Applications of Vehicle Probe Data for Performance Measurement

By:
Center for Advanced Transportation Technology (CATT)
Civil and Environmental Engineering Department
University of Maryland, College Park

For:
National Transportation Center (NTC) Seminar
Thursday, July 9, 2015
2:00-4:00 PM EST
Presenters

• John Allen (jallen35@umd.edu)

• Sepideh Eshragh (eshragh@umd.edu)

• Kaveh Farokhi (kfarokhi@umd.edu)

• Masoud Hamedi (masoud@umd.edu)

• Reuben Juster (rmjcar@umd.edu)

• Elham Sharifi (esharifi@umd.edu)
Presentations

• Probe data and access
  – Background on Probe Data and Validation
  – VPP Suite

• Applications in performance measurement
  – Freeways: Maryland Mobility Report
  – Arterials: Maryland Mobility Report
  – Weather Impact and Recovery
  – Freight Fluidity
  – Work Zones
Follow these steps to access the I-95 Corridor Coalition’s website and for more information on the Vehicle Probe Project:

1. Go to: [http://www.i95coalition.org/](http://www.i95coalition.org/)

2. Click on Vehicle Probe Project

3. Click on Quick Start Sheet for the step-by-step process in obtaining access to the Vehicle Probe Project data
Follow these steps to access the Center for Advanced Transportation Technology’s website and more information on Probe Analytics (the Vehicle Probe Project Suite):

1. Go to: [http://www.cattlab.umd.edu/](http://www.cattlab.umd.edu/)

2. Click on visual analytics and information visualization tools

3. Scroll down the Portfolio page to the Vehicle Probe Project Suite section and click on Read more >> to get additional details on the Suite tools, features and functionality
Introduction and Validation of Vehicle Probe Data

Masoud Hamedi
Center for Advanced Transportation Technology (CATT)

Ali Haghani
Department of Civil & Environmental Engineering
University of Maryland, College Park
Travel Time Measurement

**Tracking methods**
- Floating vehicle
  - GPS
- Probe vehicles
  - GPS receiver
  - Cellular phone
  - GPS on cellular phone

**Re-Identification methods**
- Signature matching
  - License plate
  - Toll tag
  - Magnetic
  - MACID Bluetooth/WiFi

These technologies can be compared based on several attributes including capital and operating costs, data processing and storage requirements, flexibility, accuracy and representativeness and sampling rate.
The World is Changing

<table>
<thead>
<tr>
<th>World Population</th>
<th>6.3 Billion</th>
<th>6.9 Billion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected Devices</td>
<td>500 Million</td>
<td>12.5 Billion</td>
</tr>
</tbody>
</table>

More connected devices than people!
Vehicle Probe Data

- Private data vendors collect and fuse data from several sources, including GPS probes
- Data is reported every minute on Traffic Message Channels (TMC)
Incoming raw GPS data (Source: INRIX)

April 2014
The I-95 Corridor Coalition

• Alliance of many transportation agencies along the East Coast
• Facilitates coordination, consensus, collaboration, and communication across state lines
• Pulled resource together on research projects
• States had issues with getting travel time data across states lines to support regional initiatives
Vehicle Probe Project (VPP I)

- UMD created and managed VPP processes for I95 Corridor Coalition, from procurement to validation
- Started in 2008 with one probe data vendor INRIX
- FIRSTS
  - First significant commercial deployment of probe data for public applications
  - A specifications driven contract for travel time and speed
  - On-going, transparent validation process to ensure quality
  - Rapid adoption by states, first for operations, then followed by planning and performance measures
Unexpected Consequences

• Acceptance and dependency of outsourced data to drive DOT processes
  – Travel time on signs
  – Performance measures
  – Mobility reports
  – Work zone assessment
  – Anticipation for use on Non-Freeway facilities
  – Questions and expectations of what other outsourced data may be available for DOT’s to leverage
Vehicle Probe Project II Highlights

• Nothing left behind from VPP I

• Added
  – Multi-vendor marketplace
  – Lower prices
  – More emphasis on non-freeway roadways
  – More coverage
  – Alternate segmentation methods
  – Validation of latency
The validation challenge

• Validate the accuracy of the freeway received data within the context of the data quality specifications
  – This grew to arterials as well about 2010
• Perform continuous validation that is representative of the entire corridor
  – Continuous from 2008 till present
• Provide ad-hoc and supplemental analysis as requested
• Adjust contractor payments to reflect data quality
• Manage expectations of multiple parties
• Experts in both public and private sector refer to this project as the most comprehensive effort for validation of traffic data in the ITS industry
  – EXTENDED TO THREE VENDORS IN 2014
Drive Test Sample Graph
Bluetooth, INRIX and Floating car data, 5 minute intervals

蓝牙观察：409
浮动汽车观察：12

蓝牙观察：318
浮动汽车观察：12
Validation Framework

Bluetooth Sensor 1

Matching

Filtering

Aggregation

Bluetooth Sensor 2

Vehicle Probe Data Archive

Equivalent Travel Time Record Calculation

Aggregation of Equivalent Records

Comparison

Validation

Graphs and Reports

Record spans more than 5 minute interval?
Technical overview

Frequency
- Initial validation July through October 2008
- Approximately monthly from 2009 till present (10 per year)
- All reports, data, and analysis open, available on website

Methodology
- Bluetooth Traffic Monitoring used as reference source
- Accommodates sophisticated filtering of outliers, and uncertainty in mean
- Segments selected based on propensity for congestion, picked in consultation with local jurisdiction

Metrics
- Average Absolute Speed Error (AASE) – measures deviation from reference source
- Speed Error Bias (SEB) – measures consistent high or low reading in data
- Analyzed in four speed bins, by segment, and overall
Validation effort

Through July 2015

- 11 states
- 55 evaluation reports
- 57 deployments, 829 days sensors on the road
- 1282 centerline mile (994 mile freeway, 288 mile arterial)
- 95,706 hour worth of ground truth data resulting from 13 million Bluetooth observations

<table>
<thead>
<tr>
<th>State</th>
<th>Validation rounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>1</td>
</tr>
<tr>
<td>DE</td>
<td>6</td>
</tr>
<tr>
<td>FL</td>
<td>1</td>
</tr>
<tr>
<td>GA</td>
<td>1</td>
</tr>
<tr>
<td>MD</td>
<td>9</td>
</tr>
<tr>
<td>NC</td>
<td>6</td>
</tr>
<tr>
<td>NJ</td>
<td>13</td>
</tr>
<tr>
<td>PA</td>
<td>8</td>
</tr>
<tr>
<td>RI</td>
<td>1</td>
</tr>
<tr>
<td>SC</td>
<td>1</td>
</tr>
<tr>
<td>VA</td>
<td>10</td>
</tr>
</tbody>
</table>

Reports are available on: [http://www.i95coalition.org/projects/vehicle-probe-project/](http://www.i95coalition.org/projects/vehicle-probe-project/)
Graphical output

- Bluetooth Data in Blue
- Narrow SEM Band
- Wide SEM Band
- VPP Data in Red
- Outliers marked with Black
Main Validation Takeaways

• Since 2008, vehicle probe vendors have been consistently making improvements and the data is safe to use for most of the freeway applications.

