Monitoring and Assessing Arterial Traffic Performance

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Center for Advanced Transportation Technology
Outline

- Outsource Probe Data Quality
  - Multi-Vendor, Freeways, & Arterials
- Completing the Picture ... Arterial Performance Measures
  - Possible to measure - not model
  - Re-identification and High-Res technologies
  - FOUR key measures to bank on
- And Beyond ...
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 miles and growing
  - Map-21 Performance Measures
I-95 Vehicle Probe Project

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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]
Non-recurring Congestion
Oct 13, 2014 10 AM to 7 PM

I-95 Corridor Coalition Vehicle Probe Project
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TMC: Pad-0006
ending at (1.23999996185303 miles)
### 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>
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<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>
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<td>33 - 90</td>
<td>14.2</td>
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<td>NJ-42</td>
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<td></td>
<td></td>
<td>8</td>
<td>2</td>
<td>25 - 54</td>
<td>12.5</td>
<td>23 / 1.8</td>
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<td>45 - 50</td>
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<tr>
<td>US-130</td>
<td>Burlington Pike</td>
<td></td>
<td></td>
<td>10</td>
<td>3</td>
<td>42</td>
<td>14.3</td>
<td>28 / 2.0</td>
<td>229</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>
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<td>NJ-73</td>
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<td></td>
<td></td>
<td>18</td>
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<td>33-74</td>
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<td>236</td>
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<td>45 - 55</td>
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<td>2 - 3+3</td>
<td>21 - 100</td>
<td>30.62</td>
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<td>PA-322</td>
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<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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<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>PA-611</td>
<td>Old York Rd</td>
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<td></td>
<td>8</td>
<td>1-2</td>
<td></td>
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<tr>
<td>PA-611</td>
<td>N Broad St</td>
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<td>16</td>
<td>2-4</td>
<td></td>
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<td></td>
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<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>
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<tr>
<td>US-29</td>
<td>Lee Hwy (S Washington St)</td>
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<td></td>
<td>4</td>
<td>2</td>
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<td></td>
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<td>VA-08</td>
<td>US-29</td>
<td>Lee Hwy</td>
<td>May 8-19, 2014</td>
<td>26</td>
<td>2-4</td>
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<td></td>
<td></td>
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<tr>
<td>MD-08</td>
<td>MD-140</td>
<td>Reistertown Rd</td>
<td>June 5-14, 2014</td>
<td>12</td>
<td>1 - 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Baltimore Blvd</td>
<td></td>
<td></td>
<td>6</td>
<td>2 - 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

- 9 Case Studies from 2013-14
- Spans NJ through NC
- Test extent of probe data
  20K AADT to 50K AADT
  4 - 6 lanes
- 0.5 to 4 signals per mile
- Objective: Reference case studies
### Arterial Probe Data Recommendations

<table>
<thead>
<tr>
<th>✓ RECOMMENDED</th>
<th>🕒 SHOULD BE TESTED</th>
<th>✗ NOT RECOMMENDED</th>
</tr>
</thead>
<tbody>
<tr>
<td>• &lt;= 1 signal per mile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• AADT &gt; 40,000 vpd (2-way)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Limited curb cuts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Principal Arterials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likely to have accurate probe data...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 1 to 2 signals per mile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• AADT 20K to 40K vpd (2-way)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Moderate number of curb cuts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor Arterials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Possibly accurate probe data...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• &gt;= 2 signals per mile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• AADT &lt; 20K (2-way) - low volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Substantial number of curb cuts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major Collectors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unlikely probe data is accurate...</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Data quality most correlated to signal density**
- **Consistent positive bias at low speeds**
  - As probe data improves, delay will increase
- **Other issues / challenges:**
  - Severe queuing, multi-cycle failures
  - Optimistic bias in bi-modal traffic
  - Insensitive to signal timing changes
- **Data Quality will improve**
  - Increased probe density
  - Point pair processing (true travel time sampling)
Shifting Gears - Measuring Arterial Performance
Roadmap for Arterial Management Systems

- Arterial Performance Measures are fundamentally different than Freeway Performance Measures
- Until now, arterial measurement has been too costly, and performance had to be modeled.
- New technology has enabled first generation large scale performance assessment
  - Re-identification data, High-Resolution Controller data
- From a DATA perspective, we are NOW (2015) with arterials, where we were in 2008/9 with freeways
- Significant opportunity - significant challenge
  - Common language, lexicon, tools
  - Bridge culture divide between traffic, planning and operations
## 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.</td>
<td>Logs <em>all</em> actuation and phasing information</td>
</tr>
<tr>
<td>Available Now - Multiple Vendors - Cost Effective</td>
<td>Works at intersection level</td>
</tr>
<tr>
<td></td>
<td>Integrated with Signal System</td>
</tr>
<tr>
<td></td>
<td>Provides detailed intersection analysis and data for optimizing signal system</td>
</tr>
</tbody>
</table>

- Direct samples vehicle travel time (5% for BT)
- Works best at corridor level
- Independent of Signal System
- Provides top-level user experience information

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

- **Travel Time & 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>
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)

Travel Time (mi)

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

CDF – Focus Hour: 4AM to 5AM

<table>
<thead>
<tr>
<th>VPP</th>
<th>BT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTI</td>
<td>1.00</td>
</tr>
<tr>
<td>PTI</td>
<td>1.24</td>
</tr>
<tr>
<td>BTI</td>
<td>1.24</td>
</tr>
<tr>
<td>25th</td>
<td>1.98</td>
</tr>
<tr>
<td>50th</td>
<td>1.98</td>
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<tr>
<td>75th</td>
<td>1.98</td>
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<tr>
<td>95th</td>
<td>2.46</td>
</tr>
<tr>
<td>IQR</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Travel Time

Comparative CFD

Travel-time Minutes

Before

After
Travel Time Reliability

Comparative CFD

Travel-time Minutes
Percent Arrival on Green (PAG) 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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Picture Source: FHWA

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

[Graphs showing time in cycle (s) vs. time of day with happy and sad faces indicating different conditions]

Purdue Univ.
Percent Arrivals on Green in the news!

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)

Purdue Univ.
Sample Metric - Intersection Movement Capacity Analysis (ROR - GOR)

![Graph showing red occupancy ratio vs. green occupancy ratio with sad and happy faces indicating different scenarios.]

Purdue Univ.
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)

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

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, Global warming (GHG emissions)
Real-Time Arterial Performance
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Conclusions - Final Thoughts

- **Arterial Performance Measures**
  - We now have the data
  - Re-identification and Hi-Res Data enable

- **Key Measures Include**
  - **Travel time** (Median of CFD)
  - **Travel-time reliability** (Slope of CFD)
  - **Quality of progression** (% Arrivals on Green)
  - **Degree of capacity saturation** (ROR/GOR)

- These Enable **Performance Management** of Arterials
And beyond ... Volume Data Everywhere

- 95 Corridor Coalition in partnership with MCOMPII (FHWA) to accelerate availability of real-time volume estimates from probe data
  - Concept of operations and data specifications
  - Requirements for accuracy and common data formats
- Testbed for Calibration and Validation
  - Pool of verified volume data contributed by states
  - Requirements for long-term viability
- Industry cooperative research project
  - Minimize risk, create win-win scenario
- Volume data needed in demanding modeling/simulations of advanced technology, and performance measures.
- Contact Reuben Juster (rmjcar@umd.edu) or myself
Thank You!

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