I-95 CORRIDOR COALITION
YEAR 17 PROJECTS

Special use lanes and ramps – Challenges to effective traffic monitoring

Prepared by University of Maryland Center for Advanced Transportation Technology

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February 2012

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Special use lanes and ramps – Challenges to effective traffic monitoring

Report

Sponsored by:

I-95 Corridor Coalition

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Executive Summary

The Vehicle Probe Project (VPP) has expanded from 1,500 freeway miles in 2008, to over 5,000 freeway miles in 2011. Initial validation efforts focused on data quality for the mainline freeway segments, as directed by the project requirements. As use of the project data expanded, questions were raised regarding the quality of the VPP data for facilities other than mainline freeway segments. This report investigates the quality of the reported speed and travel time data of the VPP for freeway ramps and special use lanes.

> *Results indicate that data quality for ramps in terms of the accuracy of reported travel time and speed are consistent with the data quality reported for mainline freeways.*

Freeway ramps were added to the VPP coverage in 2011 for all freeway to freeway interchanges within the VPP coverage area. Freeway interchanges in heavily traffic suburban and urban areas can be of significant length, have long merge and diverge areas with the mainline, and be a large contributor to overall traffic congestion. In response, systematic data collection and quality assessment began in 2011 for freeway ramps and special use lanes included in the VPP data set. Results indicate that data quality for ramps in terms of the accuracy of reported travel time and speed are consistent with the data quality reported for mainline freeways. Traffic volume on ramps, particularly non-dominant turning movements, may not be of sufficient density to provide real-time data (as indicated by the Score attribute equal 30). However, the likelihood of low-volume ramps experiencing or contributing to congestion is also minimal.

> *The speed bins adopted for freeway data validation (0-30 mph, 30-45 mph, 45-60 mph, and > 60 mph) may need to be adjusted downward for evaluating ramp data quality.*

The overall speeds observed for ramp data were generally less than that of freeways. Most data appeared in the 45 to 60 mph range, rather than greater than 60 mph for freeways. The portion of data in the 30 to 45 mph range (indicative of congestion on freeways) was significantly larger for ramps than freeways, suggesting that normal operating speed, for a portion of the freeway ramps studied, were within this range. The speed bins adopted for freeway data validation (0-30 MPH, 30-45 MPH, 45-60 MPH, and > 60 MPH) may need to be adjusted downward for evaluating ramp data quality.

> *In most instances, distinct travel time measurements for (special-use lanes) were not observed, and when they did occur, the difference in speed between the special use lane and the mainline was too minimal to determine whether the VPP accurately reported traffic conditions on the special use lane separate from the mainline.*

Special use lanes include high-occupancy vehicle (HOV) lanes, local/express lanes, high-occupancy & toll (HOT) lanes, and reversible flow lanes. A survey of the Mid-Atlantic States consisting of North Carolina, Maryland, Virginia, Delaware, and New Jersey revealed approximately 140 centerline miles of a variety of existing special use lane facilities, with another 44 miles of HOT and reversible lane centerline miles planned for operation in Maryland and Northern Virginia. Attempts to capture differential traffic flow during validation activities have been met with marginal success. In most instances distinct travel time measurements for these facilities were not observed, and when they did occur, the difference in speed between the special use lane and the mainline was too minimal to determine whether the VPP accurately reported traffic conditions on the special use lane separate from the mainline.

> *There are no general conclusions drawn on what the analysis of the VPP data shows related to bi-modal flows, each situation needs to be examined separately.*

The validation did capture on occasion significant differences in travel speed on the same roadway in which one group traveled faster or slower than the remaining traffic, referred to as bi-modal flows. This was observed and documented for heavy vehicles in mountainous areas and near weight stations. This was also observed and documented for automated tolling versus manual tolling at toll collection booths. There are no general conclusions drawn on what the analysis of the VPP data shows related to bi-modal flows, each situation needs to be examined separately.

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INTRODUCTION

Special use lanes and major freeway ramps present unique challenges to accurately monitor speed and travel time. The I-95 Vehicle Probe Project (VPP), has been providing travel time and speed information for more than 3.5 years, on over 5,000 freeway miles, including ramps between major interchanges, and several facilities with special use lanes. This report examines and presents validation data obtained on ramps, special use lanes, and other non-standard facilities (such as toll booth and mountainous areas) in order to characterize the performance of the VPP in such circumstances.

Special use lanes, often referred to as managed lanes; include high-occupancy vehicle (HOV) lanes, local/express lanes, high-occupancy and toll (HOT) lanes, and reversible flow lanes. Concerns of data quality on special use lanes emerged in the spring of 2009 when I-95 VPP validation data was collected on a facility in New Jersey with local and express lanes. Questions were raised at that time as to whether the VPP data reflected the speed of the local or express lanes brought the issue to the forefront. Since that time, data collected for the validation of the VPP has been monitored to identify any condition in which two distinct flow patterns exist on the same roadway, and to observe how the differing flow patterns were reflected in the VPP data. In addition to the special use lanes cited above, distinct travel patterns can also be observed on truck lanes in mountainous areas, acceleration and deceleration lanes at congested freeway interchanges, automated toll versus manual toll lanes at toll collection facilities, and on freeways near truck weigh stations.

Measuring ramp delay within major interchanges is becoming increasingly critical in to order to maintain an accurate overall picture of traffic flow on major urban freeways systems. As turning movements within major interchanges become congested, the acceleration/deceleration lanes on the mainline can queue and can cause delay both on the mainline, as well as for any other turning movements that share merge/diverge areas within the interchange. Similarly mainline congestion can cause backups on ramps which, if severe enough, can impact the intersecting freeway mainline movements. In metropolitan areas, choke points originating from interchanges can contribute significantly to overall freeway delay. Beginning in 2011, a portion of the monthly data collection effort for VPP validation was designated to capture major ramp traffic. Data quality from these ramps was compared to the data quality specification for mainline freeways.

This report investigates use of the VPP to measure speeds and travel times on special use lanes and freeway interchange ramps. The report characterizes the challenges of accurately monitoring such facilities, reviews the VPP validation data as it provides insight into the VPP performance in these situations, and offers guidelines for use of the VPP data on such facilities. Specific to special use lanes, this report quantifies the prevalence of such facilities within the core coverage area of the I-95 VPP, and the projected use of such facilities into the future.

SPECIAL USE LANES – HOV / HOT / Local Express / Reversible Flow Lanes:

Special use lanes encompass lanes specifically signed for one of the following purposes:

- High-Occupancy Vehicle (HOV) – Typically a single lane reserved on the far left of the roadway for vehicles with multiple passengers to encourage carpooling. Restrictions on the use of the HOV lane may include minimum number of passengers (HOV2 implies a minimum of two vehicle occupants, HOV3 implies a minimum of three occupants), and times of day when the restrictions are in place (such as morning or evening peak periods only, weekdays only, or at all times.)
- High-Occupancy and Toll (HOT) – These lanes restrict traffic to either HOV or toll. Cars with a minimum number of passengers may use the lanes without charge, or drivers can pay a toll to use the lane. Traffic between HOT lanes and normal lanes are usually separated at a minimum by some type of traffic barrier to prevent non-toll paying vehicles from entering the lanes. Periodic merge/diverge opportunities are provided, accompanied by tolling facilities, or gantries to collect toll automatically.
- Local/Express Lanes – Usually found in heavy traffic freeway corridors, these special use lanes separate through traffic from vehicles needing to access facilities in the corridor. In general, two or more lanes on the right-hand side are reserved for traffic utilizing on-ramps and off-ramps at interchanges. Periodic merge/diverge areas are provided between the local and express lanes, typically spaced between interchanges. In theory Local/Express lanes isolate congestion induced by traffic weaving near interchange ramps to local lanes, preventing interchange bottlenecks from impacting express lanes or through traffic.
- Reversible Flow Lanes –Reversible flow lanes, also known as contra-flow lanes, are a set of lanes on which direction of traffic flow is switched during the day. Reversible flow lanes may be found on freeway corridors or bridges in which the directional traffic volume differs significantly between the morning and evening peak periods due to prevailing commuter traffic patterns. A third set of lanes is reserved to service the excess peak hour traffic. In the morning, these lanes carry traffic to employment centers, and in the evening, the direction of travel is reversed, providing extra capacity for commuters returning home. On some facilities, particularly on bridges, the reversible lanes are not separate road structures, but rather the furthest left lanes on one or both directions of travel.

The primary factor influencing whether traffic data is reported separately for special use lanes within the I-95 VPP is whether these lanes are separate roadway structures, or are simply striped or segregated with barriers. This designation is linked to the segment reporting scheme used in the VPP called Traffic Management Codes (TMCs). These codes are maintained by an industry consortium of electronic map manufacturers. If TMC codes are designated separately for special use lanes, then the lanes will be reported separately in the VPP.

If special use lanes are simply segregated by use of special striping or placement of concrete barriers, it is unlikely that such facilities will have separate TMC codes, and are therefore not reported as separately from the mainline lanes in the VPP. If the special use lanes are constructed as separate roadbeds, separated by a median or a substantial physical barrier that restricts vehicle access to designated merge/diverge areas, it is likely that such lanes will have distinct TMC codes, and will be reported separately from the mainline lanes in the VPP.

Examples of various types of special use lane configurations are explained below.

Example 1 - Special Use Lanes segregated by Special Striping
Many HOV lanes are separated from normal lanes simply by special striping. Figure 1shows an approximate seven mile long HOV facility on US 50 to the west of the Washington, DC I-495 beltway. These lanes are typical of a minimally-segregated HOV facility. No physical barrier prevents traffic from merging or diverging at any time. Non-segregated lanes are not reported separately in VPP.

