CHALLENGES TO EFFECTIVE ARTERIAL TRAFFIC MONITORING: LESSONS FROM THE I-95 CORRIDOR COALITION'S VEHICLE PROBE PROJECT

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ABSTRACT

Methods to effectively monitor arterial traffic have commanded center stage as new tools and technologies such as vehicle probe data and Bluetooth™ traffic monitoring have emerged to cost-effectively provide accurate, real-time, continuous, network-wide monitoring of freeway systems. Within metropolitan areas, the network of high-volume, multi-lane arterials is critical to the daily movement of commuters to jobs and services, to distribute freeway traffic to local streets, and to provide diversion routes during major incidents. Many of the same technologies that have revolutionized freeway traffic monitoring promise to do the same for signal-controlled arterials. However, initial demonstrations and implementations reveal a variety of issues, many of which are inherent to the fundamental nature of traffic flow that differentiates arterials from freeways. The I-95 Corridor Coalition's Vehicle Probe Project (VPP) has successfully delivered high quality freeway travel time data on a roadway network comprised of over 5,000 centerline miles since its inception in 2008. The project also includes a component consisting of approximately 900 miles of arterials that link the major freeways and provide diversion routes in the event of incidents. The validation program that monitors data quality for freeways also collects data samples on the arterial network. This paper characterizes the critical challenges in providing quality traffic data on arterials based on data collected as part of the I-95 Vehicle Probe Project and through interaction of a committee of transportation professionals that provide guidance to the project. The findings from the I-95 Vehicle Probe Project are germane to any probe-based arterial traffic monitoring system.

INTRODUCTION

The scope of the I-95 VPP was to develop a traffic monitoring system that spanned the entire East Coast, providing travel time and speed data on a network of freeways and arterials that interlink the metropolitan areas, including both primary, alternate and diversion routes for interstate traffic. A contract was awarded to INRIX in 2008 to deliver traffic data on over 1500 centerline miles of freeways (and has since been expanded to over 5000 centerline miles spanning New Jersey to Florida). In addition to the contracted freeway data, the vendor donated traffic data on over 900 miles of arterials during the initial three years of VPP. Figure 1 shows an overview of the freeway and arterial coverage.

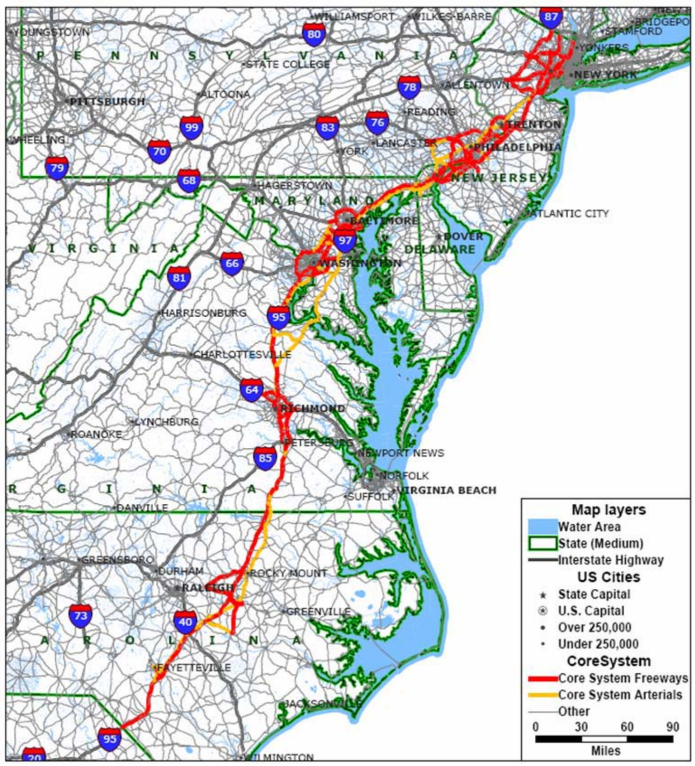

Figure 1. Freeway and Arterial Network as envisioned, and implemented in 2008 as part of the I-95 Corridor Coalition's Vehicle Probe Project.

The Coalition's goal during the initial three year period was to investigate the quality of donated arterial data so that appropriate quality specifications and value could be assessed. It was the intent of the Coalition to implement quality specification, a pricing structure, and a validation program for arterials similar in form to that was successfully implemented for freeway at the time of project renewal in 2011. In late 2009, after 18 months of freeway- oriented validation activities, the Coalition turned its attention to arterial data quality. Since late 2009, data samples have been collected on arterials as part of the monthly validation process and a committee of interested Coalition members was formed to review and guide the process. Arterial validation data and the expert committee input have revealed several technical issues to address in order to obtain usable traffic data from the VPP on arterials. Despite the challenges that were identified, the committee also affirmed the need for quality traffic data on arterials similar to that available for freeways. This paper provides the results of analyzing arterial information from various states. Although the paper was developed within the scope of the I-95 Corridor Coalition VPP, the technical and programmatic issues discussed are common to any arterial monitoring system.

The purpose of this paper is to provide a summary of the issues and concerns that have surfaced related to the VPP, and summarize the results of detailed analysis performed on four VPP data samples.

Beginning in mid 2010, the Coalition directed more time and analysis toward arterial traffic data in order to provide objective evidence to shed light and begin to resolve several of the issues of concern related to arterial traffic monitoring. Directed studies from arterials in Virginia, Pennsylvania, Maryland and Delaware dating from mid 2010 to early 2011 are presented to further characterize the issues, and begin to provide boundaries for when the VPP can provide traffic data of value on arterial networks.