• Special facilities such as managed lanes and reversible lanes remain to be a challenge.

• Arterial probe data must be approached cautiously and its quality depends on the type of arterial and its characteristics (AADT, signal density, geometry).
The Vehicle Probe Project Suite
Using Probe Data Analytics for Performance Measurement and Evaluation

By:
John C. Allen, Faculty Assistant
Center for Advanced Transportation Technology (CATT) Laboratory
University of Maryland, College Park

For:
National Transportation Center at UMD
Webinar Series
July 9, 2015
Our Topics for Today...

- Background/Context
- VPP Suite Overview
- Example Product
- The Future
  - Collaboration
- Q/A
The Demands

- Fiscal constraints at agencies demand effective capital expenditures (“bang for the buck”)

- Agency Asset Management constructs require accountability and transparency:
  - Defined goals, measures and targets
  - Regular report-outs on progress
  - Demonstrated expenditure effectiveness (“return on investment”)
  - Information must be easily understood by a wide audience

- MAP-21 necessitates the use of archived probe data (NPMRDS) for calculating national performance management measures to assess the performance of the National Highway System

The Challenges

- Agency staffing levels are inadequate (and in many cases are dwindling)
- New/rapidly evolving tech/data difficult to assimilate
- Using new data to creatively “tell the story” problematic for most
Probe Data Analytics Provide the Solution

• Probe Data Analytics (the **Vehicle Probe Project Suite**) allow agencies to meet their demands and challenges through a web-based collection of data visualization and summary tools that provide:
  - Travel Time & Reliability Analysis
  - Real-time & Historic Dashboards
  - User Delay Costs
  - Animated Historic maps
  - Region and state-wide Bottleneck Ranking
  - Performance Summary Tables
  - Graphics and Data Exports
  - Raw & aggregate Data Downloads

• VPP Suite is easy to use, powerful and fast, allowing agencies to:
  - Identify problem areas (for project development)
  - Confirm existing project viability
  - Conduct before & after studies
  - Create system performance report-outs, and more
The VPP Suite home page, your visualization gateway...

Following are actual products developed by DOTs and MPOs using these tools...
This Assessment Summary was created in about two hours - using **Region Explorer** and **Congestion Scan** - and confirmed a recurring bottleneck on I-280 WB near the Route 21 interchange.
Probable Cause Supplement

- Including an aerial collage that depicts the geometric conditions “on the ground” help give more meaning and impact to the Assessment Summary:

I-280 (from MP 14.7 to 15.9) Harrison Town, Hudson County
(Probable Causes of WB Bottleneck Conditions)

Lane Drop
(Becomes 2 Thru Lanes)

Weave Area
(2 Thru Lanes + Aux)

Ramp Merge
3rd Thru Lane Drop
(Becomes 2 Thru Lanes + Aux)

Read Probable Causes right to left

Created on 07.08.11
Technical Analysis Unit, Bureau of Systems Planning
DVRPC used VPP raw data to identify areas of long periods of congestion that can be used to help develop strategies for increasing mobility and accessibility.
Before & After Study

- NJDOT used a number of data and tools in developing this Project Assessment Summary of an interchange improvement:
Both “percent of readings below speed thresholds” and a number of performance measures (buffer time, planning time and travel time) show significant improvements in the “After” condition, indicating a successful project.
DVRPC developed this “elevator brochure” to inform the public on transit and auto travel times in a congested corridor in Chester County (PA), using innovative graphics in a “widget” style presentation:
CATT Lab developers and design staff are conceptualizing and building some MAP-21 interfaces and visualizations in anticipation of the requirements for assessing congestion, reliability and emissions:
Dashboard allows you to create your own personal layout to monitor corridor performance in regions of interest (currently you can create a dashboard with Top Bottlenecks and Performance [Speed/Travel Time] widgets):
Great tools and data require great collaboration to maximize effectiveness and productivity; we’re fortunate to have a trifecta of organizations that are well integrated and highly motivated:

- **Regional Guidance**
- **National Perspective**
- **Collaborative Decision-Making**

**I-95 Corridor Coalition VPP Team**

**Partners in Using Archived Operations Data**

**VPP Suite User Group**

**Innovation**

**Test Bed**

**Product Development**
The VPP Suite User Group has a new co-chair structure that provides a comprehensive user experience background, ensuring better guidance to tool enhancements and functionality:

- **Planning**
- **Traffic Operations**
- **Traveler Information**

A subset of the User Group – the User Focus Group – will take on specific need or challenges (e.g.; Performance Reporting template development)

- State/MPO Perspective
- Planning/Ops/Travel Info Integration & Considerations
- Better Product Development

Jesse Buerk (DVRPC)

Kelly Wells (NCDOT)
Key Takeaways

- Agencies are continually challenged to do more with less, with an ever-increasing workload and complexities.
- The VPP Suite provides the tools and data to make work easy, fast, efficient and smart.
- There are numerous ways to leverage Suite visualizations and summaries to “tell your story.”
- The Suite is constantly being improved and enhanced, to “lead the charge” in an ever-changing transportation world.

- Collaboration is absolutely vital in ensuring coordinated use of the tools and effective communication of the results, especially to senior leadership, legislators and the public.
Thank you!

For more information...

