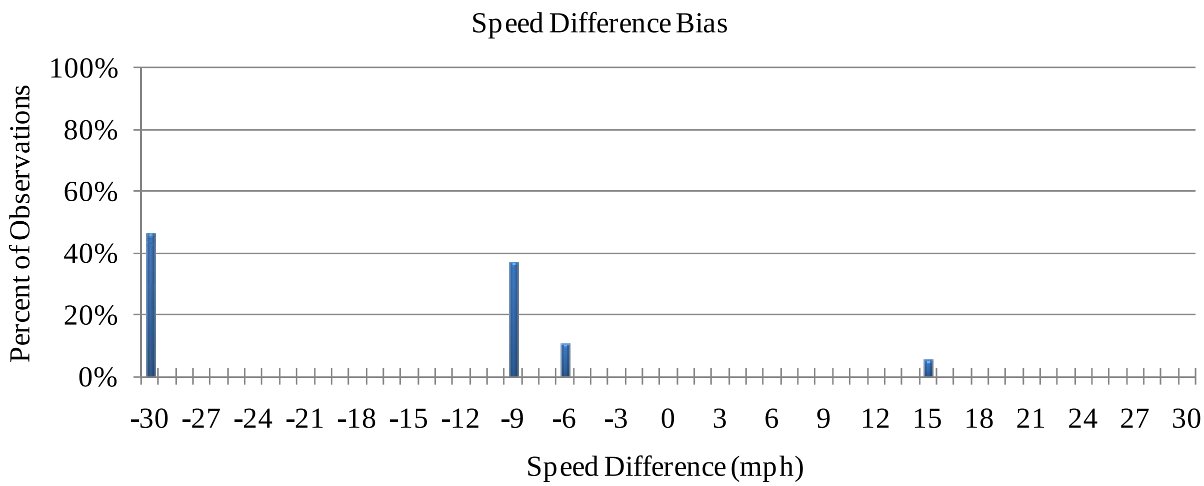


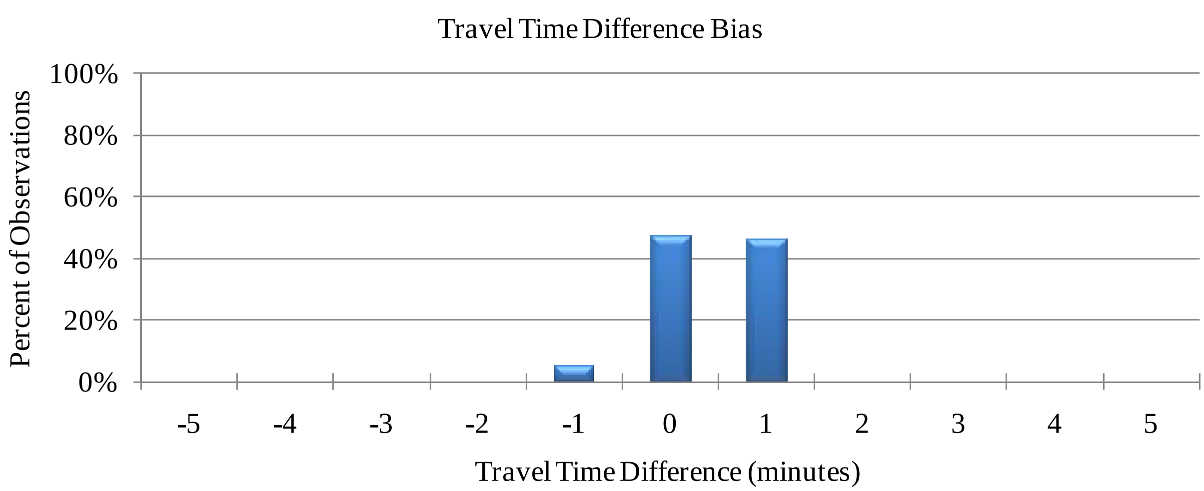


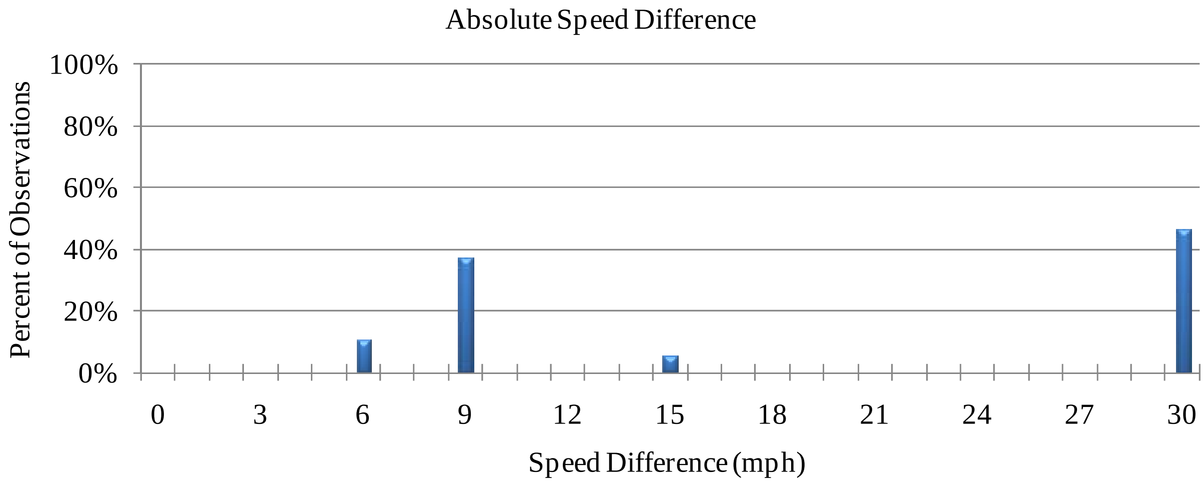

Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
5
10
15
20
25
30
35
40
45
50
Speed Difference (mph)


Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
Travel Time Difference (minutes)

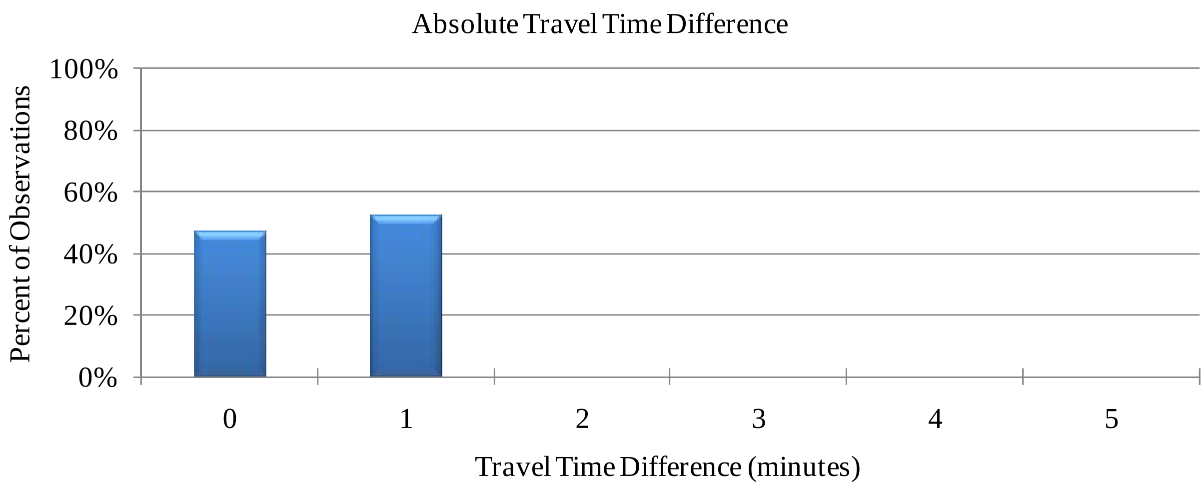
Segment 16: I-75 SB: SR 4 to US 35
Length: 2.1 miles (3.4 km)





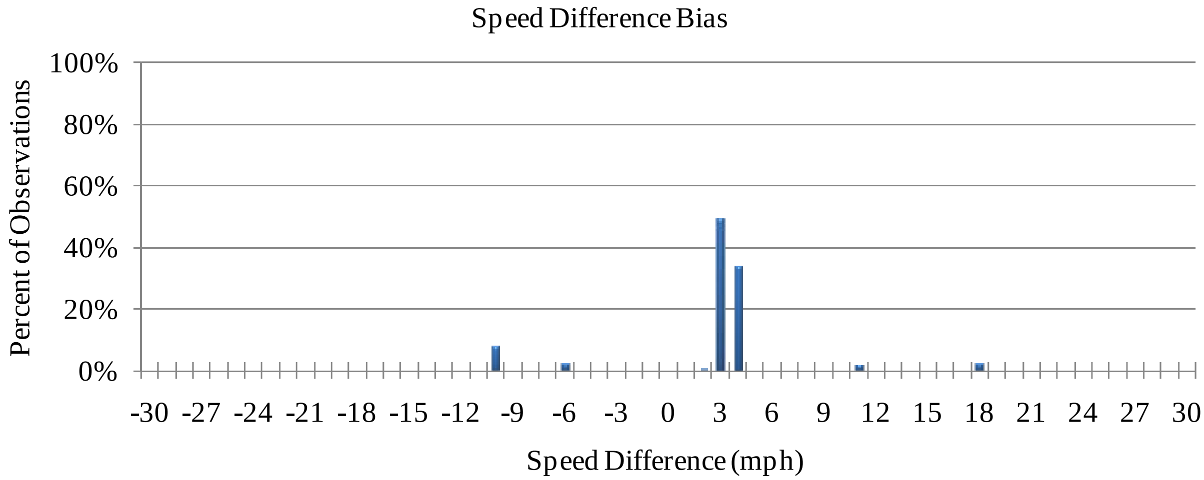


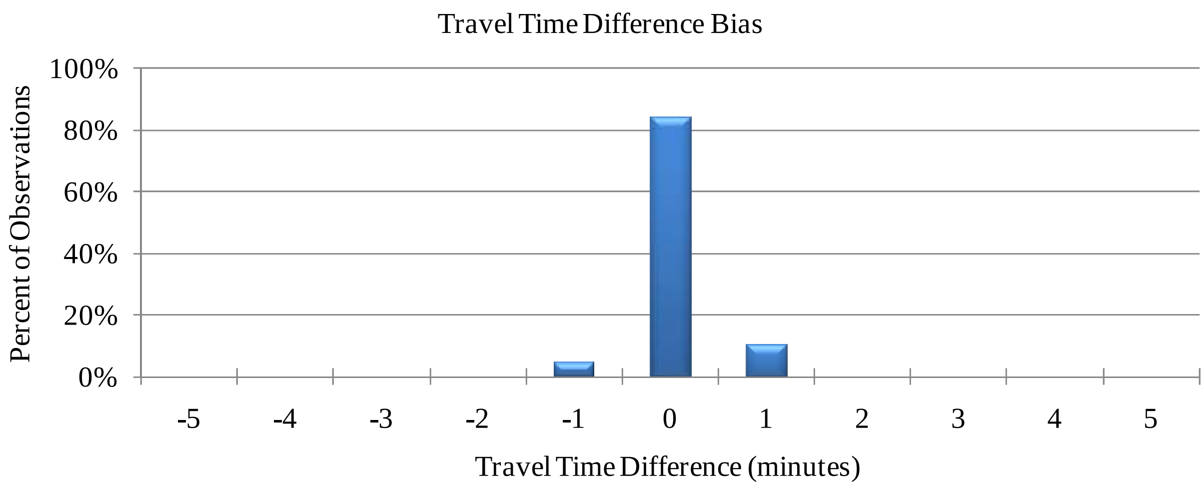
Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

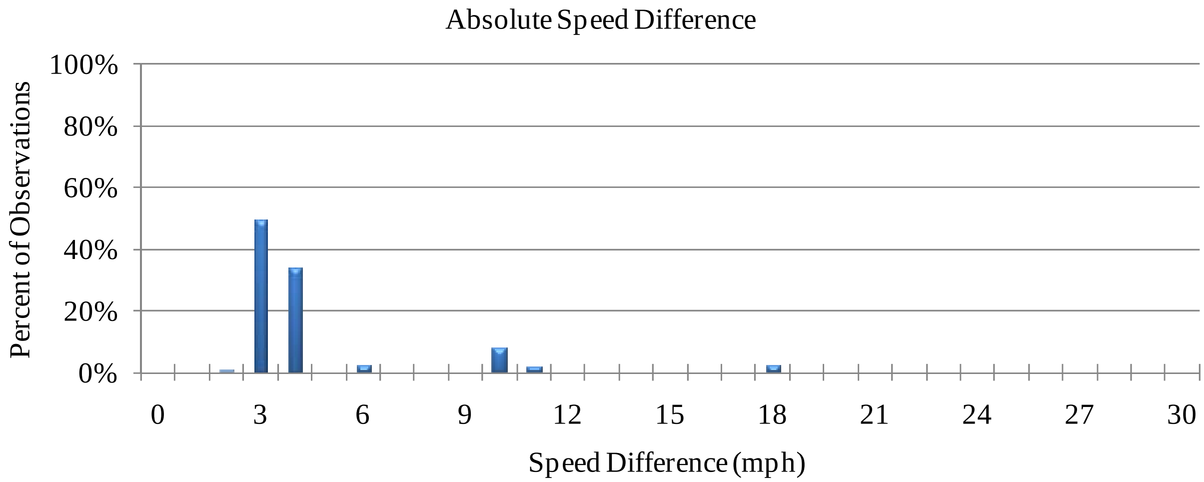


Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 17: I-75 NB: SR 4 to Timber Ln
Length: 2.9 miles (4.7 km)






Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
3
6
9
12
15
18
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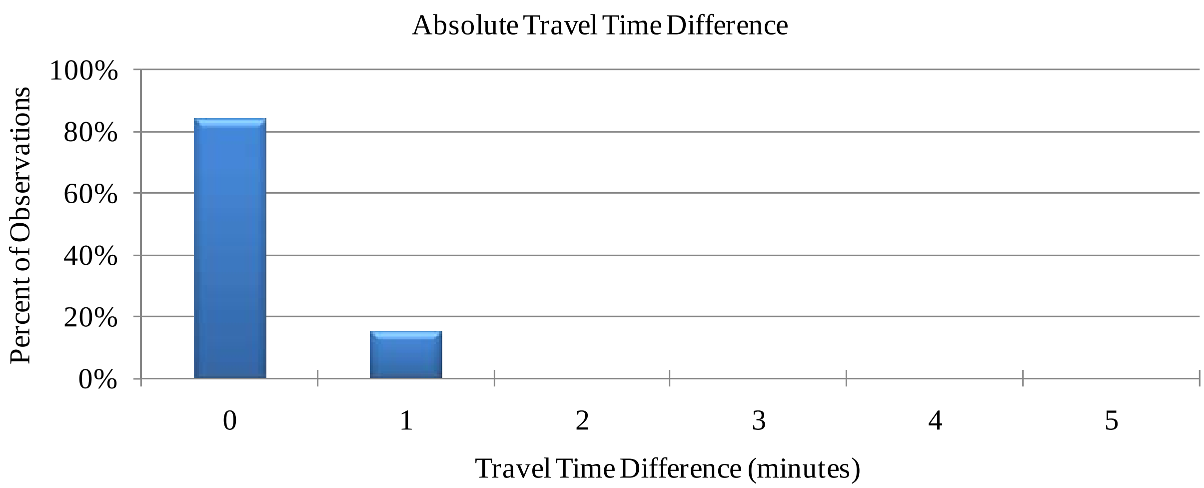
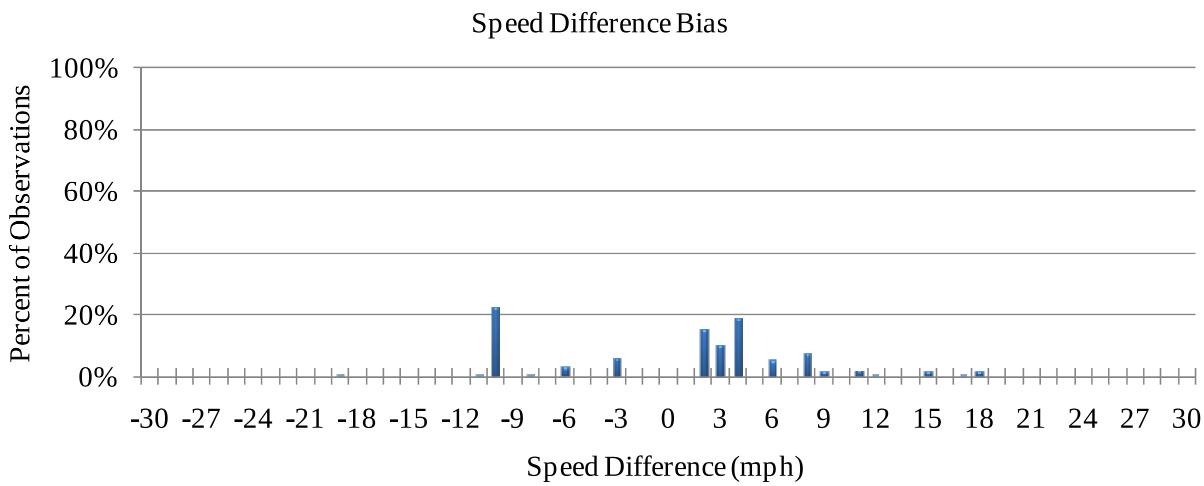
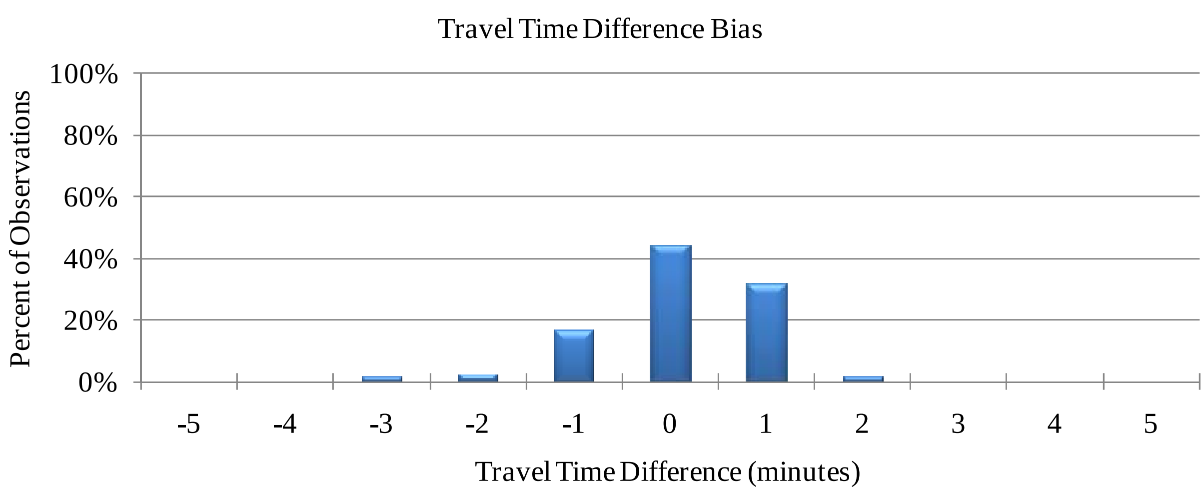
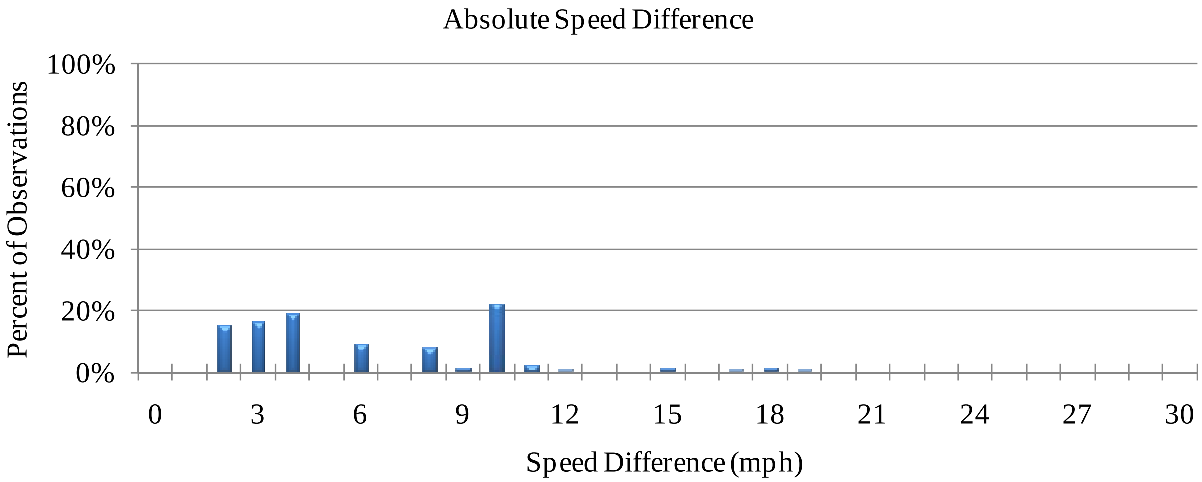
24
27
30
Speed Difference (mph)