ISSUES AND CHALLENGES IN ARTERIAL MONITORING

Data provided by INRIX since June 2008 covers both freeways and arterials. Freeways have been the primary focus of validation efforts during the first 18 months since the beginning of the project. Beginning in late 2009, the Corridor Coalition diverted some validation resources to assess quality and establish specifications of probe data appropriate to arterials. Four primary concerns and challenges emerged as a result of analyzing data on arterials and discussing the application of the data within a committee of state representatives. These issues are summarized in this section. First, the types of arterials that facilitate probe data collection are better defined. Presently the term 'arterials' as used in the initial scope of the VPP encompassed any non-freeway facility. Second, the applications that the VPP will support on arterials are better defined so that validation efforts can be customized to supporting them. Third, standards for data quality require definition specific to arterials. Current specifications were developed for freeways. Arterials exhibit a variety of phenomenon arising from the nature of traffic flow, most as a direct result of signalization that must be accommodated in data quality specifications. Fourth, unusual technical challenges that arise from using probe data for arterials are discussed, most notably are issues related to the use of industry Traffic Message Channel (TMC) codes for reporting traffic on arterials.

Types of arterials: In the original VPP program, the term arterials encompassed any road not a limited-access multi-lane freeway. Input from the committee and results from the analysis of validation data, has refined the definition of 'arterials' within the context of the VPP. The definition of arterials is narrowed to reflect high volume, multi-lane, signalized facilities that serve major corridor movements. These are typically found in suburban environments and link major freeway facilities or provide alternative parallel paths of sufficient capacity to be used during major incidents as alternative routes. The density of signals is medium to sparse, and mid-block friction caused by access to goods and services is light compared to the through movement traffic. Examples of such roadways include Route 3 connecting Route 50 and I-97 in Maryland, and Route 13 in Delaware, as will be discussed in the case studies. Objective measures of volume, turning movements, and signal density is the goal of continued case study analysis. While the operating characteristics of freeways are homogeneous from region to region and facility to facility, the operating characteristics of arterials as defined above are quite broad. These varying operating characteristics present challenges not only in the accurate monitoring of traffic data, but also in the appropriate use of the data in applications. Table 1 contrasts the operating characteristics of freeways versus studied arterials.

Table 1. Contrast between freeways and analyzed arterials.

	Freeways	**Arterials**
Volume	2200 vphpl	1400 vphpl on green
Speed range	20-70 mph	10-45 mph
Free flow speed	65 mph	Unknown, determined by signal timing
Congestion types	Recurring, non-recurring	Cycle failure, mid-block friction
Congestion signature/incident	Slowdowns < 55mph	Difficult to recognize
Flow distribution	Uniform	Higher variance, frequently bi-modal

Applications of arterial data: Since late 2009 validation data samples have been systematically collected on arterials with the aim to appropriately assess quality and establish specifications. This has led to questions of what quality is adequate to support intended applications, and what are the intended applications. From discussion with the committee, a list of target applications was assembled. Several of the intended applications are similar to that of for freeways. These applications include 511 systems, web maps, travel times on signs and operations performance measures (similar to freeways). Several potential applications were identified that were unique to the arterial environment. These arterial specific applications include traffic signal assessment, transit planning (busses) and optimal routing of transit, and inputs into signal analysis software such as Synchro. These latter applications may drive metrics and validation procedures separate from freeways, and unique to arterial corridors, thought these metrics have yet to be identified.

Data quality specifications: Lessons learned from freeway validation pointed toward several challenges in defining arterial data quality specifications.

a. <u>Defining and Observing Congestion:</u> While free flow within the freeway environment has common characteristics such as speeds greater than 60MPH, free flow is more difficult to define in terms of speed and travel time for arterials. Each arterial is unique based on signal timing plans. Furthermore, even on the same arterial, the free flow speed will be different at different times of the day depending on the signal timing plan in effect. In short, the nature of flow on arterials is most dependent on intersection operations, which is highly variable by facility and time of day. This presents challenges in identifying congestion on arterials.

<u>b. Variations in Flow within Arterials:</u> Due to traffic control devices, the travel times experienced by drivers through the same segment is disperse and tend to exhibit two distinct travel time patterns, referred to as bi-modal flow. The faster travel patterns reflect traffic that proceeds through the signals on green or other traffic controls designed for the corridor. The slower travel patterns reflect vehicles that are stopped on red at a signal within the corridor. For corridors with multiple signals, multiple modes related to stopped vehicles at various intersections may be observed. For freeways, any bi-modal flows observed are treated as an abnormality during validation of data quality, and typically excluded from the results. However, such bi-modal flows are observed frequently on arterials as evidenced for the case studies presented next. As compared to freeways, observed travel speeds exhibit much greater variance, complicating applications that rely on accurate speed estimates. Measures are needed that attempt to capture the variation in flow during non-congested periods, while still being able to identify congested flow during peak periods.

<u>c. Temporal Reporting Requirements:</u> Temporal reporting requirements with the VPP are set at a minimum of five-minute updates, with a maximum eight-minute data lag. The minimum

reporting interval is defined at the maximum time between updates. Indications are that arterial traffic patterns many need to be analyzed and observed over larger time windows in order to adequately characterize the nature of the traffic flow. As a result, summaries of traffic over ten minutes may be more appropriate to capture the central tendency and average out the signal induced variations. Validation that is currently summarized to five-minute time intervals on freeways may be more appropriately summarized over a ten- or 15-minute time interval on arterials. It is not expected that the minimum reporting interval will be changed from that of freeways, however, use of the data for applications may need to take into account timing constraints induced by traffic signals – and thus what is reported may need to reflect average conditions over a longer time period

d. Validation methodology: The nature of traffic flow on arterials is fundamentally different creating significant challenges. Large variance and bi-modal flow are frequent and the validation methodology currently employed for freeways is inadequate for arterials. The algorithms used to detect outliers and to characterize the confidence bounds of the mean speed often fail when applied to the ground truth data on arterials collected using Bluetooth™ traffic monitoring (BTM) technology. Detecting congestion versus normal or planned operations is also more difficult. The speed categorization used for freeways does not (or may not) separate flow into congestion levels. Lower volumes and compressed speed ranges enhance the difficulty of specifying and validating quality metrics. A methodology that accommodates larger variance at lower speeds, and correctly identifies BTM data point outliers are critical issues for continue development.

