

I-95 Corridor Coalition

Vehicle Probe Project *Data Use and Application Guide*

Final Report



I-95 CORRIDOR
COALITION

April 2011

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Vehicle Probe Project **Data Use and Application Guide**

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Prepared for:

I-95 Corridor Coalition

Sponsored by:

I-95 Corridor Coalition

Prepared by:

Center for Advanced Transportation Technology, University of Maryland &
KMJ Consulting, Inc.

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Introduction

With the launch of the Vehicle Probe Project (VPP) in July 2008, the vision of a traffic monitoring system that spans the entire eastern seaboard took a large step forward toward reality. The initial system of 1,500 centerline miles of freeway spanning New Jersey to North Carolina has since been expanded to over 5,000 centerline miles as of September 2010, and currently extends from New Jersey to South Carolina, with portions of the Florida freeway network as well. As a result of the VPP, the observability of freeway traffic conditions on the eastern seaboard has increased significantly, and will continue to grow as more transportation agencies take advantage of the VPP resource.

The ultimate goal of the VPP was to enable a wide-variety of operations and planning applications that require a high-quality data source. Examples of such applications include congestion management systems, traveler information systems, travel-time on changeable message signs, and performance measures. The travel-time and speed data provided by the VPP is supporting a growing number of applications within the Coalition, such as those listed above. With real-time data available on over 5,000 miles of freeways and a growing archive of speed and travel time data dating back to July 2008, the VPP is poised to enable a wide variety of applications once starved for data. Unlike other data sources which are dedicated to a single function and limited in geographic scope, the VPP data provides a central source to enable traffic operations, planning and performance measures applications across a large portion of the eastern seaboard that had previously lacked adequate data resources. Initial concerns over data quality, once a roadblock for outsourced traffic data, have been addressed through an extensive validation program. The quality of the VPP data is assessed on a monthly basis to confirm adherence to specifications. With the quality verified, focus is now turning to effective use of the data in various applications.

The purpose of this guide is to assist state, county, metropolitan planning organizations (MPO), city, and local transportation professionals who want to take advantage of the VPP resources. As such, it provides the reader with essential base-level knowledge needed to leverage the VPP data for various applications. .

Organization of the Guide Book

The guidebook is intended as a reference resource and is organized into three sections: a basic overview of the Vehicle Probe Project (VPP) including various products and data, an overview of existing and planned applications including implementation examples from Coalition members, and an overview of the validation program that ensures data quality. A considerable collection of reference literature supports the VPP. When applicable, such resources are cited in the guidebook. The appendix provides a catalogue of these resources including downloadable information.

The three sections of this guidebook are further explained below.

Overview of the Vehicle Probe Project, Data Items and Characteristics

This section educates the reader on the basic attributes of the VPP, including the original vision, history of implementation, and extent of coverage. It also provides a succinct description of the data items and data product procedures to gain access to the data, rights and limitations on use of the data, and procedures to expand coverage of the system. This section is intended for those unfamiliar with the scope and management of the project in order to orient the user of available products and services.

Current and Planned Applications using Vehicle Probe Data

This section describes various applications that take advantage of the VPP, including applications currently in deployment as well as envisioned applications. Case studies are provided (when available) of coalition members that have successfully leveraged the VPP for such applications. This section is intended for agencies seeking examples of data use, and attempting to mine any lessons-learned from other agencies. Whenever possible, the products of the VPP are cross-referenced to the applications. Additionally, guidance related to critical requirements and additional resources are provided.

Validation of the Vehicle Probe Data

This section is devoted to providing an overview of the quality control process, and a summary of the results to date. The purpose of the validation program is to ensure the data provided by the system meets the specifications of the contract and to ensure its adequacy to support the intended applications. Outsourced traffic data requires independent checks of accuracy in order to develop confidence in the quality and reliability of its data. This section provides the reader an overview of the validation methodology, a summary of the objective evidence of data quality, and points readers to the archives of detailed analysis and validation results for additional information.

Combined, these three sections form a guide to help users successfully leverage the VPP data for application development. Appendices provide a catalogue of product literature and documentation, and key contacts within the Coalition and its member agencies associated with the VPP.

Overview of the Vehicle Probe Project, Data Items and Characteristics

Vision and History

When the Vehicle Probe Project (VPP) was conceived in 2006, vehicle probe technology was emerging as a means of continuously monitoring traffic without the need for deploying and maintaining equipment in the right-of-way. Commercial firms were offering traffic data services based on a variety of methods, the most common of which were based on either cellular geo-location or fleet Global Positioning System (GPS)-based reporting technologies.

Cellular geo-location methods rely on the cooperation of cellular carriers to mine the signal timing and handoff data emanating from a cellular tower switching network. This cellular switching data provides information from which to estimate traffic conditions.

Fleet GPS-based reporting technologies derived traffic information from commercial fleet management systems. Such systems track their vehicles using GPS technology installed within vehicles and reported periodically to a central service through either a cellular or satellite communication link. Such systems, referred to Automated Vehicle Location (AVL) systems, were common in commercial trucking and were spreading to taxi, bus, delivery and other types of commercial fleets due to declining costs of mobile data communications and GPS instrumentation. AVL equipped vehicles provide periodic updates of location and speed, which, if combined with data from other AVL systems, provides enough information to estimate traffic conditions.

Early demonstrations of the various vehicle probe techniques relied heavily on a single method or technology. In 2006, systems were emerging that combined probe data from multiple sources and technologies, as well as data from existing government owned fixed-sensor networks into a comprehensive traffic information service.

By 2006, many coalition members had invested in some form of fixed-sensor network consisting of speed and volume detectors. The high cost to deploy and maintain fixed-sensor networks combined with increased demand for such data on more roadways, fueled the market for less-expensive methods to monitor large roadway networks. The proliferation of low-cost and high-speed cellular data services combined with stream-lined information access provided by smart-phones whetted consumer's appetite for accurate real-time road congestion information. These market trends heightened the pressure on public agencies to provide timely reporting of incidents and road closure information in order to allow drivers the opportunity to divert to alternate routes and thus avoid delays.

In response to this growing demand, the Coalition initiated a regional traffic monitoring project based primarily on vehicle probe technology. The monitoring system was envisioned to act as a continuous source of real-time transportation system status information along a major portion of the I-95 corridor. The data from the system was intended to drive multiple Coalition applications related to traveler information and performance measurement, as well as support a myriad of other internal engineering and planning applications. In April 2007, the I-95 Coalition released a

Request for Proposals (RFP) to procure a traffic monitoring system within the Corridor. The critical requirements of the RFP are summarized below:

- **No particular technology was specified.** The approach was limited only to methods that did not require additional physical equipment to be located in the right-of-way. Vendors were encouraged to propose innovative probe-based approaches while taking advantage of data from existing sensor-based systems, such as loops, radar, or toll-tag systems.
- **Data quality specifications were determined based on their intended use.** The quality specifications placed a limit on the error in reported travel time under varying roadway conditions. These specifications were defined in detail within the RFP, designed to be applicable to any technology that would be proposed, and written with respect to minimum requirements needed to support envisions applications of the data.
- **The accuracy of traffic data was to be independently validated with payment contingent on validated accuracy.** The results of previous demonstrations of probe techniques varied considerably and no probe-based system was currently in paid commercial operation at the time. A common attribute of most previous demonstrations was lack of publicly available reports detailing validation results. Member agencies, though enthusiastic and supportive, insisted on objective evidence of data quality before it could be offered for agency use. As such a full and open validation program was prescribed in the RFP.
- **The data provider was to retain ownership of the data for resale in commercial markets.** The Coalition (and its members) retained the rights to use the data to support all intended applications, including all internal applications in perpetuity. Restrictions were placed only on the extent, form and granularity of the data that could be released to the public or shared with other private entities.

Additional details of the requirements and specifications of the procurement are available in the project RFP. The initial program outlined a roadway network that spanned New Jersey to North Carolina and served inter-regional travel. The network included:

- Interstate 95 from New Jersey to North Carolina
- Parallel freeways that provide additional capacity and alternate routes
- Beltways around metropolitan areas that linked I-95 and the parallel freeways
- Major parallel arterials that provided alternate or diversion routes during incidents
- Freeways and major arterials that interlinked the aforementioned facilities.

Proposal evaluation concluded in December 2007 when a multi-year contract was awarded to a team headed by INRIX. INRIX's approach was based on a method to fuse data from various sources into a comprehensive picture of traffic flow.

On July 1, 2008, the traffic data on the initial core system that spanned New Jersey to North Carolina went into production. The original contract also contained provisions for network expansion by Coalition members, and subsequently the VPP network has grown to over 5,000 miles of roadway from New Jersey to Florida. The full RFP, the INRIX proposal, and resulting contract are available for review. Links to this information are shown in Appendix A, while contact information for those involved is shown in Appendix B.

The Network

The objective of the initial deployment of the VPP was to procure a corridor-wide traffic monitoring system that provided real-time traffic information to support inter-corridor movements. The monitoring system was envisioned to include a network that reflected the primary routes that support inter-regional travel. The network consisted of:

- I-95 and major parallel freeways
- Beltways and cross-linking freeways
- Major arterials that provided or enabled alternative routes

Figure 1.1 portrays the original VPP network as conveyed in the RFP. The network as deployed on July 1, 2008 closely resembles that in Figure 1.1, with differences primarily in the selection of arterials. Several expansions have occurred to the network within the first 24 months. New Jersey, North Carolina, South Carolina and Maryland have expanded coverage to encompass all Interstates and/or freeways within the state boundaries. Pennsylvania, Virginia, and Florida have expanded to portions of their freeway network. A view of coverage as of January 2011 is shown in Figure 1.2. Geographic coverage has been extended to the entire Eastern Seaboard (Maine to Florida) through the Project Monitoring Website, however, this is limited to visual real-time maps, not does not include the Extensible Markup Language (XML) data feed nor the archive.

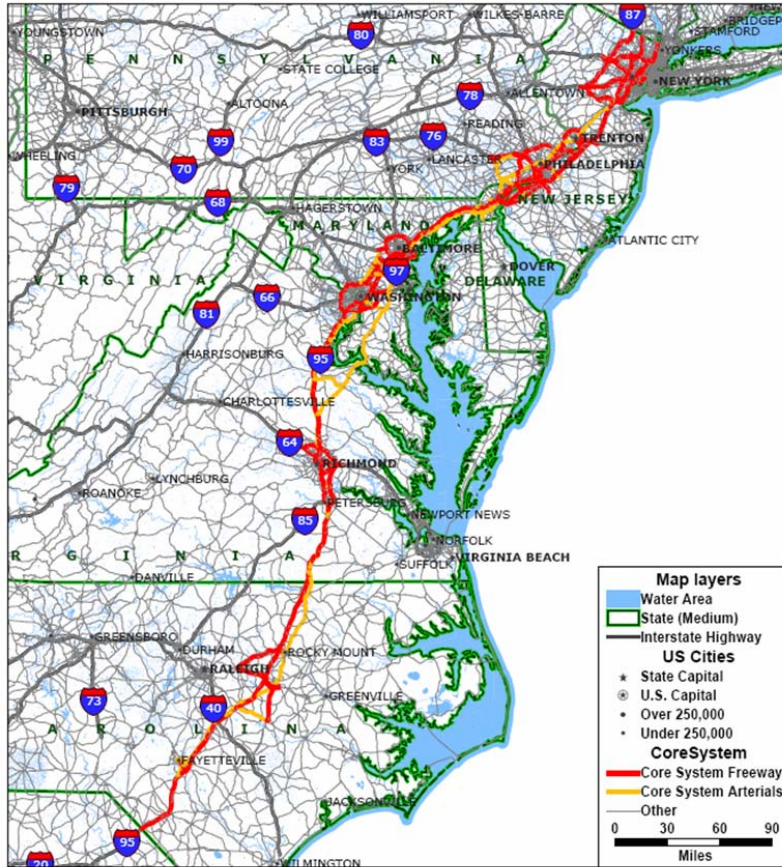


Figure 1.1: Original Coverage of the I-95 Probe Project

The VPP is structured such that States and other Coalition members can expand coverage, as several have already done. In order to make the contract as adaptable as possible, the Coalition conferred with several state procurement officers to identify and follow the most broadly accepted procurement methodology. This, in turn, allows many government agencies to opportunity to expand coverage through the Coalition, taking advantage of the volume-discount negotiated via the VPP, and avoid a lengthy procurement process.



Figure 1.2: I-95 VPP Network Coverage, January 2011

The cost of extending coverage is based on the negotiated rates within the original contract with INRIX. A basic overview of the rate structure is outlined below and can be used for estimation purposes.