Figure 1 – Typical HOV Cross-Section from US 50
US Route 50 west of Washington, DC typical cross section showing double solid stripes separating main line from HOV lane

Example 2 - Special Use Lanes Segregated by Concrete Barriers
HOT and some Local/Express lanes separate traffic through use of physical barriers, allowing traffic to merge and diverge only at specified locations. Figures 2A and 2B show an approximate 13 mile Local/Express facility along Interstate 270 northwest of the Washington, DC I-495 beltway in Maryland. The local and express lanes are segregated by a concrete barrier (Jersey barrier) restricting the intermingling of traffic to specified merge/diverge points. This facility also has a non-segregated HOV lane on the far left express lane. Figure 2A provides and overhead view of the facility and Figure 2B shows a street view.

Although lanes are separated by a concrete barrier in this I-270 example, traffic data is not reported separately in VPP. Figure 2C depicts a screen shot from the VPP monitoring site for this roadway. The color-coded bands represent northbound and southbound. Local/Express are combined in this example. If the local lanes were reported separately from the express lanes, there would be four color-coded bands; two for north-bound traffic and two for south-bound traffic.

Figure 2AB – Sample of Local / Express Lanes from I-270

A - Overhead view of Local/Express Lanes along I-270 in MD. Local lanes are marked in yellow, Express lanes in blue, and HOV lane in dashed blue. B - Street view of same facility.

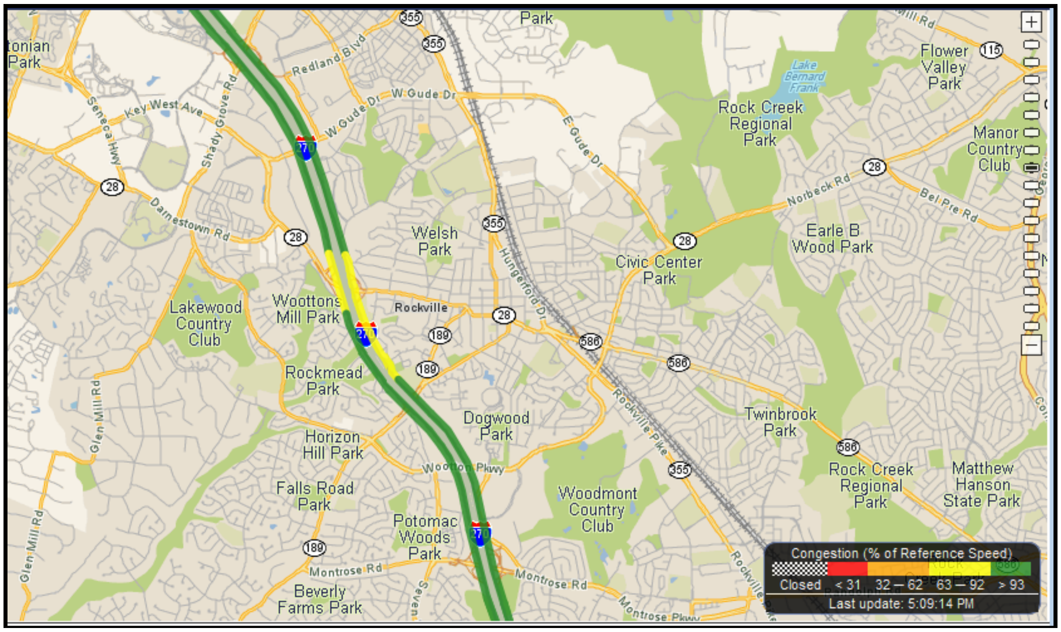

Figure 2C – Vehicle Probe Reporting of Local/Express on I-270

Project Monitoring Website view of I-270. Local/Express lanes combined into one reporting segment for each direction

Special use lanes separated by a barrier, but are not separate structures, may or may not be reported separately. The VPP monitoring website will reflect whether or not lanes are reported separately by the number of color-coded paths.

Example 3 –Special Use Lanes on Separate Facilities

Most reversible flow lanes and some Local/Express lanes are built as separate facilities from the mainline. Traffic between the main line and these facilities are restricted, requiring the equivalent of interchange ramps to facilitate cross-over traffic. Separation between facilities may be accommodated via medians or grade separated such as viaducts, in addition to possible barriers as in Example 2. Figures 3A through 3B show an approximate 18-mile reversible flow lane (also known as contra-flow lanes) facility along Interstate 95 south of the Washington, DC beltway in northern Virginia. In this example the reversible flow lanes are separate facilities as well as segregated by a concrete barrier, restricting cross-over traffic to specified merge/diverge ramp facilities. A typical cross section of the I-95 facility in this area is shown in Figure 3A. The reversible lane road-bed occupies the center portion of the ride-of-way. The reversible flow lanes are reported separately in VPP monitoring site as evidenced in Figure 3B. The three color-coded bands represent northbound, southbound, and the reversible flow lanes.

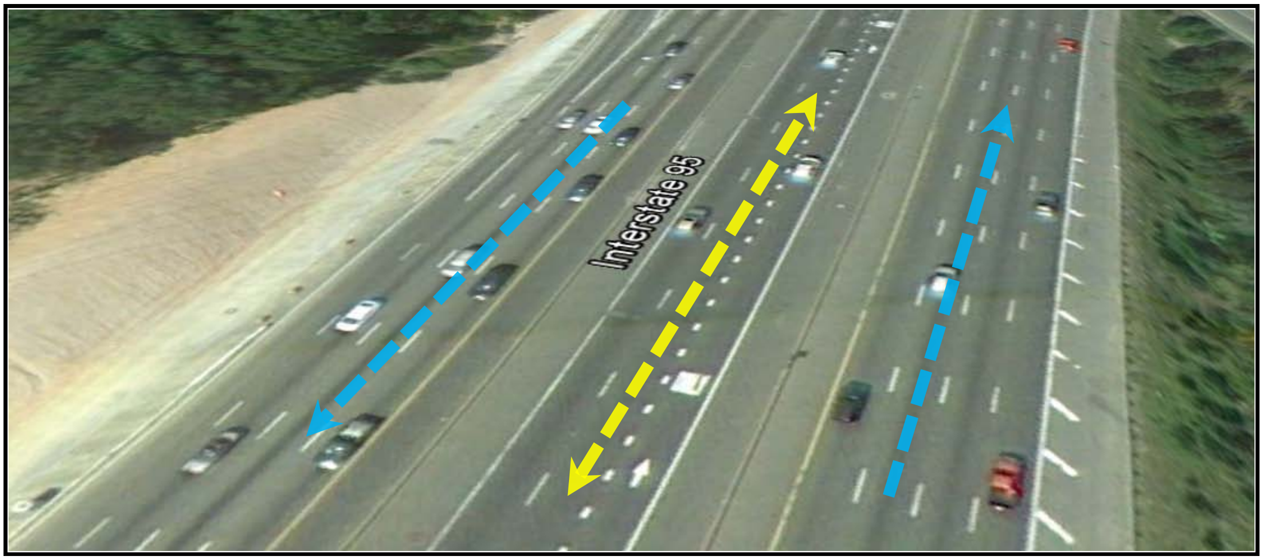

Figure 3A – Sample of Reversible Flow Lanes on I-95
Overhead view of Reversible Lanes, I-95 south of Washington DC in Virginia. Yellow dashed lines indicate reversible flow lanes.

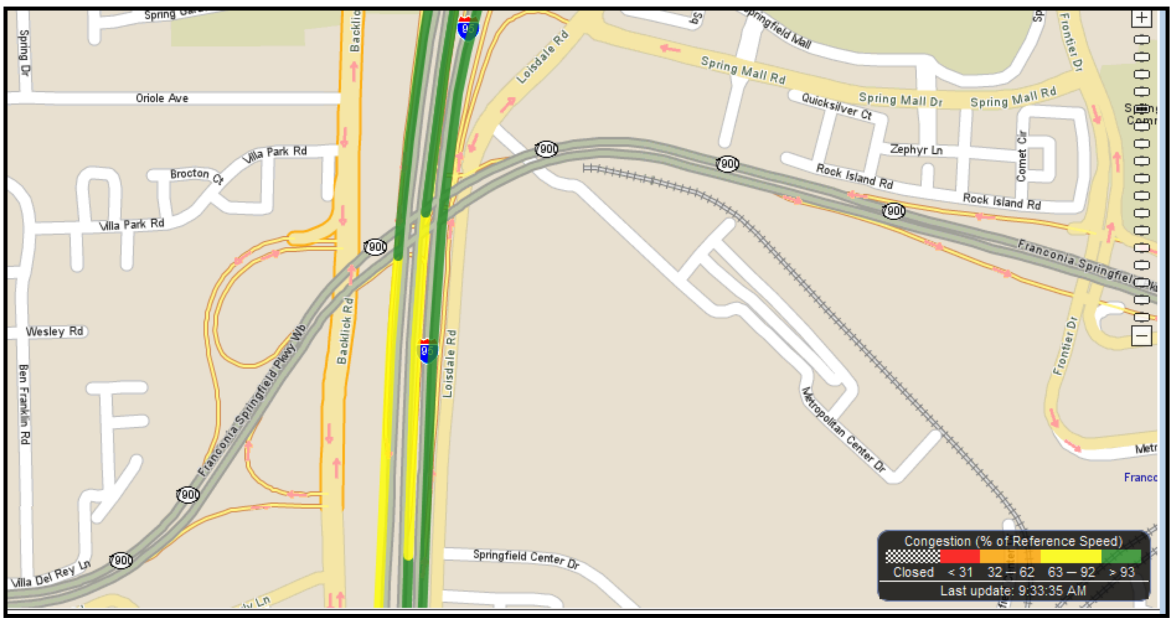

Figure 3B – Vehicle Probe Reporting of Reversible Flow Lanes on I-95
VPP monitoring website view of I-95 Reversible Lanes, south of Washington DC in Virginia. Traffic conditions on the reversible lanes are reported separately, evidenced by third color-coded speed band in the center.

When lanes are constructed as a separate structure (a distinct roadbed or viaduct), distinct TMC codes will be assigned for the lanes and traffic data will be reported separately by the VPP.

In summary, special-use lanes in which the lanes are marked only through special striping are generally not reported separately from normal lanes in the vehicle probe project. If the special-use lanes are physically segregated using concrete barrier as in example 2, the VPP may or may not report traffic conditions separately. If the special use lanes are separate road structures, the facilities will have distinct TMC codes and will be reported separately from general use lanes.