Unusual Technical Challenges for arterials: Traffic Message Channel (TMC) codes are currently used by INRIX, as well as by most commercial traffic data suppliers, to define roadway segments. These TMC codes, which are maintained as a proprietary industry standard, define the geographic extents upon which speed and travel time are reported. The segmentation based on TMC codes are used to build logical reporting segments. For example several TMC segments may comprise the freeway between two major interchanges. The individual travel times of the TMC segments are combined (sometimes with special algorithms) to develop a travel time estimated for a freeway corridor between major interchanges or landmarks, referred to as a path. This is needed to enable applications such as reporting travel times on freeway message signs. For freeways, the speeds and travel times reported in the VPP are interpreted for through movements. When a travel time is needed for a path that encompasses more than one freeway, the delay at an interchange connecting the respective freeways is either ignored, or a ramp segment is included reflecting the turning movement. Currently ramp segments are only available between major freeways. Even though reporting using TMC codes may or may not include ramps, the current resolution is sufficient to accurately estimate travel times across most interchanges, since delays due to ramps tend to be a minor contribution to overall delay.

The method used to define arterial segments emerged as a special challenge in light of the use of TMC codes. The adequacy of TMC codes to reflect arterial traffic flow has not been fully studied and several issues remain unresolved at this time. Specific to arterials, TMC knowledge and concerns include:

- TMC segments typically reflect roadway segments between intersections of major arterials or between a major arterial intersection and access to a freeway. However, unlike freeways, delays at intersections of arterials contribute significantly to overall delay. Appropriate coding and treatment of intersection movement is therefore critical to overall accuracy and usefulness of the traffic data.

- The method employed by TMC codes to model turning movements internal to the intersection is not well understood. It is unclear whether TMC codes reflect turning movements at all, and if they do, how it is coded.
- Current reporting of travel time on freeways using TMC codes indicates travel time between interchanges. Does the travel time include queue delays at the upstream intersection? At the downstream intersection? This reporting impacts the method of validation.
- Are travel times that are currently reported for arterials only reflective of through movement at the intersection? How can they be combined together to form path travel times similar to freeways when the path includes rights turn and left turns? Delays for left or right turns may be significantly different than through movement delays.
- How are segment lengths for TMC codes defined, particularly if the segments are internal to the intersection?

Several issues related to TMC codes were identified and discussed within the committee. The adequacy of TMCs to capture the arterial network logic is not well understood, and continues to be a concern. As TMC codes are a proprietary standard, INRIX volunteered to investigate the issues raised.

The four areas above summarize the concerns for effective arterial traffic monitoring. With these issues as a background, UMD began in-depth analysis of arterial data samples, which are summarized in the next section.

ARTERIAL CASE STUDIES

To study the data quality of VPP on arterial segments, several case studies were performed based on validation data collected on arterials in different states as part of the monthly VPP validation activities. A summary of these case study sites are presented in Table 2. In total, Bluetooth^{TM} traffic monitoring (BTM) equipment captured 960 hours of data on 23.7 miles of arterial segments. Given the vast amount of collected data, only representative subsets are presented to highlight the key findings. Table 2 provides various characteristics to compare and contrast the nature of the arterials studied, including their length, number of lanes, number of signals, and volume estimates. The last two columns reflect from the performance of the VPP on these roadways. The first labeled 'Score > 25' reflects the portion of real-time traffic reported during daytime hours (5AM to 10PM) as indicated by the Score metric in the VPP data. The Score is reported as 30, 20, or 10. A 30 indicates the estimate of speed is based on real-time data, while a Score of 20 or 10 indicates reliance primarily on historical data because the base data density is insufficient. The threshold of 25 is used because data from multiple base level segments and/or across multiple time reporting intervals may have been averaged to obtain the Score for the segment under study. The last column title 'Effectiveness of VPP' is a subjective measure determined by the study team of the VPP performance after reviewing all base level data comparing the VPP with Bluetooth^{TM} traffic monitoring (BTM) ground truth data for the entire 960 hours of data.

*Table 2.*Summary of VPP's arterial case study sites.

State - Time, Location	# of Test Paths	Length of Paths (mi)	# of signals	Numer of lanes per direction	Estimated AADT	Free-Flow Speed	Weekday Daytime %Score >25	Effectiveness of VPP
PA - Aug 2010, Route 1	3 NB & 3 SB	1.2 - 2.7	8-12 per segment	Primarily 2	20,000	15-30 MPH	71%	Very Low
MD - Sep 2010, Route 3	2 NB & 2 SB	1.8-2.0	4	2-3	40,000	45	57%	Good
VA- Sep 2010, Route 1	NB & SB	2.3	2	2	9,000-12,000	40-45	3.15%	Not Effective
DE - Nov 2010, Route 13	1 SB	1.06	4	3	20,000-34,000	40	76%	OK

Each segment is discussed separately in the discussion that follows. For each segment sample plots showing the VPP reported speed contrasted with ground truth speeds established using BTM devices are provided. The VPP reported speed is plotted in red diamonds, and is labeled 'Inrix' in the legend, reflecting the vendor provided data. The BTM data is plotted in blue. BTM data points marked with a black square were deemed not representative of the central tendency, and filtered from the averaging process. The standard error of the mean (SEM) band is also plotted showing the 95th percent confidence interval about the mean. The SEM takes into account sampling error and traffic flow variance. A wide band indicates higher variance in observed speeds, while narrow bands indicate consistent speeds of sampled probes.