- Rates refer to centerline miles of roadway, 24x7 coverage
- Rates apply to freeways (limited access, multi-lane facilities)
- Start-up/Mobilization is a one-time fee for activating service
- Mobilization rates(in \$/mile):
 - July 1, 2008 through June 30, 2011, \$150/mile
 - July 1, 2011 through June 30, 2014, mobilization is waived
- Annual data subscription fees (in \$/mile):
 - July 1, 2008 to June 30, 2014, \$750/mile
- Contract overhead fees will apply, the cost of which will differ based on the method used to fund and

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For more information regarding the options and mechanisms to expand VPP coverage, contact the Coalition’s administrative and support staff, as identified in the appendices.

The University of Maryland is the contracting agency on behalf of the I-95 Corridor Coalition, thus the VPP contract is executed under Maryland law between the University of Maryland and INRIX Inc., as a state contract.

An agency’s legal and procurement staff may require review the VPP contract. Copies of the contract are available by contacting the University of Maryland (See appendices for contact information).

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procure additional coverage. Historically these fees have averaged about 10% of the total cost of expansion.

Note that once mileage is added to the network, it is available to all coalition members. Before considering an expansion, check if the desired coverage is already part of the VPP. If a roadway is already part of the VPP network, then the data will be available at no additional charge.

Coalition support staff and INRIX can assist preparing quotes based on detailed description of the desired expansion area. As of January 2011, only freeway coverage is available for expansion. Pricing for arterials should be available in early 2011. See discussion below for more information on arterials.

Arterial Coverage

The scope of the I-95 VPP included traffic data on major arterials that act as alternate routes and connecting links between major freeways. Arterial links were included both in the RFP and in the implementation that began in July 2008. INRIX donated traffic data on over 900 miles of arterials as part of the initial three years of the VPP, which runs from July 1, 2008 to June 30, 2011. (See the map in Figure 1.1 for an overview of the original freeway and arterial coverage.) The Coalition's goal during the initial phase of the VPP was to investigate the quality of donated arterial data so that appropriate quality specification, monetary value, and method of validation could be assessed at the time of project renewal in 2011. That effort is ongoing. Arterial data is not subject to the specifications of the contract. The results of the validation reflect only on the quality of the freeway data. A link to the summary white paper on the challenges and issues is available in Appendix A.

Ramps and Special Use Lanes

Ramps were not included in the original deployment of the VPP. Beginning in 2010, INRIX began providing ramp data on an experimental basis, and the Coalition extended validation efforts to begin assessing data quality on ramps. Early results are promising, reflecting data quality on ramps similar to that of freeways. Data collection and analysis continues. A special report on the ramp data quality will be issued by the coalition in 2011, and ramp data will be included as a standard product beginning in mid 2011. Ramp data will generally be available for freeway to freeway interchanges. Traffic data on interchange ramps between freeways and other lower class roadways are being considered as well.

Special use lanes refer to High-Occupancy Vehicle (HOV), High-Occupancy Toll (HOT), Local/Express, Truck Lanes, and Reversible Lanes. Traffic data provided by the VPP can differentiate special use lanes ONLY IF the lanes are physically segregated, either by a median, barrier, or other type of physical separation. Special use lanes that are simply striped (such as the outer-most lane/s of a multi-lane freeway) generally are not reported as separate flow lanes in the VPP. Many HOV, HOT, and Truck Lanes in mountainous regions lanes fall into this latter category. If the special use lanes are on separate right-of-way from the normal use lanes, which is common for reversible and local/express lanes, these lanes may be reported separately in the VPP. Consult the Project Monitoring Website to determine if lanes are reported separately for a specific facility.

Extension Network

Beginning in 2009, the geographic coverage displayed on the Project Monitoring Website was extended as a graphical map-view of traffic conditions reflecting the real-time operations of the entire freeway system in the eastern half of the United States. No XML data feed, archived data, or tile overlays are available for roadways that are only included in the extension network. The extension network viewable through the website allows for general monitoring of conditions, informs agencies of available coverage, and provides samples of detailed data.

The Products – “How to access the Vehicle Probe Project Traffic Monitoring System”

Data from the traffic monitoring system can be accessed through one of four methods. Full technical details of each interface are available in the I-95 Vehicle Probe Interface Guide as referenced in Appendix A. An overview and purpose of each method is given below.

Project Monitoring Website

The Project Monitoring Website provides graphical access to the VPP in a fashion similar to online mapping services, and is typically a person’s first interaction with the VPP. The site provides a map-based interface to the entire VPP network. The monitoring site is available via the internet at <http://i95.inrix.com/>, and requires a username and password. Personnel can request an account through the website. If the corresponding agency has executed a Data Use Agreement (DUA), then registration will be granted usually within 24 hours. A sample screen of the map interface is shown in Figure 1.3. Traffic is color-coded according to severity of congestion. Individual links can be selected (as shown), and link specific data will be display in a balloon window as illustrated.

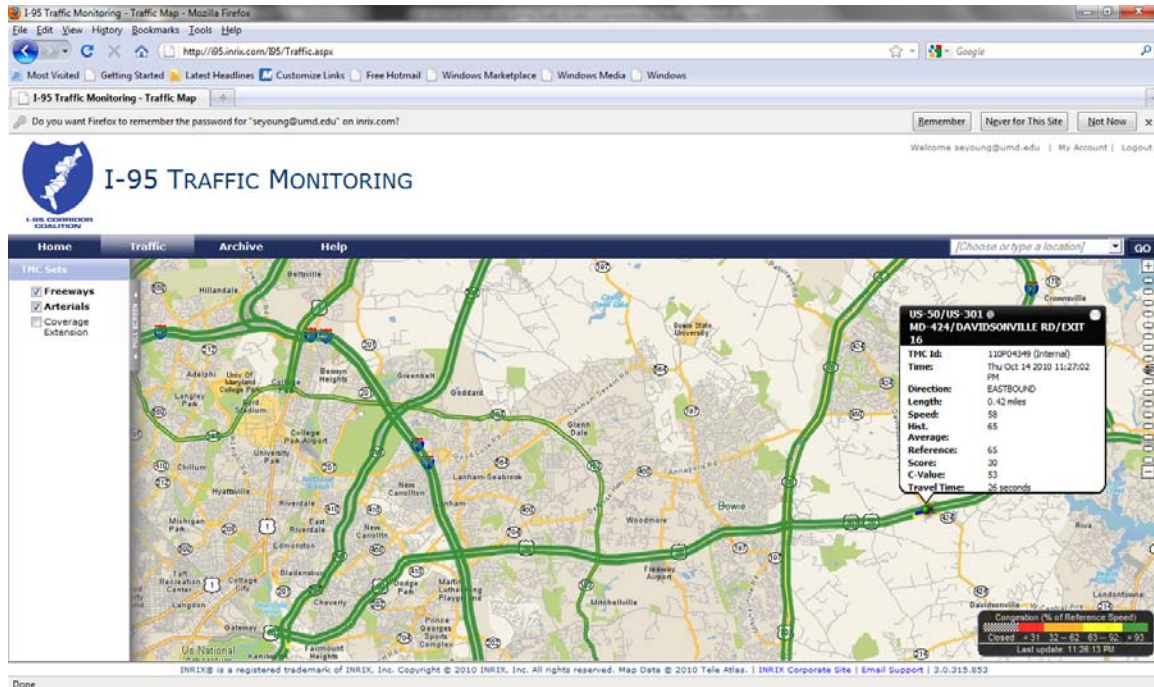


Figure 1.3: Screen shot of the Project Monitoring Website

XML Real-Time Data Feed

The heart of the VPP is a real-time, internet based data feed. This XML-based data feed provides the specific traffic reporting metrics for each link in the network. The data is accessed through an API call that is fully detailed in the Project Interface Guide. The data feed is the primary method to access and integrate real-time data into agency applications. Data can be called as frequently as once per minute.

Archive Data Services

All traffic data reported through the VPP is archived at 5 minute intervals by INRIX, and made available to Coalition members via the Project Monitoring Website. Data can be requested for a specific time period, and for a specific state. Data requests are usually serviced within 24 hours, and an email message is sent informing the user of the data availability. Data is delivered as text files that can be imported into spreadsheets and database applications.

In addition to the INRIX archive, the University of Maryland Center for Advanced Transportation Laboratory (CATT Lab) archives the VPP data at one minute intervals for the entire network. The CATT Lab archive has been active since October 2008. Visualization tools, performance measure tools, bottleneck analysis, and querying tools are being made available via the CATT Lab's data system. These tools are internet-based, and expected to be available to Coalition members in 2011. In the interim, and for assistance with detailed data queries, contact CATT Lab personnel for assistance as identified in Appendix B.

Various other roadway authorities or academic institutions may also be archiving data specific to your region.

Map Overlays

In addition to the data service, INRIX provides a more streamlined method to integrate data onto existing web-based maps. This product is intended for agencies that want to generate traffic maps customized to their jurisdiction utilizing the VPP data. The overlay provides a means to access the VPP data in a way that can be directly imported into many standard digital maps currently in use for web services. The project interface contains full details.

Data Items

Traffic data is at the heart of the system. Some data items were explicitly specified in the RFP, while other items INRIX provides as value added, and others have been added in collaboration with INRIX in order to improve the usability of the VPP data. All data items can be viewed from the Project Monitoring Website, and are available in the XML data feed.

- *Speed* - the current estimated space mean speed for the roadway segment in miles per hour.
- *Travel Time* - the current estimated time it takes to traverse the roadway segment in minutes.
- *Reference Speed* –the calculated “free flow” mean speed for the roadway segment in miles per hour (capped at 65 miles per hour). This attribute is calculated based upon the 85th-percentile of the observed speeds on that segment for all time periods, which establishes a reliable proxy for the speed of traffic at free-flow for that segment.
- *Average Speed* - the historical average mean speed for the roadway segment for that hour of the day and day of the week in miles per hour.
- *Score* - three discrete values are defined:
 - “30” – Real-time time data for that specific segment
 - “20” – Estimate of speed relies heavily on historical data, specifically the average speed. May have some real-time data.
 - “10” – Estimate of speed is based on historical data, specifically the reference speed.
- *Confidence Value (C-Value)* - in December 2009, INRIX began publishing a confidence value separate from the score attribute to provide supplemental information on the fidelity of real-time data. C-Value ranges from 0 to 100 and is provided only when the Score = “30”
- *Date and Time* - the UTC timestamp at which the response was generated.
- *TMC Segment* - the Traffic Message Channel code that defines the beginning and ending point of the roadway segment being reported.

See the Project Interface Guide for further details.

Data Quality Specifications

Data quality specifications were developed with the intent of creating a seamless network of corridor-wide traveler information systems and to facilitate and support the coordination and implementation of interagency efforts in response to major incidents and special events of regional significance. Timeliness and accuracy of data are paramount to the success of these efforts.

To this end, the Coalition developed specifications that limited the error and latency in reporting of real-time data. Accuracy is specified in two metrics: Average Absolute Speed Error (AASE) and the Speed Error Bias (SEB) as defined below. Timeliness in reporting was captured in a *DataLag* specification. Note that “Speed” is explicitly defined as the space mean speed over the specified segment or link within the context of the VPP. Section 3 of this guidebook provides an overview of the validation methodology and summary of the results to date. The original RFP provides further details on all technical specifications.

Average Absolute Speed Error

The absolute speed error is defined as the absolute value of the difference between the mean speed reported from the VPP and the ground truth mean speed for a specified time period. The AASE is the primary accuracy metric. Speed data shall have a maximum average absolute error of 10 miles per hour (MPH) in each of the following speed ranges:

- 0-30 MPH
- 30-45 MPH
- 45-60 MPH
- > 60 MPH

Speed ranges were designated to reflect various levels of congestion. Previous attempts to specify quality in a single metric (such as overall AASE independent of the speed ranges) were found to be ineffective in capturing system performance during critical congestion periods, being dominated by free-flow by the over-whelming quantity of free-flow data. By applying an accuracy metric in each of the four speed categories above, the performance of the system is determined across the full spectrum of congestion levels.

An absolute accuracy threshold of 10 MPH is specified within each range rather than a percentage. A percentage based specification appears reasonable at higher speeds. For example, a 10% accuracy specification equates to 6 or 7 MPH during free-flow conditions. However, when applied to severe congestion levels, such as 10 to 20 MPH, a percentage based approach appears unrealistically strict. For these reason an absolute threshold was used as a minimum specification, and chosen such that it could distinguish between various levels of congestion.