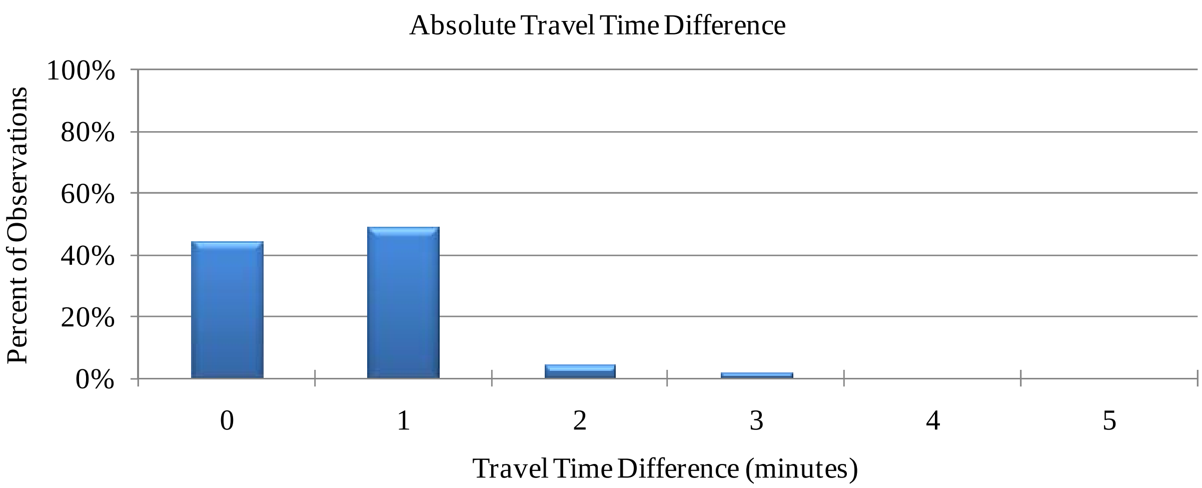

Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 18: I-75 SB: Timber Ln to SR 4
Length: 2.9 miles (4.7 km)

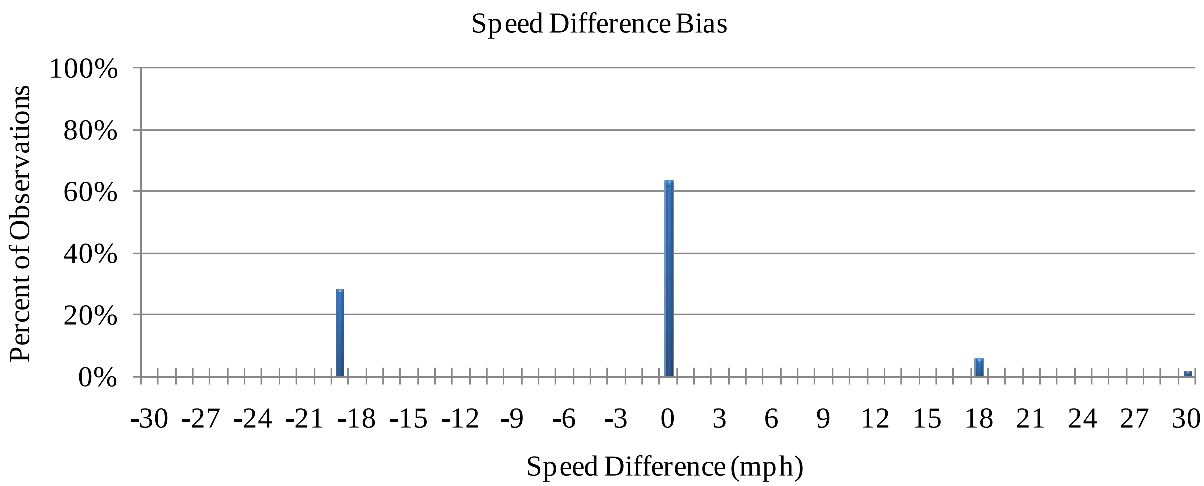


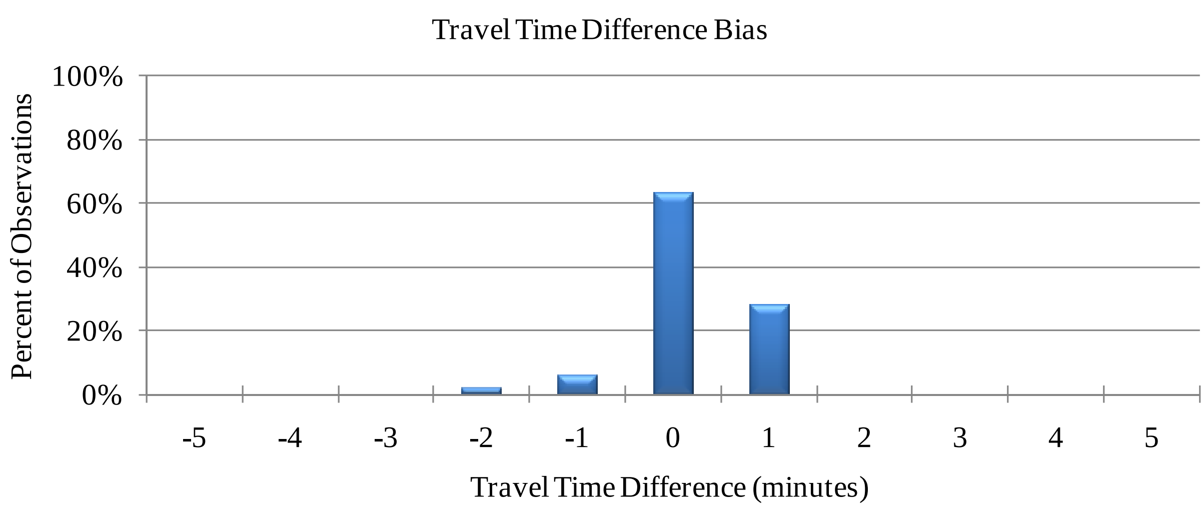


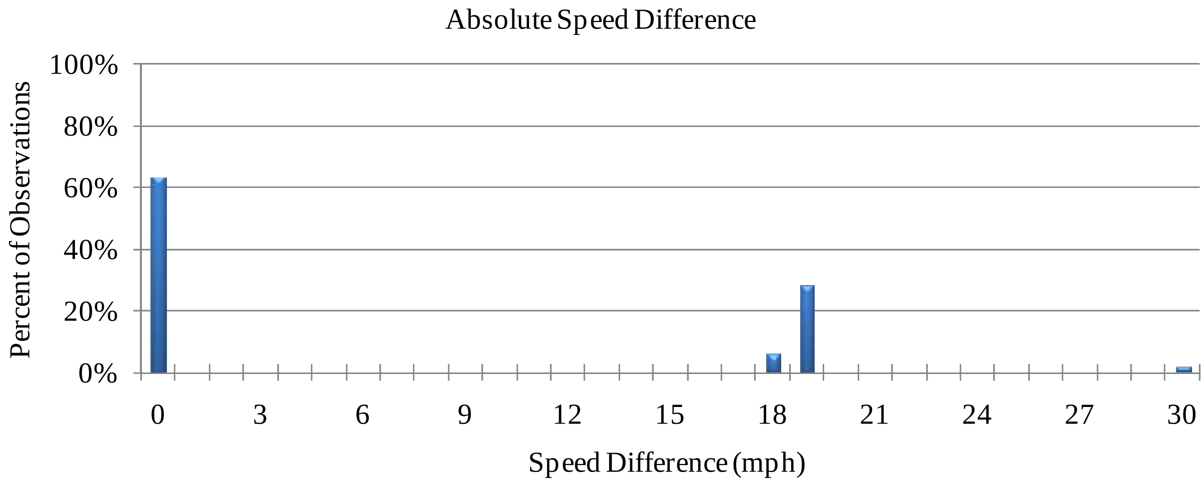

Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

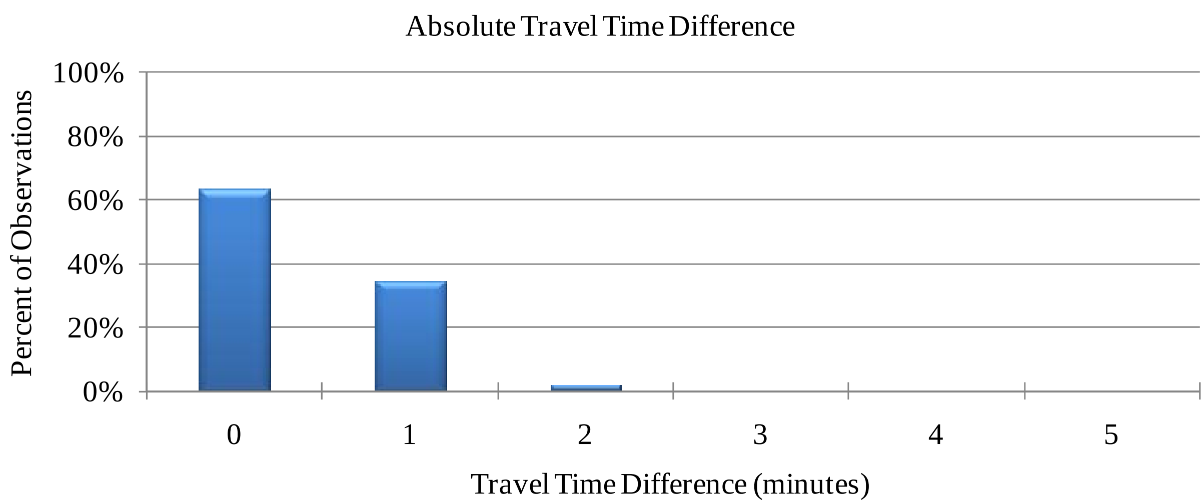

Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 19: I-75 NB: Timber Ln to I-70
Length: 3.7 miles (6.0 km)

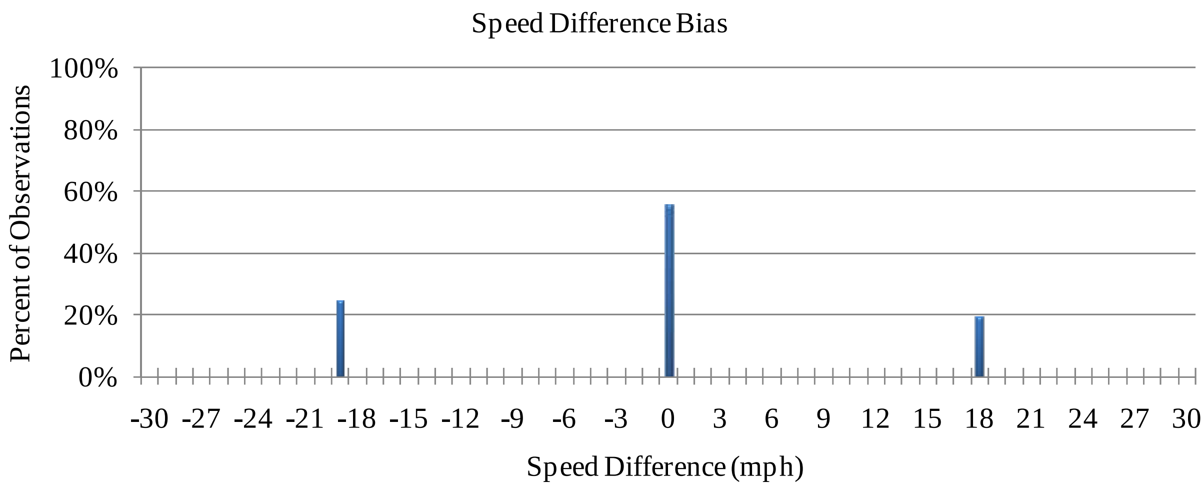


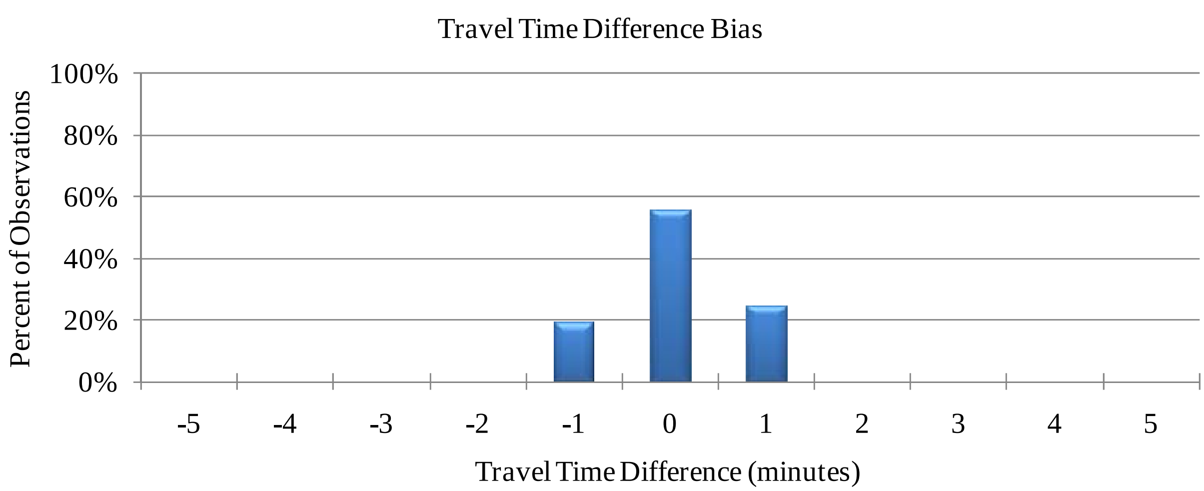


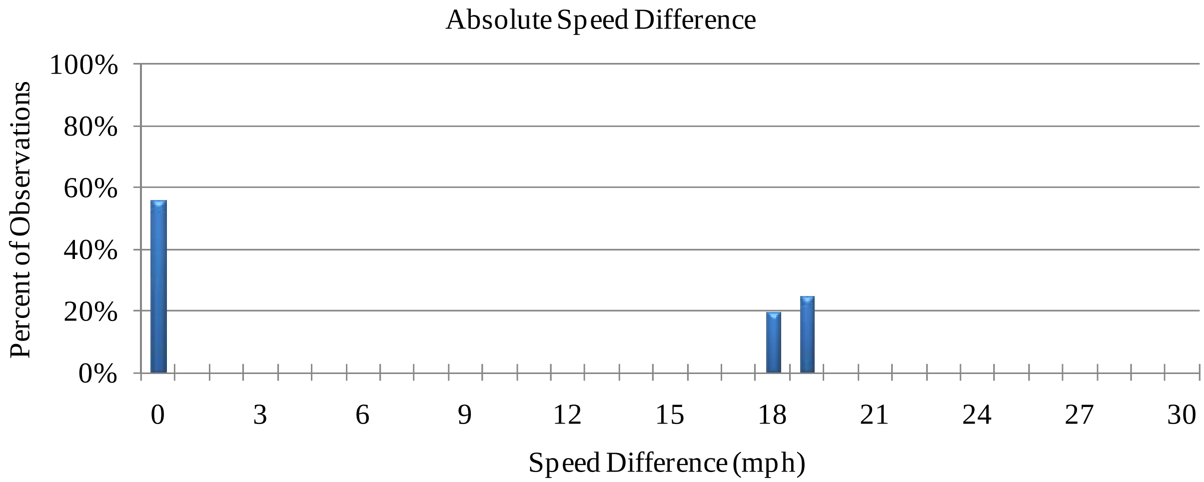

Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

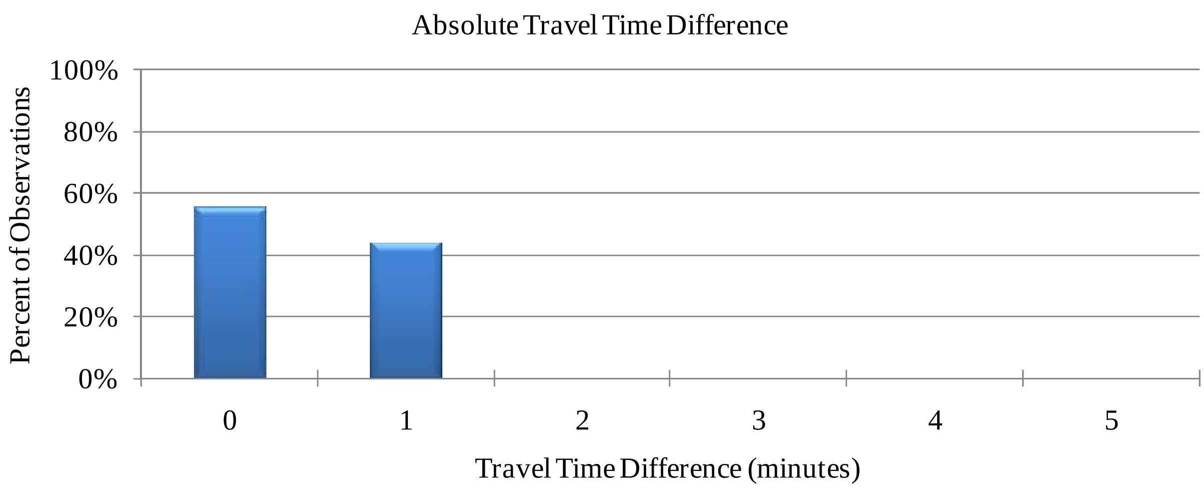

Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 20: I-75 SB: I-70 to Timber Ln
Length: 3.7 miles (6.0 km)