John C. Allen, Faculty Assistant
Center for Advanced Transportation Technology Laboratory
University of Maryland
3144 J. Kim Engineering Bldg.
College Park, MD 20743
jallen35@umd.edu

See the following slides for additional information on other VPP Suite tools
The **Bottleneck Ranking** tool allows you to see and compare various attributes of roadway bottlenecks (duration, max. length, number of occurrences) in a table, map and unique “Time Spiral.” Clickable Event/Incident data is also included:
Trend Map allows you to create animated maps of metrics derived from raw speed data and performance metrics. You can choose to analyze multiple time periods at once, displaying them side-by-side or one at a time. Below is an example of comparing the PM Peak Hour speeds of July 1st through the 4th on I-95 in Philadelphia, PA:

Clicking on the controls above allows you to play an animation for each hour. You can also pause, and move from hour to hour manually by dragging the slider button. You can also share these animations and incorporate them into a presentation, website, etc.
Performance Measurement: Freeways (Maryland Mobility Report)

Kaveh Farokhi, Ph.D.
Post-Doctoral Associate
Center for Advanced Transportation Technology (CATT)
University of Maryland, College Park
Outline

• Strategic Focus on Performance Measurement
• Data Needs (Volume/Speed)
• Network Conflation
• Bottleneck Identification
• Performance Measurement (Mobility/Reliability)
  – Segment level
  – Corridor level
• Takeaways
Strategic Focus

• Moving Ahead for Progress in the 21st Century (MAP-21) Legislation

• MD-SHA Business Plan (FY 2012-2015)
  – Goal:
    • Support Maryland’s Economy and Communities through enabling reliable movement of people and goods
  – Strategic focus areas:
    • Mobility and reliability
      • Incident management and traveler information systems
      • Multi-modalism and smart growth
      • Freight
    – Mobility is a Key Performance Area (KPA) at MD-SHA
    – Mobility Report assists in MD-SHA’s
      • Performance-based mobility efforts
      • Driving investment related decisions
National and State Level

- National
  - Urban Mobility Report (TTI)
  - Since 2010 based on probe speed data
- States
  - Washington (WSDOT)
    - The Gray Notebook
  - Maryland (SHA)
    - Mobility Report (Since 2012)
  - Indiana (IDOT)
  - ...
Data Needs – Speed

• Probe-based speed data
  • Provided by INRIX™
  • Data archived and accessed in RITIS (VPP Suite)

• Spatial coverage
  • 1,998 TMC Segments
  • 1,698 directional freeway/expressway miles

• Temporal coverage
  • 1 minute granularity
  • 365/24/7

• More than 5.7 billion data points
• Big data challenges in archiving, retrieving, and querying
Data Needs – Volume/Count

• AADT and hourly profiles
  – Provided by MD-SHA Highway Information Services Division (HISD)

• Spatial coverage
  – 79 permanent continuous Automatic Traffic Recorders (ATRs), and
  – Over 3,800 short term (48 hour) Program Count locations throughout the state
  – Of the 79 ATRs, 18 are presently equipped to perform vehicle classification counts based on the 13 FHWA vehicle classifications

• Temporal resolution
  – AADT and hourly percentages in days/hours
Data Conflation

• Volume data is given at point counters
• Speed data is given on road segments
• Mismatch b/w two segmentation standards
  – MD-SHA highway linear referencing system
  – Industry adopted TMC segments
• Data conflation performed manually to ensure maximum accuracy
• ESRI® ArcMap™ 10.0
Bottleneck Identification

• Speed-based method

• Impact factor
  – Number of occurrences
  – Average maximum queue length
  – Average duration
Performance Measurement

• Congestion: Travel Time Index (TTI)
  – Refers to the ratio of expected (average) travel time to the (minimum) free flow travel time of the segment

• Uncongested (TTI<1.15)
• Light (1.15<TTI<1.3)
• Moderate (1.3<TTI<2.0)
• Severe (TTI>2.0)
Performance Measurement

- Reliability: Planning Time Index (PTI)
  - Refers to the ratio of extreme (95th percentile) travel time to the (minimum) free flow travel time
- Reliable (PTI<1.5)
- Moderately Reliable (1.5<TTI<2.5)
- Unreliable (PTI>2.5)
Segment Level

Maryland Top 30 Unreliable TMC Segments
2013 AM Peak Hour (8AM-9AM)

Maryland Top 30 Congested TMC Segments
2013 AM Peak Hour (8AM-9AM)

2013 Maryland Top 30 Bottlenecks

Legend
- Top 30 Unreliable TMC Segments
- National Park Service Road

Legend
- Top 30 Congested TMC Segments
- National Park Service Road
Corridor Level

• Regionally significant corridors (15)
  – Travel Time Index
  – Planning Time Index
  – Daily Variability
  – Speed profile
  – Location of top bottlenecks

  • I-70 (Pennsylvania Border to US 40 (Frederick))
  • I-70 (US 40 (Frederick) to I-695)
  • I-81
  • I-83
  • I-95 (Capital Beltway to I-695 North)
  • I-95 (I-695 North to Delaware State Line)
  • I-97
  • I-495 Capital Beltway
  • I-695 Baltimore Beltway
  • I-795
  • I-895
  • US-50 (D.C Line to William Preston Lane Bridge (Bay Bridge))
  • MD 32
  • MD 100
  • MD 295
**Corridor Level**

*2014 Maryland State Highway Mobility Report*

**495 Capital Beltway**

**Trends**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>AM Peak</th>
<th>PM Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time Index</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning Time Index</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**42 miles carrying 183,000 vehicles every day**

**Speed Profiles**

<table>
<thead>
<tr>
<th>Route</th>
<th>Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
</tr>
</tbody>
</table>

**Daily Variability**

**Top Bottlenecks**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Location</th>
<th>Number of Observations</th>
<th>Average Duration (min)</th>
<th>Average Length (mi)</th>
<th>Impact Factor</th>
<th>2012 Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I-95/495 @ MD 270 East</td>
<td>123</td>
<td>12.3</td>
<td>20</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>I-95/495 @ MD 270 West</td>
<td>112</td>
<td>11.2</td>
<td>30</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

**Notes**

1. Peak Hours are defined from 7 AM to 9 AM and 4 PM to 6 PM.
2. Travel Time Index (TTI) is the ratio of the average travel time during the peak hour to the time required under free flow.
3. Planning Time Index (PTI) is the ratio of the average planning time during the peak hour to the time required under free flow.
4. Impact Factor is the product of the average number of vehicles affected by the delay and the average length of the affected travel time for a period longer than 5 minutes.
Main Takeaways

• Performance measurement and monitoring is playing a central role in decision making at both federal and state levels
• Probe speed data adequately support public sector needs for highway performance measurement
• Currently, at MD-SHA mobility performance measures inform the project development and selection process
Main Takeaways

• Since 2012 the MD-SHA has published annual Mobility Reports which summarize the state’s performance measurement efforts

• The practice is becoming more common place as other states acquire and develop necessary resources
Thank you!