Speed Error Bias

The speed error bias (SEB) is defined as the average speed error (not the absolute value) in each speed range. SEB is a measure of whether the speed reported in the VPP is consistently under or over estimates speed as compared to ground truth speed. VPP shall have a maximum SEB of +/- 5 MPH in each of speed ranges as defined above.

Data Lag

Data lag is defined as the time between when traffic is perturbed on the highway and the time it is reported in the data feed. Maximum data lag of 8 minutes is specified in the VPP.

The AASE, SEB, and Data Lag comprise the primary technical specification on data quality. Other contract specifications related to spatial, temporal, reliability and management are available from the RFP.

Data Use License and Restrictions

A key provision of the contract is that all data delivered to the Coalition, regardless of source of funding, is available to all member agencies. This includes the real-time data feed, the archived data files, and the Project Monitoring Website. Data usage is governed by the project's Data Use Agreement (DUA). The VPP DUA is groundbreaking in that it provides maximum flexibility to use, store and analyze the traffic data system, while still maintaining the vendor's ability to resell the data in the commercial space. The DUA binds INRIX, the University of Maryland and all coalition agency members that execute the DUA to a common data use policy. The DUA guarantees the right of agencies to use the data for all intended purposes, including all internal applications as well as all common uses related to traveler information. The original RFP placed technical limits on what could be displayed publicly in terms of granularity of data, and types of applications. In negotiation with the vendor, the data rights were further liberalized to reserve rights to the data for a wide variety of uses into the future, while protecting the vendor's rights to resell the data for commercial purposes. The prevailing policy is defined in contract modification M002, dated April 23, 2008, and is available by request from the University of Maryland (see Appendix B for contact information.) Prior to gaining access to VPP data products and services, agencies must acknowledge the terms of the data use policy via a separate DUA between the agency and appropriate contracting entity. This DUA that an agency executes can take on various forms depending on the legal requirements of the agency. Contact the Coalition administrative staff for assistance.

Traffic Message Channel (TMC) Codes

Although Traffic Message Channel (TMC) codes is a technical attribute of the program, any overview of the VPP would be incomplete without briefly describing the use of TMC codes within the project. When the VPP was initiated, no universal standard for encoding and reporting data on roadway segments existed. Although Geographic Information Systems (GIS) software tools proliferated, each state maintained a separate encoding standard, and no universal road segmentation scheme was supported by every state. The implementation of the VPP required

such a universal method to keep implementation and integration costs to a minimum. INRIX proposed, and the Coalition adopted, the use of TMC codes for the reporting of traffic data on the VPP. TMC codes is a road segmentation standard developed and maintained by an industry consortium consisting of electronic map providers and their primary clients. This was an emerging standard that was proliferating quickly at the time of the contract award. TMC codes provide the only known national standard for road segmentation.

Full technical data concerning the TMC codes is available in the Project Interface Guide. A listing and description of TMC codes needed for integration of data from the XML data feed is available from the University of Maryland. See Appendix B for appropriate contact information.

Current and Planned Applications Using Vehicle Probe Data

The data provided by the Vehicle Probe Project (VPP) was envisioned to enable a wide variety of applications. A variety of uses, some foreseen and others not, have been implemented within 24 months of its inception. This chapter provides an overview the applications of the data, describes the type of data used in the application, references the lead agencies within the Coalition that are integrating the VPP data for such purposes, and provides guidance on the use of vehicle probe data within the application. While some uses have not yet been completely explored, they have been included here for future consideration. The applications discussed in this guide are:

Application	Development Status	VPP Data Products
511 Systems	MATURE - Several state agencies have already integrated VPP data into their 511 systems	XML DATA FEED
Web mapping	MATURE - Used by several coalition members and supported by industry mapping standards.	TRAFFIC TILE OVERLAYS XML DATA FEED
Travel Time on Variable Message Signs	MATURING - Several examples are available to draw from. Each implementation is unique, and standards for messages delivery are emerging	XML DATA FEED
TMC Operations	MATURE - Implemented extensively by Coalition members	PROJECT MONITORING WEBSITE XML DATA FEED
Transportation Planning and Operations Performance Measures	EMERGING - Tools and practices are evolving quickly. Examples of initial implementations are available.	ARCHIVE DATA
Trip Planning Tools	EMERGING - Coalition sponsored application in production.	ARCHIVE DATA DATA FEED
Construction Staging and Planning Operations	CONCEPTUAL - no systems currently deployed based on VPP data	ARCHIVE DATA XML DATA FEED PROJECT MONITORING WEBSITE
Targeting Minor Geometric Improvements	CONCEPTUAL - current pilot requires arterials rather than freeway data	ARCHIVE DATA

Table 2.1: Applications Utilizing VPP data

Within the discussion of each of the above applications the guidebook provides:

- A thorough definition of the application
- Benefits of the subject application
- Application requirements including: applicable VPP data products, data quality requirements, and requirements unique to the application
- Resources available for application development
- Agency spotlights (as available) to show how agencies within the coalition have used or plan to use VPP data for the subject application

This chapter is intended to provide an overview of possible applications, and guidance to integrate VPP data. Contact information for any agency cited in the guidebook is provided in Appendix C. Note that the Project Interface Guide available on the project web site is a key resource critical for any application.

511 Systems

Phone-based 511 systems disseminate critical road status information such as weather alerts, closures, and construction activity through the nationally reserved 511 quick dial code. In many metropolitan areas, the 511 service has been expanded to also provide severe congestion and/or travel time alerts. Within the past few years, 511 services have expanded to include data dissemination via an agency website. VPP data is integrated into a 511 system to calculate real-time traveler information for specified routes and then disseminated to the web or telephony system. Use of VPP data to support 511 systems encompasses use of the data to create route specific travel times and congestion alerts. Color-coded maps and other representations of the data only available through a graphic interface are discussed under Web mapping, following this section.

Within the I-95 Corridor Coalition, several states have initiated or expanded their 511 capabilities with the use of vehicle probe data. Table 2 presents the 511 capabilities of several coalition members:

Coalition Member	511 Telephonic System	511 Website	Information provided
Massachusetts*	Yes	Yes	<ul style="list-style-type: none"> Travel time and speed information for segments experiencing adverse conditions
New Jersey	Yes	Yes	<ul style="list-style-type: none"> Travel time for preset origins and destination Speed mapping including a color coded speed map
Pennsylvania*	Yes	Yes	<ul style="list-style-type: none"> Traffic map displays travel time and speed
Maryland	Planned	Planned	
Virginia	Planned	Planned	
North Carolina	Yes	Yes**	<ul style="list-style-type: none"> Through the Traveler Information Management System, a travel tile overlay displays color coded speed information
South Carolina	Yes	Yes	<ul style="list-style-type: none"> Real-time traffic information on congestion
Florida	Planned	Planned	

Table 2.2: I-95 Corridor Coalition Agencies Using Vehicle Probe Project (VPP) Data in 511 Systems ***

*Massachusetts and Pennsylvania are utilizing data provided through INRIX as part of separate 511 contracts.

**North Carolina provides travel information via website on its Traveler Information Management System (TIMS).

*** Data based upon interviews occurring in December 2010 – February 2011

Benefits

Prior to the availability of vehicle probe data, route-specific travel information was obtained from expensive roadside detectors, closed-circuit television (CCTV) and other methods. The VPP provides a source for broad-based coverage to augment 511 systems both as a real-time congestion monitoring tool, and as a travel time service between landmarks. In comparison to traditional methods of obtaining travel time and speed data, the VPP substantially reduces the initial capital investment and the expense of ongoing maintenance.



Informed drivers are able to make better travel decisions, avoid congested routes and have a more accurate expectation of travel times. Personal alerts send pertinent information of congested areas to allow diversion to other roadways. When the congestion is due to a traffic incident, reducing traffic demand will decrease the time it takes to return to free flow operations. Reports of weather and the associated roadway conditions alerts also help to reduce the frequency of accidents.

Application Requirements

Implementation of a 511 system using VPP data has the following requirements:

System-wide data

Acquisition of travel time and speed data is the basic element for all roadways to be included in the 511 travel information services. Agencies may also consider incorporating construction activities and incident reports to bring greater understanding to travel conditions.

Real-time data feed

The data to be used in the 511 system must be timely; else the information will not be credible. Agencies should monitor the data results to determine if any post processing is necessary to remove anomalies, and report results within maximum and minimum travel time ranges. Depending on the time needed to complete this filtering and smoothing of the data, latency issues may result.

Web-based mapping

Although mapping is not a critical component, it is the most efficient way to communicate travel information on a regional basis.

Once the data needs are fulfilled, proper and effective 511 systems include the following services:

Congestion alerts

Congestion alerts require monitoring of both the real-time data and archive to determine unusual situations. Typical implementation requires integration of the data feed with the

jurisdiction's 511 software. The use of the archive data may be needed to determine expected flow information and resulting type of congestion alert. See the discussion in "Estimated Travel Times between Locations."

Real-time travel time estimates

Similar to the display of travel time on changeable message signs (discussed in a later section), the accuracy and timeliness of the travel time information is most important to the success of the 511 program.

Estimated Travel Times between Locations

The travel time between locations is in many cases pre-conditioned on recurring congestion patterns. The VPP data feed provides expected travel times that may be used in lieu of historical analysis, but since the data is provided on a TMC segment basis some additional processing will be required as part of its integration.

Resources

Guidelines for state transportation agencies to follow when planning 511 service for their state or regions is provided on a national level by the 511 Deployment Coalition. The 511 Deployment Coalition includes the American Association of State Highway and Transportation Officials (AASHTO) and more than 30 other transportation organizations.

It is also recommended that agencies coordinate closely with adjoining states and/or other road jurisdictions with 511 systems regarding options, user interface, and message formats in order to encourage consistency of implementation from one state to the next. Consistent implementation both decreases development costs, as well as increases usability for interstate travelers.

Agency Spotlight: North Carolina

Prior to 2009, North Carolina had less than 200 miles of VPP coverage in the state as part of the original core VPP system to provide travel information and detect incidents. The VPP was expanded to all freeways in 2009, allowing for an additional 900 miles of coverage, to include all of North Carolina's interstates. For North Carolina, availability of vehicle probe data has significantly enhanced their incident management and 511 capabilities, making it possible for North Carolina to implement a statewide 511 program. The real-time data feed through the application programming interface (API) is integrated into travel information for use on the North Carolina 511 website and call-in system. "Virtual message signs" provide 511 callers with travel time information along their selected route for the next three interchanges. In the future, users will be able to customize the information for their own interstate commuter routes including one or two interstate origin-destination pairs for travel times.

Web Maps

Many states have augmented voice-based 511 systems with websites that provide similar information, incorporating a rich interactive map environment. Color-coded real-time congestion maps have emerged as an effective way to display system-wide network performance. Initial

deployments of web maps were created as custom applications within an agency’s internal software. However with the emergence of web mapping standards, this information may be delivered directly from information services as map traffic tile overlays. The VPP system enables both implementations.

Coalition Member	Direct Integration/Traffic Tile Overlay/Other
New Jersey	Direct Integration of Data
Pennsylvania	INRIX data through 511 contract
Maryland	Planned
Virginia	Planned
North Carolina	Traffic Tile Overlays
South Carolina	Direct Integration of Data

Table 2.3: I-95 Corridor Coalition Agencies Using VPP data for Web Maps

Benefits

Web resources such as MapInfo and GoogleMaps, as well as in-vehicle Personal Navigation Devices (PNDs), have increased the expectations of the traveling public to receive critical congestion data in an easy-to-view electronic map overlay. As with 511 systems, drivers who are informed make better travel decisions, avoid congested routes and have a more accurate expectation of travel times. In contrast to text or voice-based systems, a map allows the user to comprehend the traffic situation across a whole corridor or region in a single glance.

The use of a traffic tile overlay to enable the web mapping substantially reduces the level of effort (and thus reduces cost) for deploying web-based mapping. If an agency has not integrated the data feed into its traffic management software for other purposes, the use of traffic tile overlays provides a cost effective method to quickly enable traffic web maps.

Application Requirements

Web maps may be obtained in one of two methods: use of traffic tile overlays or direct integration of the VPP data feed into existing web software. If web maps are obtained through the tile overlay process, requirements are primarily the integration of the overlay into a web mapping server capable to use the tile overlays. See the Project Interface Guide for more details on traffic tile overlays.

If the web maps are customized to the agency’s web mapping software, the requirements are similar to travel time on signs and 511 applications. Data must be received in real-time, smoothed and filtered appropriately, and converted to the appropriate screen display. The integration effort is customized to the agency’s in-house software. As with 511 applications, analysis of historical data may be needed to determine appropriate color-coding. Direct

integration of the data into traffic management software provides greater control and integration opportunities, but requires more resources than traffic tile overlays.