Prevalence of Special Use Lanes

When concern over special use lanes arose in 2009, the prevalence of their current and planned use within the Corridor Coalition was considered. An inventory of special use lanes within New Jersey, Maryland, Delaware, Virginia, and North Carolina (five member states of the VPP core coverage established in 2008) was constructed through survey of the respective states road jurisdictions. The results of the informal survey, included in Table 1, show that Maryland and Virginia are expanding use of special use lanes, particularly HOT and Reversible Flow Lanes. Other states' use of such facilities are minimal. In the case of New Jersey special use lanes, HOV lanes in particular, are being abandoned and converted to general purpose lanes.

Table 1 *Survey of Special Lanes within Maryland, Virginia, North Carolina, and New Jersey*

State	Route	Description	Length (miles)	Special Use Lane Type	Type of Segregation	Separate VPP Coverage?	NOTES
Maryland							
	EXISTING FACILITIES						
	US Route 50	East of DC Beltway	6.6	HOV	Striping	NO	
	US Route 50	Cheasapeake Bay Bridge	4	Reversible Lanes	Striping and Lights	NO	HOT lanes on I-95 North of Baltimore are planned ot be operation by 2014. Lanes begin at I95/I895 split north of Baltimore and extends 8 miles to just north of Maryland 43. The master plan includes construstion all the way to the Delaware state line
	I-270	NW of DC Beltway	12.8	Local/Express HOV on Express	Concrete Barrier Striping	NO	
	PLANNED FACILITIES						
	I-95	North of Baltimore	8	HOT	?		
Virigina							
	EXISTING FACILITIES						
	I-95	South of DC Beltway	17.9	Reversible Lanes	Separate Facility	YES	
	I-64	Norfolk/564 to 264/64	8	HOV-RR	Concrete Barrier	NO	
	PLANNED FACILITIES						
	I-495	From I95 to Dulles Toll Road	14	HOV/HOT	?		
	I-95	From Exit 158 to Exit 2 on I395	13.1	HOV/HOT	?		Adding capacity to existing HOV lanes
	I-95	From Exit 143 to 152	9.2	Reversible Lanes / HOV	Separate Facility		Exiting Reversible / HOV lanes further south on I95
Delaware							
	NO EXISTING FACILITIES						
	NO PLANNED FACILITIES						
New Jersey							
	EXISTING FACILITIES						
	NJ Turnpike	Exit 8A to Exit 14	31.4	Local / Express	Guardrail / Small median	Yes	Also has HOV (car, truck, bus lane) striped in Local lanes
	Garden State Park	105/107 to 127	26.4	Local / Express	Guardrail / Small median	Yes	
	I 287		3.3	Local / Express	Grass Median	No	Acts as extended ramps to 78E/78W
	PREVIOUS FACILITIES						
	NJ Turnpike	Exit 11 to Exit 14	13.4	HOV	?		HOV facilities removed.
	I 287	Exit 21 (I78) to Exit (I80)			Striping		HOV facilities removed.
	NO PLANNED FACILITIES						
North Carolina							
	EXISTING FACILITIES						
	I-77	Exit 19 to Exit 11	9	HOV	Striped		Southbound is 9 miles, Northbound is about 5 miles
	PLANNED FACILITIES						
	I-40	Near Raleigh		Bus on Shoulders			Considering test on I-40 in 2011

Variance of Travel Speed on Special Use Lanes

On facilities with special use lanes the accuracy of reported VPP data was questioned. On special use lanes for which the VPP does not report travel time separately (common for many HOV facilities), normal lanes may travel at a significantly different speed than the special use lanes. In such circumstances does the VPP data report mainline conditions, or the special use lane conditions, or an average of the two? Conversely, if the VPP reports traffic information separately for the specified lanes do the travel times and speed accurately reflect the differing conditions for the two facilities?

The VPP validation program utilizes Bluetooth traffic monitoring (BTM) technology to validate the accuracy of traffic data. BTM samples the travel time of approximately five percent of the traffic stream. Throughout the validation program, the validation data has on occasion reflected two different speeds on a specific freeway segment indicating that a significant portion of the traffic stream travels distinctly slower or faster than the remaining portion, thus providing opportunities to assess how the VPP reports data when lanes are traveling at differing speeds.

On average, the validation program collects approximately ten days of data from five to ten roadway segments each month. Although BTM equipment has been deployed on highway segments with special use lanes, the VPP has only captured one instance of speed differentials that could definitely be attributed to special use lanes. This speed differential was so minimal that it could not be used to determine the relative accuracy of the associated VPP reported speeds and travel times. Even a special study on the local/express lanes of I-270 (Maryland) in December of 2010 failed to capture any speed data indicating difference in speed between the local and express lanes.

However, several examples of speed differentials on freeways (not on special use lanes) have been captured in the validation process. These examples provide insight into how the VPP responds in such situations. Speed differentials between lanes have been captured as a result of a major incident, where a select group of lanes continue to flow and another set of lanes are significantly impeded. Other samples have arisen from special circumstances such as traffic through and around weigh stations, truck operations in mountainous areas, and differential speeds through automated versus manual toll collection facilities.

The following section reports on occurrences in which the VPP validation recorded speed differentials, and note how the VPP responded in each circumstance – as well as reports on facilities in which speed differential were anticipated, but none observed. The list of sample results includes:

- I-95 / I-80 local/express lanes near the Lincoln Tunnel
- I-270 in Maryland with local/express/HOV lanes
- I-40 in Mountainous Region of North Carolina
- I-95 in North Carolina near a Weigh Station
- I-95 in Delaware at Toll Collection Facility
- I-495 in New Jersey at Toll Collection Facility
- I-64 in Virginia near exit to NB I-95

I-95 / I-80 local/express lanes near the Lincoln Tunnel

Travel time samples were collected along a total length of nearly six ramp miles and approximately 16 freeway miles from Monday, April 10, 2011 through Friday, April 29, 2011 in New Jersey. A portion of the ramp and freeway segments studied were interconnecting I-80/I-95/New Jersey Turnpike in Bergen County and included local and express ramps and mainline sections. Bluetooth Traffic Monitoring (BTM) equipment, used to provide ground truth data, was placed upstream and downstream of each segment. On occasion, two distinct flow patterns were evident in the BTM travel time data, but the difference in terms of speed (MPH) was not substantial. A sample plot is shown in Figure 4. At approximately 10 PM traffic slowed significantly. Two distinct flows are shown in the Bluetooth data (the blue x's). One set of lanes slowed to less than 5 mph, while the other set traveled between 5 and 20 mph. Though they can be visually distinguished in the validation data, the difference in speed (roughly 10 MPH) is not significant compared to the accuracy specifications of the VPP.

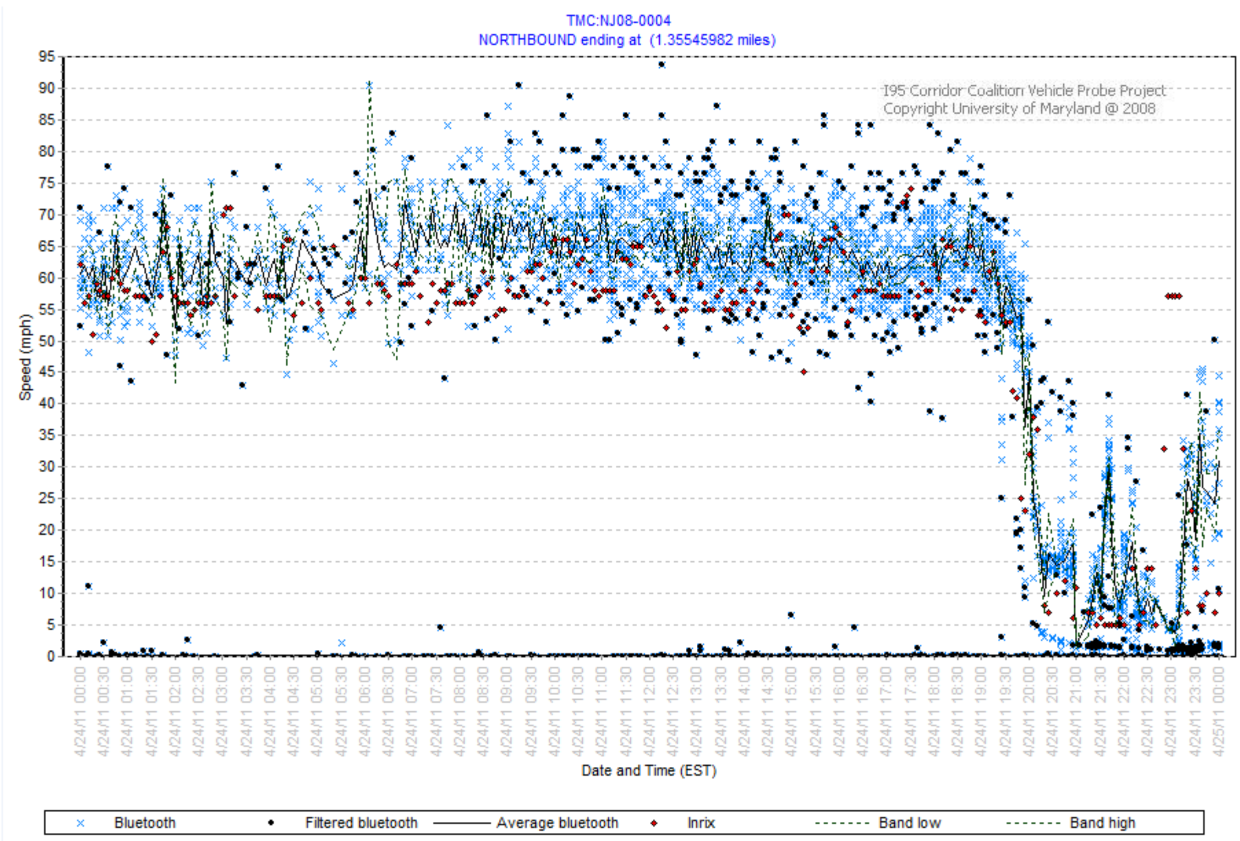

Figure 4 – Distinct Traffic Flow on Local/Express Facility

Validation data collected in New Jersey in April 2011 shows distinct differences in speed after 8:00 PM between local/express ramps at the intersection of I-95 and I-80

I-270 in Maryland with local/express/HOV lanes

A specific data collection exercise was conducted on the local and express lanes of I-270 near Washington, DC in an attempt to isolate speed differentials. The results were inconclusive as described below.