For more information...

Kaveh Farokhi, Post-Doctoral Associate
Center for Advanced Transportation Technology
University of Maryland
2223 Technology Ventures Bldg.
College Park, MD 20742
kfarokhi@umd.edu
Arterial Performance Measurement

Sepideh Eshragh
Faculty Research Assistant
Center for Advanced Transportation Technology (CATT)
University of Maryland, College Park

NTC Seminar
Thursday July 9, 2015
Outline

• Arterial Definition
• Freeways vs. Arterials
• Functional Classification
• Arterial Corridor Identification and Analysis
• Probe Based Speed Data
• Arterial Corridor Studied
• Arterial Corridor Performance Measurements
• Summary and Conclusions
Arterial Definition

- Deliver traffic from collector roads to freeways
- Interrupted-flow facility (non-freeway)
- High-capacity urban road
- Higher mobility
## Freeways vs. Arterials

<table>
<thead>
<tr>
<th></th>
<th>Freeways</th>
<th>Arterials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volume</strong></td>
<td>2200 vphpl</td>
<td>1400 vphpl on green</td>
</tr>
<tr>
<td><strong>Speed Range</strong></td>
<td>20-70 mph</td>
<td>10-45 mph</td>
</tr>
<tr>
<td><strong>Freeflow</strong></td>
<td>65 mph</td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Congestion Types</strong></td>
<td>Recurring / Non-recurring</td>
<td>Cycle Failure / Mid-Block Friction</td>
</tr>
<tr>
<td><strong>Congestion Signature / Incident</strong></td>
<td>Slowdowns &lt; 55 mph</td>
<td>Difficult to recognize</td>
</tr>
<tr>
<td><strong>Flow characteristic</strong></td>
<td>Uniform</td>
<td>Higher Variance, Frequently Bi-Modal</td>
</tr>
</tbody>
</table>
Road Classification

Several methods of classifying arterials from public and private sectors

<table>
<thead>
<tr>
<th>Classification System</th>
<th>Public/Private</th>
<th>Number of Categories</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPMS</td>
<td>Public</td>
<td>7 (from 1 to 7)</td>
<td>Traffic Data</td>
</tr>
<tr>
<td>HCM</td>
<td>Public</td>
<td>4 (from I to IV)</td>
<td>Analysis/Engineering</td>
</tr>
<tr>
<td>Navteq</td>
<td>Private</td>
<td>5 (from 0 to 4)</td>
<td>Map Provider</td>
</tr>
<tr>
<td>TeleAtlas</td>
<td>Private</td>
<td>9 (from 0 to 8)</td>
<td>Map Provider</td>
</tr>
<tr>
<td>Census Class Code</td>
<td>Public</td>
<td>7 (from A1 to A7)</td>
<td>Geo-datasets</td>
</tr>
</tbody>
</table>
Highway Performance Monitoring System Functional Classification:

- Interstate
- Freeways and Expressways
- Other Principal Arterial
- Minor Arterial
- Major Collector
- Minor Collector
- Local
Arterial Corridor Identification and Analysis

- **Arterial corridors identification**
  - Traffic volumes
  - Regional significance
  - Various operational characteristics
  - Interchanges and signalized intersections

- **Probe-based speed data**
  - Provided by INRIX™
  - Data archived and accessed in RITIS (VPP Suite)

- **Analysis**
  - Intersection and segments operations
    - Levels of service (LOS)
  - Identify congested and unreliable segments
    - Travel Time Index (TTI)
    - Reliability Index (PTI)
### Anticipated Arterial Probe Data Effectiveness

<table>
<thead>
<tr>
<th>Likely to have accurate probe data</th>
<th>Possibly accurate probe data</th>
<th>Unlikely probe data is accurate</th>
</tr>
</thead>
<tbody>
<tr>
<td>• AADT &gt; 40000</td>
<td>• AADT 20K to 40K</td>
<td>• Low Volume, AADT &lt; 20K</td>
</tr>
<tr>
<td>• 2+ lanes</td>
<td>• 2+ lanes</td>
<td>• &gt;=2 signals per mile</td>
</tr>
<tr>
<td>• &lt;= 1 signals per mile</td>
<td>• &lt;= 2 signals per mile</td>
<td>• Major Collectors (HPMS)</td>
</tr>
<tr>
<td>• Principal Arterials (HPMS)</td>
<td>• Minor Arterials (HPMS)</td>
<td>• Not recommended</td>
</tr>
<tr>
<td>• Fully or Partially captures &gt;75% slowdowns</td>
<td>• Should be tested</td>
<td></td>
</tr>
</tbody>
</table>

- **Probe data quality most correlated to signal density**
- Increased volume aids probe data, but does not overcome issues associated with signalized corridors
- Accuracy **ANTICIPATED** to improve with increased probe density and better processing
Probe-Based Speed Data

- VPP Suite Massive Raw Data Downloader
- Travel time data
- Each month of the year
Sample of Arterial Probe Speed Data

Large Variance or Envelope of Speeds

Much less data - lower Volumes
Sampled Distribution Methods

Segment: MD0735502  G to M  Weekdays Only from 07/05-07/20 2013  Length: 1.11 miles

24 Hour Overlay Plot

CDF – Focus Hour: 8AM to 9AM

Travel Time (min)

0 1 2 3 4 5

Hour of Day

0 2 4 6 8 10 12 14 16 18 20 22 24

Travel Time (minutes)

0 20 40 60 80 100

Percentile

0 20 40 60 80 100

Percentile

BlueTooth

VPP

TTI 1.09 1.29
PTT 1.59 1.50
BTT 1.46 1.16
25th 2.43 3.20
50th 2.58 3.75
75th 2.95 4.05
95th 3.76 4.25
IQR 0.52 0.77