Resources

Traffic tile overlays can be color customized to an agency's specific speed categories. See the Project Interface Guide for additional details, and contact the VPP vendor directly to arrange for custom overlays.

If data is to be directly integrated into an agency's traffic monitoring software, see the link to the VPP white papers on smoothing and filtering listed in Appendix A.

Agency Spotlight: New Jersey

The New Jersey 511 webpage (<http://www.511nj.org/>) provides “widgets” to present information on construction activities, incidents, detours, etc. Since each widget has an API, it can be imported to the users preferred home page. “Mega Projects”, or large construction projects, have pull down menus for travel time from exit to exit. There is also a fully functional interactive map widget to display construction activities, incidents, detours and travel time information. The same 511 map that is available to public is planned to be displayed at the Operations Center showing incident locations and VPP data. New Jersey is the leading example of direct integration of VPP data into traffic monitoring software to drive graphical representations of the data for web and other devices.



Figure 2.1: The 511 Website for New Jersey

Agency Spotlight: North

Carolina

North Carolina is the first I-95 Corridor Coalition member to use the VPP data in the traffic tile overlay form. Now in use for about 18 months, the traffic tile overlays are utilized in the Traffic Management Center and in the Traveler Information Management System (<http://tims.ncdot.gov/tims/default.aspx>). The speed information displayed on the traffic tile overlay is color coded to show roadways as green

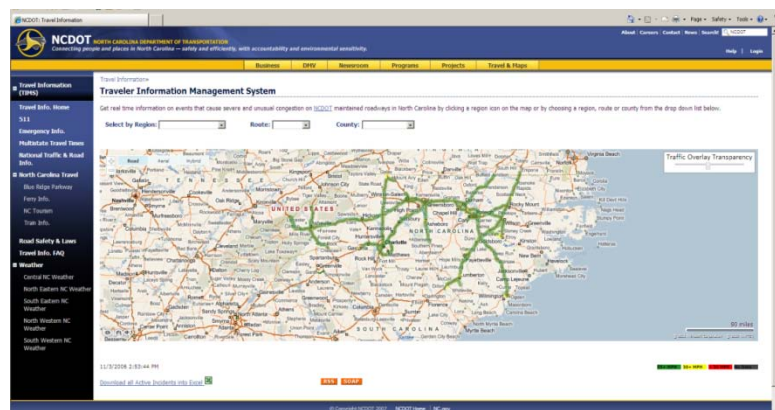


Figure 2.2: North Carolina Traveler Information Management System Website

(free flow - 55 miles per hour (MPH) or over), yellow (congested - 30 MPH to 55 MPH), or black (jammed or no data conditions - 0 to 30 MPH).

Travel Time on Changeable Message Signs

Many state, city, and regional transportation agencies have invested in changeable or variable messages signs along primary freeway and arterial roadways in order to inform drivers of time critical information such as incidents. With the increased emphasis on travel time as a primary performance metric, the need for quality data to drive the display of expected travel time has increased. Traditionally, estimates of travel time have been derived from speed sensors deployed along the roadway. However, sensor-based measurements have proven costly, both in terms of deployment and maintenance. Data from the VPP can be used as a basis for estimating travel time to display on changeable message signs.

Currently, there are six I-95 Corridor Coalition agencies using or planning to use VPP data to post travel time on changeable message signs:

- New Jersey
- Pennsylvania
- Maryland
- Virginia
- North Carolina
- South Carolina

Benefits

Drivers are informed of expected travel times along primary routes. In the event of congestion, drivers can divert to alternate routes, reducing their travel time, and curb the rate of increased congestion on the primary route.



Figure 2.3: Example Travel Time Message on Changeable Message Signs

Travel time on changeable message signs is the most direct method for informing travels of traffic and incidents. Because the information is delivered at a critical decision point on the network, the message has greater influence over route choice than 511 and web-maps. Drivers perceive the information on the signs as the most current and authoritative source of traffic data. Therefore, the information displayed on changeable message signs is scrutinized for accuracy to a greater extent than other traveler information services.

Application Requirements

Travel time and speed data from the vehicle probe project Extensible Markup Language (XML) data feed must be processed in real-time to calculate travel time estimates appropriate for the traveler. It is necessary to access the XML data feed directly, process the data to remove anomalies, and project the results per specified allowable maximum and minimum travel time ranges. The delay in processing of data may cause latency issues when posting quality data.

Due to its ability to directly impact traveler decisions and its exposure to public scrutiny, the travel time on signs application is most sensitive to data quality. Accuracy and timeliness of data are paramount. The VPP validation program provides objective data on the quality and timeliness of the data delivered. Understanding the VPP data quality, and being prepared to respond to public criticism are key application requirements.

Typical installation is accomplished through integration of the data feed with the jurisdictions Traffic Management Center software that controls the traveler information systems. Integration of the XML data feed with the agency's software requires aggregating the necessary Traffic Message Channel (TMC) segments to conform to the agency's road segment reporting methodology. As with other applications in which the VPP XML data feed is directly integrated, filtering and smoothing of the data is critical for optimal performance.

The critical requirements of a successful travel time on signs application go beyond the use of VPP data. Critical requirements include such things as message content and standards, public education, and communication policy. The I-95 Corridor Coalition is preparing a guidebook to be available in 2011 to include such areas based on the experience of Coalition members.

Resources

The Maryland State Highway Administration (as highlighted in the Agency Spotlight) recently completed integration of the VPP data feed to enable travel time on signs throughout Maryland. The process included technical aspects of capturing, storing, smoothing, and aggregating data to obtain quality travel time estimates. All technical data from Maryland is publically available, and serves as a valuable resource for other agencies. The Maryland experience also includes aspects of message standards, policies and public education which may prove valuable.

The Coalition prepared a white paper on suggested filtering and smoothing practice in use of VPP data for travel time on changeable message signs that is available from the project web site.

As with 511 systems, it is recommended that agencies coordinate closely with adjoining states and/or other road jurisdictions in order to encourage consistency of implementation from one state to the next. Consistent implementation both decreases development costs, as well as increases usability for interstate travelers.

Agency Spotlight: Maryland

Maryland State Highway Administration (SHA) has a network of changeable message signs that have been deployed over several years. The message signs had been used to post incidents, amber alerts and other general traveler information. The Maryland SHA planned to provide travel

time messages starting in 2012 when the sensor network to collect the necessary data was planned to be in place. In 2009, the Maryland SHA determined that the VPP data was of sufficient quality to estimate travel time that could be posted on the message signs based on the results of the VPP data validation program. As a result, the Maryland SHA decided to use the VPP data to implement travel time reporting on the changeable message signs. The initial rollout began in January of 2010, two full years ahead of schedule, and with significant savings in sensor infrastructure costs.

In 2010, Maryland expanded VPP coverage and the travel time reporting on changeable message signs statewide. With the cost effective and ubiquitous coverage, deployment of the application was broader in scope and less expensive than originally planned.

TMC Operations

Traffic Management Centers (TMCs) are instrumental in ensuring timely and responsive control of traffic operations. Typically equipped with video and phone capabilities, TMCs are integrating various types of traffic data to ascertain travel conditions, detect incidents and the onset of congestion as soon as possible, and to monitor the impact of incident management programs. The vehicle probe monitoring site is being used as one such tool within existing TMCs for incident and congestion detection and to aid in congestion management to cope with spikes in demand due to special events or seasonal traffic patterns.

As with web maps, VPP data can be integrated into TMC operations at two levels. At the simplest level of integration the VPP Monitoring Website is made available to TMC personnel as additional information. At a more complex level, the VPP data is ingested at the XML data feed level, possibly combined with other data sources inbound to the TMC, and displayed in an integrated fashion. Table 2.5 provides a summary of the various states use of VPP data in TMC operations.

Coalition Member	Used in TMC Operations	Notes
Maine	Yes	Monitoring site only
New Hampshire	Yes	Monitoring site only
New York	Yes	Monitoring site only
New Jersey	Yes	
Delaware	Yes	Monitoring site only
Maryland	Yes	
Virginia	Yes	
North Carolina	Yes	
South Carolina	Yes	Monitoring site information is broadcast through a separate software package; VPP Data is integrated into 511 system
Florida	Yes	

Table 2.4: I-95 Corridor Coalition Agencies Using VPP data in TMC Operations

Benefits

As agents of the public, TMC operators are charged with maintaining the safety and efficiency of the transportation system. With the technologies in place to bring greater levels of detection and forewarning of congestion events, the public saves time, money and resources. Integrating VPP data into the TMC provides an additional layer of information that compliments existing sources. The strengths and weaknesses of various TMC technologies are compared in Table 2.6. The VPP data in TMCs provide inexpensive network-wide travel time monitoring and observation of queue buildup and dispersal during incidents.

Technology	Strengths	Weaknesses
VPP Data	<ul style="list-style-type: none"> • Network wide coverage • Direct travel time measures • Observe queue buildup • <8 minute latency • Inexpensive 	<ul style="list-style-type: none"> • Cause of incident unknown • Real-time data unavailable during low volumes (<500 vehicles per hour)
CCTV	<ul style="list-style-type: none"> • Visual monitoring of incidents • No latency • Ability to observe incident response 	<ul style="list-style-type: none"> • Limited deployment • Cost / Maintenance • Camera control / sharing • Requires human interpretation
911 Calls	<ul style="list-style-type: none"> • Direct reporting of incidents • Type of incident reported 	<ul style="list-style-type: none"> • No travel time or delay estimates • Requires cellular connectivity • Occasional missed incidents
Speed Sensors	<ul style="list-style-type: none"> • Low latency • Provides volume information • Works at low volume 	<ul style="list-style-type: none"> • Limited deployment • Cost / Maintenance • Indirect travel time measure • Queue monitoring depends on density of sensors

Table 2.5: Comparison of TMC Incident and Congestion Monitoring Technologies

Application Requirements

Use of the VPP Monitoring Website within the TMC has minimal requirements and is enabled simply through the normal data use agreement (DUA) process. Display of the information is managed as another computer screen feed for TMC personnel. Coverage includes all freeways from Maine to Florida, and is not limited to states or areas with XML data coverage. Note the following agency spotlight: New York, which does not receive an XML data feed, used the Project Monitoring Website for TMC operations to its advantage during the busy holiday shopping season.

For full integration, travel time and speed data from the VPP must be processed in real-time, combined with other data (if desired), to calculate and display travel time estimates and other

parameters appropriate for the TMC software. Typical installation is accomplished through integration of the data feed with the jurisdictions TMC software. Also, integration of the XML data feed requires aggregating the necessary TMC segments to conform to the agency's road segment reporting methodology. As with other real-time applications accessing the XML data feed directly, the data should be processed and filtered to remove anomalies, and project the appropriate results per application requirements.

Resources

Consult with other Coalition members for best practices in use of VPP data within TMC operations. Also, the Project Interface Guide provides direction regarding how to access traffic data and integrate the data into applications.

Note that use of the Project Monitoring Website within TMCs is open to any agency within the Coalition that processes a DUA. The Extension Network has expanded coverage on the Project Monitoring Website to all freeways on the Eastern Seaboard. Although the XML data feed is only available for contracted coverage, the Monitoring sight currently spans the entire East Coast.



Figure 2.4: View from inside the NJDOT TMC

Agency Spotlight: New York

Thanksgiving evening and the following Black Friday were typical periods of significant delay along I-87 between the Woodbury Commons Shopping Complex and I-287. In 2009, Sergeant Ira Promisel of the New York State Police seized the opportunity to use the data provided by the I-95 Corridor Travel Time website along with data from the New York 511 website to assist in managing traffic congestion in the area.

With New York State Department of Transportation (NYSDOT) TMC operators and New York State Thruway Authority staff, police were able to look at the trouble areas and determine if/when to implement changes such as closure of full parking lots, ramp closures to prevent backups onto the freeway, and activation of advance variable message sign (VMS) messages to alert motorists of the changes ahead. As a result of using this data, Sgt. Promisel and the team were able to reduce by half the traffic queues experienced in other years. In addition, the I-95 Corridor Travel Time and New York 511 websites helped to conserve State Police resources by identifying issues on the website before sending a State Trooper to the scene.

Agency Spotlight: New Jersey

The New Jersey Department of Transportation (NJDOT) has created a “Data Fusion Engine”, or an algorithm that prioritizes the use of travel time data based on a set of business rules developed by partner agencies. These rules set the preferences of what type of data shall be used to populate

downstream applications. Travel time data sources that feed the Data Fusion Engine include VPP data, TRANSMIT, radar (ASTI), Sensys, BlueTOAD™, loops, AirSage, and historical data sources. The Data Fusion Engine is designed with an open architecture so that additional sources of travel time data can be added should they become available in the future. Currently, the VPP data is one of the top two resources of data for both NJDOT and NJ Turnpike Authority.

