Monitoring and Assessing Arterial Traffic Performance

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Outline

- Traffic Data Fidelity of Outsource Probe Data
  - Where we have been, where we are now ....
- Completing the Picture ... Arterial Performance Measures
  - Bringing in Volume Data - State Wide
  - Extending Real-Time to Arterial Networks
  - Its time for Arterial Management Systems ...
I-95 Vehicle Probe Project

- Phase I (2008-2014)
  - First Probe-based Traffic System
  - Specifications-based, validated
  - Licensing - one buys, all share
  - Began 2.5K miles, grew to 40K
  - Travel time on signs, 511 systems, operational awareness, performance measures

- Phase II (2014 forward)
  - All of the above
  - Better quality, less cost
  - Data market place (Multiple-vendors)
  - Emphasis on arterials and latency
  - 42.5K and growing
  - Map-21 Performance Measures
Vehicle Probe Project

Phase I (2008-2014)
- First Probe-based Traffic System
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- Map-21 Performance Measures
First Multi-Vendor Freeway Validation
I-83 & I-81 Harrisburg, Oct 2014

- **PA-08**
  - 14 Segments
  - 31.3 miles

- **Data collection**
  - 2300 to 2555 total hrs
  - 71 to 80 hrs [0-30]
  - 53 to 66 hrs [30-45]

- **AASE**
  - 2.1 to 4.1 mph [0-30]
  - 3.1 to 5.8 mph [30-45]
PM Peak Hour (Oct 15-16, 2014)
Non-recurring Congestion
Oct 13, 2014  10 AM to 7 PM
# Arterial Probe Data Quality Study 2013 - mid 2014

<table>
<thead>
<tr>
<th>State / Set ID</th>
<th>Road Number</th>
<th>Road Name</th>
<th>Validation Date Span</th>
<th># of Segments</th>
<th># of Through Lanes</th>
<th>AADT Range (in 1000s)</th>
<th>Length* (mile)</th>
<th># Signals / Density</th>
<th># of Access Points</th>
<th>Median Barrier</th>
<th>Speed Limit (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NJ-11</td>
<td>US-1</td>
<td>Trenton Fwy, Brunswick Pike</td>
<td>Sep 10 - 24, 2013</td>
<td>10</td>
<td>2-4</td>
<td>33 - 90</td>
<td>14.2</td>
<td>10 / 0.7</td>
<td>112</td>
<td>Yes</td>
<td>55</td>
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<tr>
<td>NJ-42</td>
<td></td>
<td>Black Horse Pike</td>
<td></td>
<td></td>
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<tr>
<td>US-130</td>
<td></td>
<td>Burlington Pike</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>NJ-12</td>
<td>NJ-38</td>
<td>Kaighn Ave.</td>
<td>Nov 5-19, 2013</td>
<td>16</td>
<td>2-4</td>
<td>32-80</td>
<td>24.5</td>
<td>44 / 1.8</td>
<td>235</td>
<td>Yes</td>
<td>50</td>
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<tr>
<td>NJ-73</td>
<td>Palmyra Bridge Rd.</td>
<td></td>
<td></td>
<td>18</td>
<td>2-4</td>
<td>33-74</td>
<td>23.9</td>
<td>41 / 1.7</td>
<td>236</td>
<td>Yes</td>
<td>50</td>
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<td>PA-05</td>
<td>US-1</td>
<td>Lincoln Highway</td>
<td>Dec 3 - 14, 2013</td>
<td>28</td>
<td>2 - 3+3</td>
<td>21 - 100</td>
<td>30.62</td>
<td>107 / 3.5</td>
<td>178</td>
<td>Yes</td>
<td>40 - 50</td>
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<tr>
<td>PA-322</td>
<td></td>
<td>Conchester Highway</td>
<td></td>
<td>6</td>
<td>1-2</td>
<td>22 - 34</td>
<td>14.28</td>
<td>7 / 0.5</td>
<td>48</td>
<td>No</td>
<td>35 - 45</td>
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<tr>
<td>PA-06</td>
<td>PA-611</td>
<td>Easton Rd</td>
<td>Jan 9 - 22, 2014</td>
<td>10</td>
<td>2-4</td>
<td>18-31</td>
<td>6.7</td>
<td>21 / 3.13</td>
<td>98</td>
<td>NO</td>
<td>40-45</td>
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<tr>
<td></td>
<td>PA-611</td>
<td>Old York Rd</td>
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<td></td>
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<tr>
<td></td>
<td>PA-611</td>
<td>N Broad St</td>
<td></td>
<td>16</td>
<td>2-4</td>
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<td></td>
<td></td>
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<tr>
<td>VA-07</td>
<td>VA-7</td>
<td>Leesburg Pike and Harry Byrd Hwy</td>
<td>April 5-16, 2014</td>
<td>30</td>
<td>2-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>35-55</td>
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<tr>
<td>VA-08</td>
<td>US-29</td>
<td>Lee Hwy (S Washington St)</td>
<td>May 8-19, 2014</td>
<td>26</td>
<td>1-3</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>MD-140</td>
<td>Reistertown Rd</td>
<td>June 5-14, 2014</td>
<td>12</td>
<td>1-2</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Baltimore Blvd</td>
<td></td>
<td>6</td>
<td>2 - 4</td>
<td></td>
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</tbody>
</table>