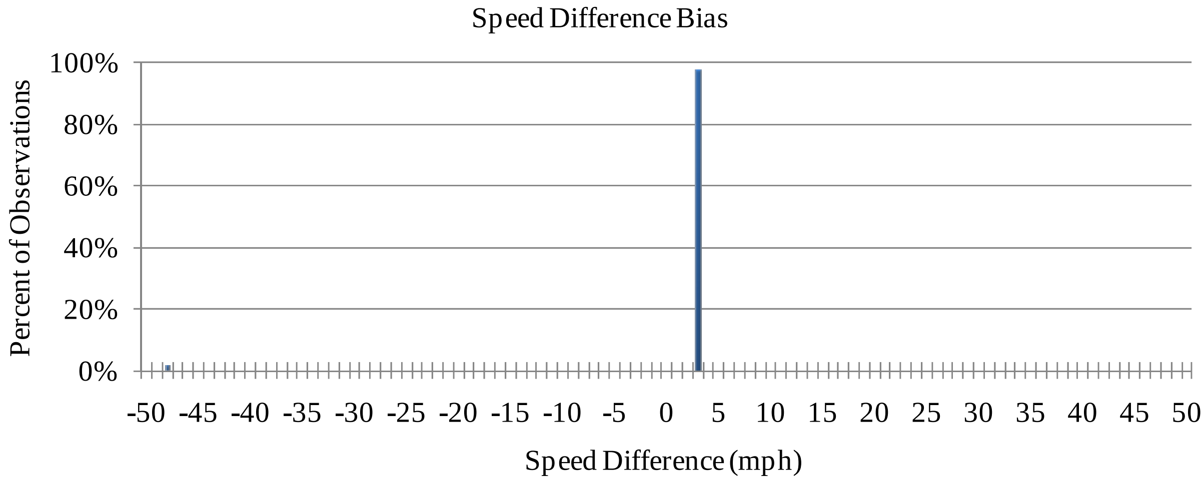


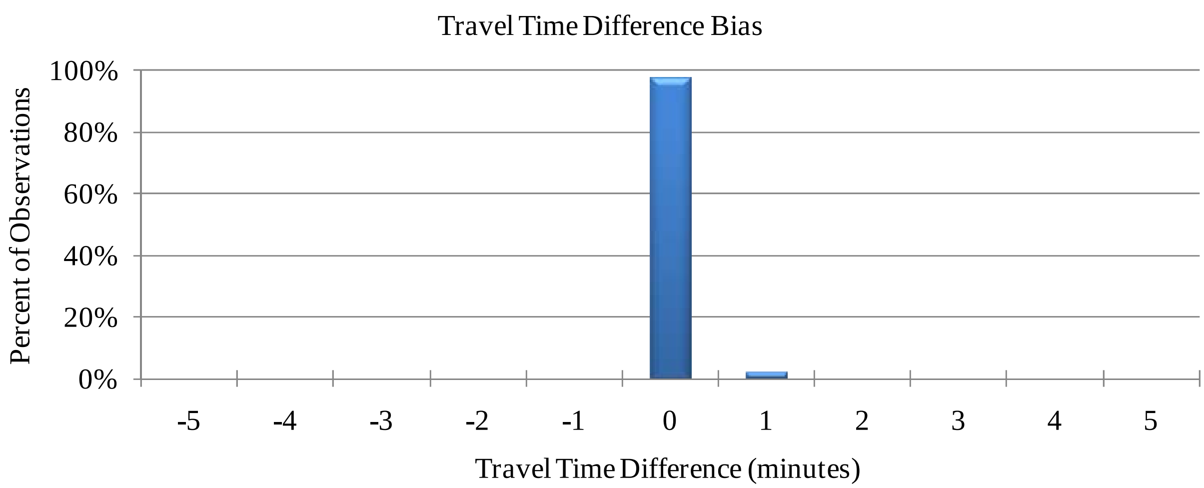



Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

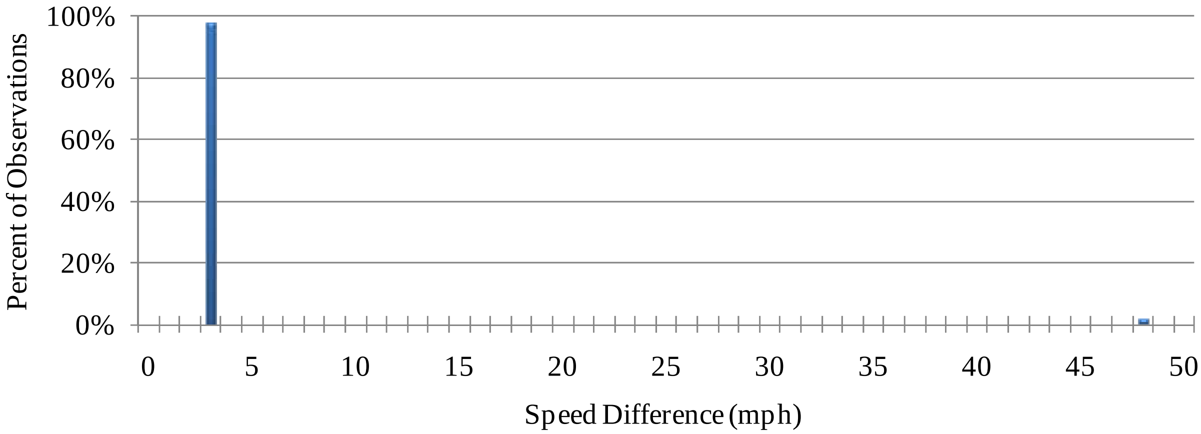

Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 21: I-75 NB: I-70 to US 40
Length: 1.8 miles (2.9 km)

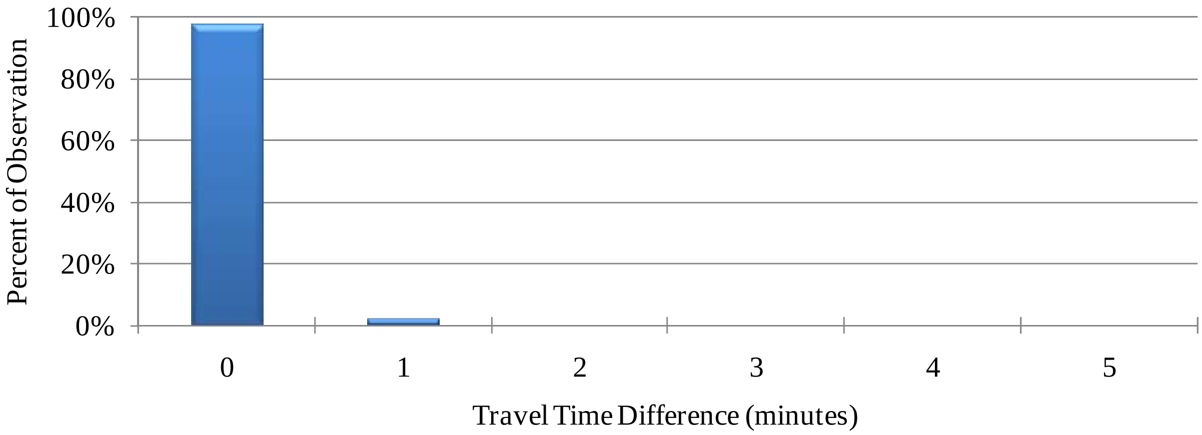




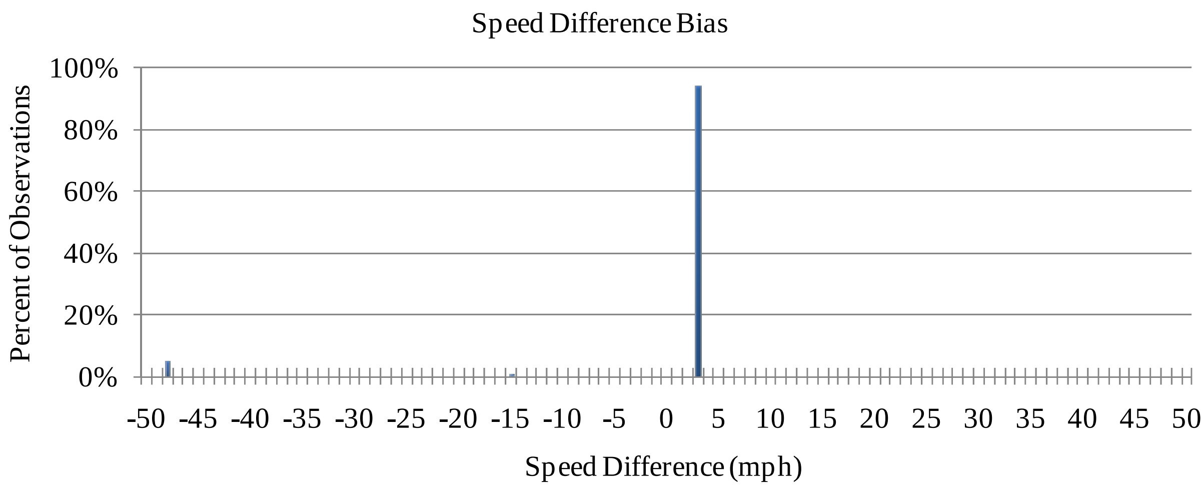
Absolute Speed Difference

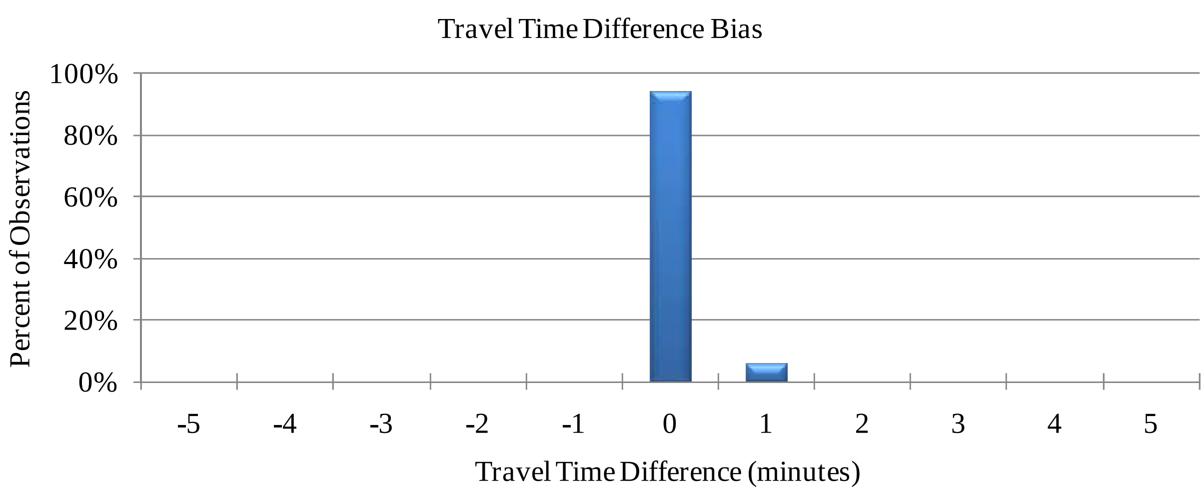


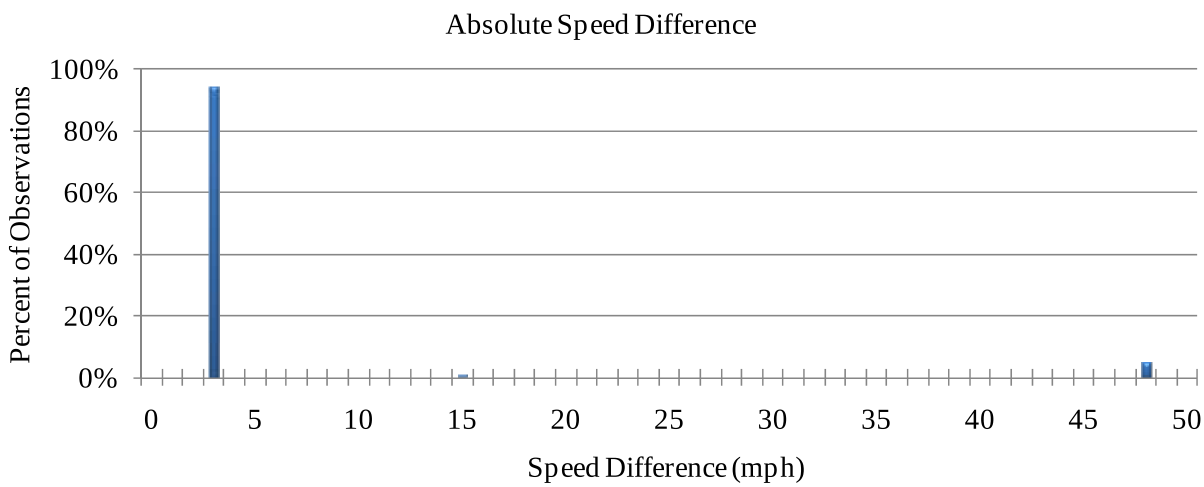
Absolute Travel Time Difference

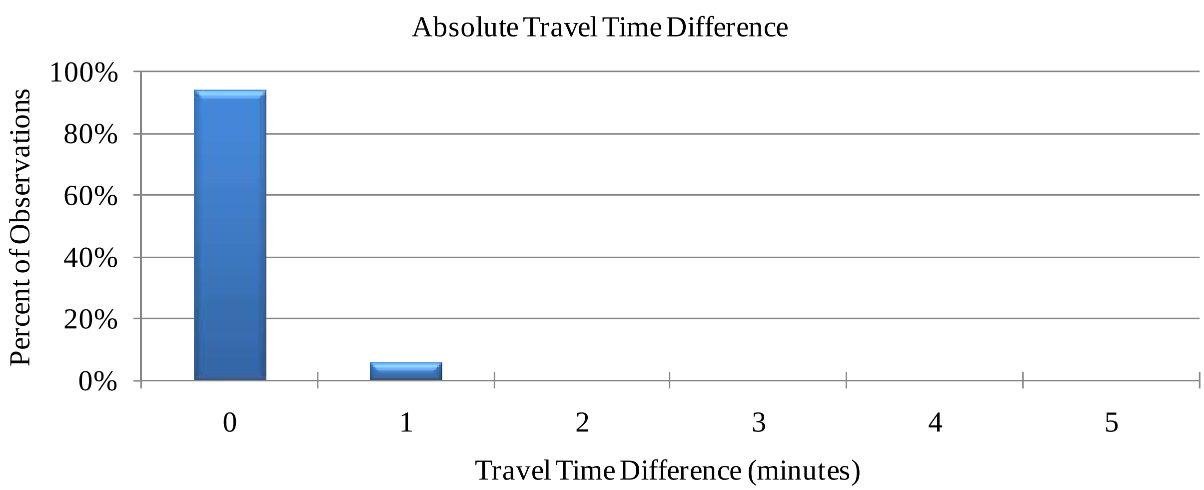


Segment 22: I-75 SB: US 40 to I-70
Length: 1.8 miles (2.9 km)

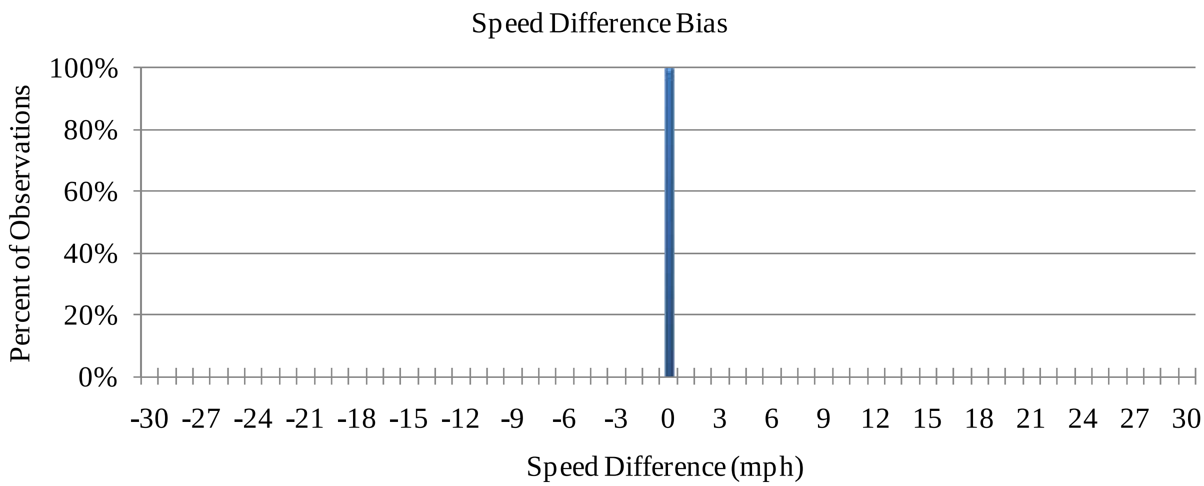


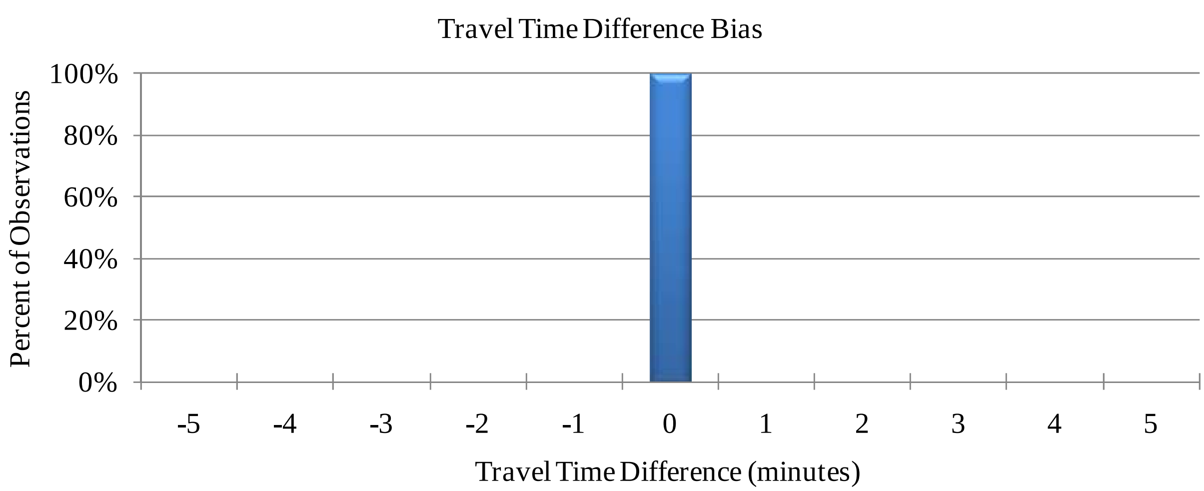


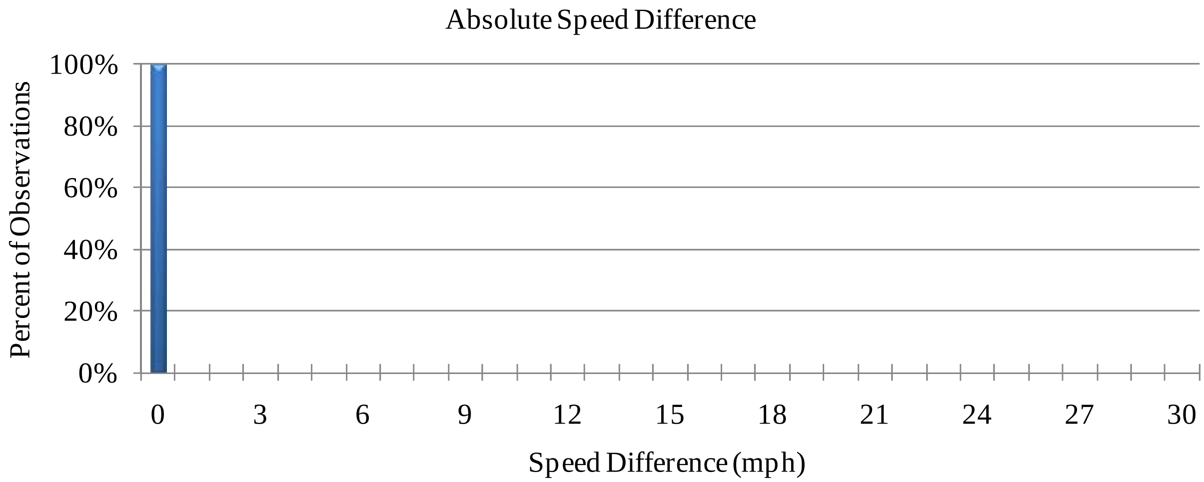

Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
5
10
15
20
25
30
35
40
45
50
Speed Difference (mph)

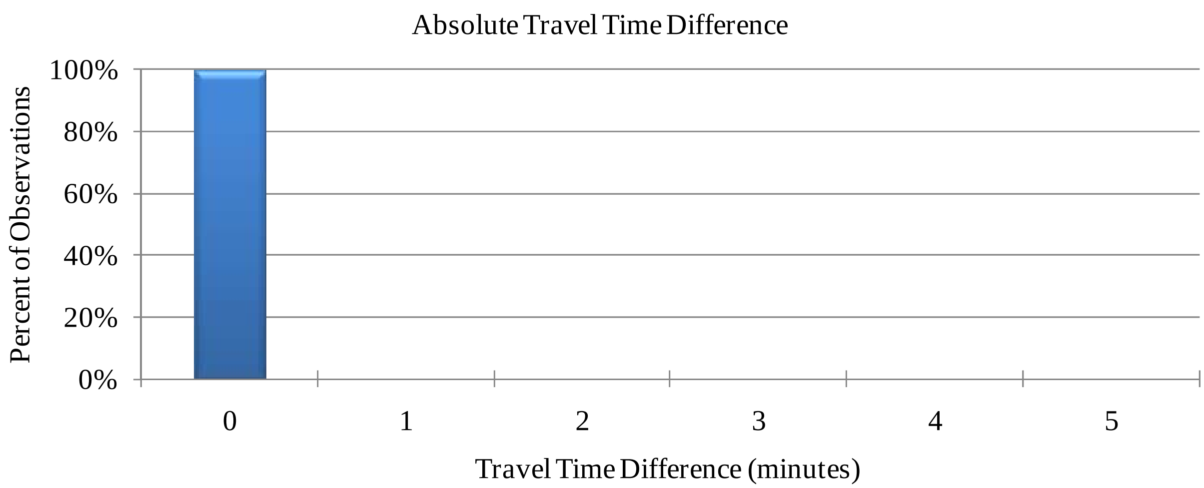

Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 23: I-75 NB: US 40 to County Line (Miami)
Length: 2.1 miles (3.4 km)