Route 1 in Pennsylvania: Six arterial segments were analyzed on US Route 1 between Presidential Blvd in Philadelphia County and West Chester Pike in Delaware County, PA. This section of Route 1 cuts through suburban Philadelphia with significant number of traffic signals. The route typically has two lanes of traffic (sometimes three) in each direction, but has significant turning movements at each intersection. The route serves both residential and commercial districts. Certain segments reported low real-time probe data during the day, as a result the VPP speed estimates were often based on historical averages.

Figure 2 shows representative results from weekday data from Route 1. Peak speeds, even during free-flow periods, averaged less than 30 mph. As shown, the INRIX speed information does not capture the slowdown during the evening peak. The percentage of real-time data for the period illustrated was 45% indicating the low probe density for this arterial segment leading to deviation from ground truth. On several days the VPP data exhibited speed estimates with no variation from one time period to the next, (referred to as flat-lined), which is an indication a heavy reliance on historical information rather than real-time conditions. Findings suggest that the conditions on this particular route are not sufficient for consistent real-time monitoring of speed and travel times. These conditions are a combination of lower volumes, high signal density, and resulting high turning movements within the corridor. However, during occasional periods when traffic volumes were high, the VPP reported speeds based on real-time probe data.

Route 3 in Maryland: A six lane arterial segment was analyzed on US Route 3 between Belair Drive and US-424 in Anne Arundel County, just west of Crofton, MD and Annapolis, MD. This section has two to three lanes in each direction and relatively high volume (30000 to 50000 estimated AADT). In contrast to PA, this arterial serves primarily as a commuter route, connecting Route 50 and I97/MD32 freeways. Though some businesses and shopping are along these segments, the amount of local traffic and turning movements is minimal compared to the through traffic for commuting purposes.

Figure 3 shows representative results for US-3 northbound on Friday, October 8, 2010. When congestion arises, between 3 PM and 8 PM in this specific segment, the SEM band significantly reduces its width, indicating all traffic is subject to uniform slowdowns during this congestion period. The relatively wide SEM band from 6 AM to 3 PM reflects primarily the signal delay; a portion makes it through on all green, and a portion is stopped on the red cycle.

In contrast to Route 1 in Pennsylvania, the VPP has adequate information to provide real-time estimates without relying on historical data. Bluetooth data indicates that there was a significant slowdown from 2 PM to 8 PM, identifying the occurrence of a major disruptive event (see Figure 2). The speed dropped from the 40's to approximately 15 mph. Furthermore, the disruptive event was captured by the VPP data almost entirely. For this stretch, the 3% to 5% sampling range results in an estimated AADT between 30,000 and 50,000 vehicles.

Figure 4 shows another sample of data from Route 3 in Maryland. In the upper plot, a sample of data is plotted, similar to that in Figure 3. In the lower plot the percent of data with Score greater than 25 for the segment is shown in a bar chart for each hour of the day. The percent Score greater than 25 is a measure of real-time data (as opposed to reliance on historical data). This plot shows the high availability of real-time data during daytime hours. During nighttime hours, when the VPP 'flat-lines' (as highlighted in regions in gray), the VPP relies on historical information. Both Figure 3 and Figure 4 show a larger variation in speed during non-congested periods typically much greater than that observed on freeways. The presence of traffic control devices leads to the large variance in speeds. The upper bound of the distribution reflects vehicles progressing through on all green, while the lower bound reflects vehicles forced to stop at signals. This lower speed bound is often similar to speeds observed during congestion when all vehicles are forced to stop at each signal.

Route 1 in Virginia: A four lane arterial segment was studied on US Route 1 between Massaponax Church Road and US-17 in Spotsylvania County, just south of Fredericksburg, VA. This is a primary a rural two lane facility leading into Fredericksburg with relatively low volume. A representative plot of VPP data on this segment is shown in Figure 5. The plot shows the 'flat-lining' indicating speed estimates are based primarily historical averages. The real-time information from the BTM sensors is also sparse for most of the day due to low volumes. However, during the evening rush hour period, the VPP data underestimates speeds.

Although signal density is sparse on this section of roadway, traffic volume is too minimal to support real-time speed reporting through the VPP.

Route 13 in Delaware: A six lane arterial segment connecting I295 to the North and Basin Road to the South was analyzed. This section of Route 13 is closest in function to Maryland Route 3 although the amount of retail in the area increases the percentage of turning movements in the corridor. Even so, high volume commuter through traffic provides a basis for probe samples.

