Bluetooth Travel Time Technology Evaluation
Using the BlueTOAD™

E01271 PennDOT District 6-0 ITS & Support Open End Contract – Work Order #1

Submitted To:

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1.0 Executive Summary

The Pennsylvania Department of Transportation (PennDOT) hosted and participated in an independent study to evaluate the functionality of an alternative technology for collecting travel time information. Bluetooth, a fast-growing technology in wireless communications has recently begun to be applied to the fields of traffic monitoring and management. TrafficCast International (TCI) has utilized Bluetooth technology to develop their *BlueTOAD*^{TM} (Travel-time Origination and Destination) device. TrafficCast initiated the study and provided data gathered by their installed *BlueTOAD*^{TM} devices to PennDOT and its consultants.

The purpose of the demonstration was to evaluate the equipment and its ability to collect and report travel times. As such, the test was conducted along I-76 at locations coincident with *EZPass* tag readers. KMJ Consulting has completed an evaluation of the device including a summary of the data collection effort, the methodology for this evaluation and results. In addition, available information on equipment costs and constructability are presented in this document.

The evaluation determined that the travel times produced by *BlueTOAD*^{TM} are comparable to those produced by the *EZPass* tag readers.

EZPass tag readers are currently located along the I-76 corridor to collect travel time information utilizing the *EZPass* toll technology. The *EZPass* tag readers detect a security protected signal from the *EZPass* transponders located in the vehicle traveling along the roadway. Likewise, the *BlueTOAD*^{TM} product reads Bluetooth signals from vehicles, or devices within vehicles, passing along a subject roadway and measures the travel time and calculates travel speed. The Bluetooth readers rely on 48-bit Machine Access Control (MAC) addresses, which are anonymous and not linked to any personal information.

TrafficCast, at no expense to the Department, placed its devices along I-76 to gather travel time data facilitating the evaluation of this Bluetooth reader. The evaluation was conducted by comparing data gathered by *BlueTOAD*^{TM} to data gathered by *EZPass*. The comparison of these technologies will aid in the determination of whether Bluetooth readers should be used in the District to collect and provide travel time information.

The sections of roadway used for this evaluation are the eastbound I-76 segment between the Montgomery Drive interchange and the Spring Garden Street overpass, and the westbound I-76 segment between Waverly Road and the I-476 interchange.

For this demonstration, TrafficCast provided 15-minute travel time and speed data, as well as matched pairs, collected by its devices during the time period from July 23, 2009 to August 15, 2009. The study days selected were Thursday, August 13, 2009 and Saturday, August 15, 2009. Traffic volume data was obtained from PennDOT's RTMS

(Remote Traffic Microwave Sensor) stations. In addition, 15-minute travel times and speeds as well as the number of matched pairs were provided by *EZPass*, through PennDOT's Transmit server.

The primary performance metric is travel time, however, this report also presents the match rate to provide greater understanding and give context to the travel time results. Equipment cost and constructability were also included in this evaluation to the extent available. The results are summarized below:

1. ***Travel Time Results Comparison*** – The travel time results for each technology were compared for both study days. The average difference in travel time between the two technologies is less than 21 seconds in the westbound direction, and less than one minute in the eastbound direction. At least 16.5 seconds of the eastbound travel time difference is attributable to the spatial difference in origin device locations. As such, it is determined that the travel times produced by the devices are comparable to those produced by the *EZPass* tag readers.

2. ***Match Rate*** – This is the percent of successfully paired matches of either Bluetooth-enabled or *EZPass*-equipped vehicles, respectively within the corresponding travel stream passing along the roadway segment under study over a specified time period. The *BlueTOAD*^{TM} data resulted in matches comprising approximately four percent of the daily traffic stream compared with the *EZPass* tag readers with a range of 10-37% of the daily traffic. The minimum number of data points to accurately depict traffic conditions, per general guidelines, was collected by each traffic monitoring system.

3. ***Cost*** – The cost of the *BlueTOAD*^{TM} equipment including pole, but excluding power, communication, data formatting and system integration is approximately $9,700 to $12,200 per device, nearly one-third the cost of *EZPass*.

4. ***Constructability and Usability*** **–** Installation and maintenance of the *BlueTOAD*^{TM} device appears to be rather uncomplicated. The range of the reader is 175 feet. This would easily cover one direction of a multi-lane highway.

As a result of this demonstration and study, we recommend that PennDOT take the next step to integrate the Bluetooth travel time and data collection method into its existing system. One of the first tasks might be to issue an RFI to the technology community to identify other Bluetooth readers and to inquire about the best way to integrate Bluetooth data into the existing travel time system. Further investigation with Transdyn is necessary to ensure that the Dynac software can accept the data into its reporting system.

2.0 Introduction

PennDOT hosted and participated in a demonstration of Bluetooth technology using the *BlueTOAD*^{TM}, a product distributed by TrafficCast International (TCI). As such, KMJ Consulting, as a sub consultant to Jacobs for the PennDOT District 6-0 ITS & Support Open End Contract, Work Order #1 (E01271), was asked to complete an evaluation of the device.

EZPass tag readers currently exist along the I-76 corridor to collect travel time information utilizing the *EZPass* transponder technology. All personal identification information is scrambled within the *EZPass* controller prior to use for travel time calculations.

The *BlueTOAD*^{TM} product reads Bluetooth signals from vehicles passing along a subject roadway to provide measurements of travel time and resulting travel speed. The Bluetooth readers rely on anonymous MAC addresses.

TrafficCast, at no expense to the Department, placed its *BlueTOAD*^{TM} sensors along I-76 to gather travel time data to evaluate its effectiveness. The evaluation was conducted by comparing the travel time results and match rates achieved through the *BlueTOAD*^{TM} devices to the current *EZPass* system. Travel time, speed, and total data points gathered through the devices were summarized in 15-minute increments, consistent with PennDOT's current reporting.

3.0 Bluetooth Technology and the *BlueTOAD™* Product

Bluetooth is an open, wireless communication platform used to connect myriad electronic devices. Many computers, car radios and dashboard systems, PDAs, cell phones, headsets, or other personal equipment are, or can be, Bluetooth-enabled to streamline the flow of information between devices.

The interconnection between Bluetooth devices is achieved through the transmission and acceptance of a 48-bit Machine Access Control, or "MAC", address between inquiring and receiving devices. A small transceiver is constantly transmitting its device-specific MAC address in an effort to find other devices with which to communicate. Once a Bluetooth device is connected to another, the transmission of this MAC address continues. Although duplicates may exist, manufacturers typically assign unique MAC addresses to Bluetooth-equipped devices. These unique addresses are not tracked or readily available when devices are sold within the marketplace, making them a personal information-free identifier. The constant broadcast of these MAC addresses is detectable and measurable without establishing a relationship to personal or otherwise sensitive information, keeping the traveling public and their information anonymous.

[Other existing technologies, such as EZPass receivers or other electronic tag reading equipment, are commonly used around the country to help collect and disseminate travel time information. However, these existing technologies require sensitive identity information, such as account numbers and/or license plate numbers, to be removed from the data set prior to use.]

As part of this evaluation, TrafficCast's *BlueTOAD™* (Travel-time Origination And Destination) devices collected MAC addresses from Bluetooth-enabled devices such as phones, headsets, personal navigation devices, and computers along the I-76 corridor. These devices send MAC addresses, sensor location and time back to TrafficCast over a wireless cellular connection. Data collected by the device is anonymous due to the nature of the MAC address (no personal information is associated with the MAC address).