Data was collected along I-270, northwest of Washington, DC from December 21, 2010 to January 9, 2011, on a section with local/express lanes as shown in Figures 2A using BTM technology. Travel time during peak hour was over twice that of the free-flow travel time due to congestion during ten of the 19 days. In each of the ten days of congested travel, no discernible difference in speed between local and express lanes was captured in the BTM data. A representative travel time plot of the results of the BTM data for this section is shown in Figure 5.

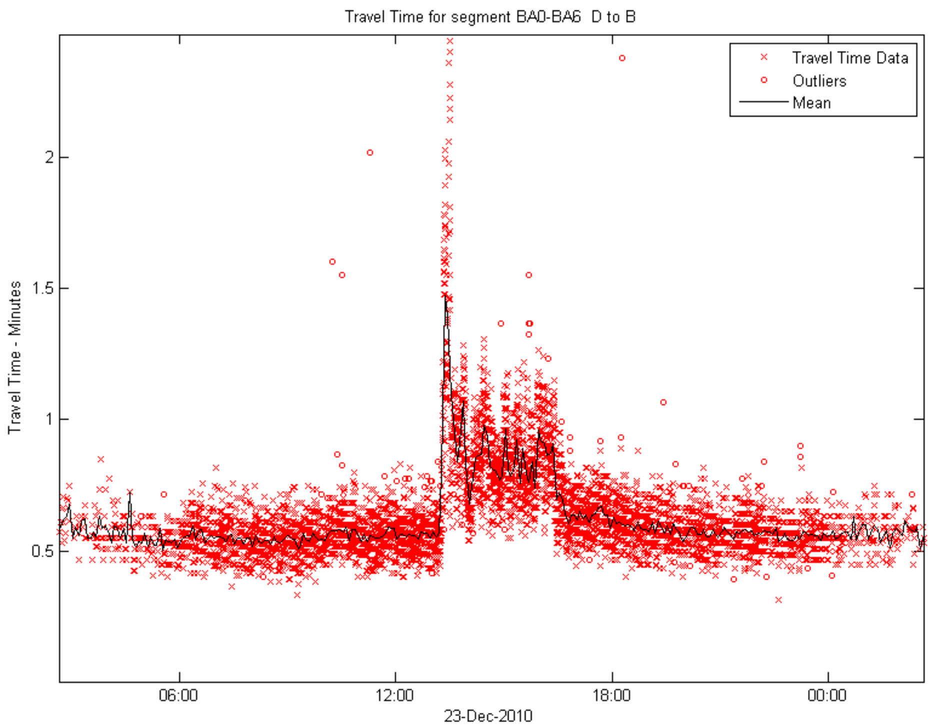

Figure 5 – Non-Distinct Traffic Flow on Local/Express Facility
Travel time data sample from I-270 along local-express lanes on Dec 23 2010.

I-40 in Mountainous Region of North Carolina

In response to anomalies in the VPP data reported by North Carolina in mountainous areas, the Coalition collected validation data in a rural mountainous area shown in Figure 6A. Data was collected from March 25, 2010 through April 3, 2010 across a 5.6-mile segment. It was suspected that heavy truck traffic in this area was traveling at significantly slower speeds than vehicular traffic. The BTM sensors were deployed to capture this phenomenon and compare it to the data reported through the VPP.

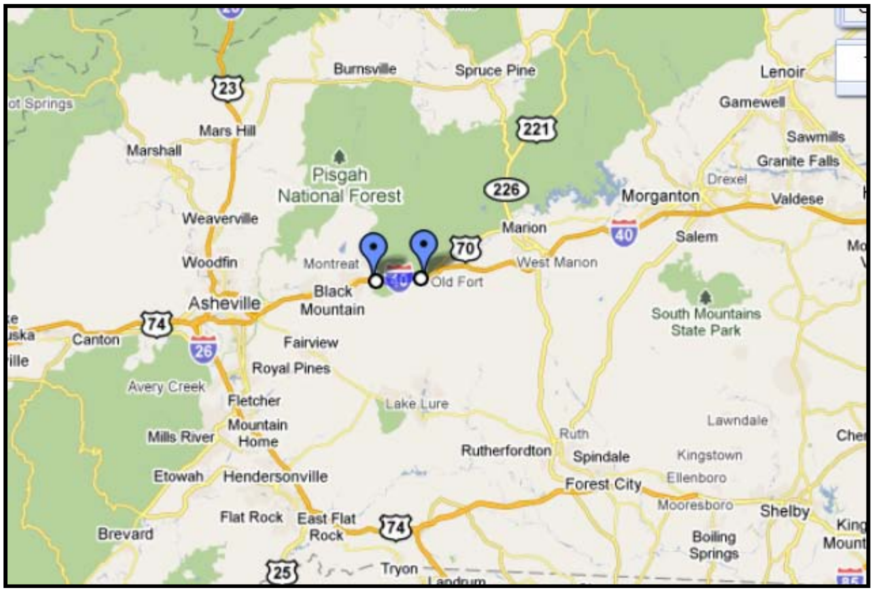

Figure 6A–I-40 in Mountainous Area of North Carolina

A representative sample of the speed data collected from March 26, 2010 is shown in Figure 6B. The BTM data (shown in blue in Figure 6B) was stratified into two speed categories. About 80 percent of the data was between 55 and 65 mph, while the remaining 20 percent of the data was centered about 30 to 45 mph. This phenomenon is caused by heavy trucks traveling on steep grades. Commercial freight and other large trucks climb at a slower rate while passenger vehicles and light trucks can maintain highway speeds though the mountainous areas.

The VPP data (shown in Figure 6B in red diamonds) varies abruptly throughout the day oscillating between 40 mph on the low end, to 60 to 65 mph per hour on the high end. The majority of VPP data was in the lower range, around 40 mph. The tendency of the VPP to follow the slower mode is an indication that the base data supplying the VPP is dominated by commercial trucking. Also, the VPP speed reported during nighttime hours at times with there is insufficient base data upon which to estimate speed (as evidenced by the 'flat-lining' of the VPP at night) is approximately 45 mph. When insufficient base data is available at night, a reference speed calculated from the 85^{th} percentile of observed speed is reported. This again reflects the speed of heavy trucks in the corridor, rather than unimpeded lighter vehicles.

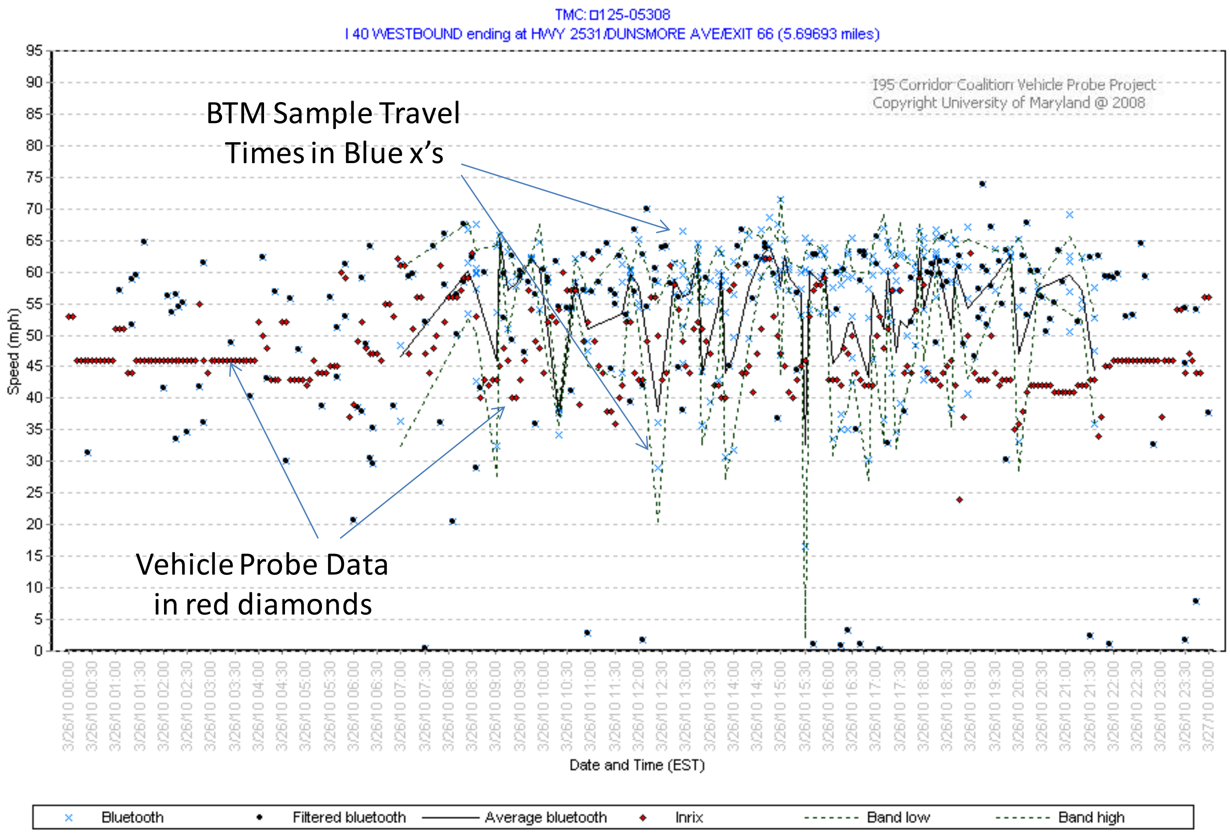

Figure 6B – Grade-Induced Speed Differential, Heavy-Truck versus Light Vehicle
BTM validation data collected from mountainous region in North Carolina

I-95 in North Carolina near a Weigh Station

In July 2009, while collecting validation data in North Carolina on southbound I-95 near exit 150, two BTM sensors were inadvertently placed so as to straddle a weigh station. A representative plot of the BTM validation data from this 3.5 miles segment is shown in Figure 7. At approximately 8:00 AM, the traffic flow divides into two distinct patterns similar to that seen in mountainous areas, and then at 10:00 PM the pattern disappears and returns to expected freeflow near 60 mph. This distinct pattern was evident on all weekdays, but disappeared on weekends, consistent with weight station operations. Unlike the data taken in mountainous areas, the VPP generally reported speeds closer to mainline traffic, rather than report speed of trucks processed through the weight station.