- 9 Case Studies from 2013-14
- Spans NJ through NC
- Test extent of probe data 15K AADT to 100K
  2 - 12 lanes
  0.5 to 10+ signals per mile
- Objective: Reference case studies

*Length based on validation date span
Arterial Probe Data Recommendations

<table>
<thead>
<tr>
<th>Likely to have usable probe data</th>
<th>Possibly usable probe data</th>
<th>Likely not usable probe data</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 1 signals per mile</td>
<td>&lt;= 2 signals per mile</td>
<td>&gt;=2 signals per mile</td>
</tr>
<tr>
<td>AADT &gt; 40000</td>
<td>AADT  20K to 40K</td>
<td>Not recommended</td>
</tr>
<tr>
<td>Fully or Partially captures &gt;75% slowdowns</td>
<td>May Fail to capture &gt; 25% of slowdowns</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Should be tested</td>
<td></td>
</tr>
</tbody>
</table>

- 2013/14 Data not ready for Prime Time
- Probe data quality most correlated to signal density
  - Consistent positive bias at low speeds
    - As probe data improves, delay will increase
- Other challenges include:
  - Severe queuing, multi-cycle failures,
  - Optimistic bias in bi-modal traffic
  - Insensitive to signal timing changes

April 30, 2015
Roadmap for Arterial Management Systems

- Arterial Performance Measures are fundamentally different than Freeway Performance Measures
- Until recently (2014), performance assessment has been too costly for broad based monitoring and performance measures
- New technology developments have enabled first generation large scale performance assessment
  - Include Re-identification data, High-Resolution Controller data
- We are NOW (2015) with arterials, where we were in 2008/9 with freeways
## Technologies Enabling Arterial Management Systems

<table>
<thead>
<tr>
<th>Re-identification</th>
<th>High-Res Signal Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both enabled by consumer wireless communication and big data processing. Available Now - Multiple Vendors - Cost Effective</td>
<td></td>
</tr>
<tr>
<td>Direct samples vehicle travel time (5% for BT)</td>
<td>Logs <em>all</em> actuation and phasing information</td>
</tr>
<tr>
<td>Works best at corridor level</td>
<td>Works at intersection level</td>
</tr>
<tr>
<td>Independent of Signal System</td>
<td>Integrated with Signal System</td>
</tr>
<tr>
<td>Provides top-level user experience information</td>
<td>Provides detailed intersection analysis and data for optimizing signal system</td>
</tr>
</tbody>
</table>

Not one or the other... but both!
Emerging Arterial Performance Measures

- **Travel Time and Travel Time Reliability** - based on sampled travel time sources
  - Enabled by re-identification data, later outsourced probe data and connected vehicle data as it matures
  - Fundamentally linked to the statistical distribution of travel time

- **Percent Arrivals on Green** - reflects quality progression
  - Supported by methods such as Purdue Coordination Diagram tools

- **Split Failures (frequency of occurrences)**
  - Reflects capacity constraints
  - Related to GOR / ROR
Re-Identification Data (Bluetooth)

- Uses a ID unique to a vehicle (MAC ID of a Bluetooth device inside vehicle)
- An initial detector identifies when a vehicle enters a corridor by the vehicle’s ID
- Another detector re-identifies the vehicle at the end of the corridor
- Travel time/speed can be directly calculated from the entry and exit time

Direct samples of Travel Time

<table>
<thead>
<tr>
<th>Car</th>
<th>MAC address</th>
<th>Entry Time hh:mm:ss</th>
<th>Exit Time hh:mm:ss</th>
</tr>
</thead>
</table>