Figure 1
Installation of *BlueTOAD™* device

BlueTOAD™ devices are required to be mounted six to ten feet above the traveled lane and installed with a solar panel to provide power. Figure 1 presents the device installed at TR-1A (on the overhead sign structure at the I-476 exit). The device was attached to the truss adjacent to the right shoulder of the exit lane.

The radius of Bluetooth detection is approximately 175 feet; any Bluetooth transmitter entering this circle will be detected. Therefore, assuming a clear sight line, a single device could collect data from both sides of the roadway.

BlueTOAD™ link travel times are calculated based upon MAC address matches for the prescribed link origins and

destinations. Space mean speed is then calculated based on the travel time along a given link.

TrafficCast removes abnormal data points using an algorithm to eliminate outliers. Outliers include illogical data pairs and any other matched pair that is outside the normally expected travel time. This processing also filters out high speed outliers resulting from the rare finding of identical MAC addresses due to manufacturer duplication, and multiple simultaneous MAC addresses from within a single vehicle, such as a bus.

4.0 Study Purpose and Test Methodology

The purpose of the demonstration was to evaluate the ability of the *BlueTOAD*^{TM} product to collect and report travel times. As such, the test was conducted along I-76 at locations coincident with *EZPass* tag readers. *BlueTOAD*^{TM} travel times and match rates were compared to the *EZPass* tag readerdata.

The demonstration links were designed by Jacobs in conjunction with PennDOT. Figures 2 and 3 present the locations of the devices, *EZPass* tag readers, and RTMS stations for the eastbound and westbound segments, respectively.

The eastbound I-76 study segment is roughly 2.9 miles long and described as the link between the Montgomery Drive interchange and the Spring Garden Street overpass. At the origin of the roadway segment, *BlueTOAD*^{TM} device 10 was placed at DMS 706 whereas TR6 is located 0.3 miles downstream. This results in the *BlueTOAD*^{TM} link being longer with an inherently longer travel time. At the destination, Spring Garden overpass, *EZPass* tag reader TR9 is mounted beneath the overpass structure; *BlueTOAD*^{TM} device 11 was mounted on a sign structure adjacent to the overpass. The volume data used in the study of this link was selected from RTMS station DA720, which monitors traffic in the vicinity of DMS 706.

The westbound I-76 segment is 2.9 miles long between Waverly Road and the I-476 interchange. *BlueTOAD*^{TM} device 13 was placed on the overhead sign structure, to the right of the shoulder of the exit lane for Exit 331B. The *EZPass* tag reader, TR1A, is also mounted on this overhead sign structure. *BlueTOAD*^{TM} device 12 was attached to a mast arm that supports the *EZPass* tag reader, TR3. RTMS volume data is retrieved from DA701, which monitors traffic between the I-476 exit (Exit 331B) and the PA Route 23 exit (Exit 332), located just before the destination sensor.

TrafficCast provided travel times and link speeds for the time period from July 23, 2009 to August 15, 2009. Travel time and speed information was also available for use between each of the four *BlueTOAD*^{TM} devices providing "end-to-end" travel time and speed information in both the eastbound and westbound directions. Therefore, six roadway segments are able to be studied through the placement of four devices. Although this analysis evaluates only the above described study links, a table providing "end-to-end" travel time results from the *BlueTOAD*^{TM} devices is provided in the Appendix.

The study days selected were Thursday, August 13, 2009 and Saturday, August 15, 2009. Traffic volume data was obtained from PennDOT's RTMS through the Dynac system. The travel time results for each *EZPass* tag reader pair are gathered and conveyed to the PennDOT Traffic Control Center as a 20-second travel time average. Forty-five readings of the 20-second travel time averages are then averaged again to calculate a 15-minute posting of the travel time along a subject link. The number of matched pairs found with the *EZPass* tag readers was provided through PennDOT's Transmit server. Likewise,

TrafficCast provided 15-minute travel times and speeds and the number of matched pairs found within each 15-minute period.

Performance Metrics

The purpose of this effort is to evaluate the particular Bluetooth equipment and its ability to collect and report travel times. The primary performance metric is travel time; however, this report also presents the match rate to provide greater understanding and context to the travel time results. The metrics reported in the evaluation are presented below.

1. ***Travel Time Results Comparison*** – For each study day, the travel time results for both technologies are charted for comparison.
2. ***Match Rate*** – This is the percent of successfully paired matches of either Bluetooth-enabled or *EZPass*-equipped vehicles, respectively within the corresponding travel stream passing along the roadway segment under study over a 15-minute period.

In addition, available general cost and constructability information is presented. Although this evaluation does not include a full design effort to compare the costs of *EZPass* and *BlueTOAD*^{TM}, general costs and construction requirements are provided.

5.0 Analysis

The data provided by TrafficCast for the study links were analyzed and compared with the *EZPass* data to complete the evaluation.

Travel Time Results Comparison

Figures 4 through 7 present the travel time comparative results for each link on the selected weekday and Saturday studied. The travel time results were compared in 15-minute time intervals during the study periods to determine the differential between the *BlueTOAD*^{TM} data as compared to the *EZPass* tag reader data. Table 1 presents the absolute value of the difference in the average travel times between *EZPass* and *BlueTOAD*^{TM}, as well as the percent difference of *BlueTOAD*^{TM} as compared to *EZPass* (assumes that *EZPass* is ground truth). As shown in the table, these aggregated values are very close for the westbound segment, whereas the eastbound segment has higher values of differential due to the lack of coincident origin locations. [*The 0.3 mile difference could translate to as little as 16.5 seconds but can be greater if delays are encountered between the origin locations.*]

Table 1 - Differential in Travel Time Results

Link	Average Travel Time Differential (seconds/percent)			
	Daily	**Weekday 6 AM to 8 PM**	**Saturday**	**Saturday 6 AM to 8 PM**
Westbound	16/7	20/8	13/6	17/7
Eastbound	44/15	56/14	57/24	58/15

The Eastbound Segment

As previously discussed, the eastbound *EZPass* tag reader physical link is 0.3 miles shorter than the *BlueTOAD*^{TM} physical link. This affects the *EZPass* travel time reported in this study, especially when traffic congestion or incidents occur along the link. However, for the purpose of this study, the travel times were not adjusted.

The eastbound study roadway segment peak travel times were recorded by the *EZPass* system at 8:30 AM (8.2 minutes) and then again at 4:30 PM (20.7 minutes). On Saturday, a peak travel time of 20.7 minutes was recorded at 1:30 PM.

Morning and afternoon commuter peak congestion is expected; however, in between these peak periods, when volume is comparatively lighter, travel time will intermittently increase due to the combination of travel demand and roadway incidents.

During the overnight hours, the *BlueTOAD*^{TM} data fluctuates possibly due to the reduced number of data points.

The Westbound Segment

As shown in Figures 10 and 11 for the weekday and Saturday comparisons, the two collection methods report very similar travel time results. Travel time increases were found between the weekday peak commuter periods and outside of the midday Saturday peak travel period, and at greater levels. Both the *BlueTOAD™* and *EZPass* technologies reported these "off-peak" surges but there was no explanation other than increased travel demand.

The *BlueTOAD™* data seems to report peak travel times about 15 minutes before the *EZPass* tag reader. Shifting the *BlueTOAD™* data 15 minutes brings about a somewhat better fit. It is possible that the "early reporting" is due to the internal clock drift. [*This is best verified through visual inspection using CCTV cameras.*]

The westbound study roadway segment peak travel times were recorded by the *EZPass* system at 6.1 minutes and 5.4 minutes during the weekday morning (7:45 AM) and weekday afternoon (5:30 PM) commuter periods, respectively. On Saturday, the travel time peaks at 5:30 PM (8.1 minutes).