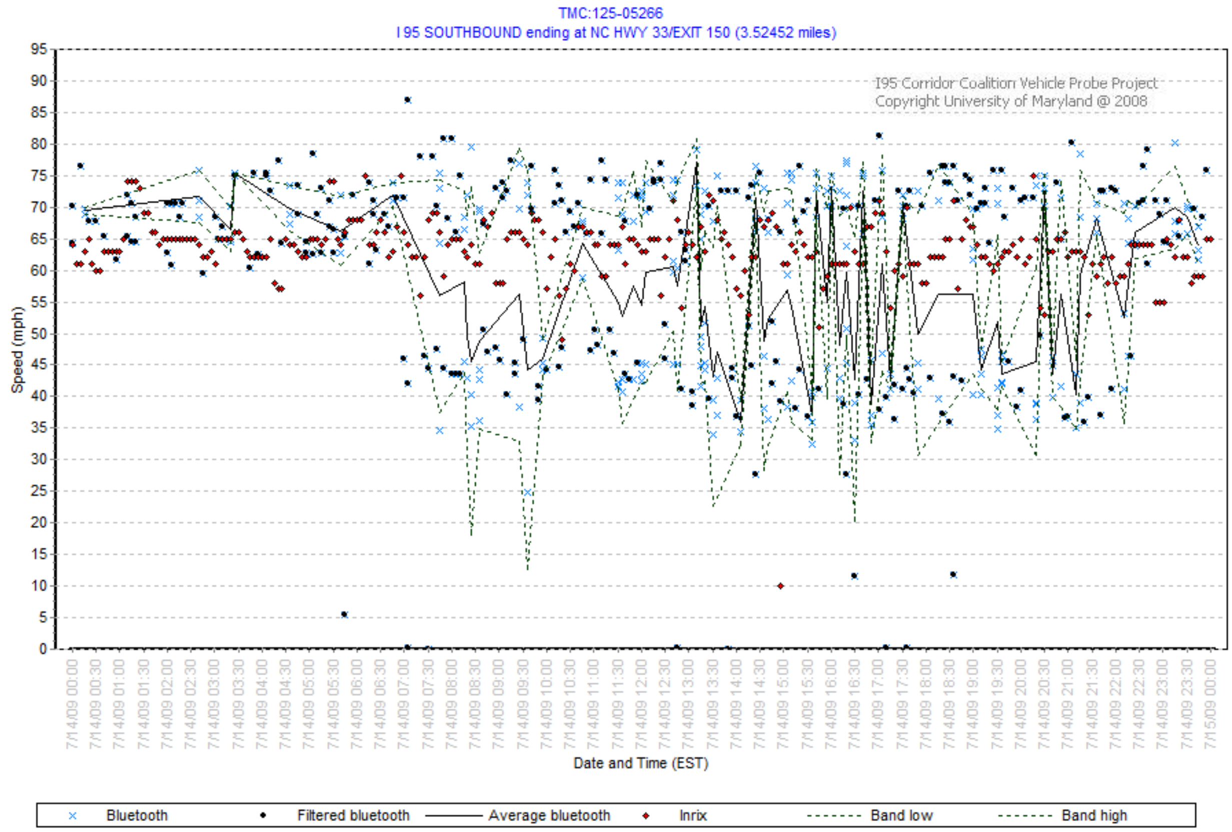

Figure 7- Speed Differential near a Weigh Station
VPP validation data collected on I-95 in North Carolina near a weigh station

I-95 in Delaware at Toll Collection Facility

In June 2011, validation data was collection in Delaware at I-95 near the border with Maryland. One pair of BTM sensors was placed so as to bracket the tolling facility on I-95 near the Maryland – Delaware state line. A representative sample of the travel time data through the tolling facility is shown in Figure 8, showing two distinct travel time patterns. A portion of traffic corresponding to vehicles with EZ-Pass toll-tag transponders proceeds through the tolling facility at an average speed of approximately 60 MPH. Another significant portion of traffic corresponding to those who pay the toll with cash proceeds through at an average speed of roughly 35 mph. This distinct pattern was evident throughout the entire 11 day data collection period. During this time the VPP reported speeds corresponding to vehicles with EZ Pass toll tags rather than the portion of traffic stopping at toll booths to pay with cash.

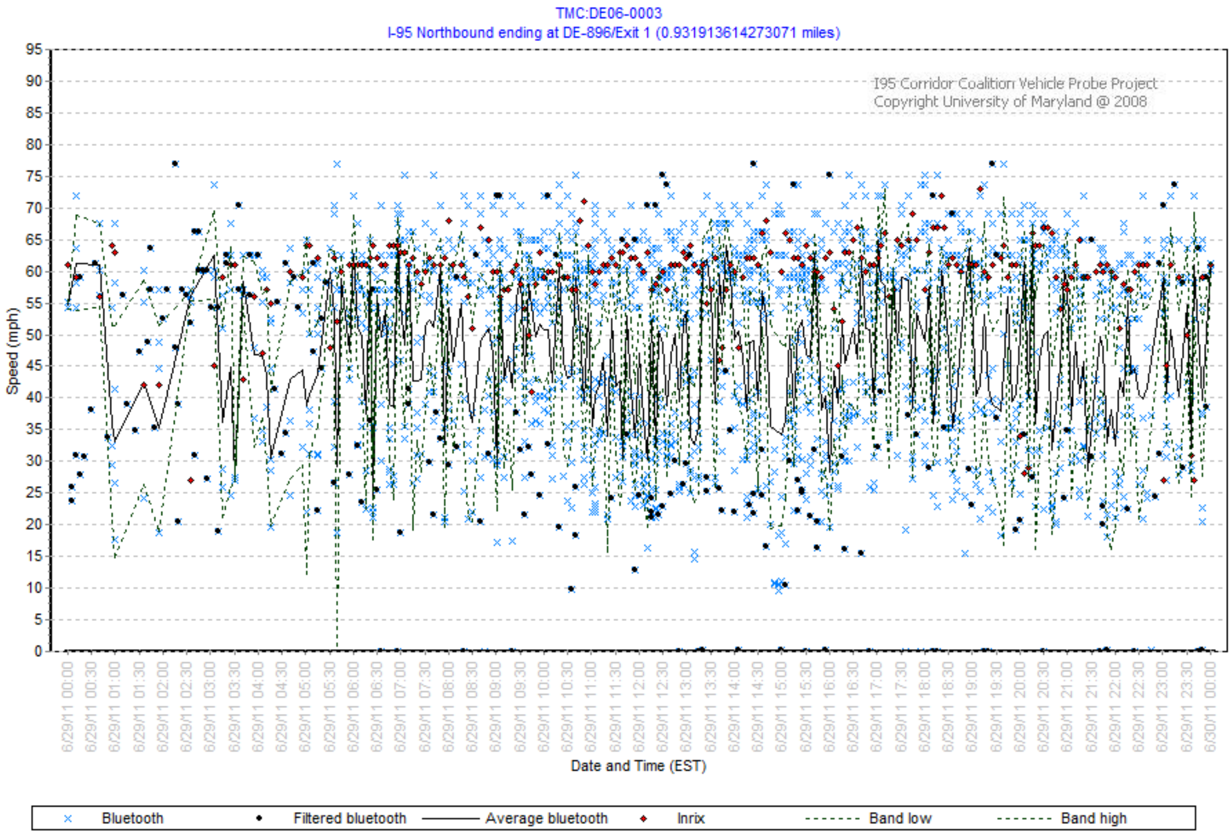

Figure 8 – Speed Differential at Delaware Toll Facility

VPP validation data collected on I-95 in Delaware in June of 2011 straddling a toll facility

I-495 in New Jersey at Toll Collection Facility

In April 2011, travel time data was gathered inadvertently across another toll collection facility in New Jersey on the ramp connecting southbound NJ-3 and eastbound I-495. Figure 9 depicts a representative plot of the data in which congestion during the morning period is experienced by a portion of the traffic stream. From approximately 7:30 AM until 9:00 AM, a portion of the traffic stream is significantly delayed, while another portion continues through the facility, averaging roughly 40 mph. As in the Delaware toll data, the VPP tends to follow the faster of the two distributions.