Picture source: libelium.com
Travel Time and Travel Time Reliability

- Based on directly sampled travel time measurements
- For arterials, can be applied ....
  - Intersection to intersection
- Corridor based
  - Network level, origin to destination
- Directly reflects concerns of the traveling public
  - Efficient and predictable travel
- Measures can be applicable to other modes of travel
  - Freeway, transit, air, etc.
Re-id Travel Time Data Fidelity

Segment: PA05-0002  B to C  Weekdays Only from 12/03-12/17 2013  Length: 1.19 miles

24 Hour Overlay Plot

Travel Time (min)

Hour of Day
CFD Statistical Performance Measures

Segment: PA05-0002  B to C  Weekdays Only from 12/03-12/17 2013  Length: 1.19 miles

24 Hour Overlay Plot

Travel Time (min)

Hour of Day

BlueTooth

Travel Time (min)

VPP

CDF – Focus Hour: 4AM to 5AM

Percentile

Travel Time (minutes)

VPP  BT
TTI  1.00  1.42
PTI  1.24  2.99
BTI  1.24  2.11
25th  1.98  2.07
50th  1.98  2.92
75th  1.98  3.88
90th  2.46  5.96
IQR  0.00  1.82
CFDs to Contrast Performance

Comparative CFD

Travel-time Minutes

Before
After
CFDs to Contrast Performance

Comparative CFD

Travel-time Minutes

Before
After
Percent Arrival on Green and Split Failures

- **Percent Arrivals on Green**
  - Measure on how effectively signals are coordinated, moving vehicles through the system
  - The higher the PAG, ...
    - Less stops, happier customers
    - Higher corridor speed, better fuel economy, less emissions
    - Direct indicator of signal system performance

- **Split Failures (i.e. Capacity Constraint)**
  - Measures percent of system (time and space) suffering from lack of capacity
  - The ‘need more capacity’ metric, or ‘get off my back’ metric, its ‘time to spread the pain’ metric ...
  - Something more than signal optimization required - capacity/demands need to be addressed
High Resolution Signal Data

- Logging of sensor and phase information
- Data forwarded periodically to central server

Applications

- Purdue Coordination Diagram
- Red-Occupancy Ration / Green Occupancy Ratio
- Volume / Demand Analysis (per movement)
- Streamlined Maintenance

Picture Source: FHWA
High Resolution Signal Data

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- Applications
  - Purdue Coordination Diagram
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Picture Source: FHWA

THIS IS CONNECTED INFRASTRUCTURE!!!!!
Sample Metric - PAGs
Purdue Coordination Diagram

[Graphs showing traffic data]

[Images of traffic congestion]
Odds of hitting a red light in Utah? Just 1-in-4

By Lee Davidson The Salt Lake Tribune
Published December 23, 2013 10:04 pm
Sample Metric - Intersection Movement Capacity Analysis (ROR - GOR)
Frequency of Split Failures

- Indicator of oversaturation
  - When demand overruns capacity
- Indicates when additional capacity or demand management is required
- Also known as the metric for ....
  - ‘Get off my back, nothing left to do’
  - ‘Time to share the pain’
  - ‘Give me another lane if you want this solved’
Current State of Arterial Management Systems (AMS)

- Consensus Established on Performance Measures
- Standard Data Collection Methodologies Developed
- Development of Formal Data-Driven Management Systems
- Integration of Management Systems And Decision Making
- Integration of Management Systems And Engineering Practices


Pavement Management Systems
Arterial Management Systems
Challenges / Benefits to Arterial Performance Measures

- Created a common lexicon/language
  - Between Traffic, Ops, Planning
  - Define Performance Levels (Good, Mediocre, and Ugly)
  - Effective communication with management and public

- Systematic approach
  - Link performance to budget/funding
  - Long term performance tracking
  - Predictable return on investment

- Linking to other Priorities
  - Operations during freeway incidents
  - Energy efficiency, dGlobal warming (GHG emissions)
Real-Time Arterial Performance
Conclusions - Final Thoughts

- Arterial Performance Fundamentally Different than Freeways
- Re-identification and Hi-Res Data enable full observability
- Key Measures Include
  - Travel time and travel-time reliability
  - Quality of progression
  - Degree of capacity saturation
- These Enable **Performance Management** of Arterials
Thank You!

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