In addition to supporting TMC operations, the Data Fusion Engine populates 511 web and phone applications, such as My 511NJ Personalized services, an interactive map widget, a 511 “Shore Traffic” widget, and a 511 map at the Operations Center. In the future, the data fusion engine will automate VPP data to be displayed on VMS boards. It also provides the data for the Event Playback tool.

Agency Spotlight: Florida

The Florida Department of Transportation (FDOT) is currently using VPP data to supplement data collection efforts on two rural facilities. The FDOT was looking for a quick-to-implement data collection system that did not require infrastructure deployment to provide information over long stretches of roadway. Unlike the license plate reader system and the toll transponder reader system, the VPP data did not require deployment of infrastructure, saving money in equipment and maintenance. Also, the VPP data has been proven to be more practical over long distances of rural highways than using a sensor-based system. A sensor-based system on long-distance rural highways would require significantly more equipment and corresponding maintenance.

As part of the VPP, FDOT has access to the Project Monitoring website allowing TMC operators to view graphic representations of traffic flow, aiding in the detection of incidents and also bringing insight to TMC operators of when events are cleared and flow has been restored to normal levels.

Planning and Operations Performance Measures

The VPP archive, dating from July 2008, provides a central source of travel time and speed data from which to calculate operations performance measures such as mean travel time, and travel time reliability. State and Metropolitan Planning Organizations (MPO) planning departments that once relied on incomplete or sparsely sampled data now have a network-wide travel time archive that provides both historical speed and travel time data in all time periods. This archive, which contains data starting from July 2008, is feeding an ever growing array of applications such as Congestion Management Systems to track freeway performance levels.

Operations performance measures require historical data to monitor congestion levels, evaluate mitigation techniques, identify bottlenecks, and distinguish recurring from non-recurring congestion. At the time of deployment of the VPP in 2008, operations performance measures were an emerging practice relying primarily on data from permanent sensors. Applications were limited by availability of data, and travel time information needed to be inferred from point speed sensors. Now with a rich archive of network-wide travel time data, the application of operations performance measures is growing both in terms of network coverage as well in the variety of and richness of measures. In 2008, standard performance measures included travel time, delay, and

travel time reliability measures. These are now being assessed network wide, and new measures to characterize bottlenecks are in development.

It is expected that the availability of high quality data, derived from sources such as the VPP, will accelerate the availability of tools that transportation agencies can use to effectively plan and manage transportation systems and evaluate operations.

Benefits

VPP data is valuable in the planning and resource allocation tasks, such as identifying the areas experiencing the greatest level and duration of congested conditions. With data available for many states and regions, comparisons can be made for various locations. The VPP archive makes it possible to rank roadways based on travel time reliability as a way to document improvements to the roadway network or to identify where improvement is needed.

The relative cost of VPP data versus other forms of network performance data is amplified in planning and operations performance measures. The cost of permanent sensors typically limits deployment to roadways where congestion is already a known problem. The VPP allows for continuous monitoring, and thus a continuous archive of data not only on high priority freeways, but on the entire freeway network. This allows for observing the onset of congestion, the upstream and downstream effects of incidents, critical bottlenecks, and more.

Furthermore, since the VPP data spans multiple regions and states, performance measures from city to city and region to region can be compared. Standardized performance measures combined with consistent, high-quality network-wide data provides for full observance of the freeway system performance across state or city jurisdictions.

Additional benefit results from the standardization of the data. Where once processing procedures, filters, and algorithms had to be constructed specific to the type and deployment location of traffic monitoring technology, now the same procedures and processing can serve multiple jurisdictions. See the agency spotlight of the University of Maryland Center for Advanced Transportation Laboratory performance measurement tools as an example.

Application Requirements

Historical data from the VPP archive is the primary data source. This data must be processed so that individual segments are aggregated appropriately for desired routes, and then processed for mean travel time, and other desired metrics and performance measures.

Resources

System-wide VPP archive data is available from two sources:

- 1) INRIX Corporation maintains a five-minute archive of VPP data that is accessible from the Project Monitoring Website. Data is available dating from July 2008 for any roadway segment for which full XML data coverage is provided. NOTE: Even if the XML coverage was purchased after July 2008, the archive contains data beginning on July 1, 2008, corresponding to the start of the VPP.

2) The University of Maryland Center for Advanced Transportation Technology Laboratory (CATT Lab) also maintains an archive of the VPP data. The archive is created by logging all VPP data as it was delivered through the XML data feed. The data is recorded every minute on average, and is available beginning in October 2008. See the North Carolina agency spotlight for a description of not only the CATT Lab archive, but also the variety of performance measure tools that have been developed and made available centrally through a web interface. CATT Lab archive data includes all data delivered through the XML data feed beginning in October 2008. As additional highways were added to the VPP XML data feed, the available archive begins with the start date of the XML data feed (it is NOT populated retroactively back to July 2008 as with the INRIX archive).

Additional regional archives data may also, such as at state university centers, MPOs, or state operations centers.

Publication **National Cooperative Highway Research Program (NCHRP) 20-7 Guide to Benchmarking Operations Performance Measures** provides an overview of standardized measures of travel time, delay, and travel time reliability.

Agency Spotlight: Metropolitan Washington Council of Governments (MWCOC)

In response to the federal The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) transportation legislation and supporting metropolitan planning regulations, MWCOC developed a Congestion Management Process (CMP) for the region to provide detailed information on data, strategies, and regional programs for congestion management. Congestion monitoring is completed through comprehensive aerial photography surveys and through VPP data. VPP data has been found to be advantageous due to its continuous (24/7/365) monitoring on a roadway segment basis. Data regarding the number of hours of congestion per mile and travel time indices for all the VPP covered freeways helped identify the top ten congested locations in the region. Further, the CMP was able to examine travel time reliability through the leveraging of VPP data. A sample graphic depicting Buffer Index for the region derived from the VPP data is shown below.

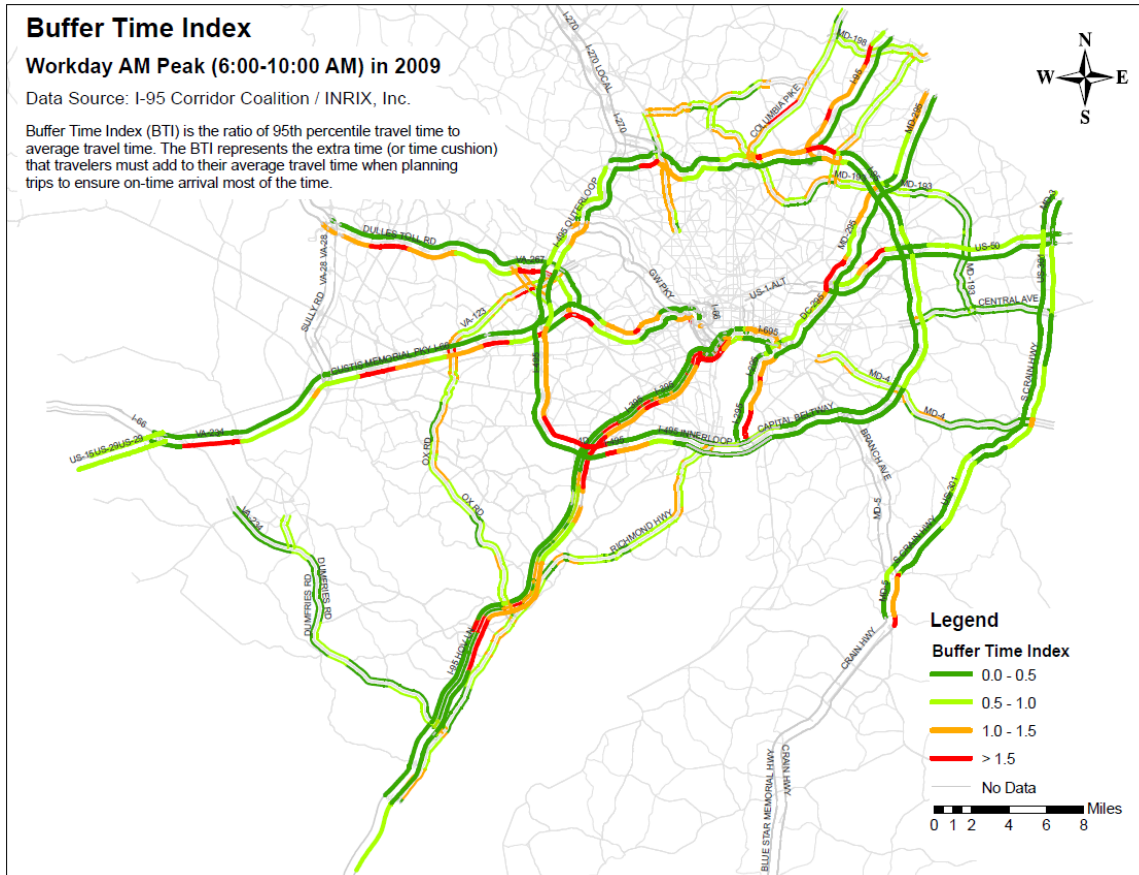


Figure 2.5: Example of the Buffer Index within the MWCOG-CMP as derived from VPP data

Agency Spotlight: North Carolina and the University of Maryland Center for Advanced Transportation Technology Laboratory

North Carolina is moving ahead to formulate performance measures using the VPP data to monitor congestion and speed data and also plans to use VPP data to populate incident duration times as a performance measure for its planned “dashboard.” The University of Maryland is working with North Carolina to develop a performance measure prototype using a steady stream of travel time data over a period of time that can be used as a model for other states.



Figure 2.6: Dashboard envisioned by North Carolina

Through this effort, a bottleneck measure was also created. A bottleneck begins anytime the speed on a segment falls below 60% of the free flow speed for more than five minutes. A bottleneck ends when the speed rises above the 60% free flow threshold for longer than 10 minutes. Bottlenecks can be viewed in real-time as shown below. The head of the bottleneck is shown in dark blue and the tail in light blue.

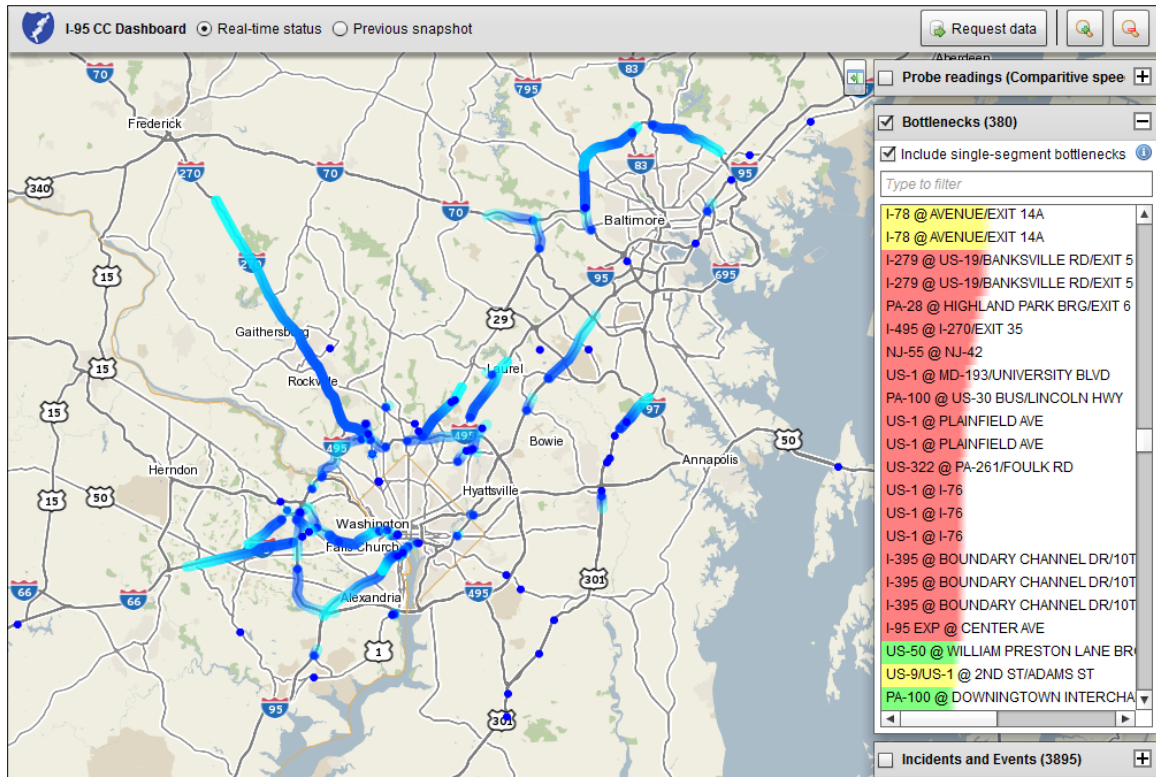


Figure 2.7: Bottleneck Performance Measure Results Displayed in North Carolina's Dashboard

The work at the CATT Lab on performance measures has expanded through partnership with additional sponsors to include traditional performance measure assessment (travel time index, delay, and travel time reliability measures), and to provide a data download tool similar to that provided on the Project Monitoring Website.