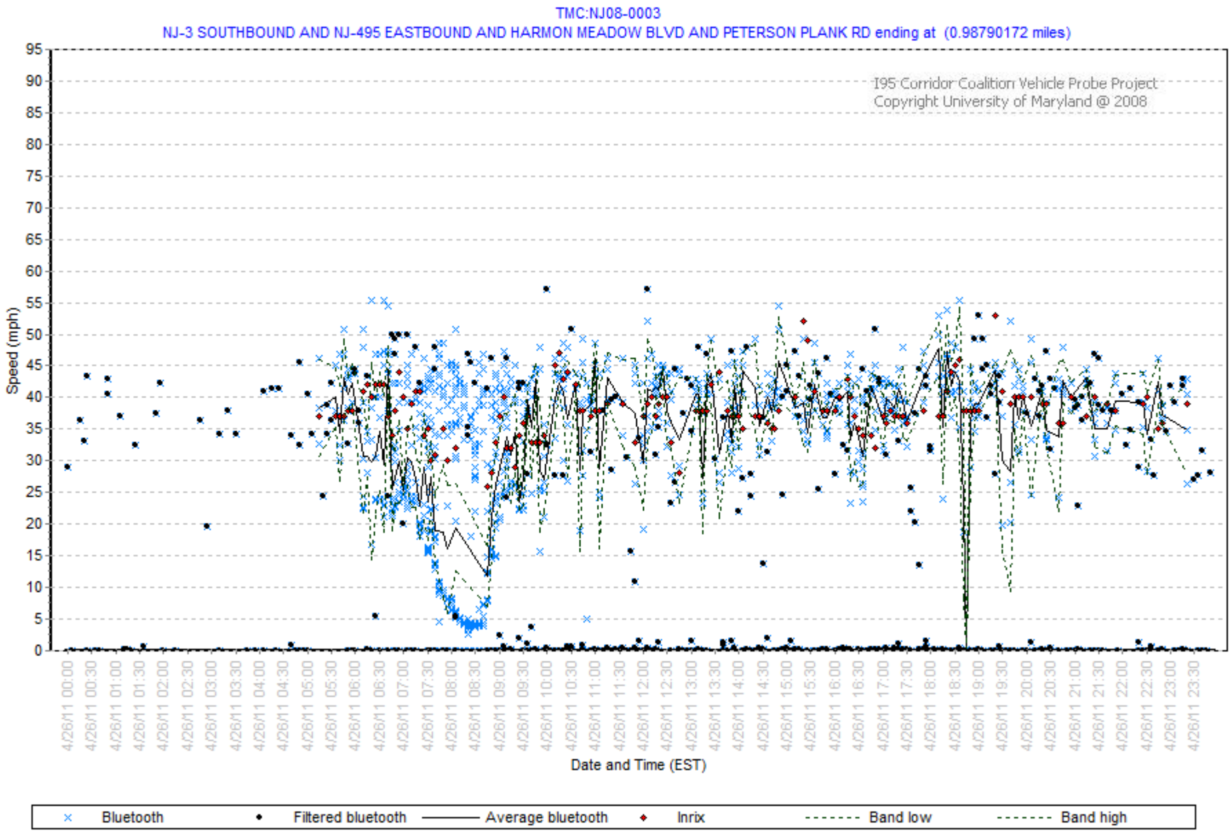

Figure 9 – Speed Differential at New Jersey Toll Facility
VPP validation data collected across a toll collection facility on a ramp connecting I-95 to I-495 in New Jersey

I-64 in Virginia near exit to NB I-95

In November 2008, travel time data was gathered on I-64 in Richmond, Virginia, near the interchange with I-95. The sample data in Figure 10 comes from a segment immediately preceding the exit from I-64 westbound to I-95 northbound. As indicated by the arrows two distinct travel speeds are observed in the evening peak period. The large portion of traffic exiting I-64 onto I-95 northbound causes congestion even on the mainline of I-64 due to vehicles queuing for the exit. The faster of the two speeds corresponds to the through traffic impacted by the congestion but still getting through on the left. The slower of the two speeds corresponds to traffic exiting to the I-95 northbound ramp, and having to wait in queues on the I-64 mainline prior to the exit. In this example, the speed reported by the VPP alternated between the slower and faster modes on an almost equal proportion, not showing any specific tendency toward either the faster through traffic or the slower exiting traffic.

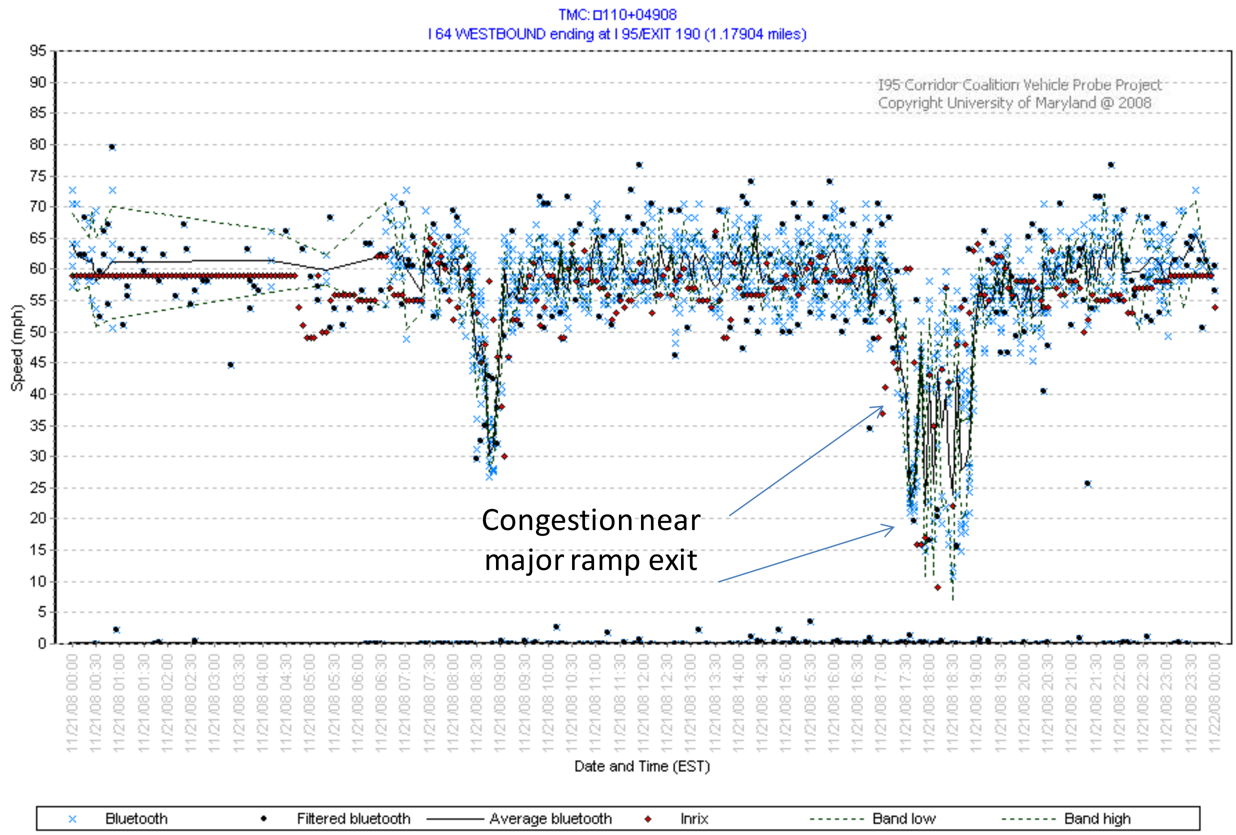

Figure 10 – Differential Traffic Flow near Freeway Ramp
Validation data from I-64 in Richmond, Virginia near exit to I-95

VPP Data Quality on Ramps

Ramps were not included in the original deployment of the VPP. Beginning in 2010, INRIX began providing ramp data on an experimental basis. In 2010, the I-95 Corridor Coalition extended validation efforts to begin assessing the quality of data provided on freeway ramps. Sample data from ramps were collected in New Jersey and Maryland in 2010 and North Carolina in 2011 as listed in Table 2. Ramp data was included for all freeway to freeway interchanges in the corridor beginning in July of 2011. Since that time, ramp data samples are collected as part of the validation effort whenever possible in addition to mainline freeway travel time samples. Data included in this review is listed in Table 2.

Table 2 – Location of Freeway Ramp Data Collection

State	TMC/PATH IDENTIFIER	FROM	TO	DATE	Length (miles)	Map Link
NJ	120P26195	NB I-287	WB I-78	May-10	1.4	http://goo.gl/maps/ItVK
NJ	103N04210	SB I-295	SB I-76	Jun-10	1.1	http://goo.gl/maps/vbAB
NJ	103P14571	NB I-76	NB I-295		0.5	http://goo.gl/maps/4ZSU
MD	MD04-0007	EB 50	SB I-95/495	Oct-10	2.64	http://goo.gl/maps/MwvE
MD	MD04-0008	EB 50	NB I-95/495		3.23	http://goo.gl/maps/TSV3
MD	MD04-0009	WB 50	NB I-95/495		1.54	http://goo.gl/maps/RoC7
MD	MD04-0010	WB 50	SB I-95/495		1.74	http://goo.gl/maps/icuf
MD	MD04-0011	NB I-95/495	EB 50		1.86	http://goo.gl/maps/SaBo
MD	MD04-0012	SB I-95/495	WB 50		1.43	http://goo.gl/maps/sk2Q
MD	MD04-0013	SB I-95/495	EB 50		2.62	http://goo.gl/maps/0RsU
NC	NC04-0005	EB I-85	SB I-77	Mar-11	0.8	Click Here
NC	NC04-0006	NB I-77	EB I-85		1.0	Click Here
NC	NC04-0007	WB I-85	NB I-77		0.9	Click Here

Data was also collected on ramps in New Jersey in April, 2011. These ramps included both local and express facilities, as well as travel time across a toll collection facility. Sample plots form this deployment were included in the Special Use Lanes section. Due to the unique nature of these segments, they are not included in the summary results presented in this section, as they would not be representative of most freeway ramps in the corridor. (A summary report of the ramps from New Jersey was published separately and is available on the I-95 Corridor Coalition website.)

Data from ramps were processed using the same methodology applied to freeway segments. Summary validation results of all ramps are shown in Table 3, and individual results are shown in Table 4.