The highest levels of variability between the travel times reported by each data collection method are seen in the early morning hours between midnight and 6:00 AM, possibly a function of the fewer data points.

Match Rate

Figures 8 through 11 present the match rates for each technology in comparison to the RTMS-measured traffic volume for the same period. Table 2 presents the match rate achieved by each system during the weekday and Saturday study days.

Table 2 - Match Rate Comparison

Link	Device	Match Rate (percent)				
		Weekday			Saturday	
		Daily	AM Peak Period	PM Peak Period	Daily	Mid-day Peak Period
Eastbound	*BlueTOAD™*	3.5	3.5	4.6	3.8	4.5
	EZPass	29.5	37.1	34.7	24.1	24.5
Westbound	*BlueTOAD™*	4.1	4.0	4.0	4.0	4.7
	EZPass	12.9	15.6	16.1	10.3	12.5

The through volume for the eastbound study link was difficult to estimate due to the opportunities for traffic to enter and exit the roadway between the origin and destination points. As a result, it was not possible to ascertain the true through volume. Therefore, it is likely that the eastbound match rates for both systems are higher than those reported above. In the westbound direction, the through volume utilized to calculate the match

rate was not affected by the off ramp between the origin and destination sensors; therefore, the volume used to calculate the match rate represents the through volume for the link.

[*After completion of the data collection effort, it was learned that the BlueTOAD™ sensors were programmed to accept only 16 MAC addresses per minute per sensor. Despite this truncation in gathered data, the westbound roadway segment study still demonstrated adequate match rates. With the removal of this cap, and as Bluetooth-enabled devices increase within the vehicular population, the match rates are predicted to rise in future applications.*]

A general rule of thumb is to achieve three matched pairs every five minutes, or nine matched pairs per 15 minutes, 36 matched pairs an hour, or 864 per day. Well-placed sensors should provide a four percent detection rate for roadways of 36,000 AADT or greater (based upon research conducted by the University of Maryland). *"From statistical theory, the minimum number of data samples to ensure adequate confidence levels is an absolute number, rather than the percentage of sample. Therefore, a two percent match rate on a roadway of 100,000 AADT would provide more than enough hits to accurately generate mean travel times in five-minute intervals; two percent of 100,000 AADT is still a very large number of probes." (Stanley Young, University of Maryland).* However, roads with lower volume would require a larger match percentage to attain an adequate sample. Table 3, below presents a comparison of the number of matches achieved with each traffic monitoring system as compared to the general data requirements. As shown below, both the *BlueTOAD™* and *EZPass* systems gathered sufficient data per the general requirements.

Table 3 – Minimum Number Matches Found Compared to General Requirements

General Requirement	**Eastbound**					
	BlueTOAD™			***EZPass***		
	AM Peak Period	PM Peak Period	Sat Midday Peak Period	AM Peak Period	PM Peak Period	Sat Midday Peak Period
9 matched pairs per 15-minutes	23	19	18	367	358	179
36 matched pairs per hour	145	189	126	1,852	1,559	771
864 matched pairs per day	3,288		3,297	27,903		19,719
General Requirement	**Westbound**					
	BlueTOAD™			***EZPass***		
	AM Peak Period	PM Peak Period	Sat Midday Peak Period	AM Peak Period	PM Peak Period	Sat Midday Peak Period
9 matched pairs per 15-minutes	16	18	31	67	79	82
36 matched pairs per hour	94	94	143	411	377	384
864 matched pairs per day	2,171		1,988	7,379		5,193

Another factor in the ability to attain an acceptable number of data matches is the very existence of Bluetooth devices or possibility of a match. The subject test site of I-76 is within the greater Philadelphia area and therefore presumed to have a preponderance of Bluetooth-enabled devices. As a result, the combination of traffic volume and potential number of Bluetooth enabled devices would lead one to believe that there would be an acceptable number of matches. Daily traffic volume on I-76 for the eastbound study segment ranges from approximately 83,000 to 91,000 vehicles per day; the westbound segment carries approximately 51,000 to 58,000 vehicles per day.

General Cost and Constructability

Available information on cost and observations on constructability were gathered to provide additional context to this evaluation. Table 4 presents the order-of-magnitude equipment and mounting costs for *BlueTOAD™* and *EZPass*. As shown, the *BlueTOAD™* costs are approximately one-third the cost of *EZPass*. Note that these costs do not include power, communication, data formatting or system integration. General pricing information for the *BlueTOAD™* devices is provided within the Appendix. To meet PennDOT's system requirements, TrafficCast could develop a front-end processor that would reside at PennDOT to properly filter the data. The cost for the processor, and possible data exchange between TrafficCast and PennDOT would need to be negotiated.

Table 4 – General Cost Information for EZPass and BlueTOAD™ Systems

EZPass		*BlueTOAD™*	
Tag Reader, lane kit and cabinet, mast arm and pole structure	$34,000 to $36,000	*BlueTOAD™* base unit, solar battery, cellular modem, vertical strain pole	$9,700 to $12,200

From a constructability standpoint, it appears that the *BlueTOAD™* or any Bluetooth device is quite flexible in terms of installation and use. The device needs to be positioned along the side of the roadway at a height of six to ten feet. The sensing range is 175 feet. The device can be pole-mounted and does not require an overhead structure. Further, in contrast to other devices, such as RTMS, device tuning is not required. It is necessary, however, to synchronize the internal clock to avoid drift. Lastly, from a usability standpoint, a single Bluetooth device is able to monitor multiple lanes of travel regardless of direction; a six-lane freeway might require only one or two devices whereas multiple *EZPass* lane kits are needed to cover the same number of lanes. In some cases, the Bluetooth device can cover several lanes in both directions.

6.0 Conclusions

The evaluation determined that the travel times produced by the Bluetooth technology and the *BlueTOAD*^{TM} device are comparable to those produced by the *EZPass* tag readers. The results of this evaluation are summarized below:

1. ***Travel Time Results Comparison*** – The travel time results for each technology were compared for both study days. The average difference in travel time between the two technologies is less than 21 seconds in the westbound direction, and less than one minute in the eastbound direction. At least 16.5 seconds of the eastbound travel time difference is attributable to the spatial difference in origin device locations. As such, it is determined that the travel times produced by the *BlueTOAD*^{TM} are comparable to those produced by the *EZPass* tag readers.

2. ***Match Rate*** – This is the percent of successfully paired matches of either Bluetooth-enabled or *EZPass*-equipped vehicles, respectively within the corresponding travel stream passing along the roadway segment under study over a specified time period. The *BlueTOAD*^{TM} data resulted in matches comprising approximately four percent of the daily traffic stream compared with the *EZPass* tag readers with a range of 10-37% of the daily traffic. The minimum number of data points (needed as the general rule of thumb) to accurately depict traffic conditions was collected by each traffic monitoring system.

3. ***Cost*** – The cost of the *BlueTOAD*^{TM} equipment including pole, but excluding power, communication, data formatting and system integration is approximately $9,700 to $12,200 per device, nearly one third the cost of *EZPass*.

4. ***Constructability and Usability*** **–** Installation and maintenance of the *BlueTOAD*^{TM} device appears to be rather uncomplicated. The range of the reader is 175 feet. This would easily cover one direction of a multi-lane highway.