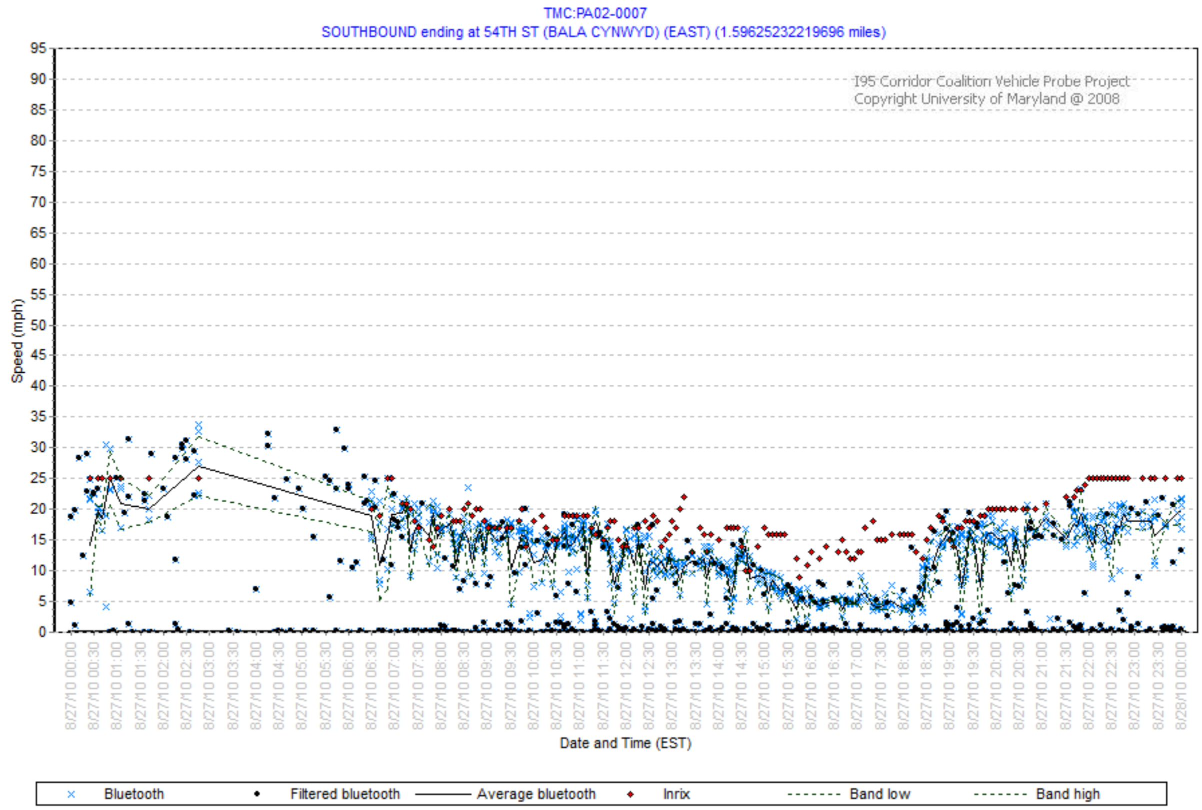

Figure 2. Representative data results from Pennsylvania's US-1 SB from August 27, 2010

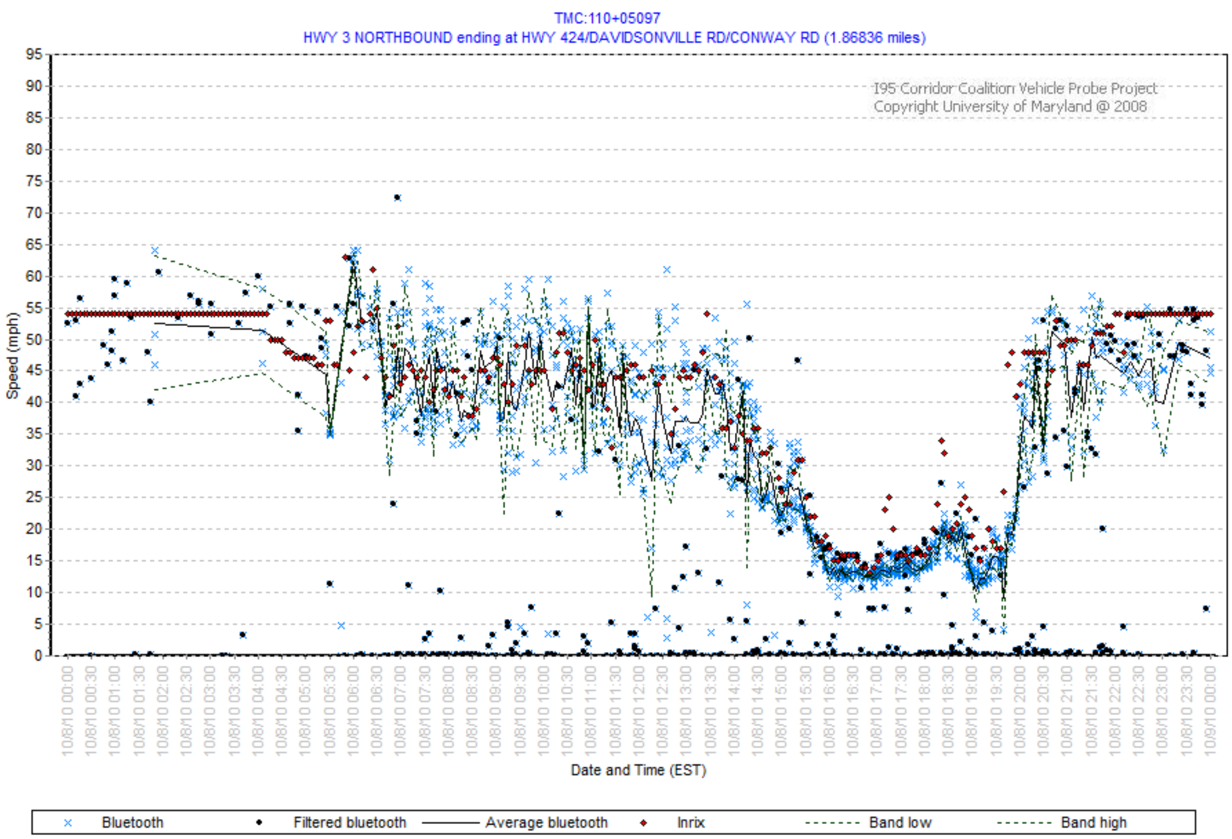

Figure 3. Representative results for Maryland's US-3 NB on Friday, October 8th, 2010.