Travel Time (minutes)
Arterial Corridors Studied

- US 1 - MD 410 to MD 198
- US 1 - MD Baltimore City Line to Honeygo Blvd.
- US 29 - MD 97 to MD 650
- US 301 - Billingsley Road to MD 5
- Maryland 3 - I-97 to US 50/301
- Maryland 4 - Washington DC Line to I-95
- Maryland 2/4 - Prince Frederick
- Maryland 5 - I-95 to Washington D.C. Line
- Maryland 5 - US 301 to I-95
- Maryland 24 - US 40 to US 1
- Maryland 26 - Baltimore City Line to MD 32
- Maryland 28 - MD 124 to MD 97
- Maryland 32 - MD 108 to MD 26
- Maryland 43 - I-695 to US 40
- Maryland 45 - Baltimore City Line to Shawan Road
- Maryland 65 - MD 68 to 4th Street
- Maryland 85 - Executive Way to MD 355
- Maryland 97 - Washington DC Line to MD 108
- Maryland 124 - MD 28 to MD 108
- Maryland 140 - Baltimore City Line to MD 97
- Maryland 170 - Norcross Lane to MD 100
- Maryland 175 - MD 32 to US 29
- Maryland 185 - Washington DC Line to MD 97
- Maryland 210 - I-95 to MD 228
- Maryland 214 - Washington DC Line to I-95
- Maryland 228 - MD 210 to US 301
- Maryland 235 - Airport Rd to MD 246
- Maryland 355 - Washington DC Line to MD 27
Arterial Corridor Performance Measurement

• Road characteristics
  – Corridor Length
  – Speed Limit
  – Number of Lanes
  – Signal Controlled Intersections
  – Grade Separated Interchanges
  – Major Cross Streets
  – Routes and Ridership
    • (AADT, %Trucks, Peak hour traffic)

• Intersection and Segments Operations (LOS)
Traffic Analysis

- **Travel Time Index (TTI)**
  - Uncongested (TTI<1.15)
  - Light Congestion (1.15<TTI<1.3)
  - High Congestion (1.3<TTI<2.0)
  - Severe Congestion (TTI>2.0)

- **Reliability Index (PTI)**
  - Reliable (PTI<1.5)
  - Moderately to Highly Unreliable (1.5<PTI<2.5)
  - Extremely Unreliable (PTI>2.5)

<table>
<thead>
<tr>
<th>Color Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1.0 - 1.5)</td>
</tr>
<tr>
<td>(1.5 - 2.5)</td>
</tr>
<tr>
<td>(2.5 - 2.0)</td>
</tr>
<tr>
<td>No data</td>
</tr>
</tbody>
</table>
## Samples of Arterial Corridor Performance

### MD 32

- **Limits:** MD 108 (Clarksville Pkwy) to MD 26 (Liberty Road)
- **Corridor Length:** 16.3 miles
- **Speed Limit:** 40 - 50 MPH
- **Travel Lanes:** (1 - 2) Northbound (1 - 2) Southbound
- **Signal Controlled Intersections:** 11
- **Grade Separated Interchanges:** 3
- **Major Cross Streets:** MD 108, Burntwoods Rd, MD 144, MD 26

### US 1

- **Limits:** MD 410 to MD 155
- **Corridor Length:** 10.7 miles
- **Speed Limit:** 35 - 50 MPH
- **Travel Lanes:** (2 - 4) Northbound (2 - 4) Southbound
- **Signal Controlled Intersections:** 40
- **Grade Separated Interchanges:** 3
- **Major Cross Streets:** MD 410, MD 190, I-95, Rhode Island Ave, Ewing Rd, MD 212, Minquisk Rd, Concorde Rd, Cherry Ln

### Data Table:

<table>
<thead>
<tr>
<th>Segment Operations</th>
<th>Level of Service</th>
<th>Northbound AM / PM (Miles of Roadway)</th>
<th>Southbound AM / PM (Miles of Roadway)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOS D or Better</strong></td>
<td>AM Peak Hour</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td><strong>LOS E</strong></td>
<td>PM Peak Hour</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td><strong>LOS F</strong></td>
<td></td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Functional Class</th>
<th>Roadway Segment</th>
<th>Length (miles)</th>
<th>PTI</th>
<th>TTI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban Other Principal Arterial</strong></td>
<td>Liberty Rd (MD-26) - Springfield Ave (MD-51)</td>
<td>2.5</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td>Springfield Ave (MD-51)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sleepy Hollow Rd (MD-54)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sleepy Hollow Rd (MD-54)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Friendship Rd, MD-51</td>
<td>1.1</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td><strong>Urban Minor Arterial</strong></td>
<td>River Rd, Old Frederick Rd (MD-16)</td>
<td>1.3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Olmstead Rd (MD-14)</td>
<td>4.1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Olmstead Rd (MD-14)</td>
<td>4.1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Rural Other Principal Arterial</strong></td>
<td>Burntwoods Rd (MD-108)</td>
<td>5.4</td>
<td>W</td>
<td>W</td>
</tr>
</tbody>
</table>

**PTI** planning time index (50th percentile travel time / freeflow travel time)  
**TTI** travel time index (50th percentile travel time / freeflow travel time)  
}(300,300)
Summary and Conclusions

- Probe data **accurate** on highest class arterials
  - Signal density < 1 per mile on average
  - Will still miss slowdowns
  - Not yet freeway quality

- Use with caution on mid class and below
  - Signal density > 1 per mile on average
  - Will miss large portion of slowdowns

- At low signal densities, VPP is proportional to BTM reference data
  - Congestion patterns are similar
Thank You!

Sepideh Eshragh, Faculty Research Assistant
Center for Advanced Transportation Technology (CATT)
University of Maryland
eshragh@umd.edu
Estimating Winter Weather Road Restoration Time using Probe-based Speed Data: Three Case Studies in Maryland

Elham Sharifi
Center for Advanced Transportation Technology (CATT)
University of Maryland, College Park

Funded by Maryland State Highway Administration's Office of CHART
Collaborators

• Stanley Young(UMD-CATT)
• Thomas Jacobs(UMD-CATT)
• Steven Rochon(MD-SHA)
• ‘Time to bare pavement’.

• Most DOTs use their personnel

• Improvements in technology_ use of traffic data to find restoration time.

