Applications of Vehicle Probe Data for Performance Measurement

ITS Maryland Annual Meeting

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Center for Advanced Transportation Technology
Presentation

• Probe data background
• Applications in performance measurement
  – Freeways: Maryland Mobility Report
  – Arterials: Maryland Mobility Report
  – Weather Impact and Recovery
  – Freight Fluidity
  – Work Zones
• Vehicle Probe Project (VPP) Suite
Background - 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>

Connected Devices Per Person

- 2003: 0.08
- 2010: 1.81
- 2015: 3.47
- 2020: 6.58

More connected devices than people!
Background: 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)
Background: Incoming raw GPS data
(Source: INRIX)
Background: 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/
Background: Graphical output

- Bluetooth Data in Blue
- Narrow SEM Band
- Wide SEM Band
- VPP Data in Red
- Outliers marked with Black
Mobility Reporting: 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)
  – ...
Mobility Reporting: 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)
Mobility Reporting: 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)
Mobility Reporting: Corridor Level Example

2014 Maryland State Highway Mobility Report

495 Capital Beltway

Trends

Travel Time Index

Planning Time Index

Speed Profiles

Daily Variability

Top Bottlenecks

Notes

1. Peak hours are considered as 6:00am and 6:00pm.
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 worst case travel time (95th percentile) during peak hour to the free-flow travel time.
4. Daily Variability indicates the degree of fluctuation of the travel times during the 24-hour day.
5. Top 10 bottlenecks on the facility, ranked by impact factor.
6. Impact factor is the product of the number of occurrences by the average duration and by the average length. Bottlenecks are sorted by impact factor and then by average length.
Mobility Reporting: Samples of Arterial Corridor Performance

**MD 32**
- **Limits:** MD 108 (Clarksville Pike) 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, Burnthrogs Rd, MD 114, MD 26

<table>
<thead>
<tr>
<th>Routes</th>
<th>Avg. Daily Ridership</th>
<th>2013 AADT</th>
<th>Trucks</th>
<th>Peak Hour Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>20,000 - 20,000</td>
<td>7% - 11%</td>
<td>0%</td>
</tr>
</tbody>
</table>

**US 1**
- **Limits:** MD 410 to MD 108
- **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 193, I-495, Rhode Island Ave, Fallow Rd, MD 312, Narrow St, MD 314, Cherry Coke, Cherry Lane

<table>
<thead>
<tr>
<th>Routes</th>
<th>Avg. Daily Ridership</th>
<th>2013 AADT</th>
<th>Trucks</th>
<th>Peak Hour Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>10,000 - 40,000</td>
<td>3% - 7%</td>
<td>0.5% - 8.5%</td>
</tr>
</tbody>
</table>

**Color Key**
- LOS D or Better
- LOS E
- LOS F
- LOS 'E' Intersections
- LOS 'F' Intersections

**Functional Class**
- **Urban Other Principal Arterial**
- **Rural Minor Arterial**
- **Rural Other Principal Arterial**

**Roadway Segment**
- West to South

<table>
<thead>
<tr>
<th>Length (miles)</th>
<th>AM</th>
<th>PM</th>
<th>TTI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NB</td>
<td>SB</td>
<td>SB</td>
</tr>
<tr>
<td>Liberty Rd.</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>Springfield Ave. (MD 851)</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>Old Frederick Rd. (MD 108)</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>US 1 (Edgewood Rd)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Old Frederick Rd. (MD 144)</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>Burnthrogs Rd (MD 108)</td>
<td>W</td>
<td>W</td>
<td>W</td>
</tr>
</tbody>
</table>

**Planning Time Index (PTI)**
- 0-1.5
- 1.5-2.5
- >2.5

**Travel Time Index (TTI)**
- 0-1.5
- 1.5-2.5
- >2.5

**Notes:**
- PTI: planning time index (95th percentile travel time/freeflow travel time)
- TTI: travel time index (95th percentile travel time/freeflow travel time)
## Mobility Reporting: 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</td>
<td>• Should be tested</td>
<td></td>
</tr>
<tr>
<td>&gt;75% slowdowns</td>
<td></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
Mobility Performance: Ex. Winter Weather “Restoration Time” on I-695