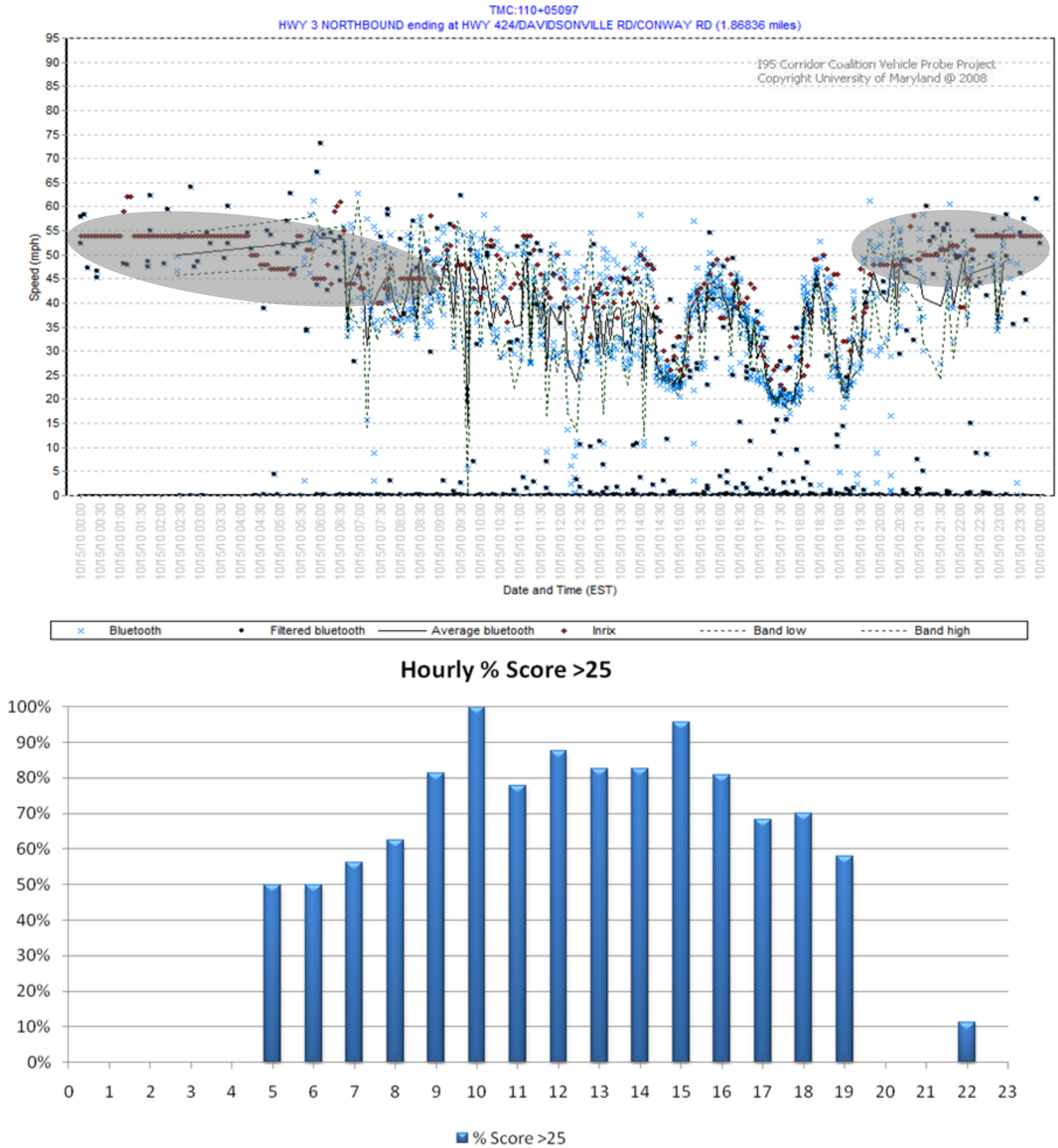

Figure 4. VPP data performance based on data density and % Score >25 for US-3 NB on Friday, October 15, 2010.

On certain days during the analysis period, such as November 7, 2010, the fraction of time for which real-time data was available during daytime hours was only 18%. The VPP indicates a free flow speed of 40 mph. The VPP data in Delaware was able to capture slowdowns in traffic speeds as shown in Figure 6 during the evening peak period. The VPP was not as accurate as it was on Maryland Route 3, but generally followed the congestion trends as shown in Figure 6. The methodology used to determine the mean BTM ground truth speed and to assess outliers on arterials was the same as that developed for freeways. At times the freeway methodology performed adequately, and at other times the freeway methodology was unable to distinguish outliers correctly. Examples of this are shown in Figure 6 when the VPP mean and SEM band incorrectly dip abruptly due to inclusion of data points that should have been flagged as outliers. The freeway methodology that provides the measures of average absolute speed error (AASE) and speed error bias (SEB) for freeways needs to be amended to better filter outliers, and adapt to the slower speeds exhibited on arterials.

Key Results

The results of the four case studies indicate that the VPP effectiveness is primarily volume dependent, although other factors impact quality of data. VPP data were deemed effective on Route 3 in Maryland and Route 13 in Delaware. The VPP data generally followed the envelope of speeds, particularly during congested periods. Performance on Route 3 was the better than on Route 13. This can be attributed to higher traffic volumes and less turning movements at intersections. The volume on Route 3 (estimated between 30,000 and 50,000 AADT) was greater than any other arterial studied, and sufficient to support real-time monitoring during day time hours. Additionally, the intersection geometry of Route 3 (use of dedicated turning bays) limited turning movement conflicts, resulting in more consistent travel time observations. The implications for VPP data are that arterials with efficient geometric designs and minimal traffic control devices are more suited for probe data monitoring.