• Objective: Examine the I-95 VPP data to determine whether it can be used as a basis to calculate winter weather road restoration performance measures.
Introduction

- Algorithm based on reduction of speed and change in confidence score
- By analyzing the data for hurricane Sandy and then evaluated by two other case studies.
- 3 case studies:
  - Hurricane Sandy impact on I-68 in Western Maryland (2012)
  - Snow event impact on I-695 (2011)
  - Snow event impact on MD-100 (2013)
Hurricane Sandy Impact on I-68


- Heavy winds and rains in most areas in Maryland but in western Maryland some snow

- I-68 received 24 to 30 inches of snow.
Selected Segment on I-68

- One segment
- Between MD-42 / Exit 4 intersection and US-219 / Exit 14 intersection
- Eastbound with 9.2 miles length.
Probe-based Data

- Every minute
- Not having enough reliable field observation
- A confidence indicator shows whether the system has sufficient base level traffic data.
- Inrix:
  - 30 - data driven by actual field observations.
  - 10 or 20 - data primarily on historical data.
- The first step is identifying the normal variation in the confidence score.
Hourly Percentage of Real Time Data

Eastbound Segment on I-68

- Oct_29_Monday
- Oct_30_Tuesday
- Average for after storm weekdays
Speed and Percentage of Real Time data

- Based on 15 Minute Intervals
Speed and Percentage of Real Time data

- Based on 15 Minute Rolling Horizon for Each Minute
- Using Only Real Time Data
Winter Road Restoration
Time Algorithm

Based on the Speed and Confidence Score reported in VPP:

1) Establish a speed thresholds based on historical data.

2) Establish a confidence threshold based on historical.

3) Use 15 minute rolling horizon for each minute. The speed only based on real time speeds.
4) Beginning: When the percentage of score 30 drops below 40% of reference confidence at nights or below 80% of reference confidence at days or speed drops below 50% of reference speed for at least 30 minutes.

5) Ending: When the percentage of score 30 rises above 40% of reference confidence at nights or above 80% of reference confidence at days and speed rises above 50% of reference speed for at least 1 hour.

6) The time difference establishes the restoration time.
Restoration Time on I-68

Interval for Winter Road Restoration Time  |  Beginning Time  |  Ending Time  |  Duration
--- | --- | --- | ---
1 | 21:53 | 36:13 | 14:20
Case Study-2: Snow Event Impact on I-695

- Storm hit the Washington and Baltimore metropolitan areas on Wednesday, January 26th, 2011.
- Two waves: First in northern Maryland, early morning. Second a stronger one late afternoon and evening and brought heavy snow.
- So many reports of commuters delayed for 5 to 10 hours while others abandoned their vehicles.
- The Baltimore beltway received between 9 and 10 inches of snowfall.
Segment on I-695

- One segment
- Counterclockwise Direction on Northwest of I-695
- From I-83, exit 24 to I-795, exit 19
- 5.9 Miles
Restoration Time on I-695

<table>
<thead>
<tr>
<th>Interval for Winter Road Restoration Time</th>
<th>Beginning Time</th>
<th>Ending Time</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17:32</td>
<td>25:00</td>
<td>7:28</td>
</tr>
</tbody>
</table>
Case Study-3: Snow Event Impact on MD-100

• On Feb 13th around 5:30 PM, snow started on MD-100 and it lasted until around 0:30 AM on Feb 14th.
• Congestion was reported on MD-100 in Anne Arundel County.
• A 6.4 mile segment on eastbound of MD-100 was analyzed.
## Interval for Winter Road Restoration Time

<table>
<thead>
<tr>
<th>Interval</th>
<th>Beginning Time</th>
<th>Ending Time</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24:47</td>
<td>26:37</td>
<td>1:50</td>
</tr>
<tr>
<td>2</td>
<td>30:28</td>
<td>31:16</td>
<td>0:48</td>
</tr>
</tbody>
</table>

### Eastbound Segment on MD-100

The graph illustrates the speed variations over time, with highlighted intervals indicating specific events related to road restoration. The data points reflect the changes in speed and the duration of these events.
Main Takeaways

• Probe-based data successfully used

• Use of percentage of real time data

• Enable state DOTs to find winter weather road restoration performance measurement

• Algorithm detects unusual activity related to a winter weather, but difficult to distinguish between a weather event and a major incident.

• Extension into overnight hours can be problematic.

• Has been used on severe storms.
Thank you!

For more information...

Elham Sharifi, Faculty Assistant
Center for Advanced Transportation Technology
University of Maryland
esharifi@umd.edu
Freight Fluidity

Reuben Juster, EIT
Faculty Research Assistant
Center for Advanced Transportation Technology (CATT)
University of Maryland, College Park
Background

- Transport Canada popularized concept of “fluidity indicator”
- Defined it as total transit time and travel time reliability of goods along defined supply chains
- Federal Highway Administration (FHWA) interested in adapting “freight fluidity” in the United States
Background

• Multi-modal nature of freight
• Different aspects of supply chain “fluidity”

<table>
<thead>
<tr>
<th>Mobility</th>
<th>Reliability</th>
<th>Resiliency</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Mobility" /></td>
<td><img src="image" alt="Reliability" /></td>
<td><img src="image" alt="Resiliency" /></td>
</tr>
</tbody>
</table>

• Data needs
  – Travel time
  – Volume, weight, value – and by commodity type
  – Network-wide to understand flows and to weight performance measures across the supply chain
Efficient freight movement is critical
MDSHA and MDOT actively studying freight
- *Maryland State Highway Mobility Report*
- *Maryland Statewide Freight Plan*
- *Maryland Freight System Performance Annual Report*
- *Freight Implementation Plan*

CATT and TTI tasked to put existing work/data into the context of “freight fluidity,”
- Organizational framework
- Calculate freight performance measures
- Identify implications
Data Needs

• CY 2013
• AM peak: 6-10
• PM peak: 3-7
• Travel time
  – Third party archived probe data
    • VPP Suite (INRIX™ data) – 15 minute aggregation
    • VPP isn’t the only probe data source (NPMRDS)
• Volume
  – Statewide inventories and/or FHWA Highway Performance Monitoring System (HPMS)
    • AADT and 15 minute breakdown factors
National Performance Management Research Data Set

• Travel time data acquired by feds
• Monthly basis
• Free to State DOTs and MPOs
• Unfiltered
• Separate data by mode
• Comparison study performed by CATT
Geographic Scope