Agency Spotlight: Delaware Valley Regional Planning Commission (DVRPC)

The DVRPC used the VPP data in their Congestion Management Plan (CMP) analysis to assess duration of congestion in the Delaware Valley in 2010. Using VPP data archive available through the CATT Lab archive, duration of congestion was calculated on freeways in the nine-county bi-state region. The method to measure congestion was based on one peak hour, 5-6 PM, on weekdays. The percent of time traffic speed fell below 70% of the posted speed limited was assessed, and then mapped. In the future DVRPC will track changes in the duration of delay, and incorporate a second measure about reliability.

Project Spotlight: I-95 Corridor Coalition Vehicle Probe Dashboard & Data Download Tool

This application was envisioned at the onset of the VPP. As the data and tools to use the VPP data have matured, the VPP is poised to impact this application area. However, no use cases are currently known within the Coalition.

The University of Maryland's CATT Lab is collecting and archiving VPP data in one minute intervals. When integrated with other data sources through the Regional Integrated Transportation Information System (RITIS), the congestion measures data is computed to support the needs of traveler information systems, congestion monitoring and performance reporting. Travel time, reliability indices and bottleneck observations are tracked and compared over various time periods to allow for a comparative analysis. Initially developed for the North Carolina Department of Transportation, the performance measuring tools will be available to all VPP participating agencies. The CATT Lab is also continuing to develop a suite of visual analytics, performance measures, and data download tools as part of a "Vehicle Probe Data Analysis Suite" to broaden the ability to observe and compare traffic congestion.

Trip Planning Tools

Mileage tables have long been a staple of state transportation maps, now with comprehensive historical travel time data, such tools can take on a new dimension. Whether printed or made available online, the historical data can provide expected travel time between locations by time of day and day of week – and even for annual holiday periods. Furthermore the service can also provide reliability measures, advising travelers of buffer time.

“One of the Coalition’s goals is to make it easy to learn about traffic conditions along the I-95 Corridor. The website (www.i95travelinfo.net) continues to be an important element in supporting that goal at a time when travelers along the corridor can benefit from our efforts the most.”

George Schoener,
Executive Director,
I-95 Corridor Coalition

Benefits

Such information can allow travelers to plan trips for low congestion periods, or allow sufficient time for critical trips such as airline reservations or medical appointments.

Application Requirements

The primary data source is historical data available in the VPP archives. This data must be processed so that individual segments are aggregated appropriately for desired routes, and then processed for mean travel time, and other desired metrics and performance measures.

Resources

Primary resource is the VPP data archive.

Project Spotlight: The Long Distance Trip Planning Website



Launched at www.i95travelinfo.net in June 2009, this website is based on the I-95 Corridor Coalition/INRIX Vehicle Probe data. Users can view real-time traffic conditions across state borders from Maine to Florida - over 15 states and 24 metropolitan areas along the I-95 Corridor. The website provides speed, congestion information, and both the current and normal travel times between various cities, airports, and other landmarks on key routes in the multi-state region.

Figure 2.8: The Long Distance Trip Planning Website

Origins and destinations are selected from a list of pre-defined locations on the “Travel Time” page. The system then calculates the estimated travel time, the regular travel time at that time of day, the distance between the two points, and a time stamp showing the time since conditions were last updated.

Traffic congestion information is presented using various color codes; green to indicate free flow, yellow for moderate congestion, red for heavy congestion, maroon for stop-and-go, and black to indicate a closed road within the coverage area. Visitors to the site also have the ability to zoom the map to obtain a closer look at traffic conditions.

Construction Staging and Planning Operations

The delays incurred during construction can be significant. It is estimated that the magnitude of delays incurred during construction, in some instances, do not offset the time savings afforded by the newly expanded facility. VPP data provides the ability to lessen the effect of construction delays on individual drivers in three ways. First, the data can be used during the project work zone planning and construction staging/design phase to identify the temporal and spatial distribution of speeds and thereby determine possible choke points and detour routes. Second, during construction, VPP data can be used to provide motorists with travel time reports through the work zone, through the designated detour route, or through other diversion routes. Lastly, VPP data, when merged with other sources, can identify the operational effects of construction activities system-wide.

Benefits

Agencies using archive data can determine how a construction project may affect roadway conditions. Limiting construction activities to certain times of day or months of the year will help to maintain smooth traffic flow, or at least lessen the extent of traffic delay.

Application Requirements

Such sophisticated applications will access and integrate all aspects of the VPP. Archive data will be needed in planning and modeling, and integration of real-time data will be required during actual construction activities.

Targeting Minor Geometric Improvements

An undersigned interchange, ramp, merge area, or intersection may act as the seed to induce congestion and delay along an entire corridor. Modest infrastructure investments specifically targeted for geometric improvements can have a significant impact on overall system operations. Identifying such locations and correctly modeling the impact of proposed spot improvements is the key to a successful minor geometric improvement program. Funds need to be targeted at the root cause and not downstream effects. Also there is danger in resolving an upstream bottleneck, simply to create a downstream bottleneck of equal or greater magnitude. The VPP project aids in providing comprehensive system data to identify, model, and correctly target minor geometric improvements.

Benefits

In contrast to major geometric improvements in which plans are made to meet future traffic demands, targeted geometric improvements are designed to relieve existing traffic congestion by enabling full utilization of existing capacity. Travelers benefit from immediate relief at choke points, and agencies benefit from increased return on major infrastructure by extending its life.

Application Requirements

The identification and modeling needed to support this application would require full archive data, not only of the targeted facility, but also upstream and downstream segments and corridors. Volume data is needed as well to compliment the delay information provided by the VPP project.

Project Spotlight: Maryland State Highway Administration Congested Intersection Program Fund 87

The Congested Intersection Program, “Fund 87”, is a pilot program that addresses major improvements needed at failing intersections on state highways. Failing intersections are identified as exhibiting Level of Service E or F conditions, and where intersection volume exceeds capacity for one or more movements. The program targets intersections that suffer from daily congestion due to geometrics constraints (assuming that all traffic management options such as signal timing and phasing have been exhausted). Data from multiple sources are used to identify locations, and assess impact on corridor performances and system performance. Due to the high cost of data collection and current restrictions in funding for additional data collection, the VPP data was evaluated as an alternative data source. Due to the unvalidated status of VPP arterial data, and the sparseness of arterial coverage, VPP is limited to freeway analysis at this time.

Validation of the Vehicle Probe Data

The purpose of the validation is to ensure the data provided by the Vehicle Probe Project (VPP) is of sufficient quality to support the intended applications. The quality of traffic data derived from sensors installed along the roadway relies primarily on consistent maintenance and routine calibration. Quality control programs typically consist of specifying and verifying routine maintenance of calibration activities. In contrast, outsourced traffic data requires independent comparisons of the data to a known 'ground truth data source' to periodically confirm quality and accuracy. This section provides an overview of the validation program employed by the I-95 Corridor Coalition to ensure the accuracy of the data provided through the VPP.

Overview of the Validation Program

As of January 2011, the quality of the traffic data delivered through the VPP had been routinely tested on a monthly basis for over two and a half years. As a result of this effort, the fidelity of VPP data for freeways is well understood and well documented, which in turn has enabled agencies to use the data confidently in various applications. This was not the case at the onset of the VPP in 2006. The use of non-intrusive, probe-based technologies had been researched and demonstrated with varying degrees of success. Although promising, objective evidence of data quality was generally scant. Several short duration demonstrations had been conducted, but the results of most were considered confidential. Agency personnel were generally unfavorable to outsourced data due to the high cost of sensor-based data, but they were also generally extremely cautious of vendor claims. The quality of the VPP data had to be rigorously tested for quality before agencies could begin to use it within their own applications. Therefore, an independent data validation program was funded to verify the VPP met the data quality specifications in the contract.

An initial validation from July through October 2008 served as a systems acceptance test. Ongoing monthly validations began in November of 2008 to periodically monitor the quality of the data throughout the life of the project. The University of Maryland (UMD) Department of Civil and Environmental Engineering manages the validation effort under the leadership of Dr. Ali Haghani.

In the spring of 2008, a cost effective ground truth data collection method was identified based on Bluetooth traffic monitoring (BTM) technology. The BTM technology was being developed at the University of Maryland, Center for Advanced Transportation Technology. After verifying the fidelity of BTM as a means to sample ground truth data, the UMD validation team developed and refined a data collection logistics template, scheduled and coordinated data collection with Coalition agency members, and established data analysis procedures and reporting tools.

Full details related to the method of data collection, processing, and analysis are included in the Initial Validation Report completed in January 2009. As the methodology was refined, any alterations or additions were documented in subsequent monthly validation reports. This methodology continues to serve as the basis for ongoing validation performed monthly. A summary of the tenets of the validation effort are below:

- Data collection for validation purposes is performed monthly. The state where data is collected rotates among participating Coalition members. Freeway segments are selected that have a high likelihood of exhibiting congestion. Ground truth data is collected on 10 to 20 miles of freeway segments for seven to fourteen days.
- Data is analyzed and results reported in a manner consistent with the accuracy specifications requirements of the contract.
- The results of the three most recent freeway validations are utilized on a monthly basis for input into a payment formula. If quality specifications are fully met, payment for data is 100% as specified in the contract. If data fails to meet minimum quality specifications, payment for data is reduced accordingly.
- All data, analysis, and reports are open and available for review.
- Arterial data, though collected and analyzed, is not subject to the contract specifications for quality. The Coalition is in the process of establishing arterial specific specifications and validation methodology, independent of freeway specifications.
- As unexpected issues and questions arise in the VPP, the validation is adjusted to explore and resolve such issues. Examples of this in the first 24 months include investigating data quality in local/express lanes, truck lanes in mountainous areas, and ramps.

Initial Validation

From July through October 2008, the UMD evaluated the quality of the VPP data at a level of detail necessary to determine if its accuracy met the minimum requirements, as determined in the contract. The evaluation was conducted by comparing VPP data to ground truth data collected on approximately 92 miles of representative roadway segments within the states of Maryland, Virginia, Delaware and New Jersey. The initial evaluation had three basic stages: 1) collect ground truth data, 2) establish the statistical measures for comparison of VPP data to ground truth, and 3) compare the data to ground truth and draw conclusions.

Traditionally, floating car methods (a method in which an instrumented vehicle travels with the traffic stream, in a manner that is intended to replicate the speeds and travel times of the majority of the vehicles in the stream) are used to collect ground truth data. However, this method is costly and produces a sparse amount of data not well suited to the requirements of the VPP validation. Consequently, a new data collection methodology was utilized that directly samples the travel time of the traffic stream. This method receives anonymous emissions from Bluetooth equipped accessories (cell phones, car radios, personal digital assistant (PDAs), personal computer (PCs), etc.) in passing vehicles that have been activated in the discovery mode. Bluetooth protocol uses an electronic identifier, or tag, in each device called a Media Access Control (MAC) address. In order to collect ground truth data, pairs of Bluetooth receivers are deployed temporarily along the roadside as presented in Figure 3.1. Bluetooth devices observed by consecutive receivers served as the basis to sample the travel time of the traffic stream between two detectors similar to the use of toll-tag transponders to assess travel time between successive toll gantries. The Bluetooth technique captures the travel times for approximately five percent of the vehicles within the

traffic stream and has proved to be a cost-effective and accurate tool to determine ground-truth travel time.