Table 3 - *Overall Ramp Data Quality*

SPEED BIN	Data Quality Measures				No. of Obs.	Proportion of Data
	1.96 SE Band		Mean			
	Speed Error Bias	Average Absolute Speed Error	Speed Error Bias	Average Absolute Speed Error		
0-30	3.94	4.62	6.49	7.93	707	5%
30-45	0.92	2.17	2.33	4.91	1580	11%
45-60	-0.92	1.79	-1.49	3.99	9328	65%
60+	-3.75	3.75	-6.42	6.81	2833	20%

Table 4 - *Individual Ramp Validation Results*

TMC	Standard TMC length	Bluetooth distance	SPEED BIN	Data Quality Measures for: 1.96 SE Band – Speed Error Bias	1.96 SE Band – Average Absolute Speed Error	Mean – Speed Error Bias	Mean – Average Absolute Speed Error	No. of Obs.
			0-30	1.1	5.2	0.8	6.9	14*
			30-45	-4.6	5.8	-4	12.9	5*
			45-60	0	1.8	1.8	4.5	667
120P26195	1.45	0.85	60+	-2.5	2.5	-4.3	5	1589
			0-30	1.5	3	1.8	4.1	133
			30-45	-0.4	1.8	-0.3	3.1	366
			45-60	-2.5	2.7	-4.1	4.6	2029
103N04210	**1.05**	**1.18**	60+	-12.1	12.1	-14.8	14.8	2*
			0-30	2.1	2.3	5.4	6.2	124
			30-45	-0.1	1.4	0.5	3.8	207
			45-60	-1.4	1.6	-2.9	3.9	931
NJ07-0009	**1.15**	**1.21**	60+	-7.3	7.3	-10.2	10.2	1*
			0-30	12.4	12.4	18.1	18.1	2*
			30-45					
			45-60	0.4	0.7	1	3.1	38
MD04-0007	**2.67**	**2.64**	60+	-1	1	-2.9	3.1	10*
			0-30	10.6	10.6	20.3	20.3	10*
			30-45	2.5	3.7	7.5	9.6	8*
			45-60	0.3	0.8	0.9	2.9	129
MD04-0008	**3.29**	**3.23**	60+	-1.7	1.7	-3.7	3.7	3*
			0-30	12.1	12.1	16.5	16.6	60
			30-45	4.8	5.1	8.2	9.5	73
			45-60	-0.5	1.3	-1	3.5	828
MD04-0009	**1.68**	**1.54**	60+	-3.4	3.4	-7.1	7.1	137
			0-30	2.5	2.5	9	9.6	7*
			30-45	1	1.1	4.1	5.4	47
			45-60	-1.5	1.7	-3.3	4.2	616
MD04-0010	**1.73**	**1.74**	60+	-7.7	7.7	-11.6	11.6	8*
			0-30	2.3	2.5	4	4.6	158
			30-45	3.3	3.5	6.5	7.1	133
			45-60	0.6	1.1	2.1	3.4	498
MD04-0011	**2.04**	**1.86**	60+	-1.3	1.3	-3.6	3.6	46
			0-30	3.6	4	10.7	11.2	5*
MD04-0012	**1.43**	**1.43**	30-45	2.2	2.2	6.5	6.5	14*

			45-60	0.2	1.1	1.3	3.7	235
			60+	-4.9	4.9	-9	9	9*
			0-30	2.6	3.4	11.4	13.8	24*
			30-45	-0.3	1.6	1.6	6.1	61
			45-60	-0.4	0.8	-1.2	2.8	862
MD04-0013	**2.48**	**2.62**	60+	-2.7	2.7	-6	6	250
			0-30					
			30-45	0	0	5.2	5.2	1*
			45-60	0.2	0.5	0.7	3	50
NC04-0005	**0.83**	**0.65**	60+	-2.6	2.6	-6	6	17*
			0-30	3.1	4.6	3.8	6.6	55
			30-45	4	6.3	8.6	12.2	20*
			45-60	1.8	1.9	4	4.5	761
NC04-0006	**1.06**	**1.1**	60+	-1	1.2	-3.2	3.4	18*
			0-30	0	0	14.6	14.6	1*
			30-45	-0.1	4.3	4.4	12.1	11*
			45-60	-0.7	0.8	-1	3.4	93
NC04-0007	**0.89**	**0.86**	60+	-5.3	5.3	-7.1	7.1	3*

*Results in the specified row may not be reliable due to small number of observations

The results in Table 3 and 4 indicate data quality on ramps similar to that of freeways. The AASE in the lower two speed bins averaged 4.62 and 2.17 mph, respectively. Note that the largest proportion of data on ramps, over 65 percent, is in the 45-60 mph range, indicating that free-flow speeds on ramps is less than that on the mainline. The proportion of data in the 30-45 mph speed range is 11 percent, which is higher than for freeway operations. This suggests that normal operating speed for a number of ramps may border on, or be less than 45 mph. Therefore, the speed bins for ramps may need to be adjusted appropriately to isolate congested conditions from uncongested conditions.

The volume of validation data on ramps varies significantly as evidenced by the fluctuations of the total number of observations from segment to segment. Observations are only registered if three or more Bluetooth observations are made in the five minute period. If less than three Bluetooth observations are made in 5 minutes, it is an indication of low flow periods, approximately 500 vehicles per hour or less.

Figures 11 through 15 show representative samples of validation data taken from ramps in New Jersey and Maryland.