- Corridor b/w Baltimore (BWI) airport to the Maryland/Delaware state line
  - Primary: I-95
  - Secondary: US-40
- Specific routes/OD
  - BWI airport
  - Port of Baltimore
  - Aberdeen, MD
  - MD/DE state line
Measures

• *Performance (“Ps”)* of freight fluidity computed
  – Travel time (and speed)
  – Path-based planning time index
  – Path-based travel time index
  – Delay (roadway links, total section, per trip)
  – Delay per mile (of section)
  – Cost of delay (roadway link, total section, per truck trip)

• *The Quantity (“Qs”) of freight fluidity computed*
  – Section vehicle-miles of travel (VMT)
  – Section truck-miles of travel (TMT)
<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>BWI Primary</th>
<th>BWI Secondary</th>
<th>Port of Baltimore Primary</th>
<th>Port of Baltimore Secondary</th>
<th>Aberdeen Primary</th>
<th>Aberdeen Secondary</th>
<th>MD/DE State Line Primary</th>
<th>MD/DE State Line Secondary</th>
</tr>
</thead>
<tbody>
<tr>
<td>BWI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Port of Baltimore</td>
<td></td>
<td>1.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aberdeen</td>
<td></td>
<td>1.10</td>
<td>1.15</td>
<td>1.09</td>
<td>1.16</td>
<td></td>
<td></td>
<td>1.03</td>
<td>1.12</td>
</tr>
<tr>
<td>MD/DE State Line</td>
<td></td>
<td>1.09</td>
<td>1.14</td>
<td>1.07</td>
<td>1.14</td>
<td>1.06</td>
<td>1.12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sample Results (Segment Based)
Sample Results
(Segment Based)
Sample Results (Path Based)

Freight Paths from the Port of Baltimore to Aberdeen

<table>
<thead>
<tr>
<th>Route</th>
<th>Length (miles)</th>
<th>Avg. AM Peak Travel Time (Min)</th>
<th>Annual AM Peak Delay (Minutes Per Mile)</th>
<th>Annual Truck Delay Cost ($1000s/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>30.0</td>
<td>32</td>
<td>0.02</td>
<td>$3,648</td>
</tr>
<tr>
<td>Secondary</td>
<td>26.8</td>
<td>36</td>
<td>0.12</td>
<td>$948</td>
</tr>
</tbody>
</table>
Sample Results (Path Based)

Freight Paths from Aberdeen to the Port of Baltimore

<table>
<thead>
<tr>
<th>Route</th>
<th>Length (miles)</th>
<th>Avg. AM Peak Travel Time (Min)</th>
<th>Annual AM Peak Delay (Minutes Per Mile)</th>
<th>Annual Truck Delay Cost ($1000s/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>28.3</td>
<td>32</td>
<td>0.13</td>
<td>$2,327</td>
</tr>
<tr>
<td>Secondary</td>
<td>28.2</td>
<td>38</td>
<td>0.17</td>
<td>$856</td>
</tr>
</tbody>
</table>

Map showing freight paths from Aberdeen to the Port of Baltimore, with data on length, travel time, and delay costs.
Takeaways

• Directional congestion & unreliability
• Location of Express Toll Lanes (ETL) had worst performance
  – Analysis was done before ETL
  – Current data might show improvement
• US-40 tended to perform worse
• Northern part of corridor had best performance
• Volume/OD data is the limiting factor in this analysis
Performance Measurement: Work Zones

Kaveh Farokhi, Ph.D.
Post-Doctoral Associate
Center for Advanced Transportation Technology (CATT)
University of Maryland, College Park
Outline

• Introduction
• WZ Performance Measures
• WZ Mobility Performance Measures
• Congestion
• Queue Length
• Sample Applications
• Takeaways
Introduction

• Nationwide...
  – Work zones on freeways account for nearly 24% of non-recurrent delay
  – Work zones constitute about 10% of overall congestion
    • $700M annual fuel loss
  – Work zone lane closures
    • Two-thirds 9-11AM
    • One quarter 6-7PM

Source: FHWA
Some Challenges

- Spatial segmentation used in probe speed reporting does not necessarily line up with work zone boundaries and alignments.
- Work zones tend to be very dynamic!
- Work zone operations are not fully captured by probe data
  - Speed advisories
  - Speed enforcements
WZ Performance Measures

- Exposure
  - Volume
  - Site specific data
- Safety
  - Volume
  - Crash/incident data
- Mobility
  - Volume
  - Speed (probe data)
<table>
<thead>
<tr>
<th>Work Zone Mobility PMs (Traffic Operations)</th>
<th>Data requirement</th>
<th>To be included?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>speed</td>
<td>volume</td>
</tr>
<tr>
<td><strong>Queuing:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Number or % of days or work activity periods when queuing occurred</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>• Average queue duration</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>• Average queue length</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>• Maximum queue length</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>• % Time when work zone queue length exceeds XX miles</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>• Amount (or % of ADT) that encounters a queue</td>
<td>✓ ✓</td>
<td></td>
</tr>
<tr>
<td><strong>Delay:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Vehicle-hours of delay per:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Work period</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>- Work period when queues are present</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Peak period</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>- Project</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Average delay per:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Entering vehicle</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>- Queued vehicle</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>- Peak period vehicle</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Maximum per-vehicle delay</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Number (or % of ADT) Vehicles experiencing delays greater than XX minutes</td>
<td>✓ ✓</td>
<td></td>
</tr>
</tbody>
</table>
Sample Results

- Westbound I-70, East of Frederick
  – May 8-9, 2012
Sample Results

- Westbound I-70, East of Frederick
  - May 8-9, 2012
Sample Results

• Westbound I-70, East of Frederick
  – WZ3: Performance Measures
    • Right shoulder + One right lane closed
    • Start: May 8, 2012 @ 20:08
    • End: May 9, 2012 @ 00:13