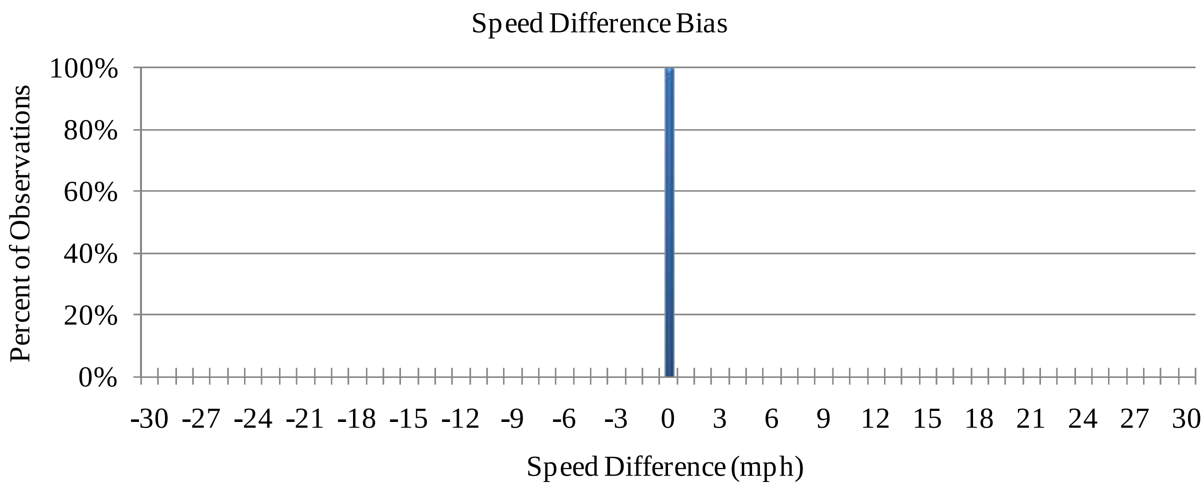


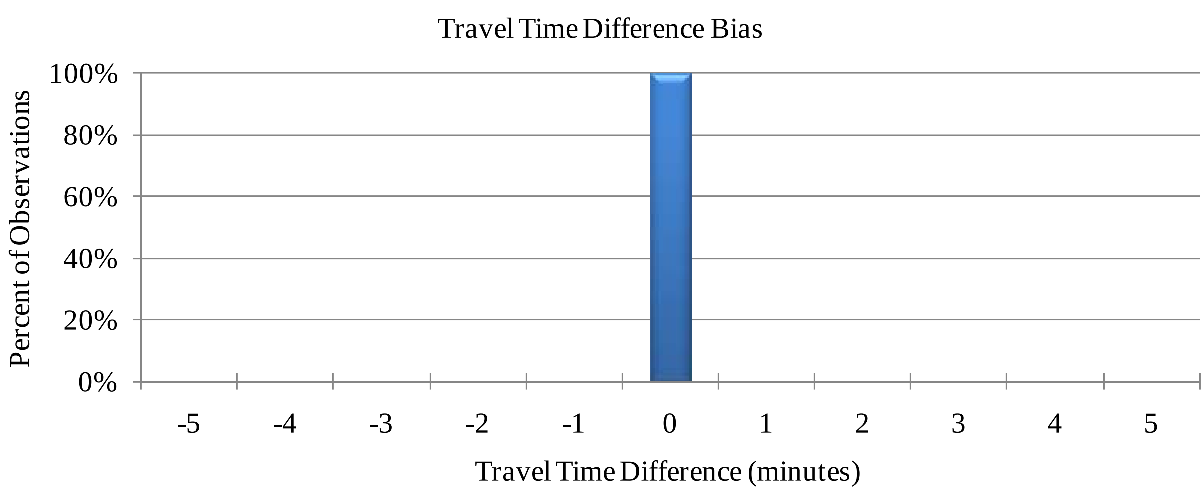


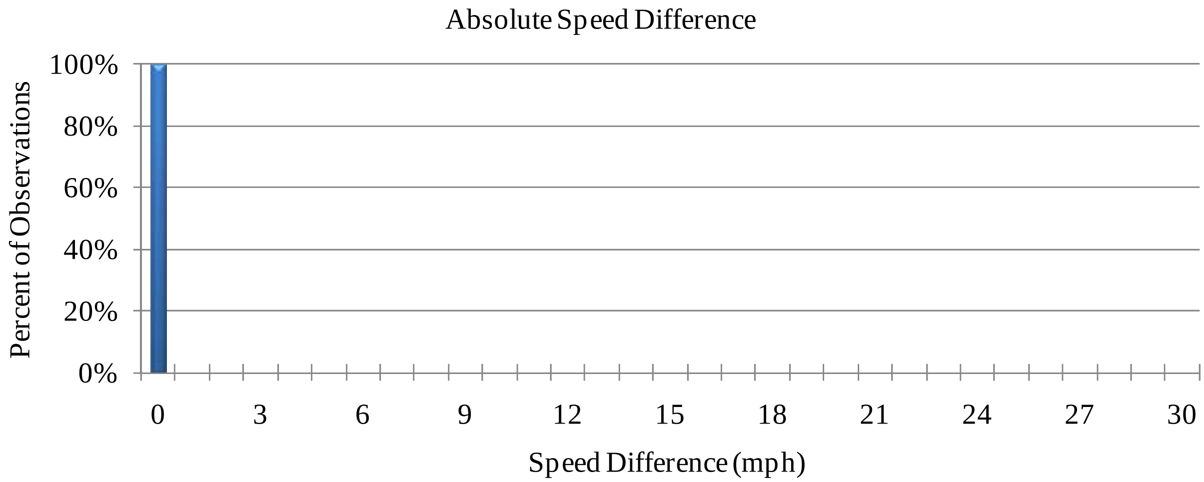

Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

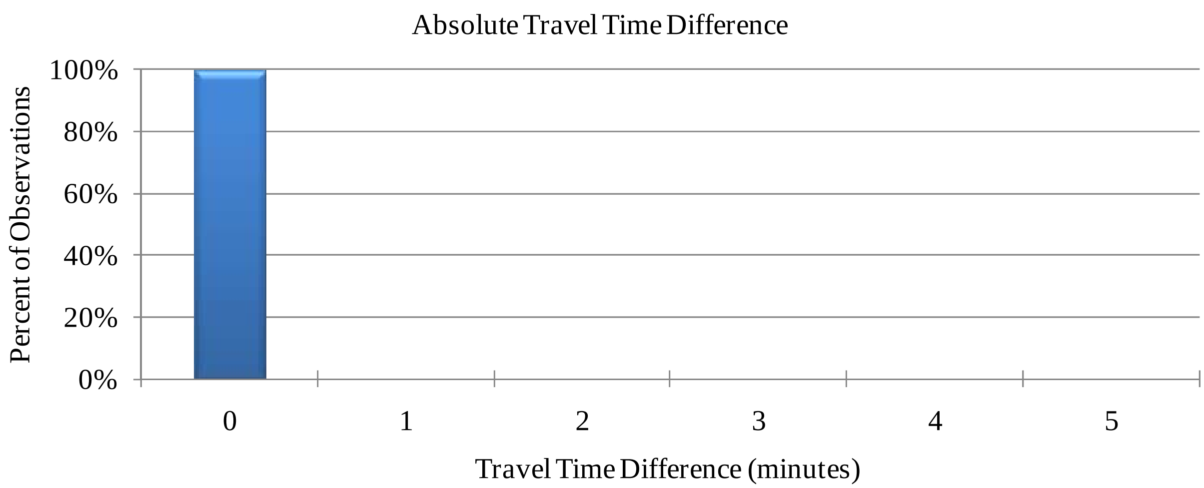

Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 24: I-75 SB: County Line (Miami) to US 40
Length: 2.1 miles (3.4 km)

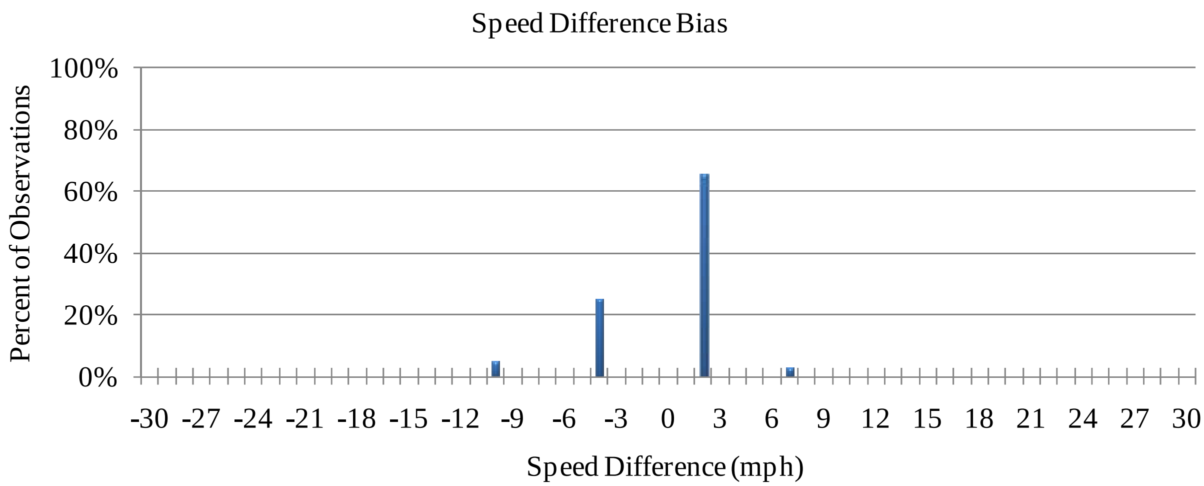


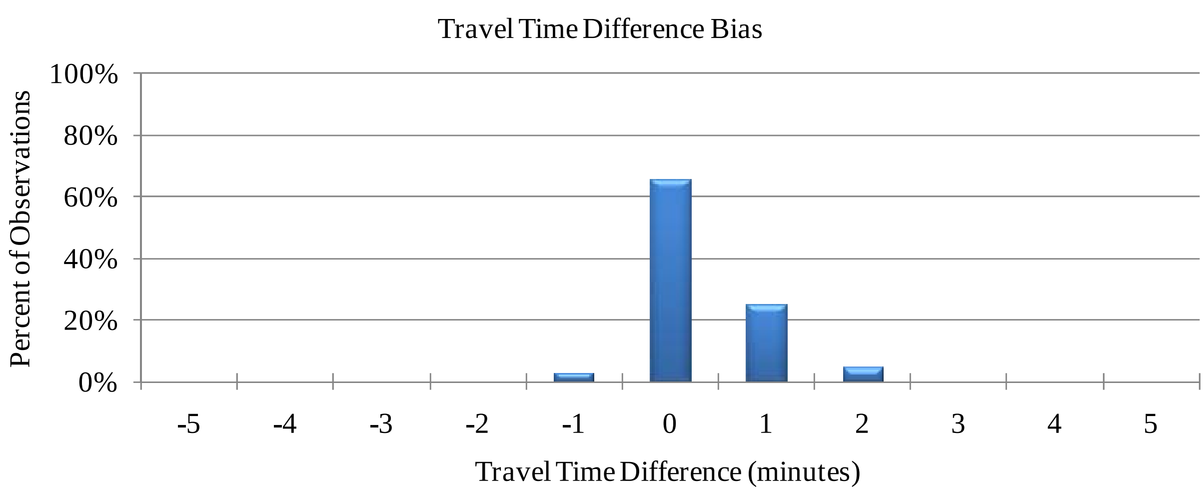


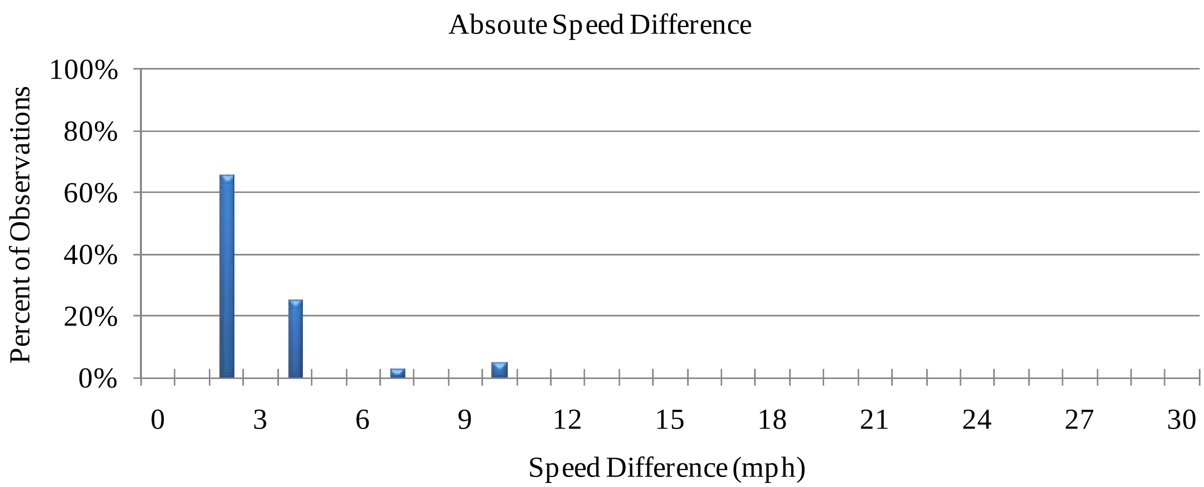

Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

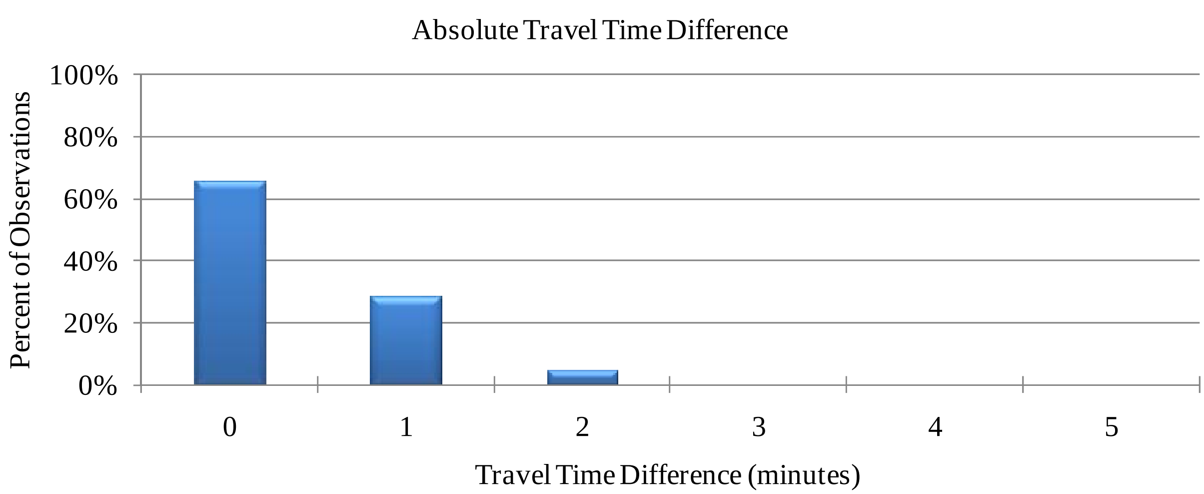

Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 25: I-675 NB: I-75 to US 35
Length: 12.7 miles (20.4 km)