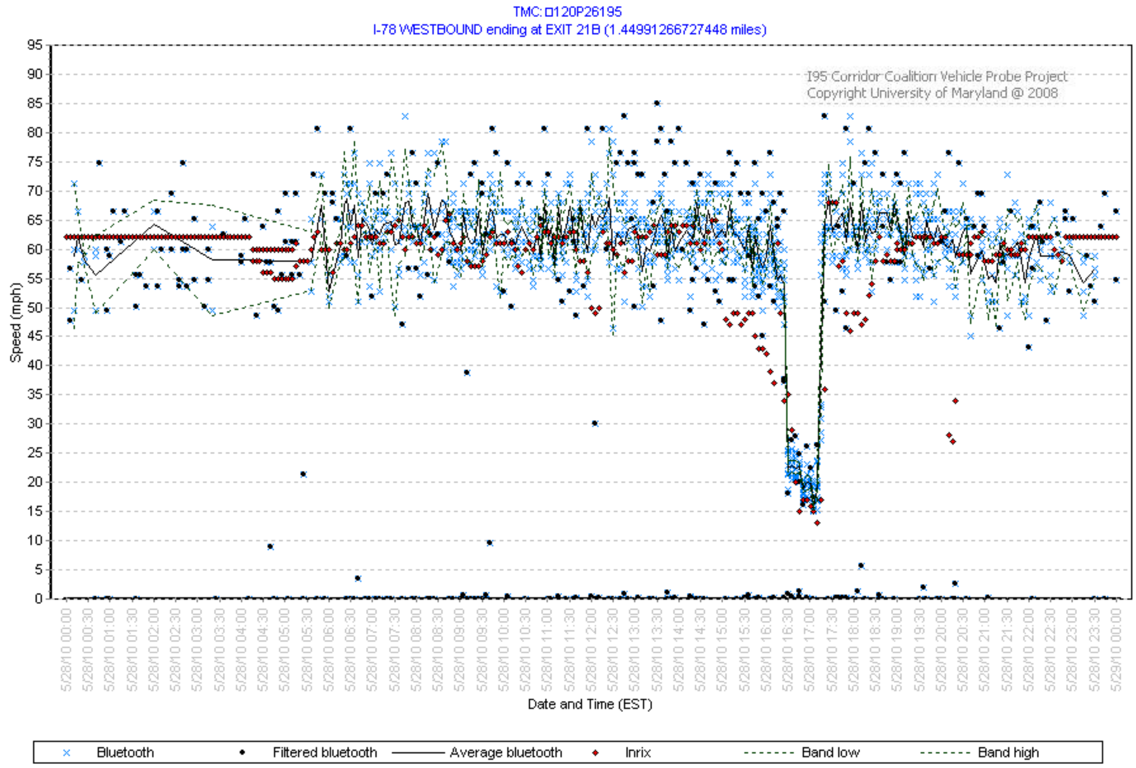

Figure 11 – Representative Ramp Data from New Jersey, May 28, 2010

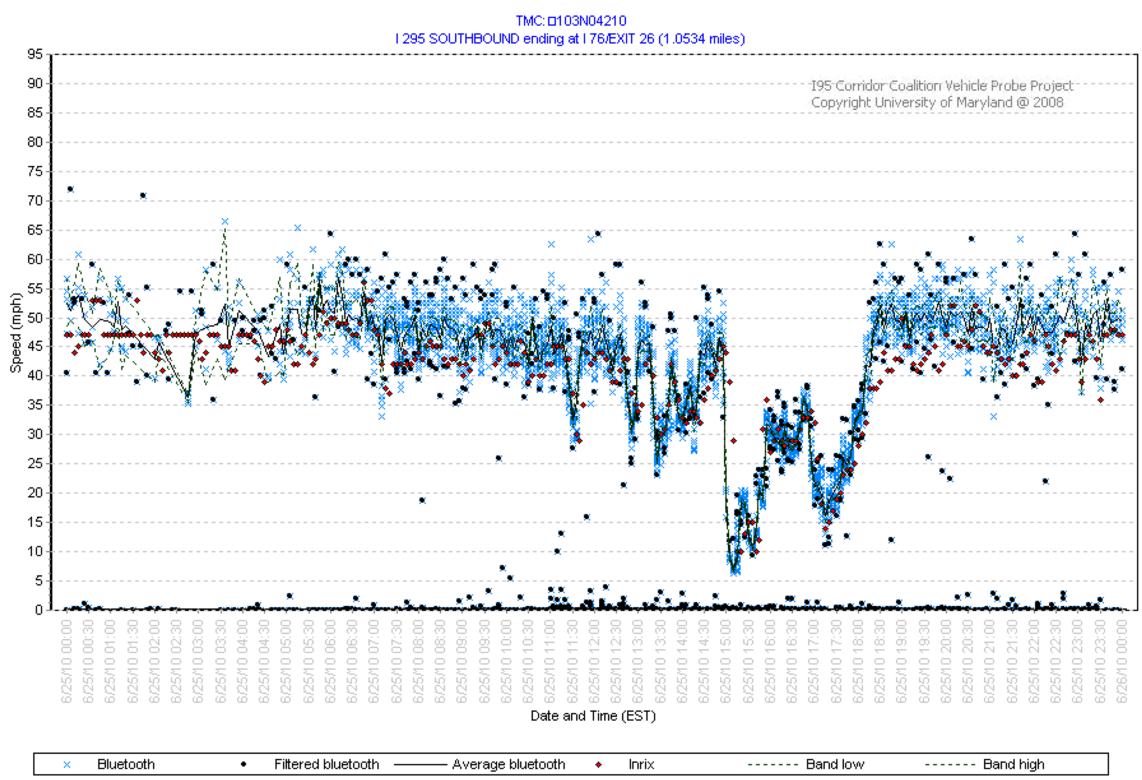

Figure 12 – Representative Ramp Data from New Jersey, June 25, 2010

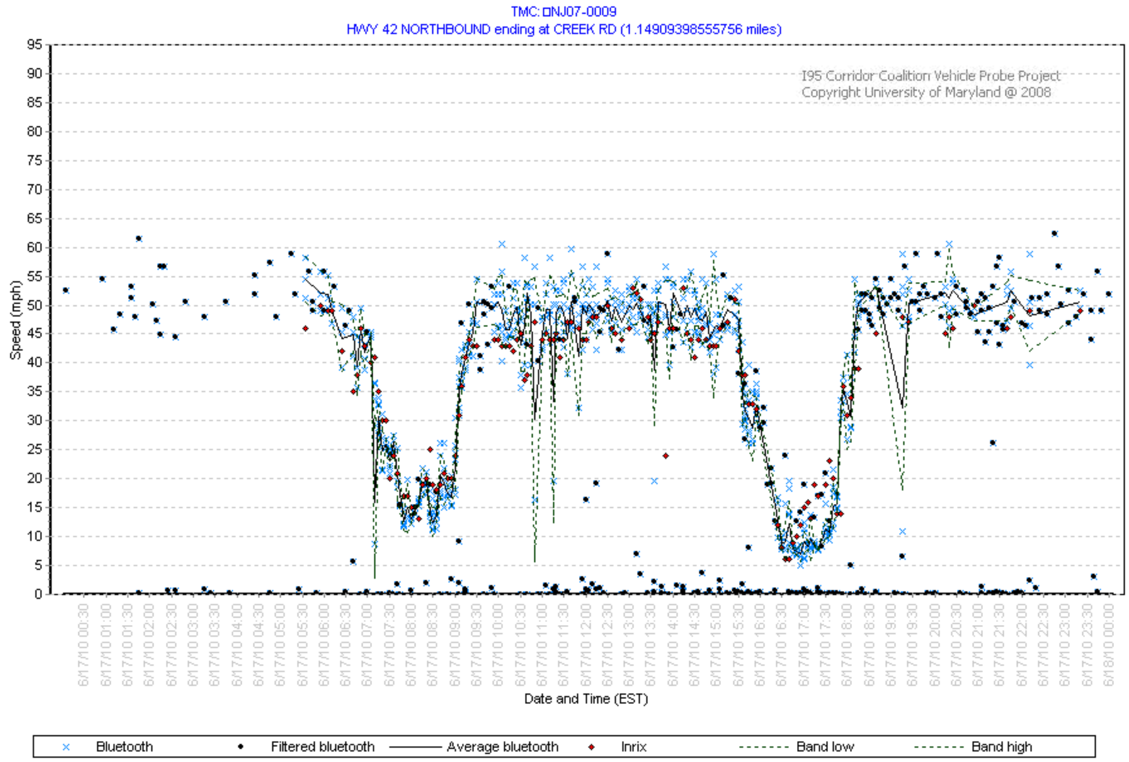

Figure 13 – Representative Ramp Data from New Jersey, June 17, 2010

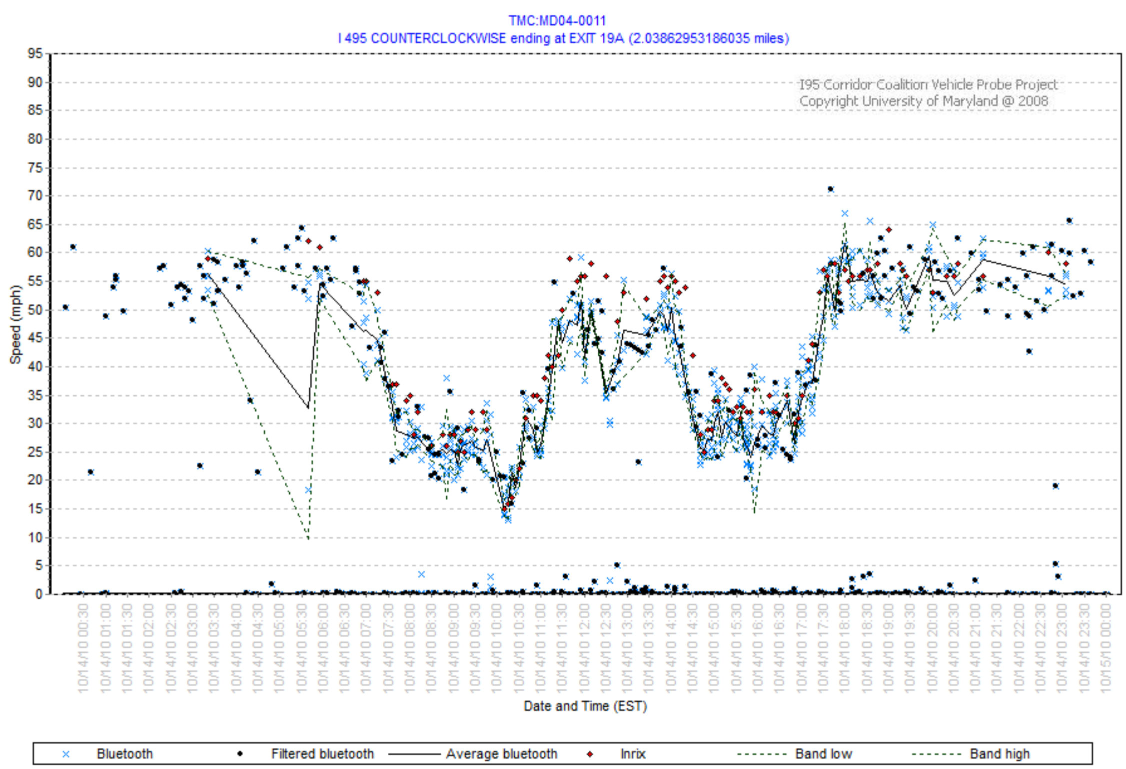

Figure 14 – Representative Ramp Data from Maryland, October 14, 2010

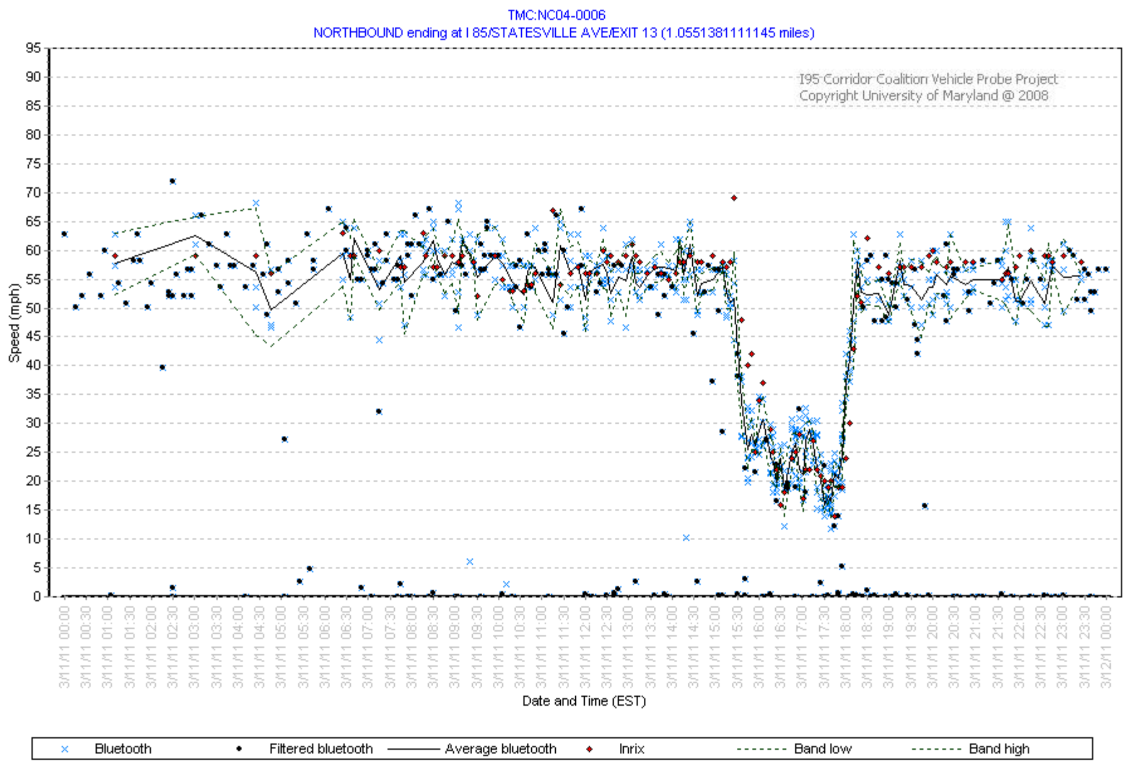

Figure 15 – Representative Ramp Data from North Carolina, March 11, 2011

Data collection and analysis of ramp data continues as part of the I95 Vehicle Probe Project validation program. Ramp data was included for major freeway to freeway interchanges beginning in July 2011after the release of version 3.7 of the TMC tables. Ramp data is available for freeway to freeway interchanges in the top 100 metropolitan areas, which will include a majority of the metropolitan areas served by the Vehicle Probe Project. If both of the intersecting freeways are part of VPP coverage (and included in the 3.7 version of the TMC tables), the ramp data will be included in the VPP data feed. Traffic data on interchange ramps between freeways and other lower class roadways are not available at this time, but are being considered as a future enhancement.