VPP data were deemed ineffective on Route 1 in PA and Route 1 in Virginia. In Virginia, traffic volume was simply insufficient for any real-time reporting. Traffic volume on Route 1 in PA approached that of Route 13 in Delaware, but the density of signals and resulting increased turning movements rendered the VPP ineffective for monitoring peak delay. Also the free-flow speed on Route 1 in PA was significantly less than any other route studied due again to the density of traffic signals.

Trip purposes, and therefore land-use pattern of surroundings areas, also impact the effectiveness VPP. Routes 1 and 13, in Maryland and Pennsylvania respectively, are primarily commuter route during weekdays in comparison to Route 1 in PA, which is primarily a distributer to residential areas.

Generally, VPP is effective only during daytime hours on any of the facilities studies. During nighttime hours, the VPP relies predominantly on historical data as evidenced in the flat-lining effect as well as percent of Score less than 25.

The patterns of normal traffic and congestion on arterials differ significantly from freeway, as evidenced by the BTM sensor data. During normal operations, arterial travel speed can have large variance, reflecting portions of traffic progressing on green versus the portion forced to stop. Many times this creates two distinct speed clusters in the data, referred to as a bi-modal statistical distribution. During congested periods, all traffic is forced to wait on the red cycle, slowing speeds, but also reducing variance in travel time. This suggests a possible method for detecting congestion on arterials. Low speed observations taken in conjunction with low variance may serve as indicators of congestion. This warrants further research.

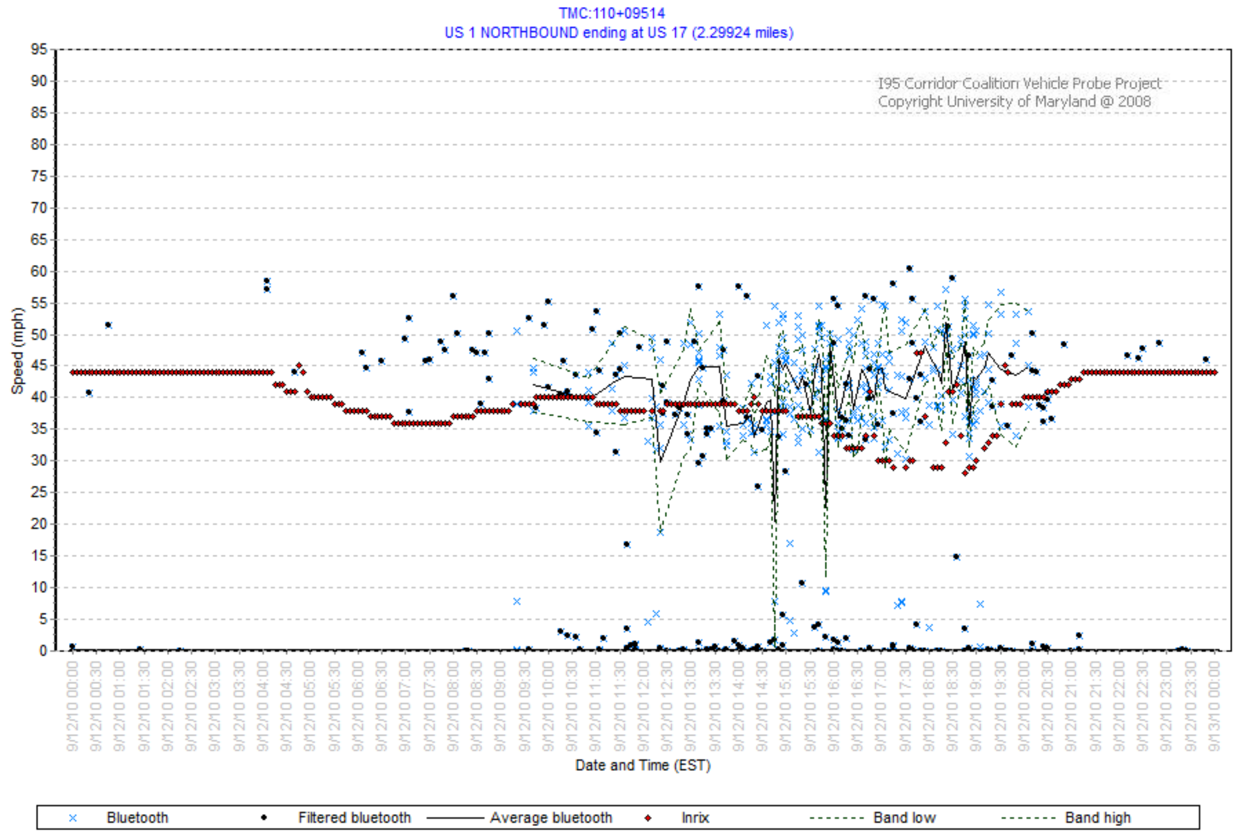

Figure 5. Representative data results from US-1 NB from September 11, 2010.