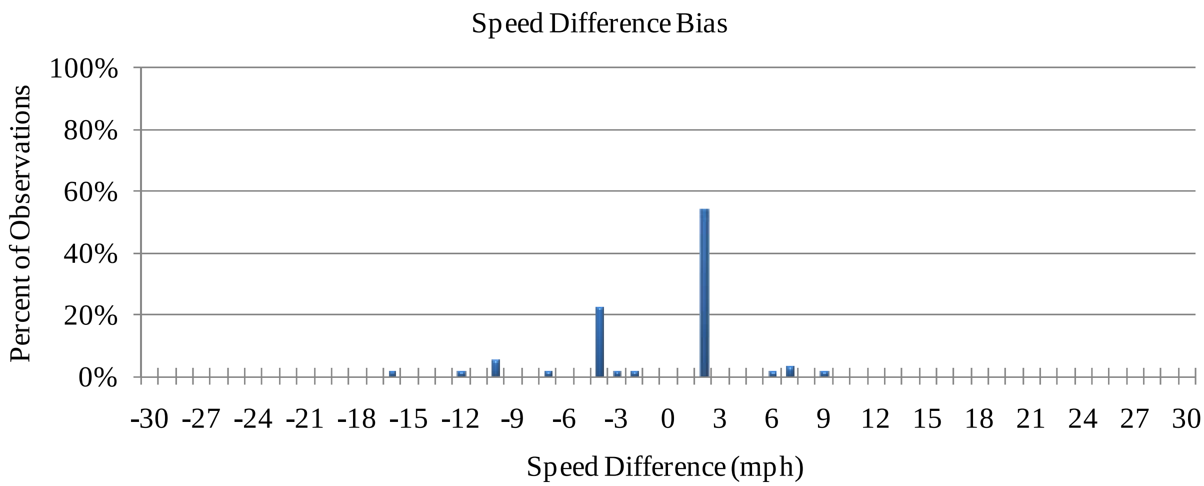


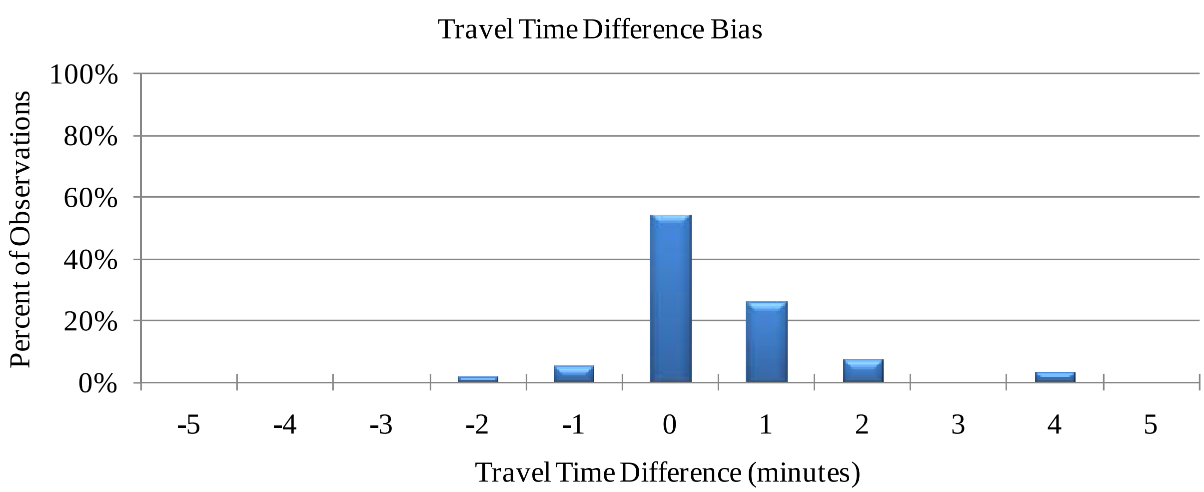


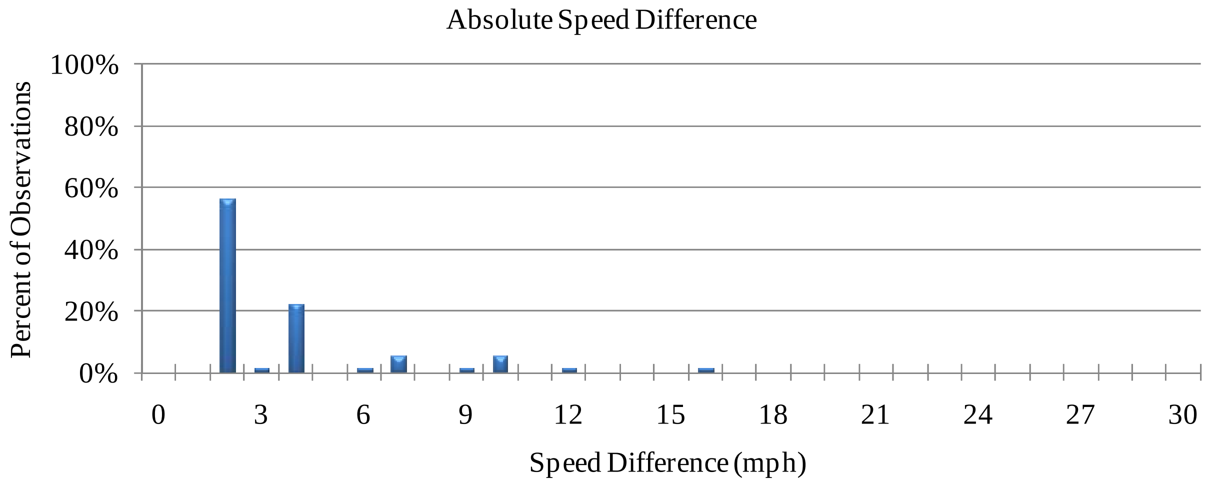

Absoute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

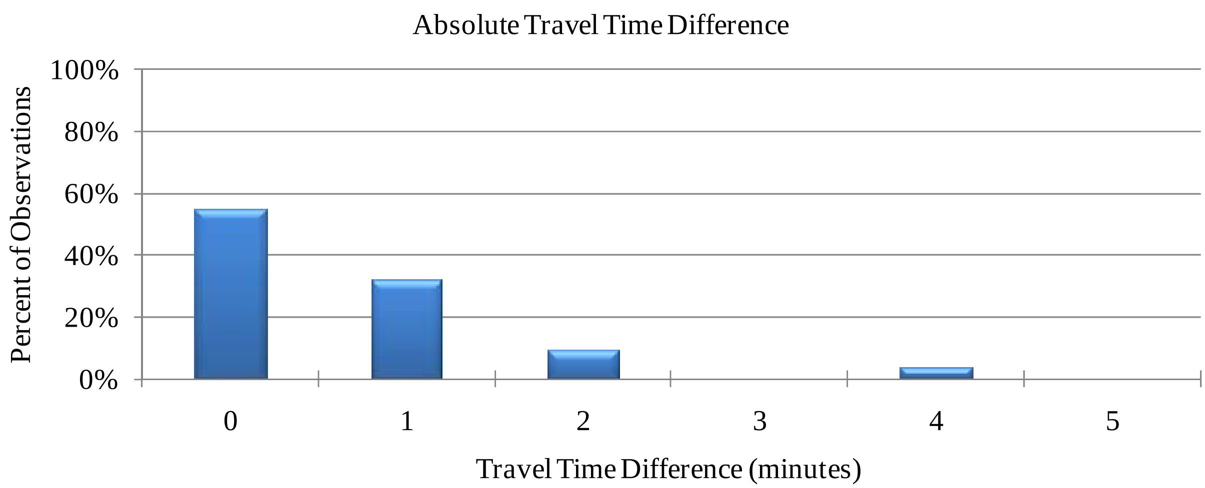

Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 26: I-675 SB: US 35 to I-75
Length: 12.7 miles (20.4 km)

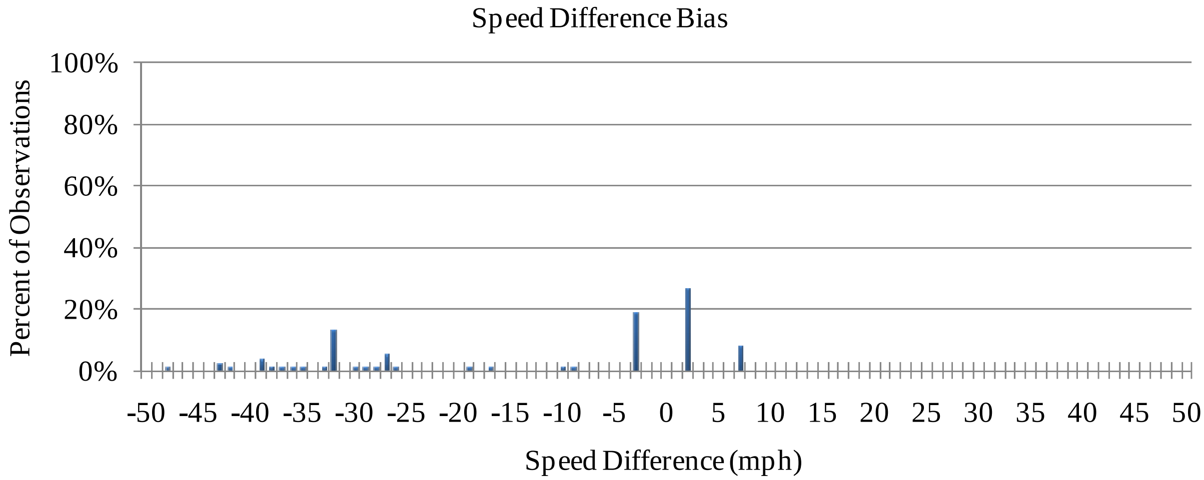


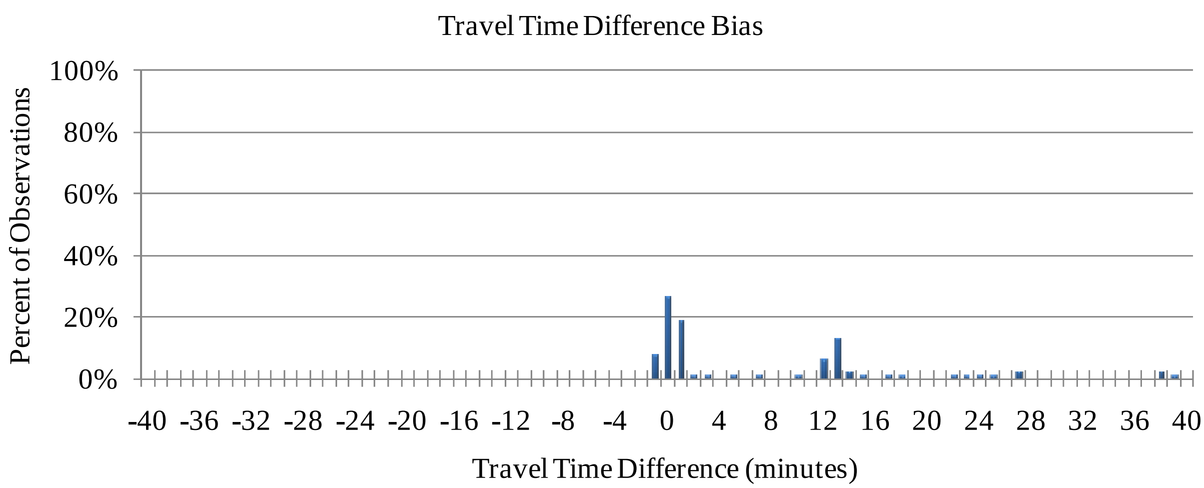


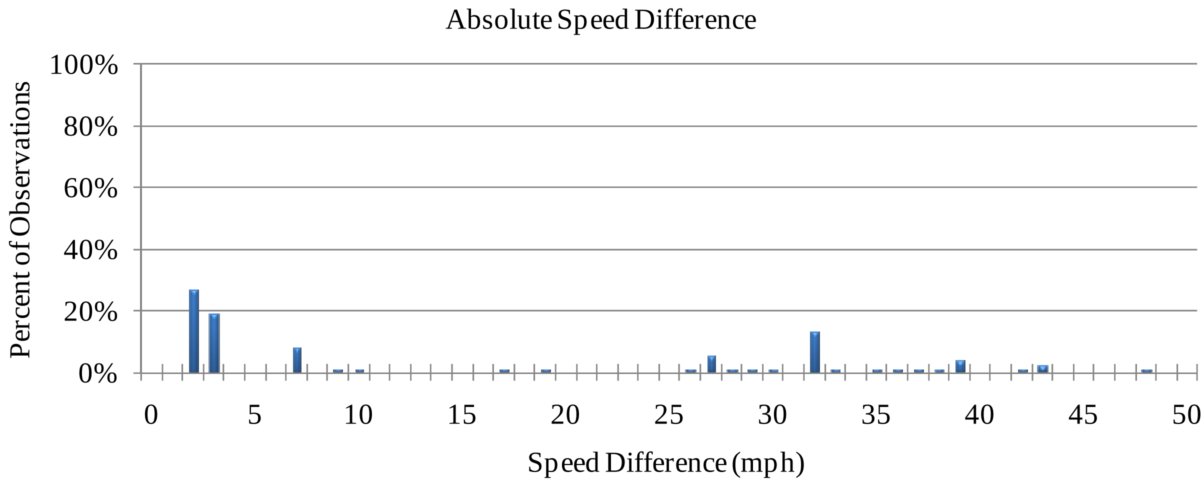

Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

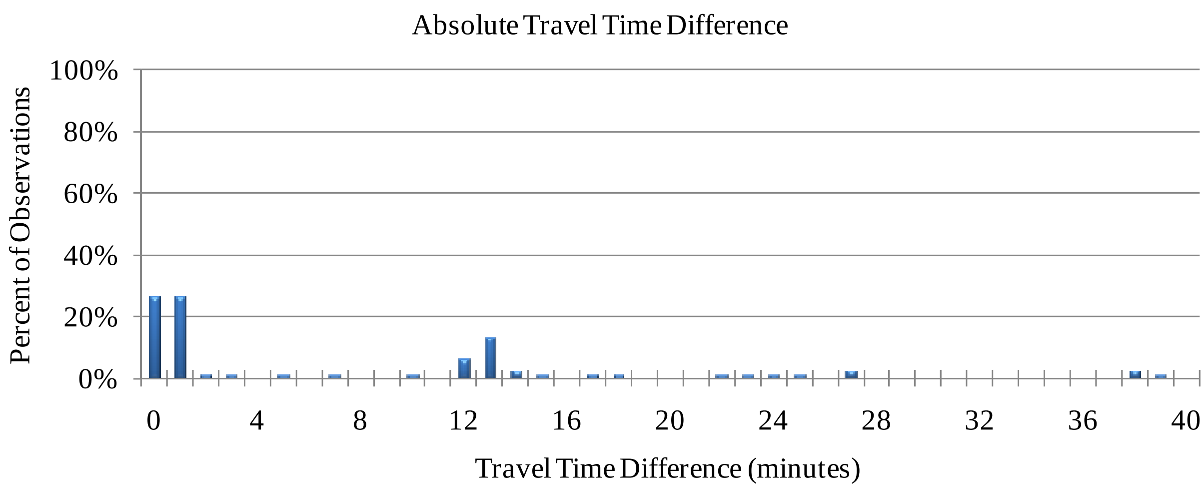

Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 27: I-675 NB: US 35 to I-70
Length: 13.2 miles (21.2 km)

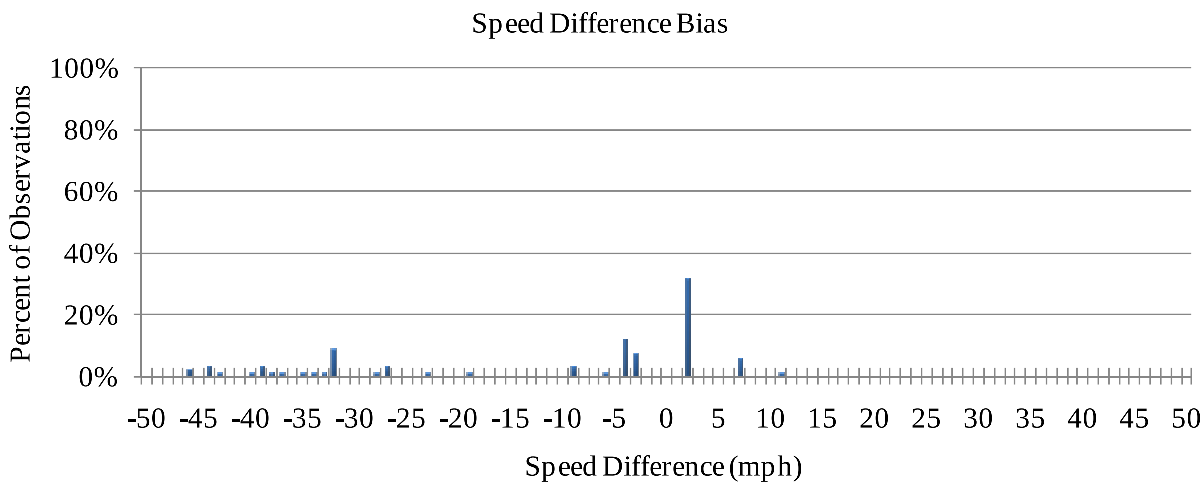


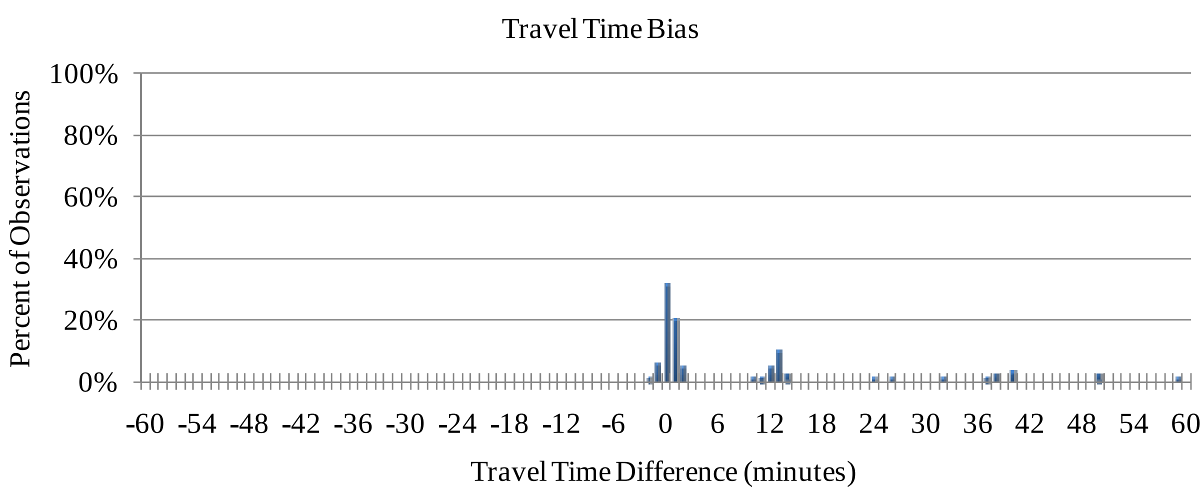


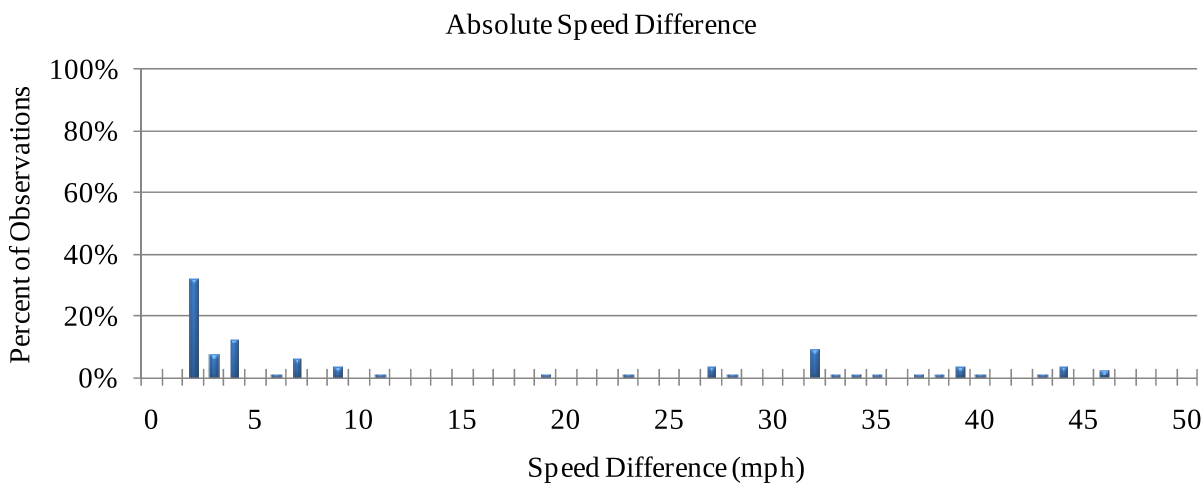

Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
5
10
15
20
25
30
35
40
45
50
Speed Difference (mph)

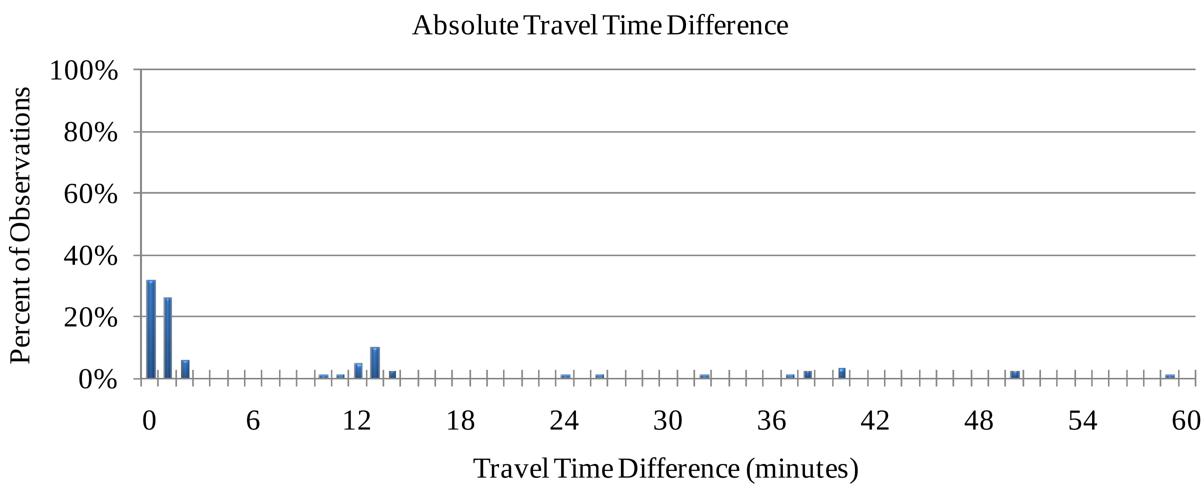

Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
4
8
12
16
20
24
28
32
36
40
Travel Time Difference (minutes)

Segment 28: I-675 SB: I-70 to US 35
Length: 13.2 miles (21.2 km)