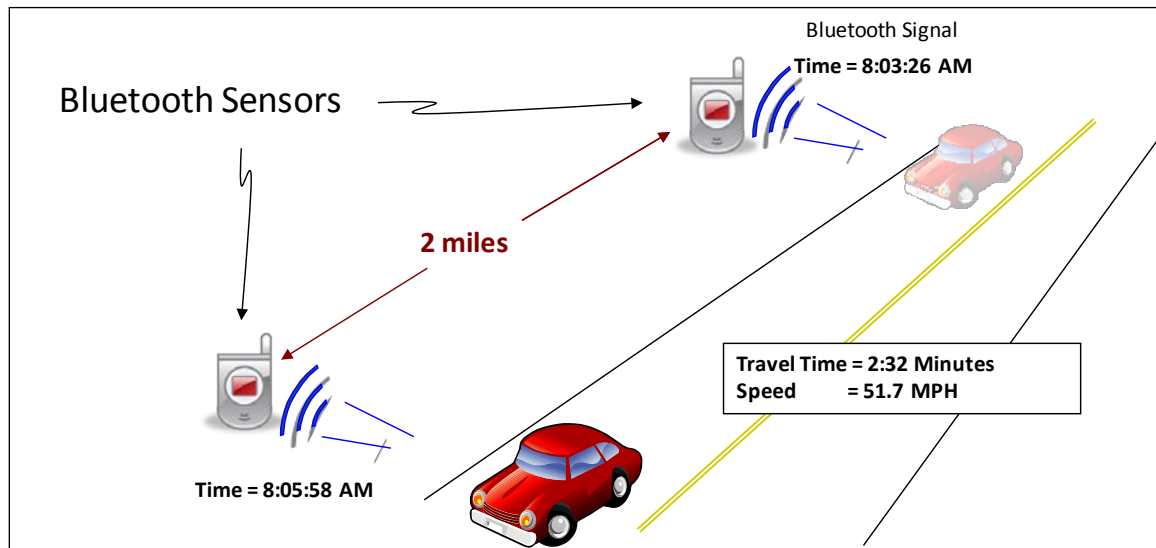


Figure 3.1: Bluetooth Data Collection Method

In 2008, at the beginning of the VPP validation program, BTM was itself a new technology. The verification of BTM accuracy was an important initial step of the evaluation. In Maryland and Virginia, a limited number of floating car runs were performed during morning and afternoon rush hours. Bluetooth sensors were deployed at the same time that the floating car runs were made with the objective of providing a comparison of the ability of the Bluetooth technology to provide ground truth travel times and speeds. A total of nine days of floating car testing were carried out in Maryland and Northern Virginia. The results of these comparisons confirmed the accuracy of the Bluetooth technology for sampling ground truth travel times.

On any roadway section there are significant speed and travel time variations depending on driver, vehicle and roadway characteristics. In order to account for this variation when determining ground truth, as well as accounting for the uncertainty in sampling statistics, a confidence band was defined that represents the uncertainty existing in the definition of the ground truth mean speed and travel time. The uncertainty measure chosen to represent this confidence band was the standard error of the mean (SEM). An example of the SEM band is shown in Figure 3.2. The SEM band narrows as the number of samples increase and as the variation in the data decreases to reflect a higher confidence in the ground truth speed. The SEM band widens when fewer samples are available, or when the natural variation of the travel stream increases. The SEM band is a surrogate for the 95 percent confidence interval of the ground truth mean speed.

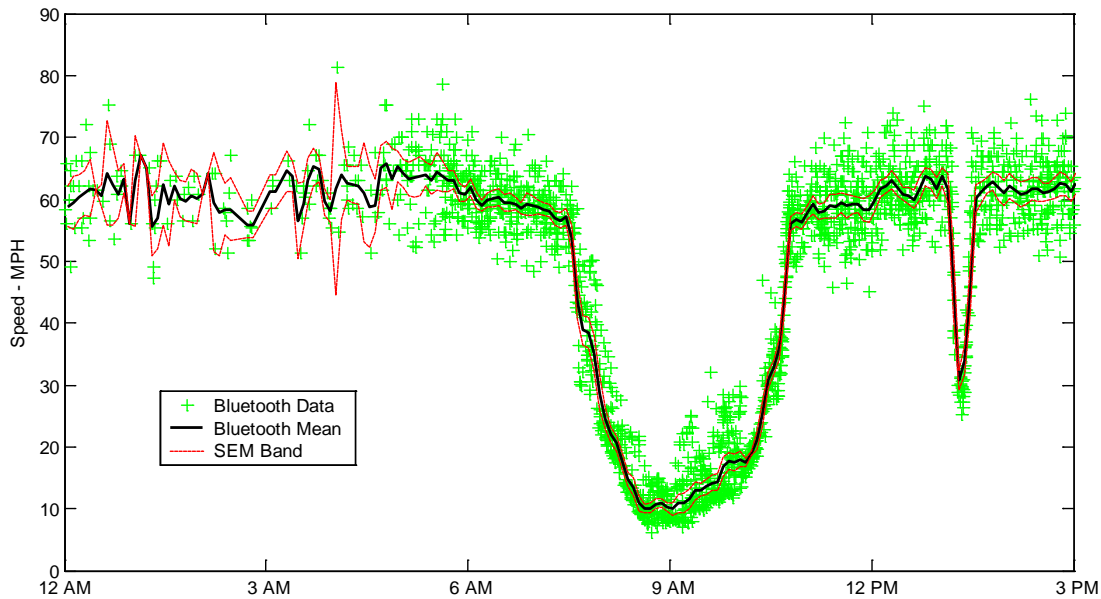


Figure 3.2: Example of Standard Error of the Mean (SEM) Band

A statistical analysis of the difference between VPP data and BTM ground truth data was conducted for the speed ranges defined in the contract: 0 to 30 miles per hour (MPH), 30 to 45 MPH, 45 to 60 MPH and greater than 60 MPH. The average absolute speed error (AASE) and speed error bias (SEB) were calculated with reference to the SEM band and mean of the BTM data. The allowable maximum for the AASE and SEB against the SEM band is 10 MPH and 5 MPH, respectively.

The initial evaluation focused primarily on the accuracy of data collected along the freeways in the corridor. Based on the statistical comparison described above, it was concluded that the VPP travel time and speed data across the system and by individual state generally satisfied the accuracy specifications of the contract (AASE less than 10 MPH and SEB less than 5 MPH). The AASE in the lower two speed bins (0-30 MPH and 30-45 MPH), which are indicative of freeway congestion, proved the most challenging accuracy requirement to meet. Furthermore, a subjective review of the initial validation established that the VPP positively identified the majority of congestion events. A congestion event was defined as traffic slowing to 40 MPH or less for more than 15 minutes. These results confirmed that the VPP data provided an accurate overall picture of traffic conditions for limited access roadways within the Corridor.

Table 3.1 presents the initial evaluation results by individual state and a composite of all states. The AASE and SEB are presented for comparison to both the mean and SEM band of the ground truth Bluetooth data in each of the four speed ranges. The following conclusions were drawn:

- The average absolute speed error (AASE) specification is satisfied in comparison with the SEM band for data collected in all states at all speed ranges.
- The speed error bias (SEB) specification is satisfied in comparison with the SEM band for data collected in all states at all speed ranges with two exceptions in the 0-30MPH speed range and one exception in the 30-45MPH speed range.

- Taken in aggregate, all AASE and SEB contract specifications are met by the VPP data.

State	Average Absolute Speed Error (less than 10mph)		Speed Error Bias (less than 5mph)		Hours of data collection
	Comparison with SEM Band	Comparison with Mean	Comparison with SEM Band	Comparison with Mean	
Virginia					
0-30 MPH	4.10	5.30	2.20	2.60	16.7
30-45 MPH	5.70	7.40	1.40	1.70	24.3
45-60 MPH	2.90	5.20	0.20	0.90	87.2
> 60 MPH	2.20	4.30	-1.60	-2.80	101.7
All Speeds	2.97	5.04	-0.32	-0.53	229.8
Maryland					
0-30 MPH	7.80	11.70	7.20	10.60	2.4
30-45 MPH	6.70	10.70	4.00	6.10	5.8
45-60 MPH	3.30	6.20	-0.70	-0.20	30.8
> 60 MPH	1.80	4.00	-1.30	-2.20	108.2
All Speeds	2.40	4.85	-0.83	-1.25	147.2
Delaware					
0-30 MPH	6.50	10.90	-0.20	2.50	3.0
30-45 MPH	8.50	11.80	-1.90	-0.10	9.0
45-60 MPH	1.20	3.60	-0.10	0.00	74.4
> 60 MPH	2.50	5.50	-2.40	-4.90	112.4
All Speeds	2.35	5.16	-1.48	-2.74	198.8
New Jersey					
0-30 MPH	9.50	12.50	8.30	10.90	6.6
30-45 MPH	8.30	11.60	5.30	7.60	14.0
45-60 MPH	2.40	4.80	0.70	1.90	132.9
> 60 MPH	1.90	4.20	-1.60	-3.10	854.3
All Speeds	2.10	4.44	-1.14	-2.20	1007.8
All States					
0-30 MPH	5.90	8.10	3.80	5.20	28.7
30-45 MPH	6.90	9.60	2.20	3.40	53.0
45-60 MPH	2.30	4.70	0.20	1.00	325.3
> 60 MPH	2.30	4.30	-1.70	-3.20	1176.5
All Speeds	2.52	4.63	-1.08	-1.96	1583.5

Table 3.1: Initial Evaluation Results

The results of the initial validation confirmed the quality of the VPP data, and the methodology laid the framework for an ongoing validation program that continues to monitor the data quality of the VPP on a monthly basis.

Ongoing Validation

Beginning in October 2008, the ongoing validation commenced. Based on the templates and procedures of the initial validation, the ongoing effort consisted of collecting and analyzing data, and reporting results on an approximate monthly basis. The VPP travel time and freeway speed data were compared to BTM travel time and speed collected in the states of New Jersey, Pennsylvania, Delaware, Maryland, Virginia and North Carolina to ensure compliance to contract accuracy specifications (AASE less than 10 MPH and SEB less than 5 MPH). Each validation

event studied six to ten road segments over a period of seven to fourteen days. The validation methodology remained essentially consistent to that used in the initial validation. Minor modifications have been made from time to time to accommodate efficiency of the validation program and to address data anomalies and concerns as they arise.

Monthly validation results are reported to the coalition for review and use in its contractual payment formula. A complete and growing archive of the monthly validation results is available under the highlights page of the I-95 Corridor Coalitions project webpage (see link in Appendix A).

Each month, several road segments in a particular state are selected for study in cooperation with the representatives from the respective department of transportation. Road segments are targeted that have a high likelihood of exhibiting congestion over a seven to ten day period. In order to achieve what is considered a representative sample of data, at least 25 hours of observations in each speed category is desirable each month. During some of the monthly validation efforts, particularly in the first 18 months of the validation data collection, the data collection in the lower two speed bins in some states were less than 50 hours combined. Through strategic selection of segments in close coordination with agency personnel, data collection efforts have improved so that the validation program has consistently logged significant congestion samples over the last twelve months of the program. Over the first 24 months of the validation program, from July 1, 2008 through June 30, 2010, over 24,000 hours of ground truth data has been collected through completion of 22 individual validation events across approximately 390 miles. Figure 3.3 presents the distribution of volume of data collected in each of the four speed ranges (speed bins): 0-30 MPH, 30-45 MPH, 45-60 MPH and > 60 MPH.

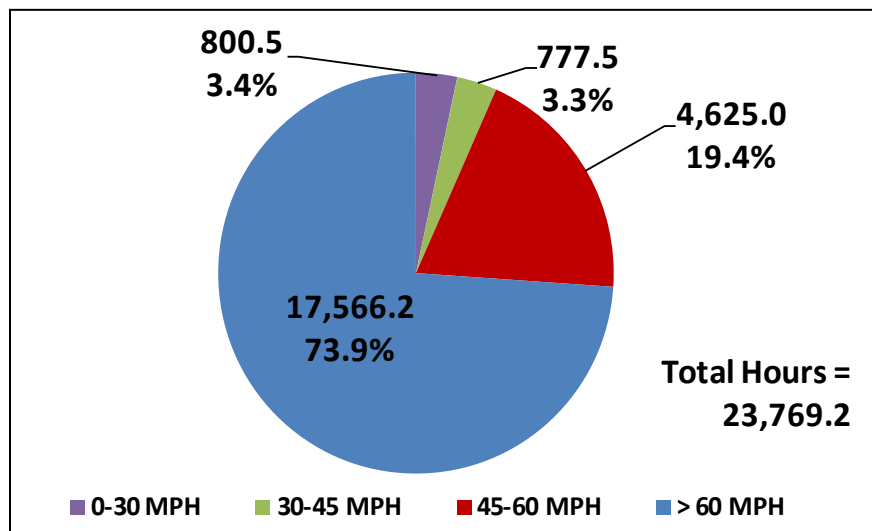


Figure 3.3: Cumulative Hours of Data Collected from July 2008 through June 2010

Table 3.2 presents the cumulative results of the validation over the first 24 months of the program. As shown in the table, the VPP meets the minimum contract specifications for AASE specification, and SEB in all speed ranges. Noting that performance of the VPP is most critical

during times of congestion, key performance parameters are the AASE in the lower two speed bins, those of 0-30 MPH and 30-45 MPH. These lower two speed bins reflects major and severe congestion on freeways and the AASE in these two categories have proven to be primary indicators of data quality and responsiveness of the VPP to changing traffic conditions.