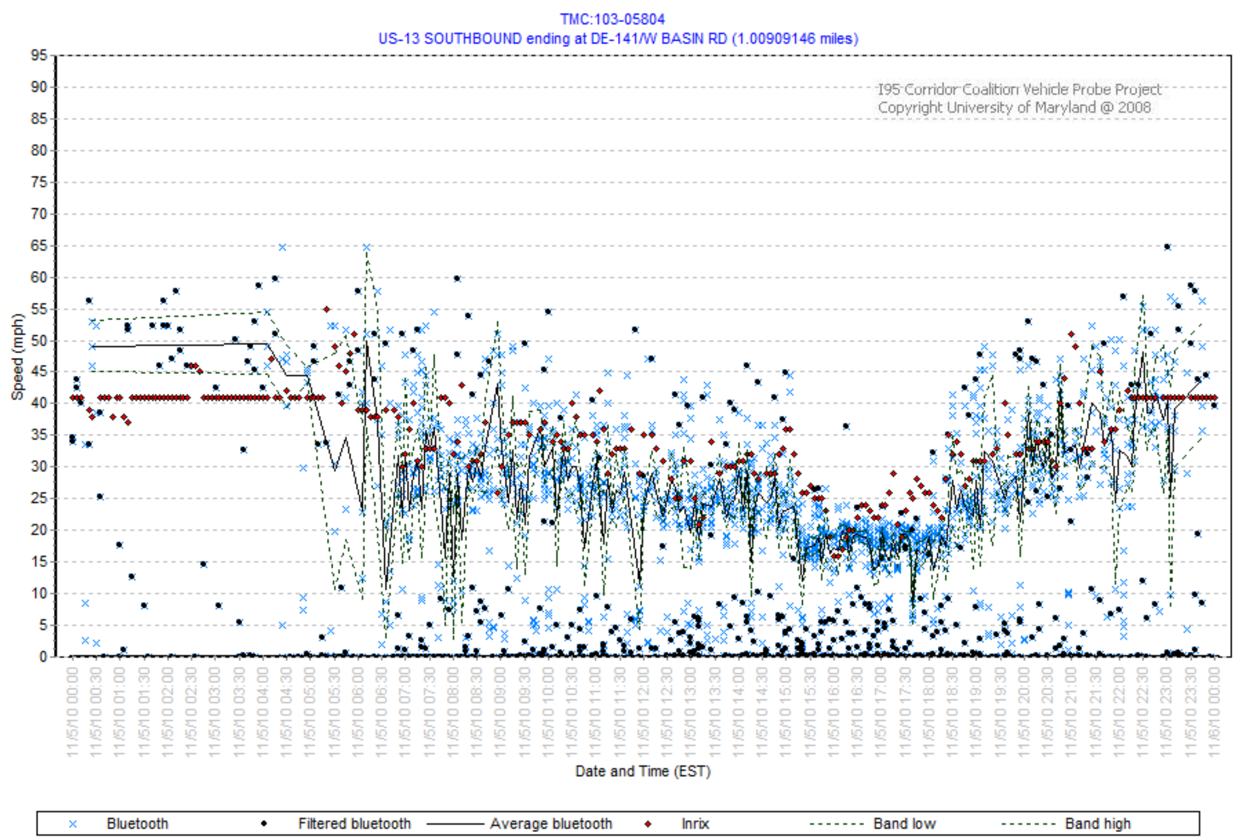

Figure 6. Representative data for Route 13 in Delaware for November 5, 2010

SUMMARY OF CRITICAL ISSUES

a) 'Arterials' as referred to in the initial VPP project included any road category that was not a limited access freeway. Arterials of interest and for which quality traffic data may by attainable in the near term encompass high-volume, multi-lane arterials that can serve as diversion routes during incidents and link major freeways. Such arterials exhibit sparse signal spacing, and medium to low mid-block friction.
b) Traffic flow on arterials is more diverse than on freeways, requiring a higher sampling rate to attain the same level of data quality. This high variance is induced primarily by the influence of signalized intersections, but increased turning opportunities and mid-block access to goods and services contributes as well.
c) In addition to higher overall variance in speeds, traffic signals tend to divide traffic in pulsed flows, with two or more distinct travel times. The faster travel time corresponds to the portion of traffic that progressed through on green, while the slower travel times reflect the portion stopped on red and forced to wait for the next signal cycle. These bi-modal flows are the largest technical challenge to obtaining and effectively using arterial traffic data.
d) Volumes on arterials are generally half that of freeways for the same geometric configuration (number of lanes). Due to the variance issues described above, larger sample sizes are required to achieve levels of accuracy comparable to that of freeways within the VPP. The combined effect significantly increases the difficulty of delivering quality traffic data for arterials. This impacts not only the VPP's ability to provide quality data, but also limits validation opportunities.
e) Congested flow on arterials is difficult to discern from free-flow. Whereas congested flow on freeways can be identified with a simple speed threshold, differing travel times on arterials occur due to different signal timing plans in effect throughout the day. The assessment of data quality on freeways concentrated on the performance of the system during congested periods. A similar approach with arterials will be more difficult to design.
f) It is uncertain whether the commercial traffic data standard used to defined roadway segments, called Traffic Message Channel (TMC) codes, are adequate to reflect the complexity of arterial networks. The method used to reflect turning movements within intersections requires additional investigation. Current TMC coding does not reflect varying delays for left-turn, through, and right-turn movements. This simplification of signalized intersection within prevailing TMC coding may limit its effectiveness as a reporting standard.

Despite the challenges described above, the demand for arterial data continues to grow. Applications for which arterial data are needed are similar to that of freeways. Traveler information services are expanding to include information for alternate routes that encompass major arterials that parallel freeways, arterial travel time on changeable signs and web maps, and information on diversion routes during incidents which typically include signal-controlled roadways. In addition, local commute patterns and transit frequently require arterial travel time data to support scheduling and other services. So in spite of the difficulties in providing quality travel time data on arterials, the need for the data is not diminished, but is growing. Unlike freeway traffic data in which many applications, uses, and quality metrics are available to draw upon, arterial traffic monitoring is not as mature. Definitions, specifications, and methods will need to be reviewed and refined as more data and additional experience is obtained.