### Interval for Winter Road Restoration Time

<table>
<thead>
<tr>
<th></th>
<th>Beginning Time</th>
<th>Ending Time</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval</td>
<td>17:32</td>
<td>25:00</td>
<td>7:28</td>
</tr>
</tbody>
</table>
Mobility Performance: Freight Fluidity

- 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
Mobility Performance: Freight Fluidity

- 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="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></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
Mobility Performance: Freight Fluidity

- 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
### Table 2: PM Peak Period Travel Time Index (TTI)

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>BWI Primary</th>
<th>Secondary</th>
<th>Port of Baltimore Primary</th>
<th>Secondary</th>
<th>Aberdeen Primary</th>
<th>Secondary</th>
<th>MD/DE State Line Primary</th>
<th>Secondary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BWI</td>
<td></td>
<td>1.44</td>
<td></td>
<td></td>
<td></td>
<td>1.50</td>
<td>1.42</td>
<td>1.27</td>
<td>1.28</td>
</tr>
<tr>
<td>Port of Baltimore</td>
<td>1.15</td>
<td>1.61</td>
<td>1.50</td>
<td>1.33</td>
<td>1.31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aberdeen</td>
<td>1.10</td>
<td>1.09</td>
<td>1.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.03</td>
<td>1.12</td>
</tr>
<tr>
<td>MD/DE State Line</td>
<td>1.09</td>
<td>1.07</td>
<td>1.14</td>
<td></td>
<td>1.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mobility Performance: Work Zones

- Exposure
  - Volume
  - Site specific data
- Safety
  - Volume
  - Crash/incident data
- Mobility
  - Volume
  - Speed (probe data)
Sample Results

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

![Graph showing speed variations over time for Westbound I-70, East of Frederick during work zone operations.](image)
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>
Mobility Performance: Work Zone PM Dashboard

Source: RITIS
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
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.
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:

**Before Condition**

- **Buffer time (minutes)**
  - Monday: 1.12
  - Tuesday: 1.76
  - Wednesday: 1.17
  - Thursday: 1.12
  - Friday: 1.47
  - Saturday: 1.07
  - Sunday: 0.58
  - Weekends: 1.78
- **Planning time (minutes)**
  - Monday: 4.88
  - Tuesday: 5.56
  - Wednesday: 4.91
  - Thursday: 4.88
  - Friday: 5.23
  - Saturday: 4.62
  - Sunday: 4.09
  - Weekends: 5.23
- **Travel time (minutes)**
  - Monday: 3.81
  - Tuesday: 3.91
  - Wednesday: 3.87
  - Thursday: 3.82
  - Friday: 3.9
  - Saturday: 3.64
  - Sunday: 3.55
  - Weekends: 3.72

**After Condition**

- **Buffer time (minutes)**
  - Monday: 1.1
  - Tuesday: 0.62
  - Wednesday: 0.61
  - Thursday: 0.0
  - Friday: 0.52
  - Saturday: 0.41
  - Sunday: 0.57
  - Weekends: 1.07
- **Planning time (minutes)**
  - Monday: 4.85
  - Tuesday: 4.42
  - Wednesday: 4.35
  - Thursday: 4.76
  - Friday: 4.28
  - Saturday: 3.96
  - Sunday: 4.08
  - Weekends: 4.53
- **Travel time (minutes)**
  - Monday: 3.72
  - Tuesday: 3.7
  - Wednesday: 3.66
  - Thursday: 3.71
  - Friday: 3.64
  - Saturday: 3.43
  - Sunday: 3.48
  - Weekends: 3.61

**Percent Changes**

- **Before Condition**
  - 9% (Weekdays)
  - 34% (5 PM)

- **After Condition**
  - 7% (Weekdays)
  - 16% (5 PM)

**Total Percent Changes**

- **Before & After Study**
  - 25% (Weekdays)
  - 11% (Weekdays)
  - 9% (Weekdays)
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):
Thank you!

For more information...

http://ter.ps/ntcpробедата

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