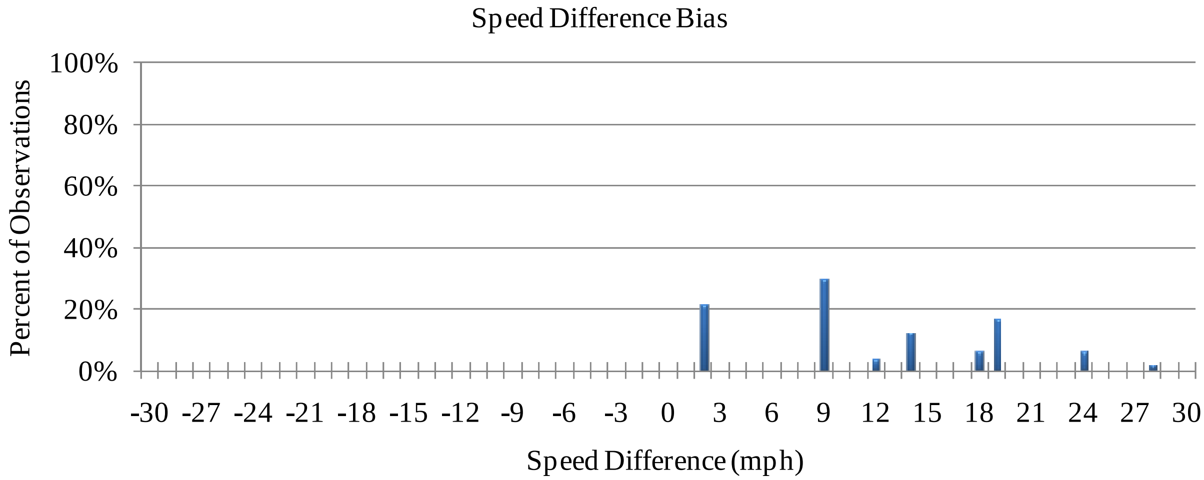


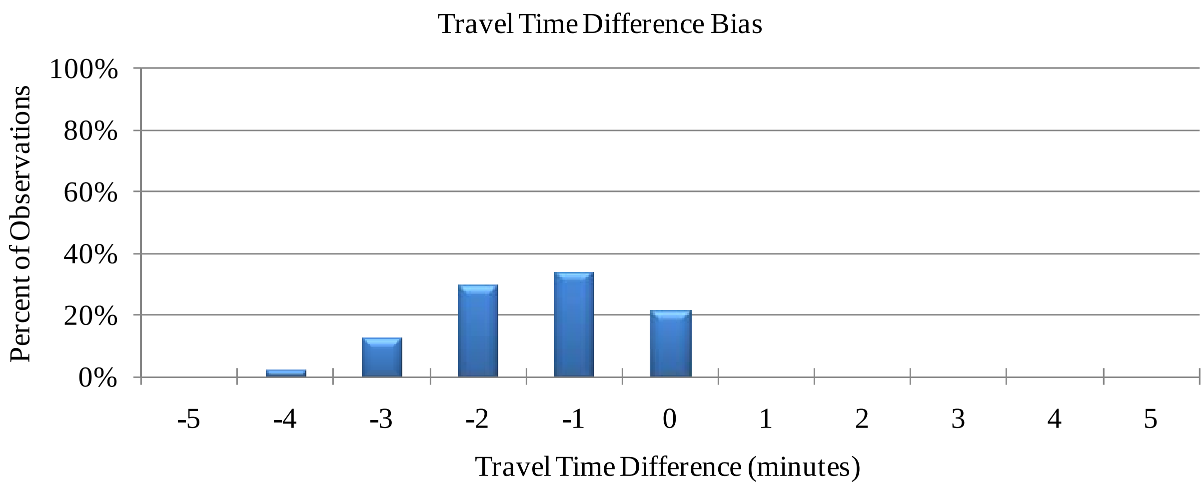


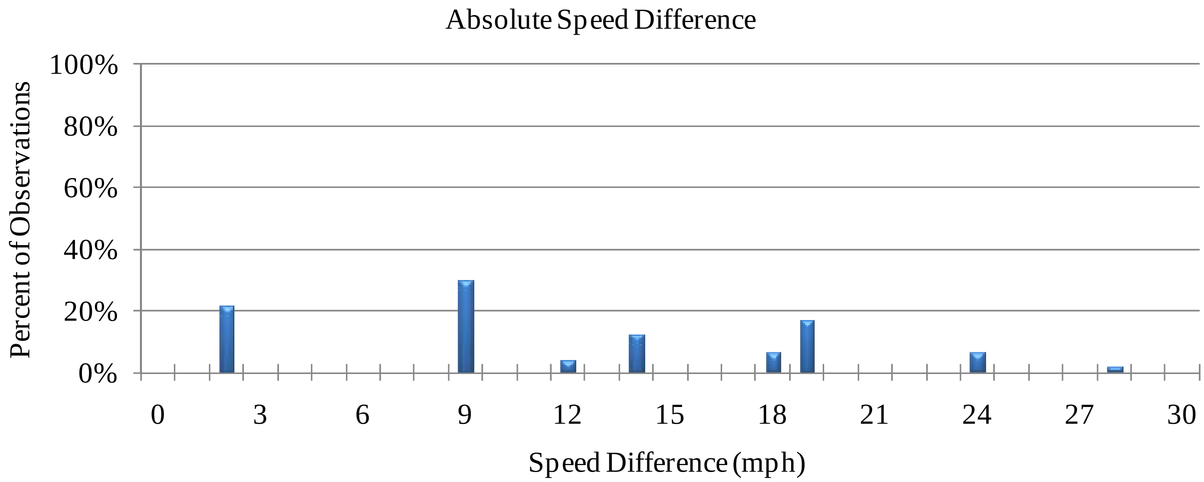

Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
5
10
15
20
25
30
35
40
45
50
Speed Difference (mph)

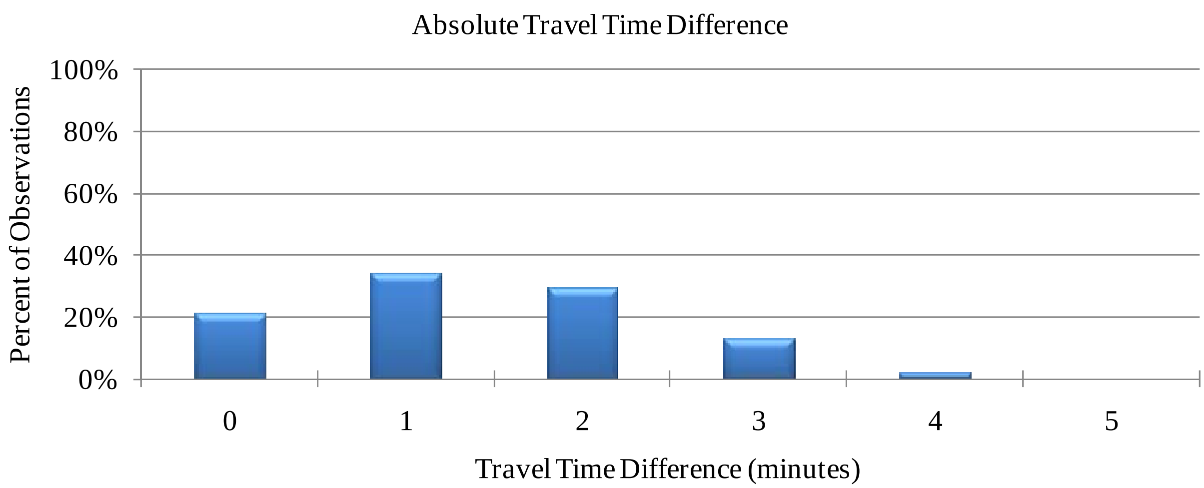

Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
6
12
18
24
30
36
42
48
54
60
Travel Time Difference (minutes)

Segment 29: US 35 EB: SR 49 to I-75
Length: 5.1 miles (8.2 km)

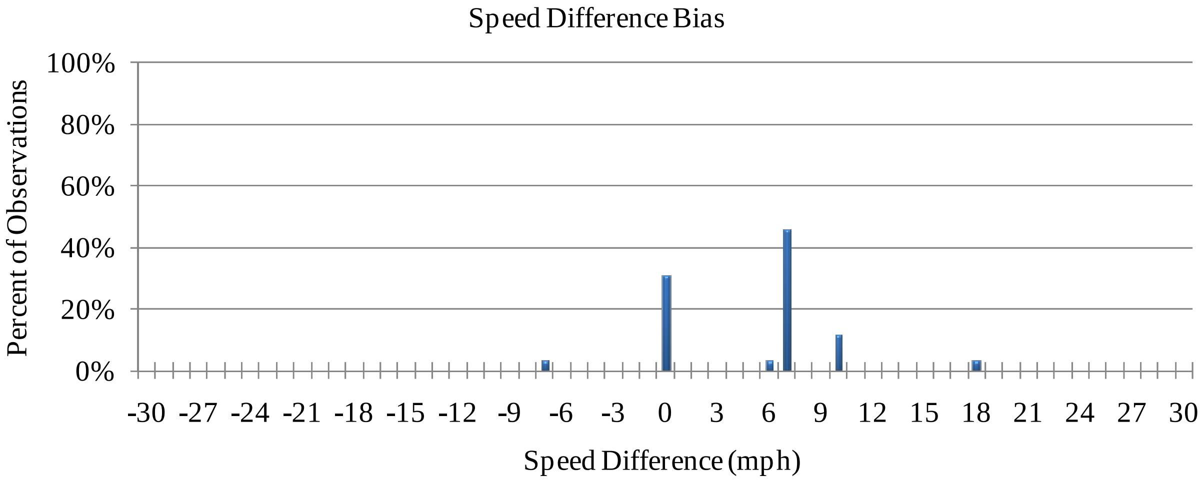


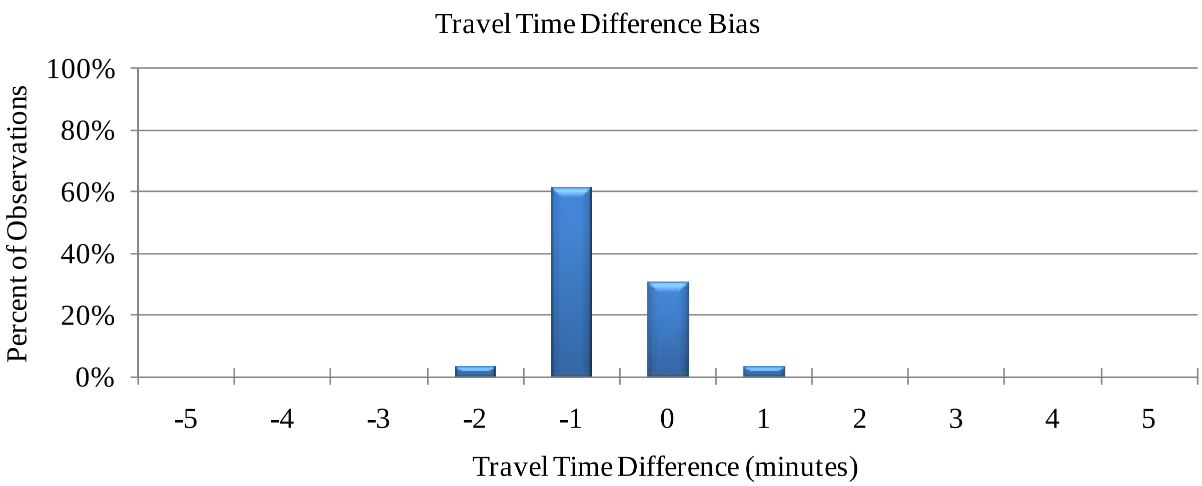


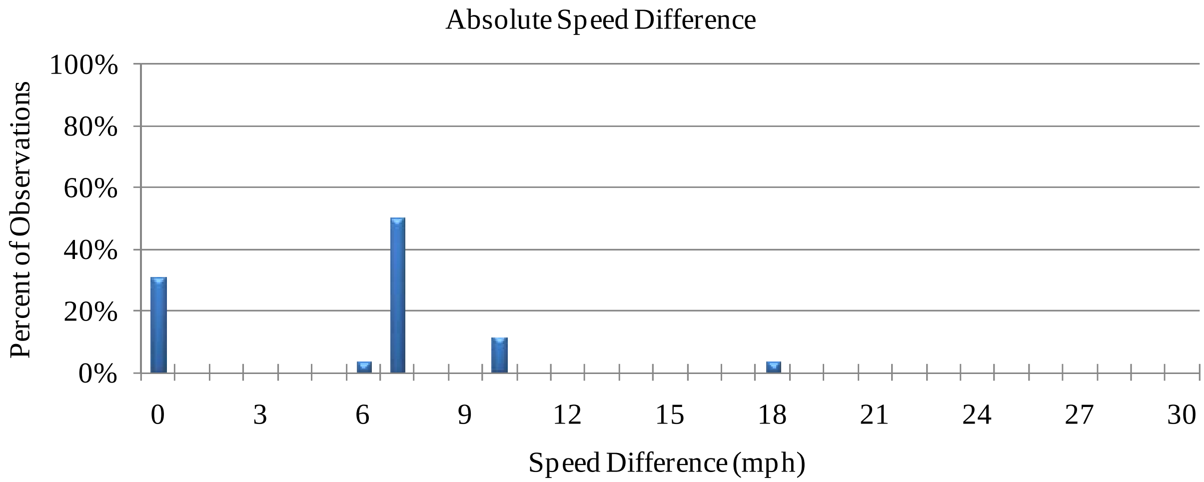

Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

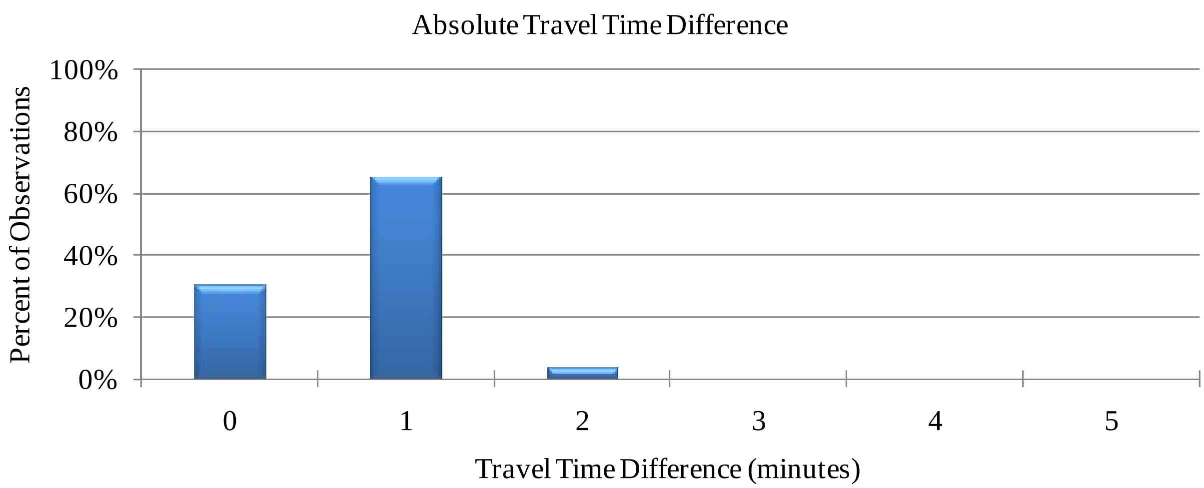

Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 30: US 35 WB: I-75 to SR 49
Length: 5.1 miles (8.2 km)

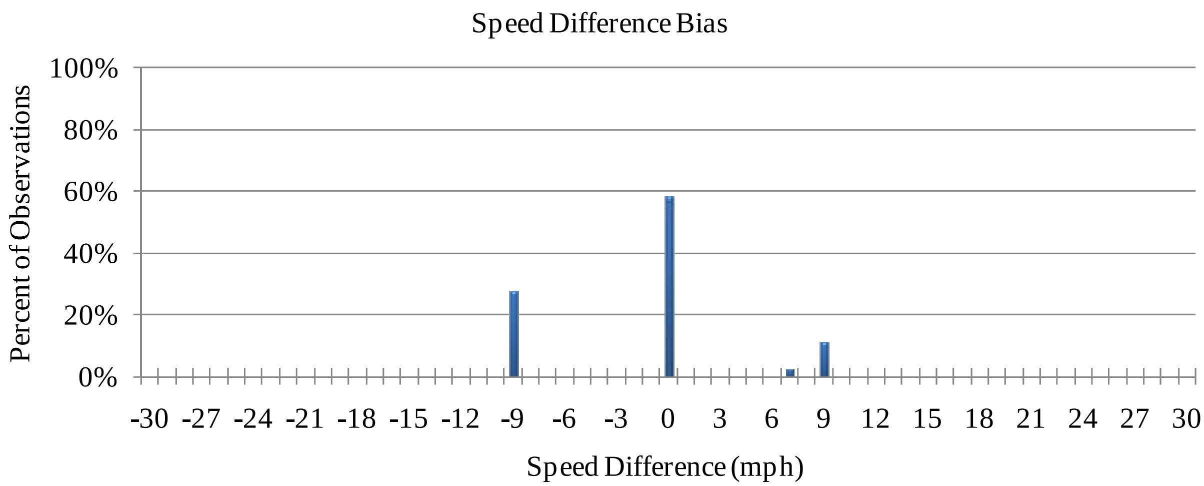


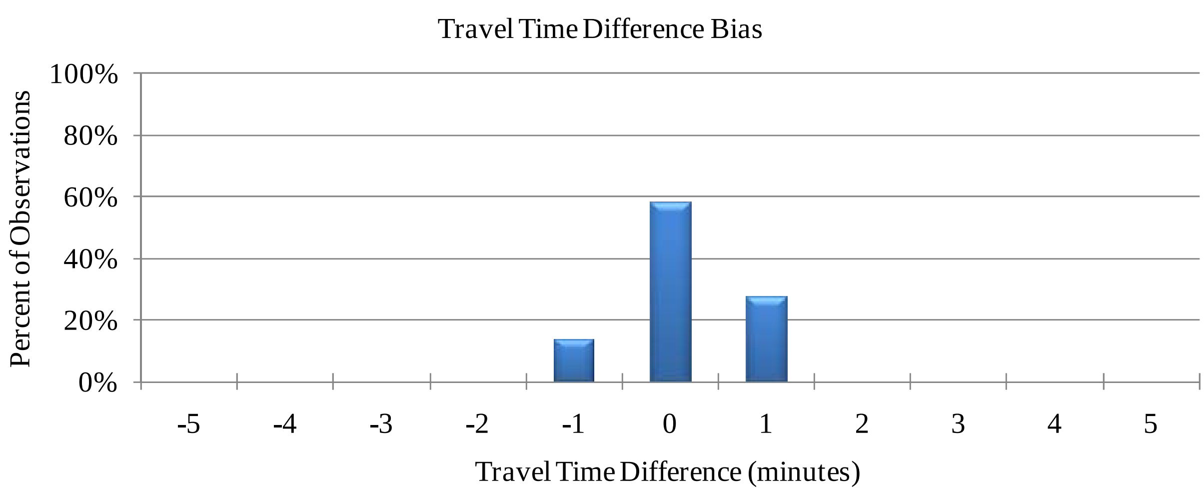


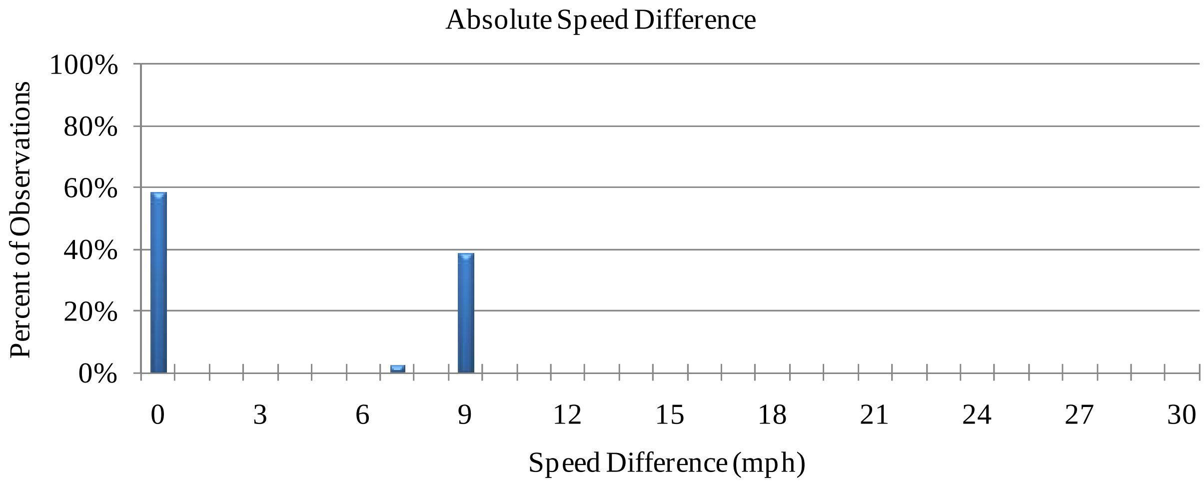

Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

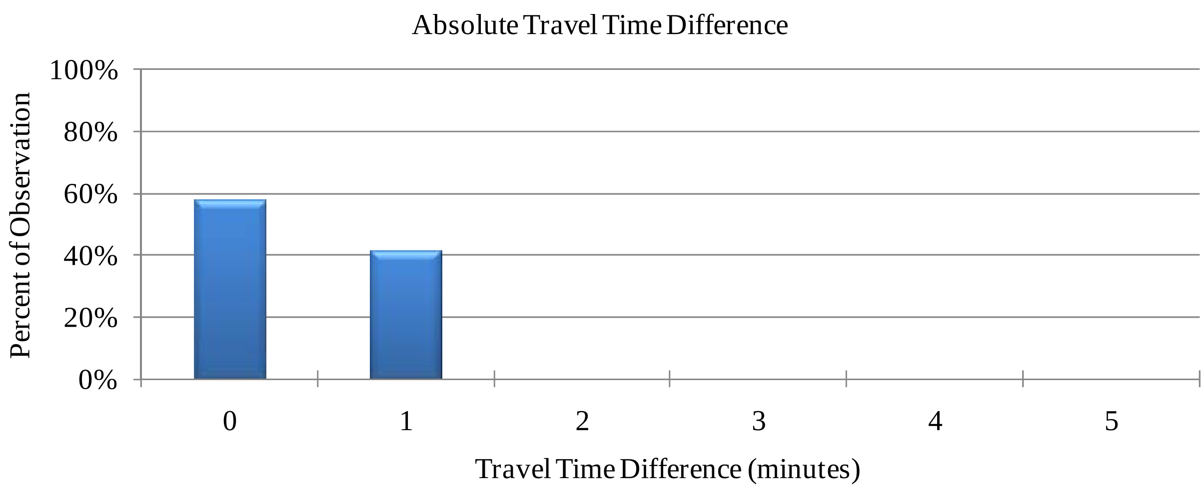

Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 31: US 35 EB: I-75 to I-675
Length: 6.4 miles (10.3 km)