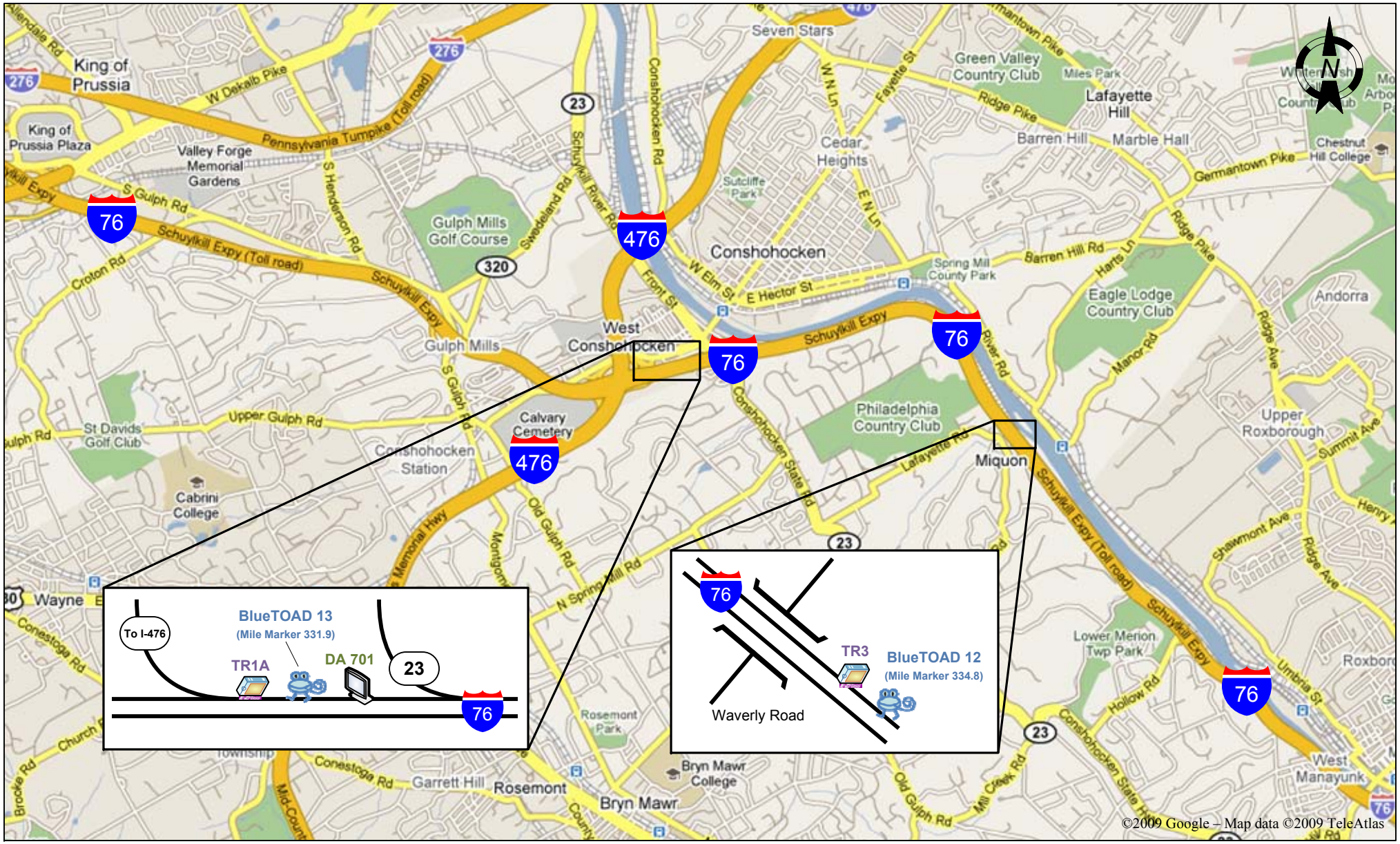
As a result of this demonstration and study, we recommend that PennDOT take the next step to integrate the Bluetooth travel time and data collection method into its existing system. One of the first tasks might be to issue an RFI to the technology community to identify other Bluetooth readers and to inquire about the best way to integrate Bluetooth data into the existing travel time system. The RFI should include a test to determine the level of Bluetooth signals available on the subject arterial route. Contact information for two potential vendors of this technology is provided within the appendix. Further investigation with Transdyn is also necessary to ensure that the Dynac software can accept the data into its reporting system.

Location Map – Eastbound I-76 Segment

Figure 2

Legend:

BlueTOAD Device XX TR (EZPass) Reader XX PennDOT RTMS (DA) XXX



Location Map – Westbound I-76 Segment

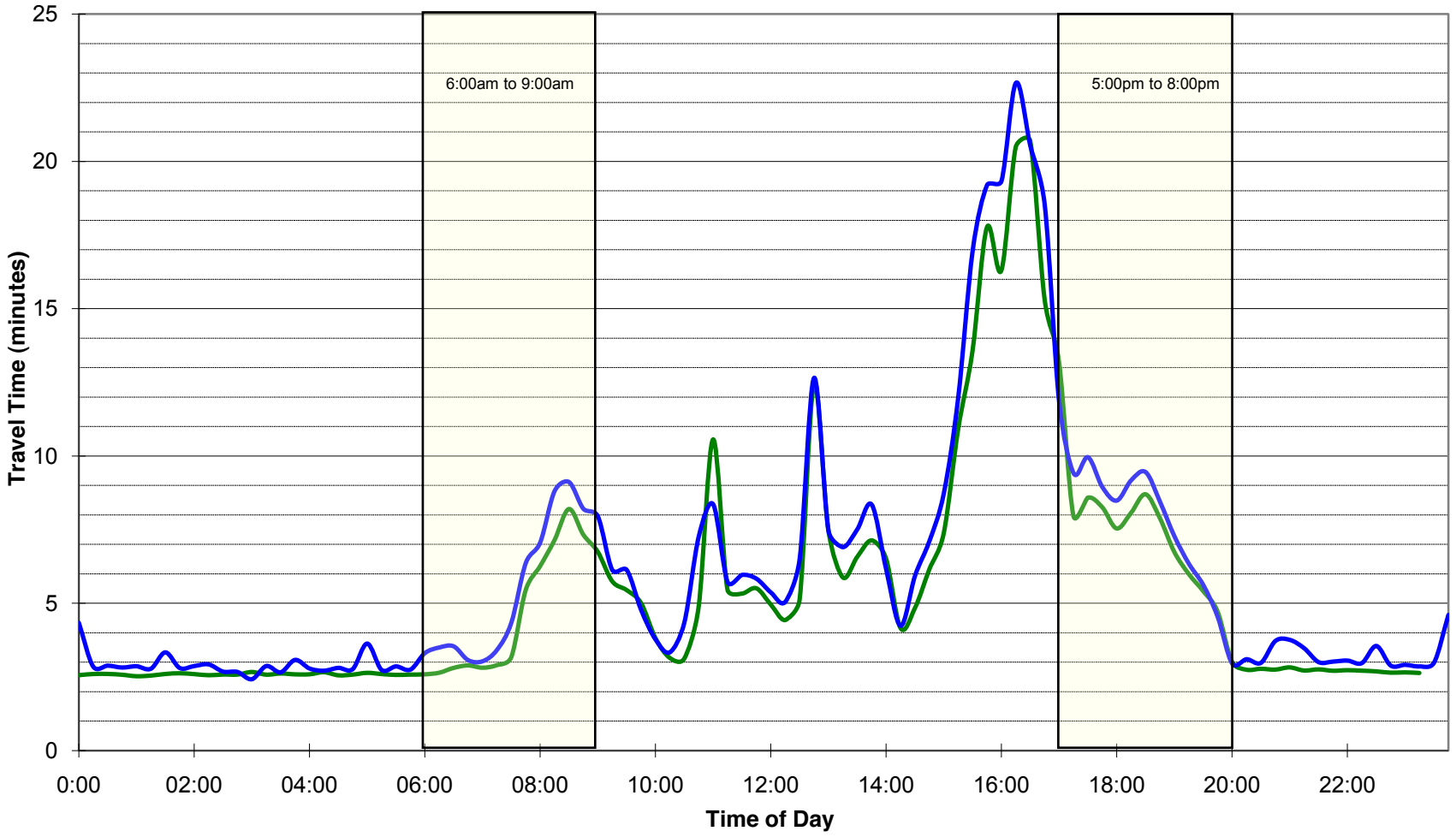
Legend:

BlueTOAD Device XX

TR (EZPass) Reader XX

PennDOT RTMS (DA) XXX

Figure 3



Comparison of Weekday Travel Time Results - Eastbound I-76 between Montgomery Drive and Spring Garden Street

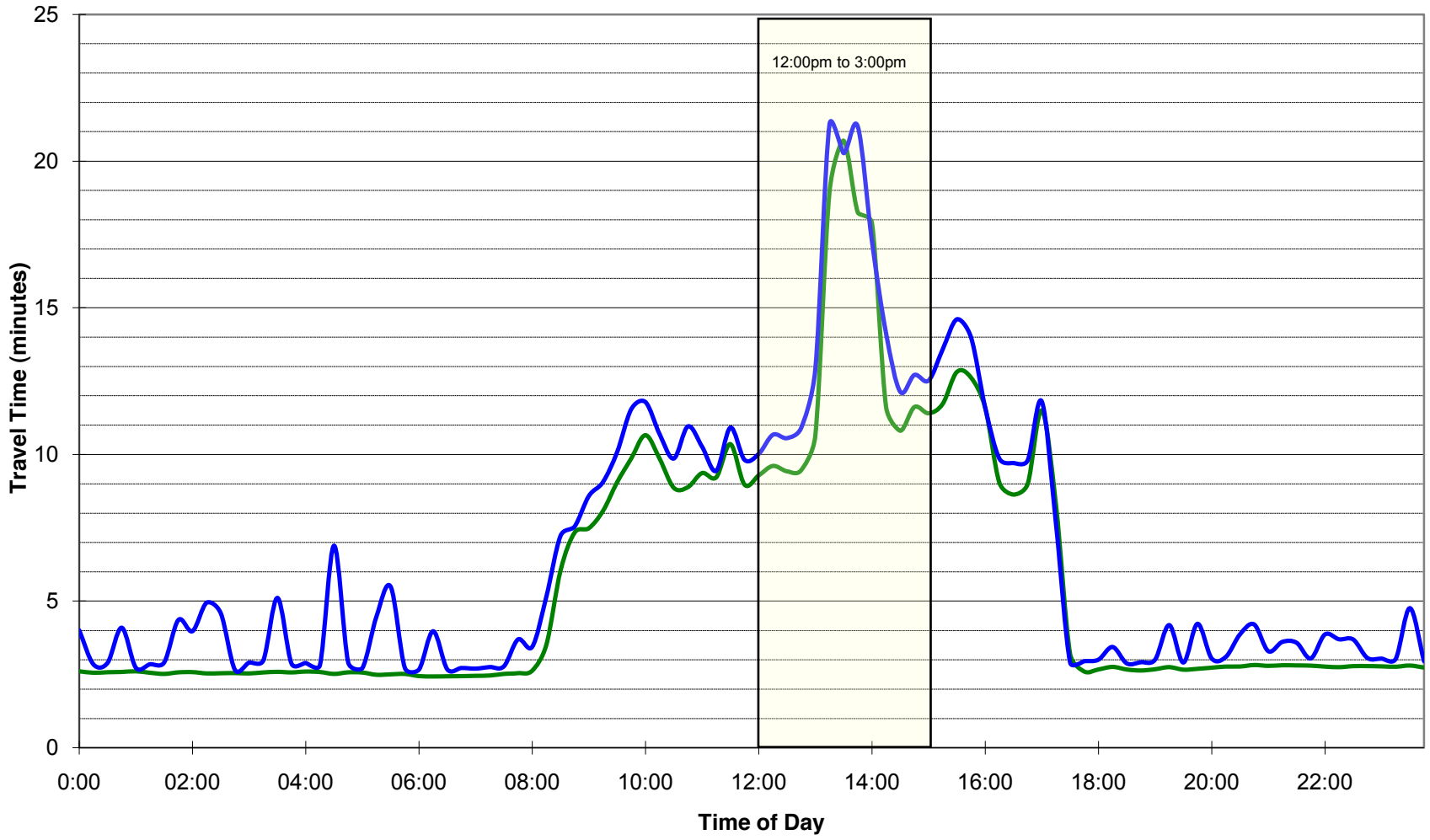
Legend:

EZPass Readers (TR6 to TR9) 2.6 miles

BlueTOAD Devices (10 to 11) 2.9 miles

***Due to geometric constraints, the physical location of the originating EZPass reader is approximately 0.3 miles downstream from the Blue TOAD™ device. Therefore, a nominal increase in travel time is found for the BlueTOAD results.**

Figure 4



Comparison of Saturday Travel Time Results - Eastbound I-76 between Montgomery Drive and Spring Garden Street

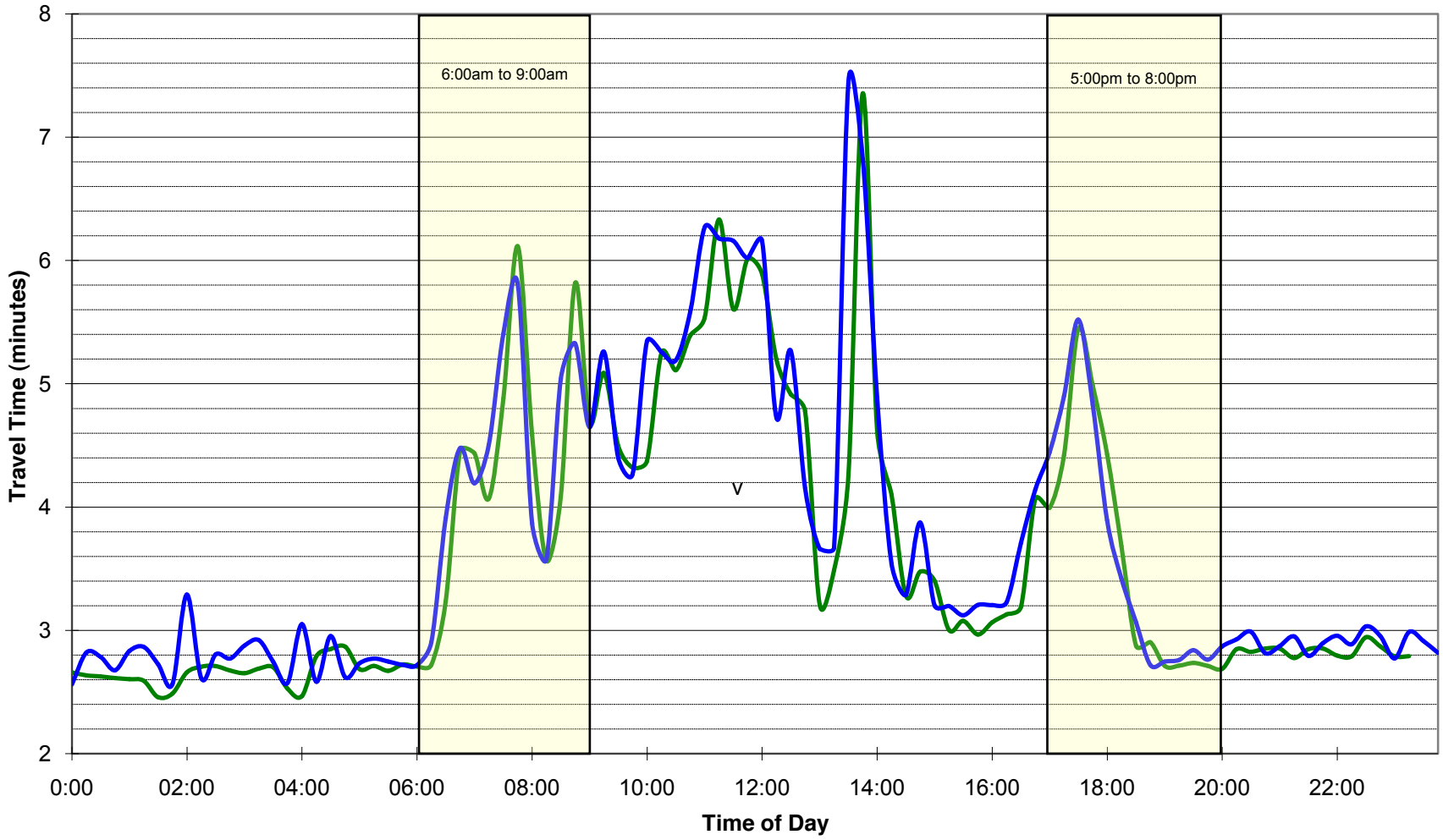
Legend:

EZPass Readers (TR6 to TR9) 2.6 miles

BlueTOAD Devices (10 to 11) 2.9 miles

Figure 5

***Due to geometric constraints, the physical location of the originating EZPass reader is approximately 0.3 miles downstream from the Blue TOAD™ device. Therefore, a nominal increase in travel time is found for the BlueTOAD results.**



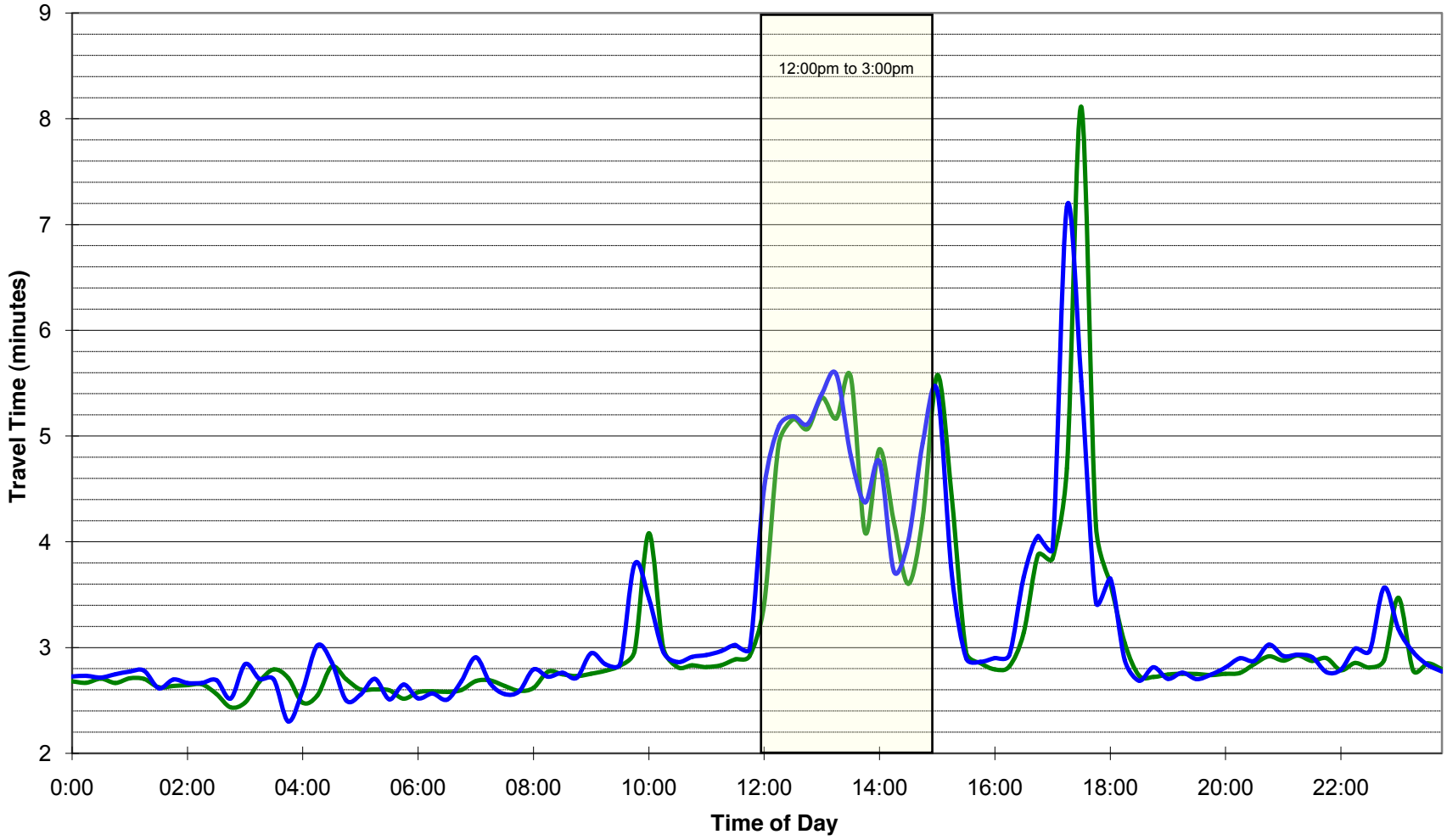
Comparison of Weekday Travel Time Results Westbound I-76 between Waverly Road and I-476

Legend:

EZPass Readers (TR3 to TR1A) 2.9 miles

BlueTOAD Devices (12 to 13) 2.9 miles

Figure 6



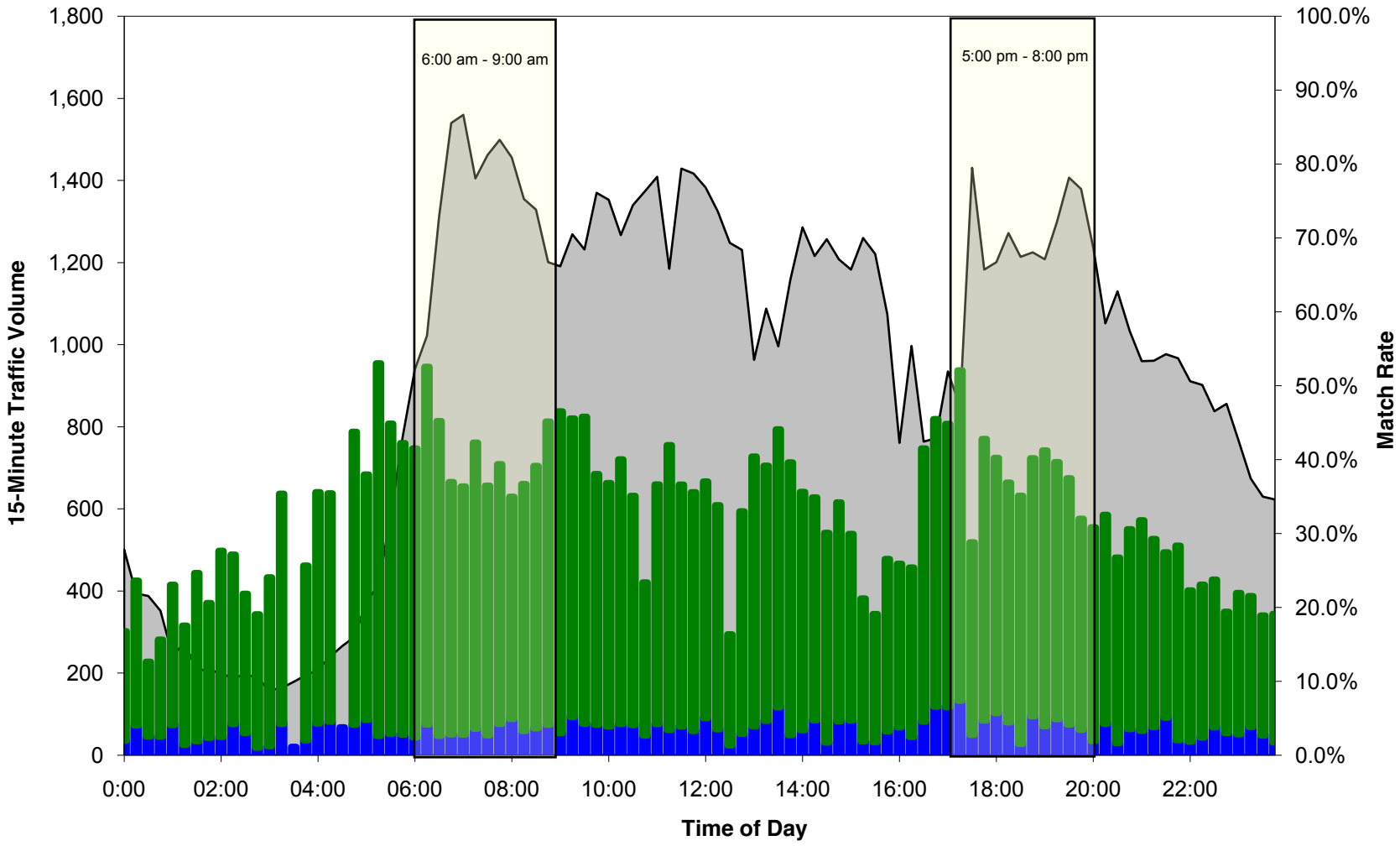
Comparison of Saturday Travel Time Results Westbound I-76 between Waverly Road and I-476

Legend:

EZPass Readers (TR3 to TR1A) 2.9 miles

BlueTOAD Devices (12 to 13) 2.9 miles

Figure 7

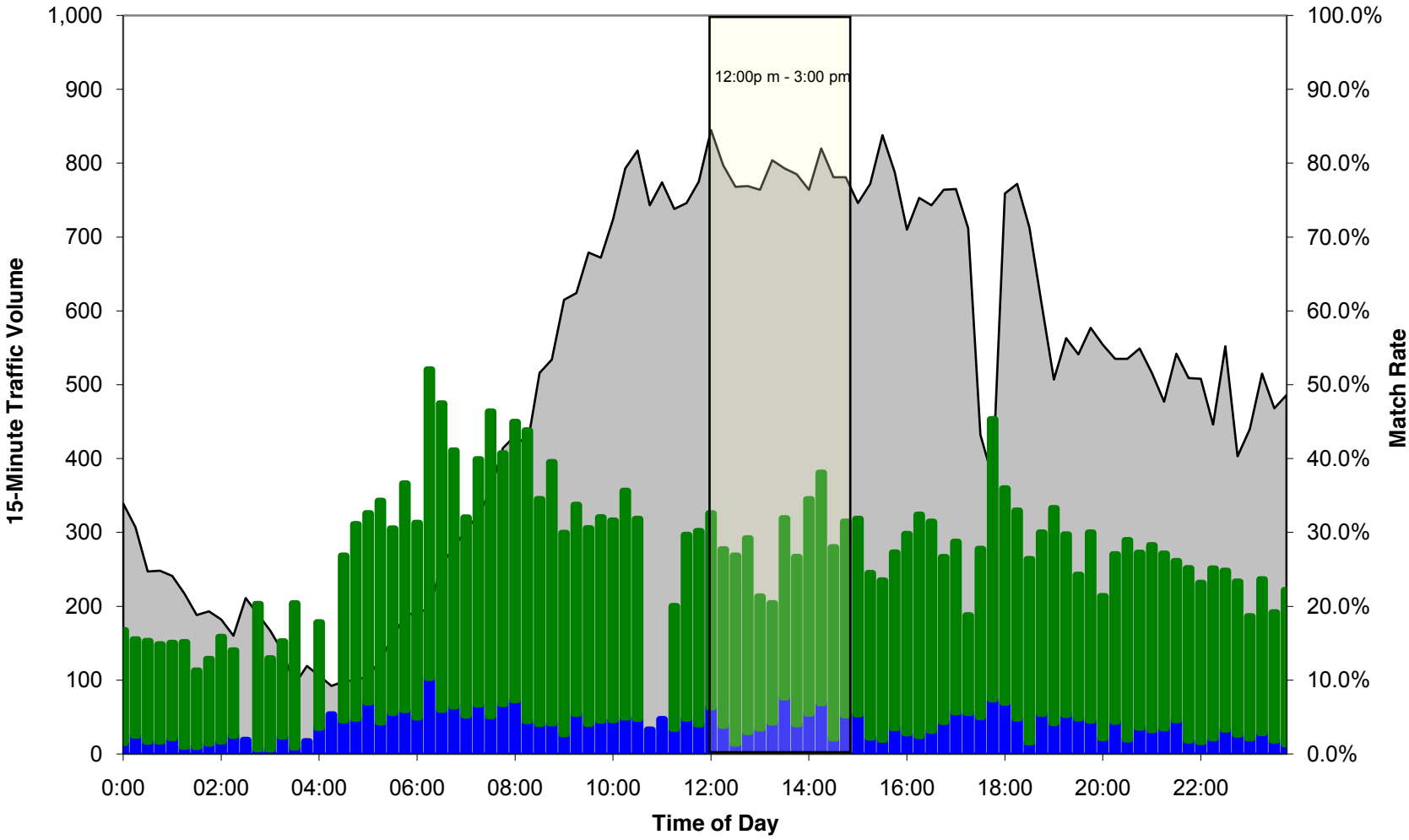


Weekday Match Rate with Corresponding Traffic Volume - Eastbound I-76 between Montgomery Drive and Spring Garden Street

Legend:

Traffic Volumes (Recorded by RTMS# DA720EB) BlueTOAD Match Rate EZPass Match Rate