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Unit</th>
<th>Upstream</th>
<th>Work Area</th>
<th>Downstream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Mile</td>
<td>17.85</td>
<td>0.20</td>
<td>0.81</td>
</tr>
<tr>
<td>Average Delay</td>
<td>Minute</td>
<td>0.27</td>
<td>0.04</td>
<td>0.14</td>
</tr>
<tr>
<td>Maximum Delay</td>
<td>Minute</td>
<td>1.09</td>
<td>0.17</td>
<td>0.50</td>
</tr>
<tr>
<td>Queue Duration</td>
<td>Minute</td>
<td>245</td>
<td>230</td>
<td>228</td>
</tr>
<tr>
<td>Average Queue Length</td>
<td>Mile</td>
<td>0.55</td>
<td>0.07</td>
<td>0.28</td>
</tr>
<tr>
<td>Maximum Queue Length</td>
<td>Mile</td>
<td>2.07</td>
<td>0.20</td>
<td>0.81</td>
</tr>
<tr>
<td>Percent Time Queue Length Exceeds 1 miles</td>
<td>%</td>
<td>22.04</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Sample Results

- Westbound I-70, East of Frederick
  - WZ3: Speeds
Sample Results

- Westbound I-70, East of Frederick
  - WZ3: Delays

Graph: Delay at Work Zone
I-70 WEST AT E SOUTH ST
Start time: 08-May-2012 20:08:00
End time: 09-May-2012 00:13:00

- Road Maintenance Operations
- Lane Closure(s): Right Shoulder + 1 Right Lane
Sample Results

- Westbound I-70, East of Frederick
  - WZ3: Queue Length
### Work Zone Dashboard

#### Current Work Zones in Maryland

<table>
<thead>
<tr>
<th>Region/Event</th>
<th># of Nearby Incidents</th>
<th>Queue Length (m)</th>
<th>User Delay Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charles</td>
<td>2</td>
<td>0</td>
<td>$82.9K</td>
</tr>
<tr>
<td>Dorchester</td>
<td>0</td>
<td>0</td>
<td>$737</td>
</tr>
<tr>
<td>Frederick</td>
<td>1</td>
<td>0</td>
<td>$12.4K</td>
</tr>
<tr>
<td>Harford</td>
<td>34</td>
<td>0</td>
<td>$10.9M</td>
</tr>
<tr>
<td>Howard</td>
<td>0</td>
<td>0</td>
<td>$2.9K</td>
</tr>
<tr>
<td>Montgomery</td>
<td>11</td>
<td>0</td>
<td>$7.7K</td>
</tr>
<tr>
<td>Prince Georges</td>
<td>2</td>
<td>0.1</td>
<td>$33.4K</td>
</tr>
<tr>
<td>US 50 East at Elim...</td>
<td>0</td>
<td>0</td>
<td>$88</td>
</tr>
<tr>
<td>MD 210 North Between...</td>
<td>0</td>
<td>0</td>
<td>$210.87</td>
</tr>
<tr>
<td>US 5 North at Amund...</td>
<td>0</td>
<td>0</td>
<td>$70.2</td>
</tr>
<tr>
<td>US 1 South Between C...</td>
<td>0</td>
<td>0</td>
<td>$187.2</td>
</tr>
<tr>
<td>MD 221 West at Capital...</td>
<td>0</td>
<td>0</td>
<td>$2.97</td>
</tr>
<tr>
<td>MD 5 South Between D...</td>
<td>0</td>
<td>0</td>
<td>$1.3K</td>
</tr>
</tbody>
</table>

#### Top Critical Work Zones

- **Severity/Event**: Critical
- **Location**: MD 90 East at St Martins Neck Rd
- **Lane Status**: 2 lanes
- **Queue Length (m)**: 2.2
- **User Delay Cost ($)**: $1.9K

### Work Zone Locations

#### User Delay Cost by Corridor and Day of Week

<table>
<thead>
<tr>
<th>Day</th>
<th>I-95</th>
<th>I-695</th>
<th>I-495</th>
<th>US-50</th>
<th>I-70</th>
<th>Daily Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tue 6/30</td>
<td>$237.7K</td>
<td>$234.5K</td>
<td>$900.9K</td>
<td>$131.9K</td>
<td>$30.4K</td>
<td>$1.6M</td>
</tr>
<tr>
<td>Wed 7/01</td>
<td>$365.9K</td>
<td>$339.7K</td>
<td>$785.6K</td>
<td>$190.6K</td>
<td>$120.3K</td>
<td>$1.8M</td>
</tr>
<tr>
<td>Thu 7/02</td>
<td>$491.7K</td>
<td>$416.8K</td>
<td>$1.2K</td>
<td>$310.2K</td>
<td>$95.3K</td>
<td>$2.5K</td>
</tr>
<tr>
<td>Fri 7/03</td>
<td>$3.4K</td>
<td>$8.3K</td>
<td>$79.5K</td>
<td>$126.9K</td>
<td>$121.4K</td>
<td>$419.0K</td>
</tr>
<tr>
<td>Sat 7/04</td>
<td>$17.4K</td>
<td>$14.3K</td>
<td>$45.1K</td>
<td>$30.4K</td>
<td>$20.8K</td>
<td>$177.0K</td>
</tr>
<tr>
<td>Sun 7/05</td>
<td>$314.0K</td>
<td>$7.3K</td>
<td>$65.4K</td>
<td>$103.0K</td>
<td>$122.9K</td>
<td>$692.9K</td>
</tr>
<tr>
<td>Mon 7/06</td>
<td>$16.6K</td>
<td>$443.9K</td>
<td>$405.4K</td>
<td>$129.4K</td>
<td>$40.8K</td>
<td>$1.3M</td>
</tr>
<tr>
<td>Tue 7/07</td>
<td>$200.1K</td>
<td>$355.4K</td>
<td>$178.2K</td>
<td>$100.4K</td>
<td>$45.5K</td>
<td>$1.6M</td>
</tr>
</tbody>
</table>

**Corridor Totals**: $2.0M | $1.4M | $4.3M | $1.3M | $661.3K | $8.5M
Takeaways

• Work zones have a large impact on traffic especially during construction seasons
• Probe data is good at capturing the reality of speeds on the ground, but it cannot provide a complete story!
• Comprehensive performance measurement requires access to accurate additional data on
  – Incidents
  – Location and lane closure patterns
  – Traffic guidance (signage and delineation)
  – Speed advisories and enforcement
Thank you!

For more information...

Kaveh Farokhi, Post-Doctoral Associate
Center for Advanced Transportation Technology
University of Maryland
2223 Technology Ventures Bldg.
College Park, MD 20742
kfarokhi@umd.edu