Speed Bin	Average Absolute Speed Error (<10mph)	Speed Error Bias (<5mph)	Hours of Data Collection	Percent of Total Data
	Comparison with SEM Band	Comparison with SEM Band		
0-30 MPH	5.3	2.7	800.5	3.4%
30-45 MPH	6.3	2.1	777.5	3.3%
45-60 MPH	2.4	0.0	4,625.0	19.4%
> 60 MPH	2.6	-2.3	17,566.2	73.9%
All Speeds	2.8	-1.5	23,769.2	100.0%

Table 3.2: Cumulative Validation Results for All States from July 2008 through June 2010

In the fall of 2010, the Coalition authored a comprehensive statistical summary of all validation efforts completed within the first 24 months of the project. This report is available on the I-95 Corridor Coalition web site, a link to which is noted in Appendix A. Readers are encouraged to reference that document for detailed graphical summaries of the validation effort from July 2008 through June 2010. It contains both cumulative statistics from the validation program, as well as summaries of each monthly validation organized on a state by state basis.

Special Studies and Concerns

In addition to the regular monthly assessment of freeway data quality, the Coalition also funds special studies on a variety of topics. This section presents summaries of the issues studied, the results obtained, and where to go for additional information.

Data Quality on Arterials

From the onset, the Coalition envisioned a traffic monitoring system that spanned all roadways that facilitated interstate movement, including major arterials that either cross-linked freeways or provided alternative routes in the event of major incidents, weather events, or evacuations. Although some data was collected and analyzed on arterials during the initial six months of the validation program, interest in the arterial data quality and focused validation efforts really began in the fall of 2009. At that time, sufficient data on freeways had been analyzed to assure VPP data quality on freeways. With positive validation results, Coalition members began building applications that leveraged the VPP data on freeways, and interest in arterial data quality began to grow as well. Beginning in the fall of 2009, samples of arterial data were collected along with freeway data on a monthly basis as opportunity allowed. Note that the amount of arterial coverage in each state varies considerably. New Jersey, Delaware, and North Carolina have a limited network of arterials in the VPP, while Maryland, Pennsylvania, and Virginia have extensive arterial networks in the VPP. Arterial data samples were collected primarily in the

states with extensive arterial networks, resulting in data samples about every other month on average.

In the spring of 2010 the Coalition initiated the effort to review the result of the arterial validation data, examine issues related to its quality, and determine the best course of action. The goal of the effort was to determine quality specifications appropriate to arterials, create work an effective validation program, and assess the quality and usability of the VPP arterial data. That effort is currently ongoing, and current status is summarized in a white paper issued in 2010 available on the project website.

Improvement in Data Quality

While the monthly validation provides evidence of ongoing data quality, a study was initiated to determine if the VPP data quality was improving in time. Although the monthly reports provided some evidence that data quality was improving, the sample sizes were not sufficient to definitively measure the amount of improvement. The Score metric provided in the XML data feed provides an indication on whether speed data is based on real-time information or relies primarily on historical data. Analyzing the Score metric over the life of the project provides an indication on the improvement in data quality. Each estimate of speed and travel time is accompanied by a quality Score of “10”, “20”, or “30”. These three discrete values correspond to:

“30” – high confidence, based on real-time time data for that specific segment

“20” – medium confidence, based on real-time data across multiple segments and/or based on a combination of expected and real-time data

“10” – low confidence, based primarily on historical data

Anything less than of “30” is an indication of reliance on some type of historical data or averaging of data across a broad geographic area. Figure 3.4 tracks the distribution of scores “30” on a hourly basis from October 2008 through October 2010. On average, the amount of real-time data improved approximately 15% between 2008 and 2010, with most of the improvement occurring between 2008 and 2009. The complete analysis of the Score metric as an indication of VPP quality is available from the Vehicle Probe Project website.

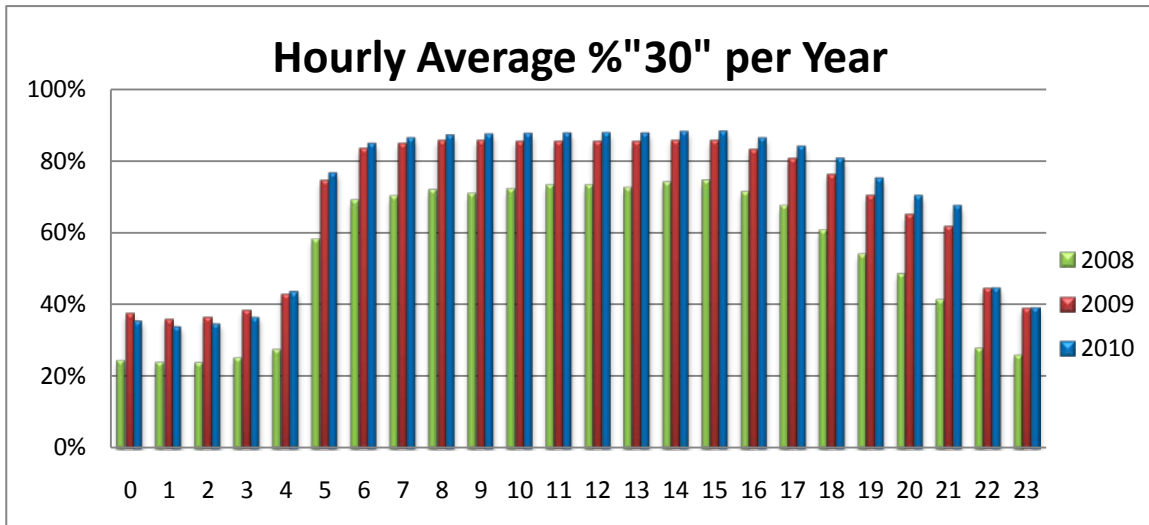


Figure 3.4: VPP Data Quality Improvement Evidenced by Percent of Score 30 (2008-2010)

Data Quality on Ramps and Mixed Use Lanes

Ramps were not included in the original deployment of the VPP. Beginning in 2010, INRIX began providing ramp data on an experimental basis, and the Coalition extended validation efforts to begin assessing data quality on ramps. Early results are promising, reflecting data quality on ramps similar to that of freeways. Data collection and analysis continues. A special report on the ramp data quality will be issued by the coalition in 2011.

Special use lanes refer to High-Occupancy Vehicle (HOV), High-Occupancy Toll (HOT), Local/Express, Truck Lanes, and Reversible Lanes. Concerns were raised whether the VPP was able to differentiate speeds on such lanes. Data was analyzed on roadways in New Jersey and North Carolina to examine the behavior of the VPP in the presence of special use lanes. On special use lanes, the ground truth data collected with Bluetooth traffic monitoring technology captured two distinct travel tendencies, generally a faster and slower group of vehicles, causing the statistics to exhibit a bi-modal distribution – that is two distinct means within the data. The conclusion of the analysis was that the VPP can differentiate special use lanes ONLY IF the lanes are physically segregated, either by a median, barrier, or other type of physical separation. Special use lanes that are simply striped (such as the outer-most lane/s of a multi-lane freeway, or truck lanes in mountainous area) generally are not reported as separate flow lanes in the VPP. If the special use lanes are on separate right-of-way from the normal use lanes, which is common for reversible and local/express lanes, these lanes may be reported separately in the VPP. Consult the Project Monitoring Website to determine if lanes are reported separately for a specific facility.

Appendix A

Useful Links

Information	Date	Location
I-95 Corridor Coalition Vehicle Probe Project Highlights Page	Continuously Updated	http://www.i95coalition.org/i95/Projects/ProjectDatabase/tabid/120/agentType/View/PropertyID/107/Default.aspx
Arterials White Paper	November 2010	http://www.i95coalition.org/i95/Portals/0/Public_Files/uploaded/Vehicle-Probe/2%20November%202010%20%20Arterial%20Validation%20White%20Paper-final.pdf
Project Interface Guide	June 2010	http://www.i95coalition.org/i95/Portals/0/Public_Files/uploaded/Vehicle-Probe/I95_Interface_Guide_June_20_2010.pdf
Confidence Value and Smoothing Paper	April 2010	http://www.i95coalition.org/i95/Portals/0/Public_Files/uploaded/Vehicle-Probe/VP%20Conf%20value%20White%20Paper%204_14_2010_final-4.pdf
Publication NCHRP 20-7	February 2008	http://www.catt.umd.edu/research/nchrp-guide.html
Full RFP	April 2007	http://www.i95coalition.org/i95/Projects/ProjectDatabase/tabid/120/agentType/View/PropertyID/107/Default.aspx#Contract - Highlights, Contract Documents
INRIX Proposal	June 2007	http://www.i95coalition.org/i95/Portals/0/Public_Files/uploaded/Vehicle-Probe/INRIX-I-95-Coalition-Proposal-Confidential-Sections-Redacted-1-08.pdf
Overall Vehicle Probe Project Benefits Paper	August 2010	http://www.i95coalition.org/i95/Portals/0/Public_Files/uploaded/Vehicle-Probe/VP%20Project%20benefits%20General%2012%20August%202010_FIN.pdf
Data Validation Plan	June 2008	http://www.i95coalition.org/i95/Portals/0/Public_Files/uploaded/Vehicle-Probe/Data%20Validation%20Plan_June%206%202008.pdf

Appendix B

I-95 Corridor Coalition Vehicle Probe Project Contacts

Last Name	First Name	Organization	Phone Number	E-Mail Address
Frankle	Kathy	University of Maryland	410-414-2925	kfrankle@umd.edu
Jehanian	Karen	KMJ Consulting, Consultant Team	610-896-1996	kjehanian@kmjinc.com
Pantalone	Marie	KMJ Consulting, Consultant Team	610-324-6985	mpantalone@kmjinc.com
Reagle	Joanna	KMJ Consulting, Consultant Team	610-662-5569	jreagle@kmjinc.com
Schoener	George	I-95 Corridor Coalition	703-389-9281	geschoener@comcast.net
Schuman	Rick	INRIX	407-298-4346	rick@inrix.com
Stoeckert	Bill	I-95 Corridor Coalition	774-207-0367	wstoeckert@yahoo.com
Tarnoff	Phil	Consultant	301-929-1358	philip.tarnoff@verizon.net
Young	Stan	University of Maryland	301-403-4593	seyoung@umd.edu

Appendix C

I-95 Corridor Coalition Member Agency Contacts

State	Name	Organization	Phone Number	E-Mail Address
Maine	Susan Moreau	Maine DOT	207-624-3239	susan.moreau@maine.gov
New Hampshire	Denise Markow	New Hampshire DOT	603-271-6862	dmarkow@dot.state.nh.us
Vermont	Robert T. White	Vermont Agency of Transportation	802-828-2781	robertt.white@state.vt.us
Massachusetts	Russ Bond	Massachusetts Highway Dept.	617-973-7358	russ.bond@state.ma.us
Rhode Island	Joe Bucci	Rhode Island DOT	401-222-5826 ext. 4200	jbucci@dot.ri.gov
Connecticut	Bob Kennedy	Connecticut DOT	860-594-3458	Robert.Kennedy@ct.gov
New York	Todd Westhuis	New York State DOT	518-457-0271	twesthuis@dot.state.ny.us
New Jersey	Jim Hadden	New Jersey DOT	609-530-2938	james.hadden@dot.state.nj.us
Pennsylvania	Bob Pento	Pennsylvania DOT	717-783-6265	rpento@state.pa.us
Delaware	Gene Donaldson	Delaware DOT	302-659-4601	gene.donaldson@state.de.us
Virginia	Scott Silva	Virginia DOT	804-786-0186	Scott.Silva@VDOT.Virginia.gov
North Carolina	Jennifer Portanova	North Carolina DOT	919-696-8857	jportanova@ncdot.gov
South Carolina	Tony Sheppard	South Carolina DOT	803-737-1459	sheppardts@scdot.org
Georgia	Mark Demidovich	Georgia DOT	404-635-8014	mark.demidovich@dot.state.ga.us
Florida	Gene Glotzbach	Florida DOT	850-410-5616	Gene.Glotzbach@dot.state.fl.us