Figure 8

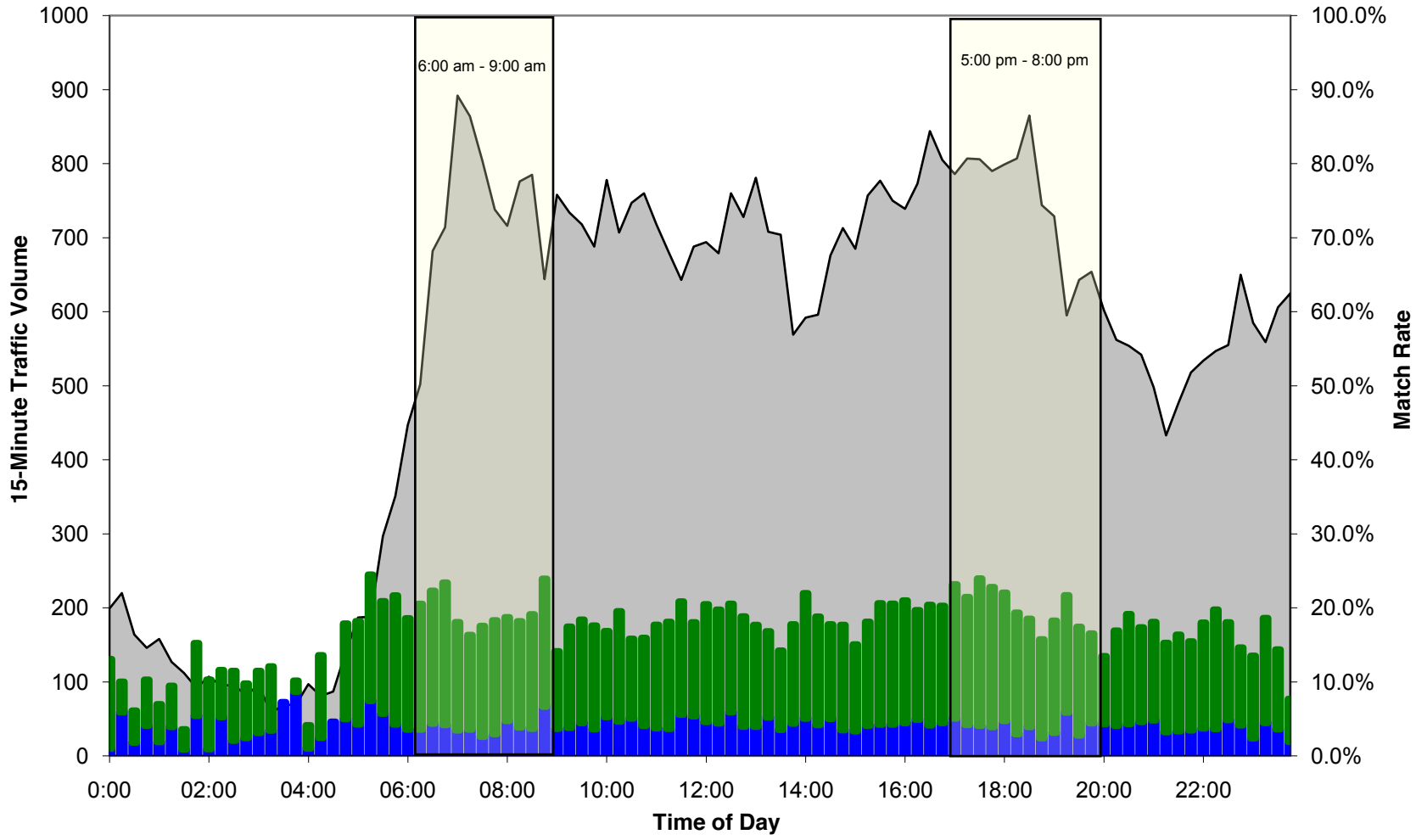


Saturday Match Rates with Corresponding Traffic Volume - Eastbound I-76 between Montgomery Drive and Spring Garden Street

Legend:

Traffic Volumes (Recorded By RTMS# DA720EB) BlueTOAD Match Rate EZPass Match Rate

Figure 9

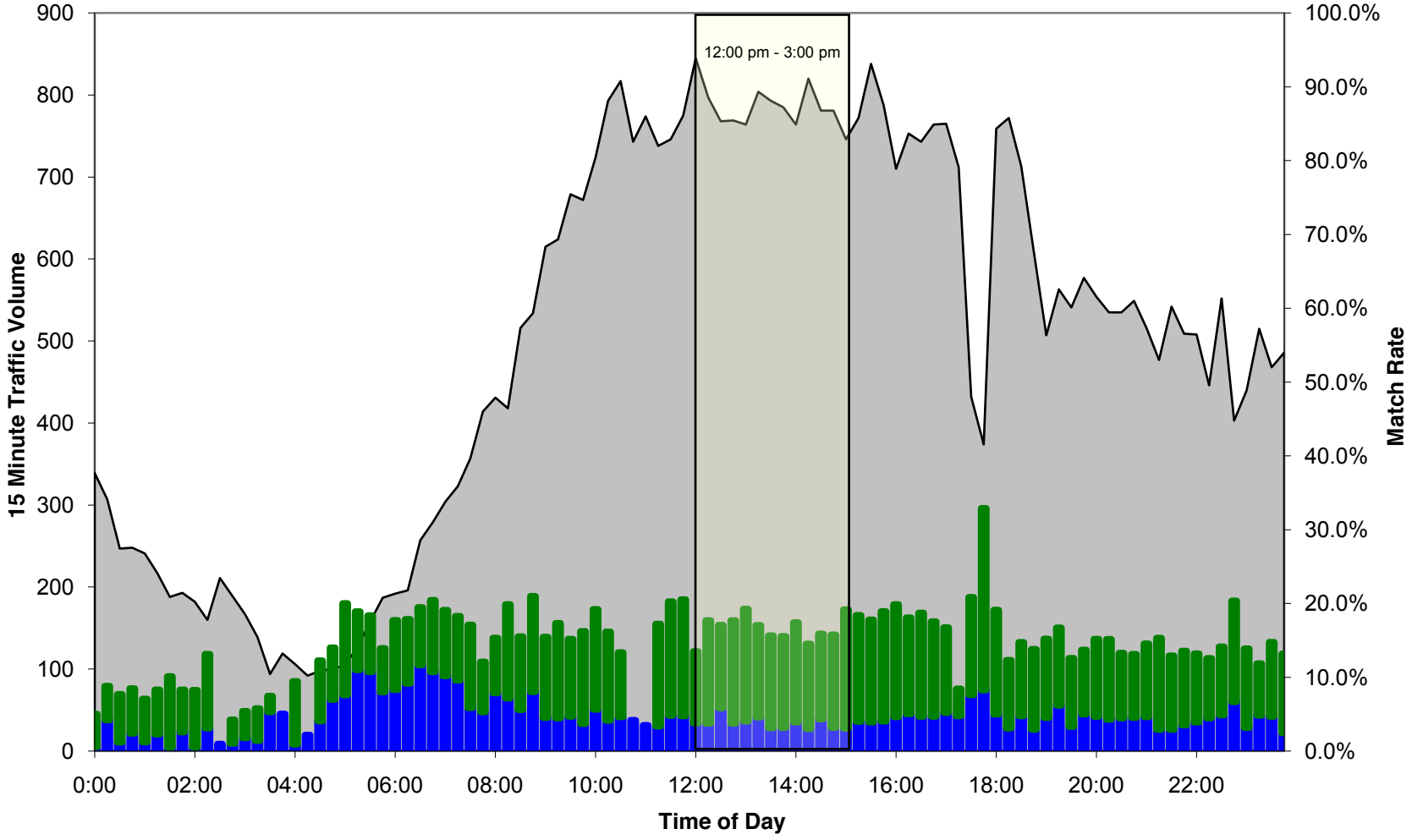


Weekday Match Rates with Corresponding Traffic Volume - Westbound I-76 between Waverly Road and I-476

Legend:

Traffic Volume (Recorded by RTMS# DA701WB) BlueTOAD Match Rate EZPass Match Rate

Figure 10



Saturday Match Rates with Corresponding Traffic Volume - Westbound I-76 between Waverly Road and I-476

Legend:

Traffic Volume (Recorded by RTMS# DA701WB) BlueTOAD Match Rate EZPass Match Rate

Figure 11