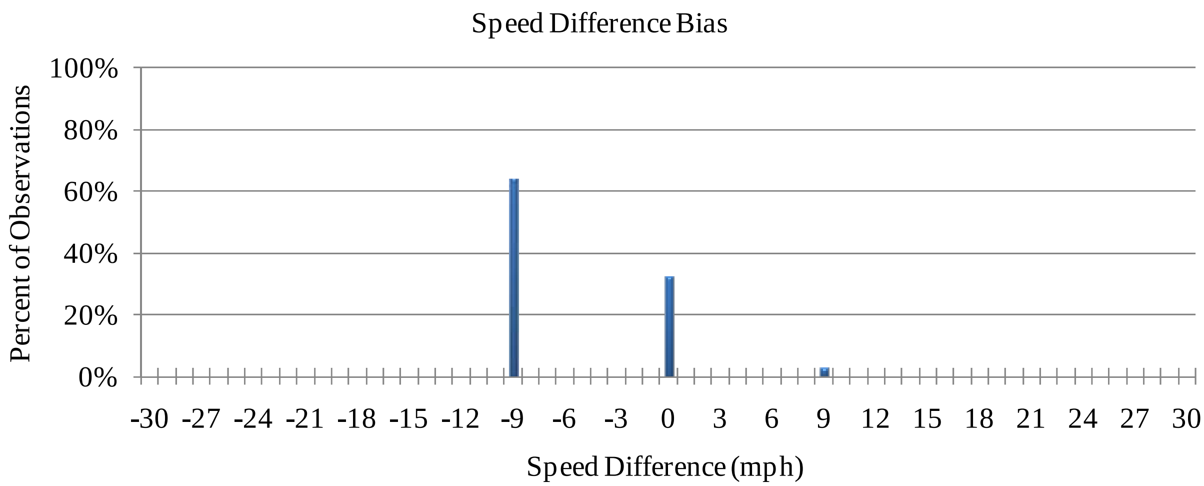


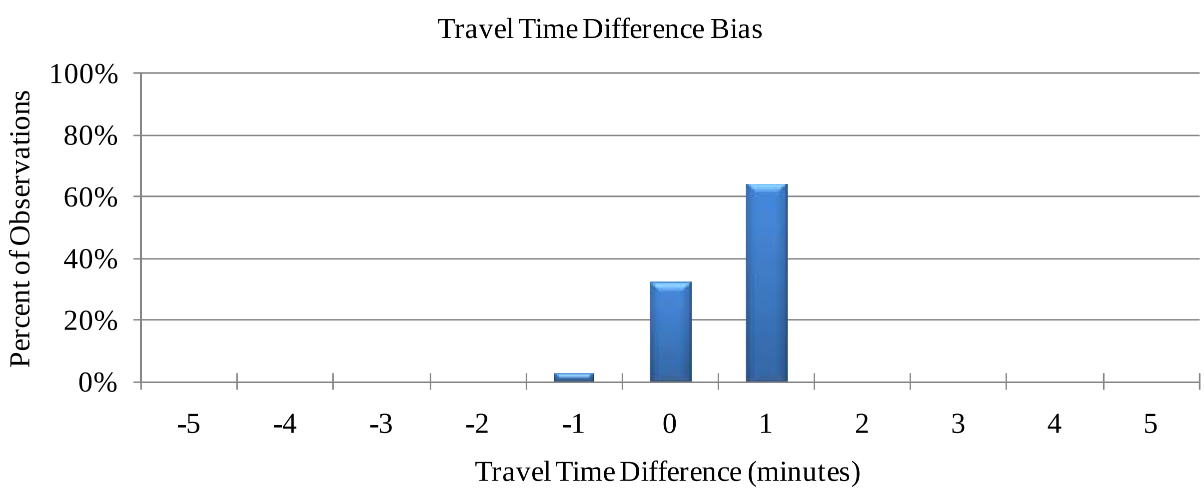


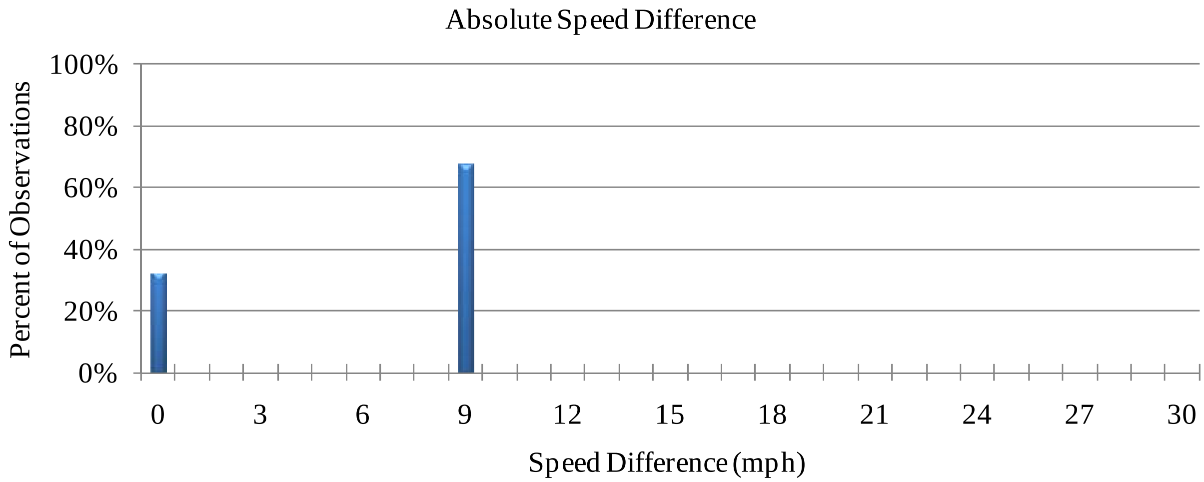

Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

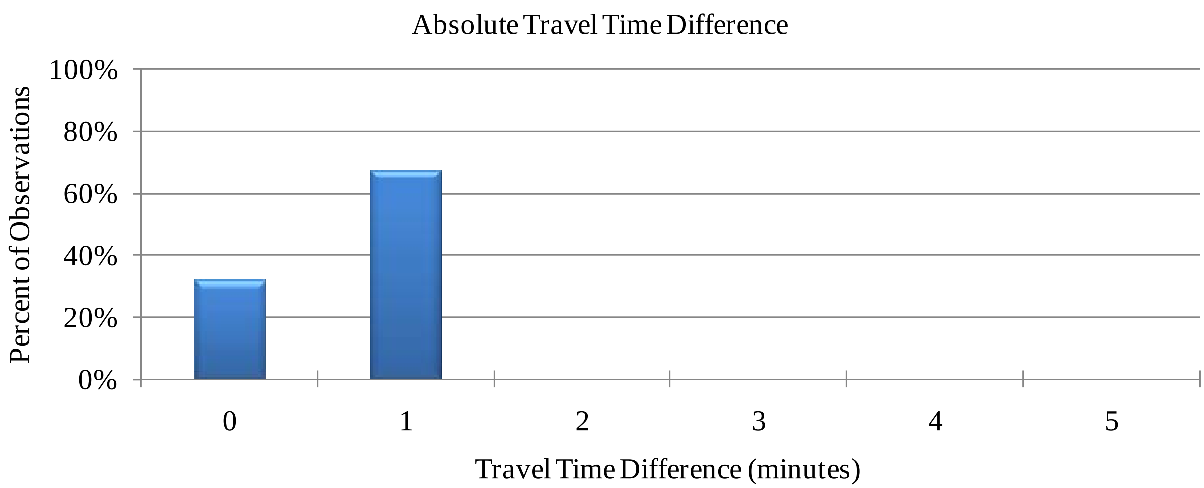

Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observation
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 32: US 35 WB: I-675 to I-75
Length: 6.4 miles (10.3 km)

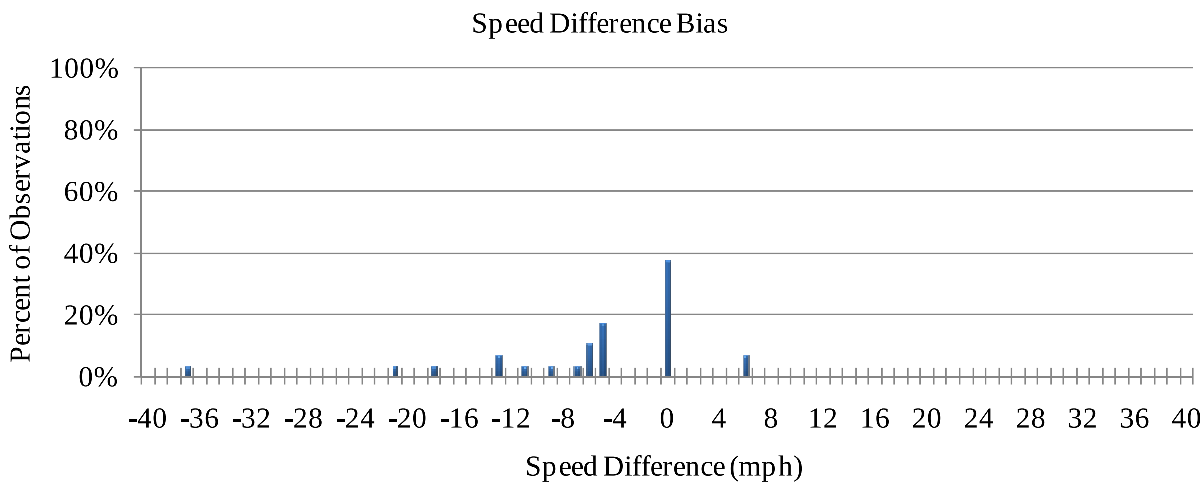


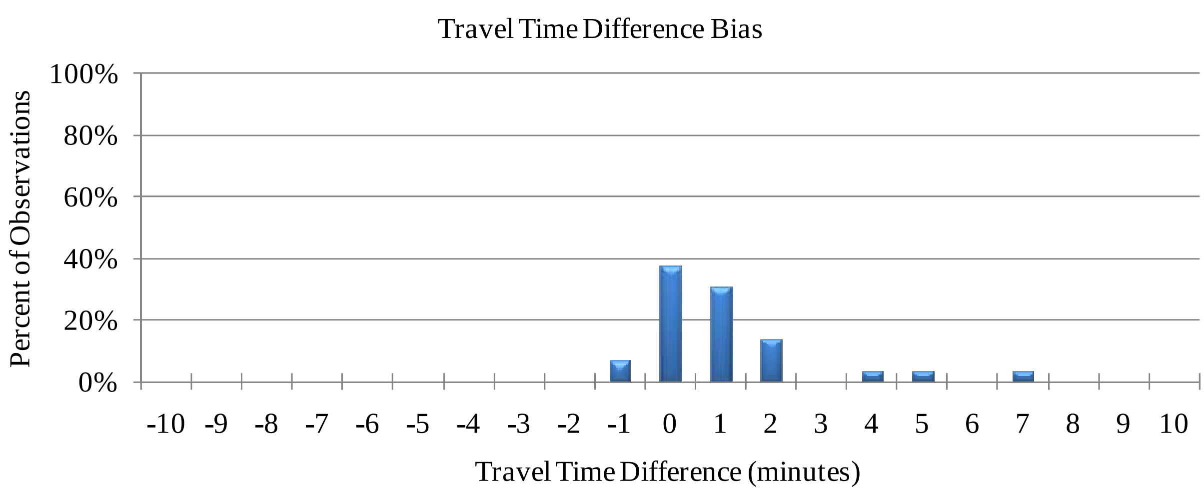


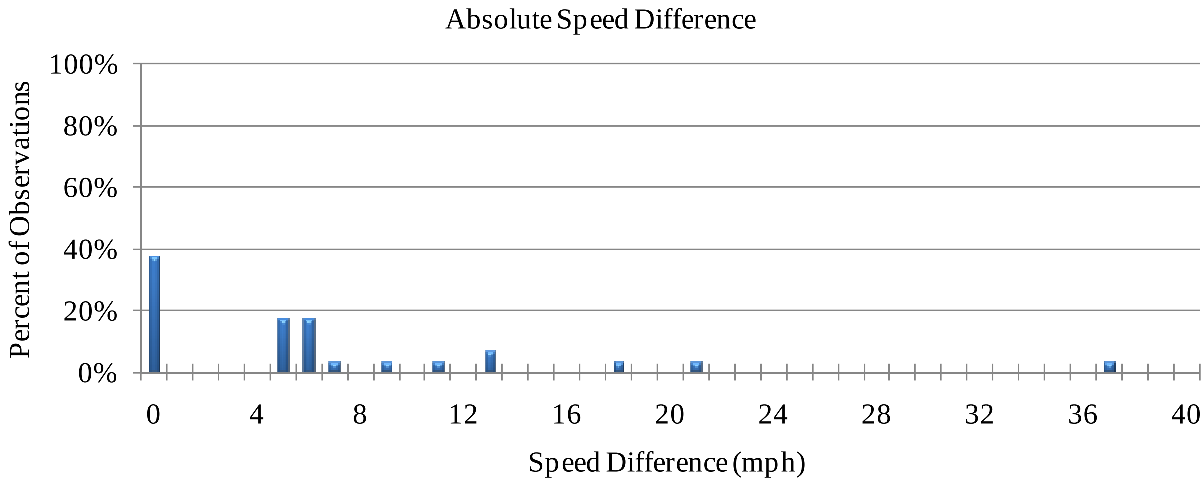

Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

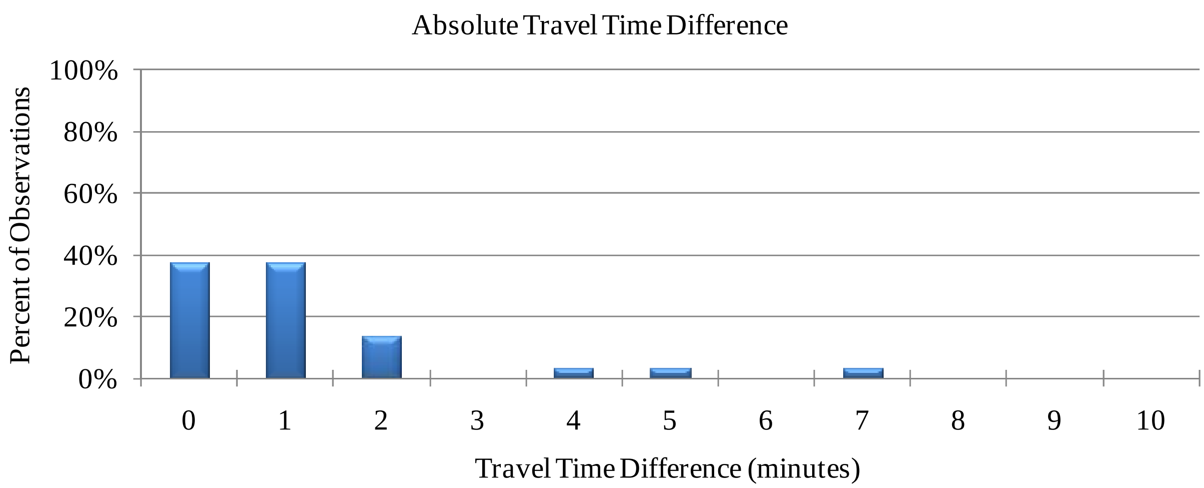

Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 33: SR 4 NB: I-75 to I-70
Length: 10.7 miles (17.2 km)

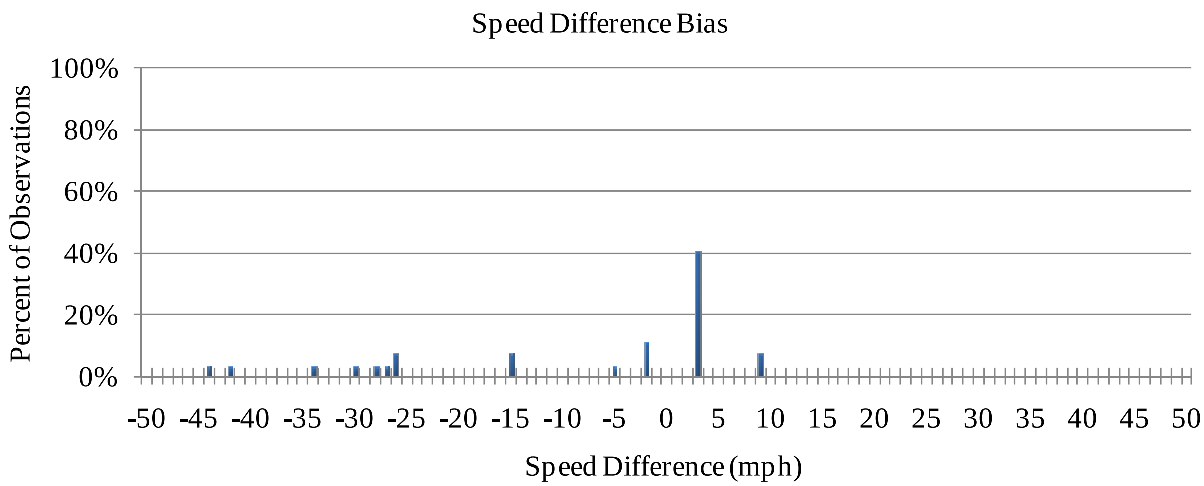


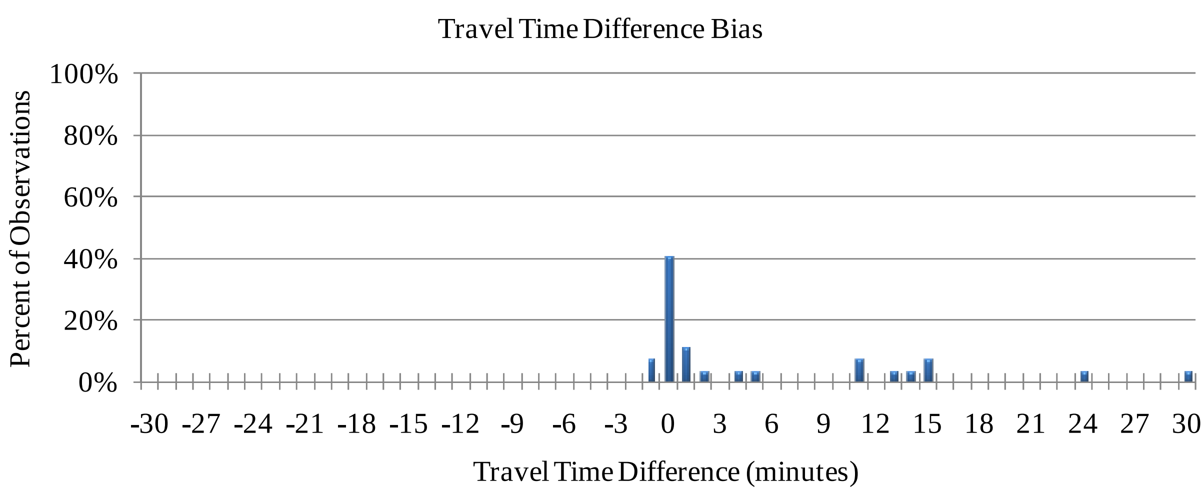


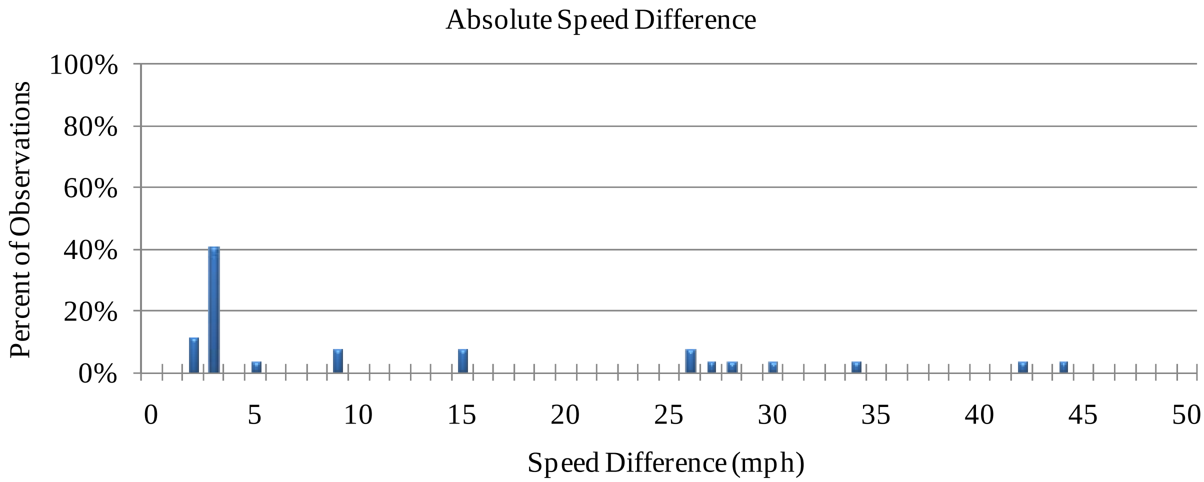

Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
4
8
12
16
20
24
28
32
36
40
Speed Difference (mph)


Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
6
7
8
9
10
Travel Time Difference (minutes)

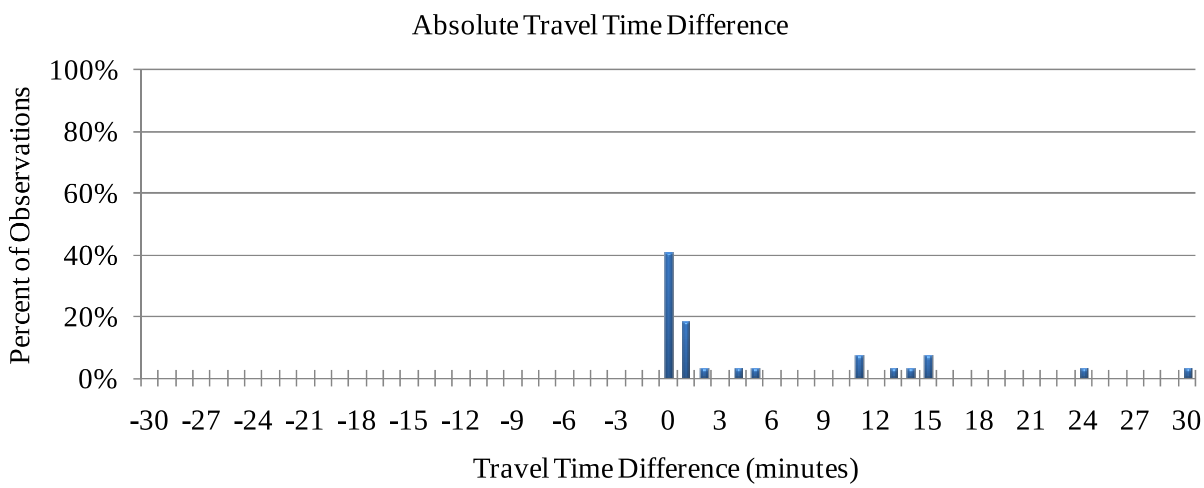
Segment 34: SR 4 SB: I-70 to I-75
Length: 10.7 miles (17.2 km)





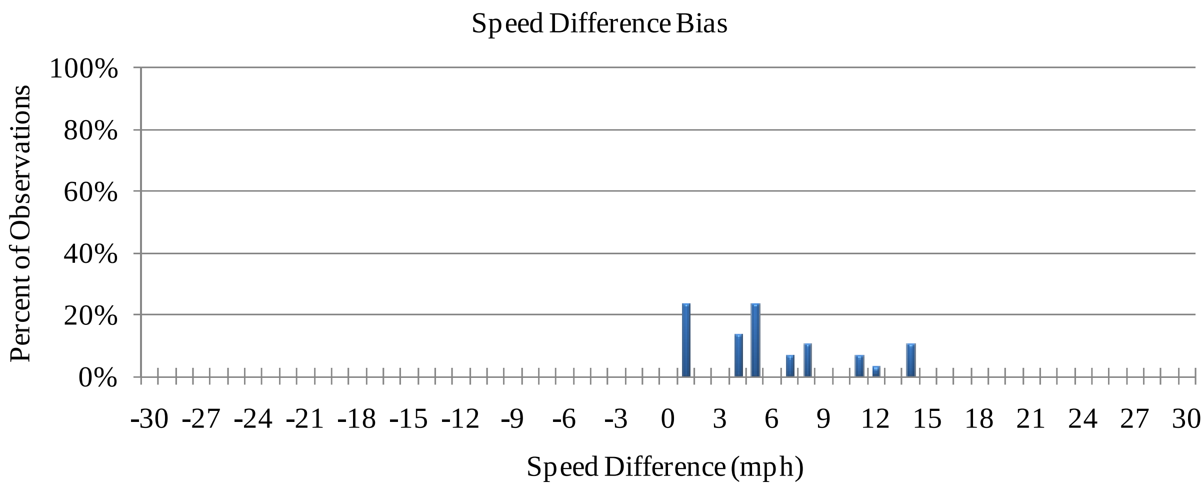


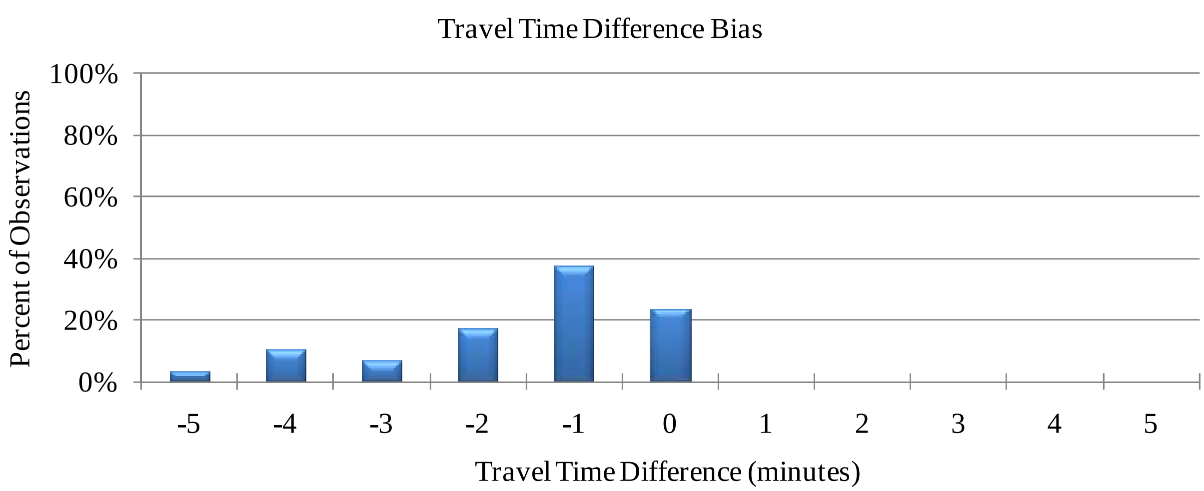
Absolute Speed Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
5
10
15
20
25
30
35
40
45
50
Speed Difference (mph)

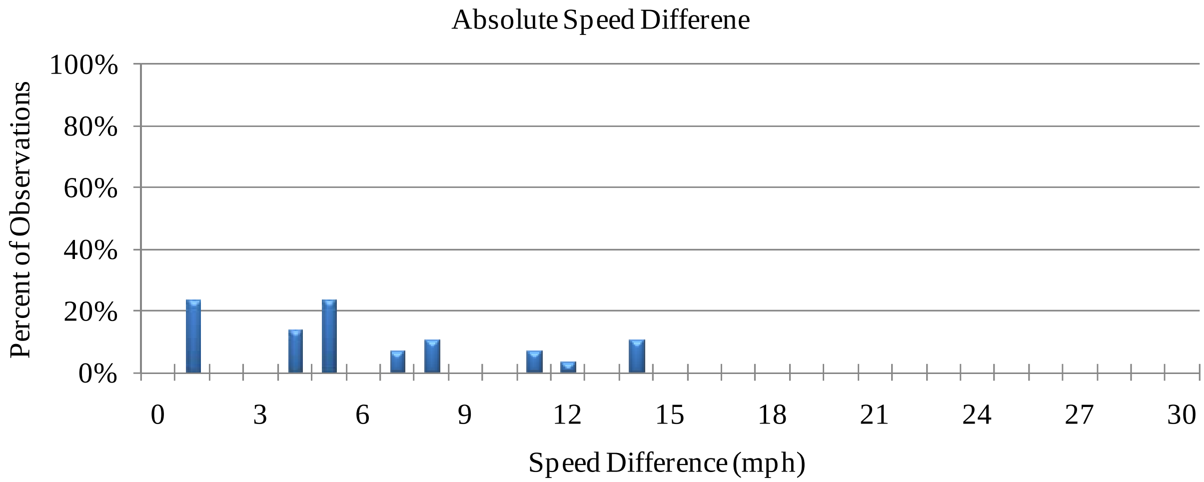


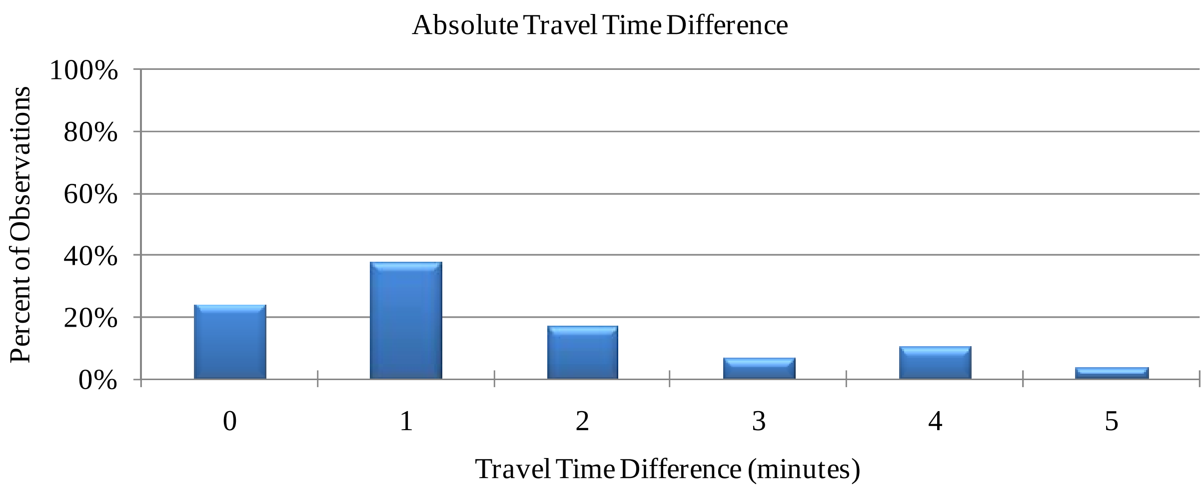
Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
-30
-27
-24
-21
-18
-15
-12
-9
-6
-3
0
3
6
9
12
15
18
21
24
27
30
Travel Time Difference (minutes)

Segment 35: SR 49 NB: US 35 to I-70
Length: 9.0 miles (14.5 km)

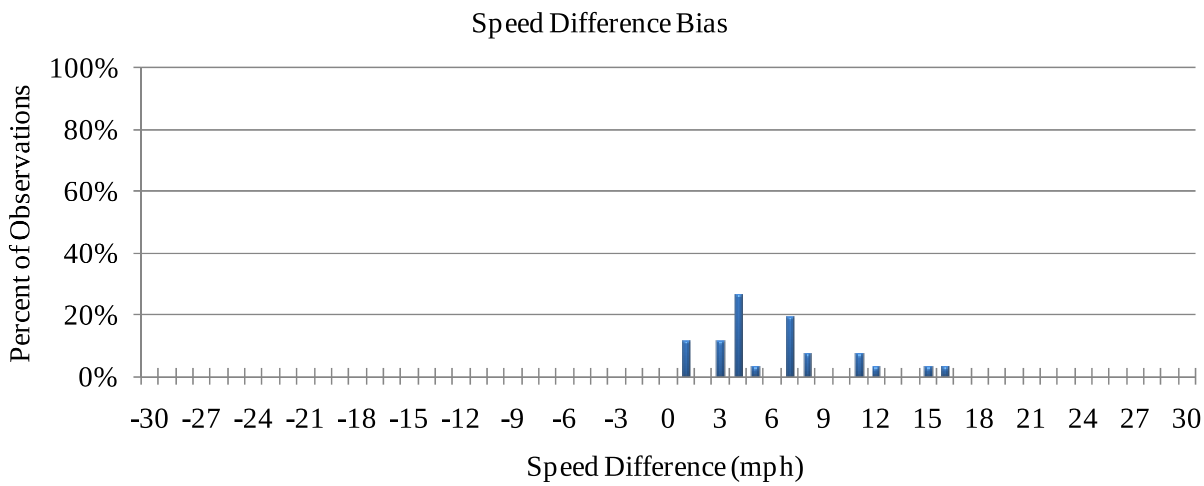


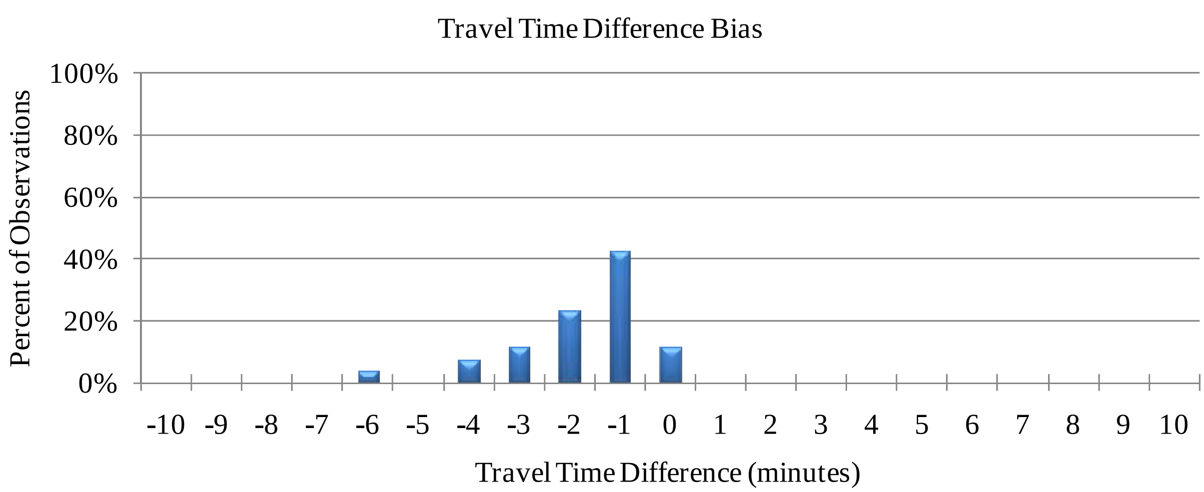


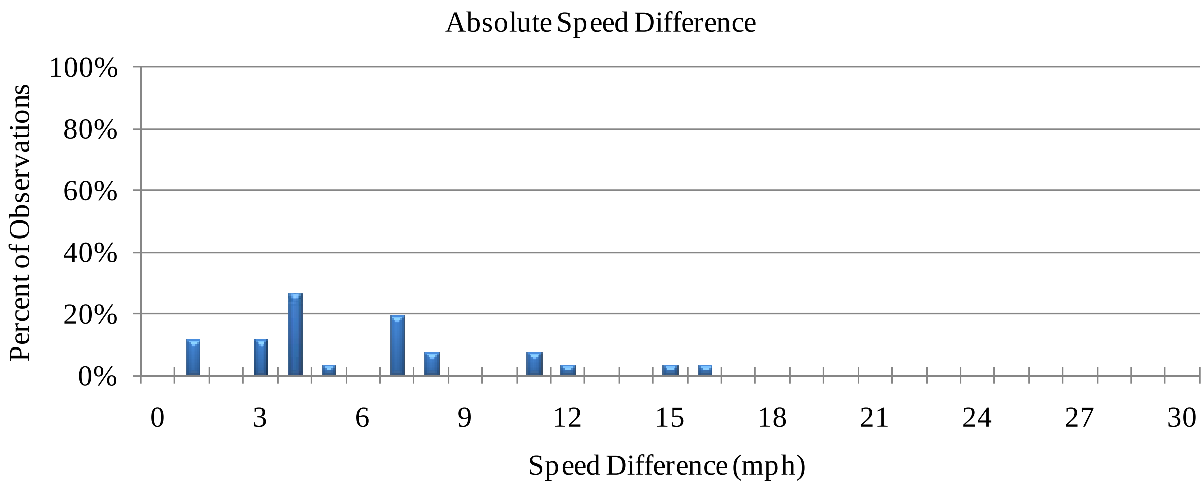

Absolute Speed Differene
100%
80%
60%
40%
20%
0%
Percent of Observations
0
3
6
9
12
15
18
21
24
27
30
Speed Difference (mph)

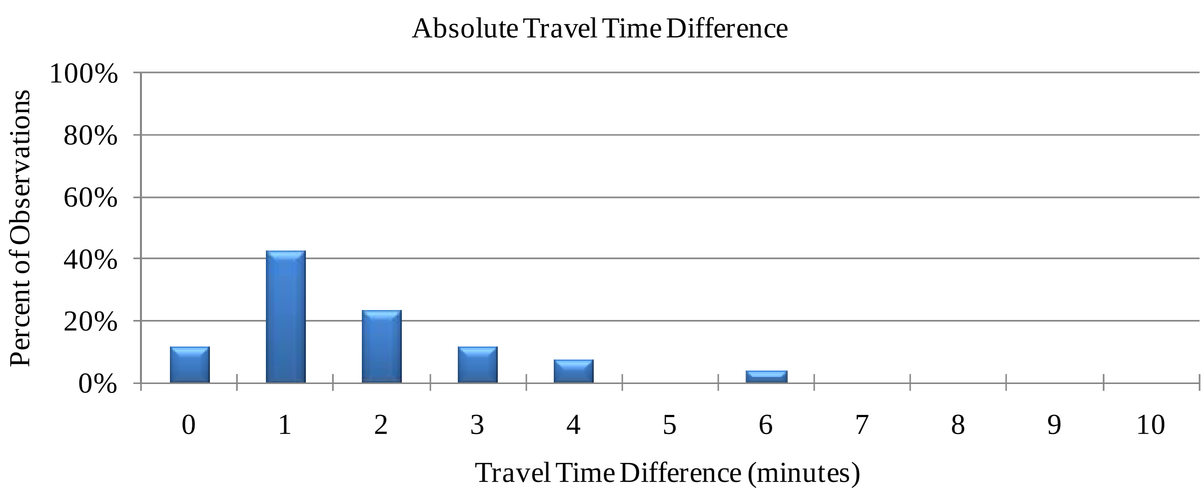

Absolute Travel Time Difference
100%
80%
60%
40%
20%
0%
Percent of Observations
0
1
2
3
4
5
Travel Time Difference (minutes)

Segment 36: SR 49 SB: I-70 to US 35
Length: 9.0 miles (14.5 km)






Absolute Speed Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0 3 6 9 12 15 18 21 24 27 30
Speed Difference (mph)


Absolute Travel Time Difference
Percent of Observations
100%
80%
60%
40%
20%
0%
0 1 2 3 4 5 6 7 8 9 10
Travel Time Difference (minutes)