Monitoring and Assessing Arterial Traffic Performance

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Traffax Inc.
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Center for Advanced Transportation Technology
Outline

- Outsource Probe Data Quality on Arterials
- Completing the Picture ... Arterial Performance Measures
  - It's now possible to measure - not model
  - Re-identification and High-Res technologies
  - FOUR key measures to bank on
- Future Work - Ubiquitous Volume Data
## Arterial Probe Data Quality Study
### 2013 - mid 2014

<table>
<thead>
<tr>
<th>State / Set ID</th>
<th>Road Number</th>
<th>Road Name / Description</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>
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<td>10</td>
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<td>33 - 90</td>
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<td>8</td>
<td>2</td>
<td>25-54</td>
<td>12.5</td>
<td>23 / 1.8</td>
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<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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<td>NJ-12</td>
<td>NJ-38</td>
<td>Kaimhn Ave.</td>
<td>Nov 5-19, 2013</td>
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<td>2-4</td>
<td>32-80</td>
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<td>33-74</td>
<td>23.9</td>
<td>41 / 1.7</td>
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<td>US-1</td>
<td>Lincoln Highway Conchester 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>
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<td>US-322</td>
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<td>6</td>
<td>1-2</td>
<td>22 - 34</td>
<td>14.28</td>
<td>7 / 0.5</td>
<td>48</td>
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<td>35 - 45</td>
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<td>PA-611</td>
<td>Easton Rd</td>
<td>Jan 9 - 22, 2014</td>
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<td>2-4</td>
<td>18-31</td>
<td>6.7</td>
<td>21 / 3.13</td>
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<td>NO</td>
<td>40-45</td>
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<tr>
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<td>PA-611</td>
<td>Old York Rd</td>
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<td>2-4</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>
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<td>Lee Hwy (S Washington St)</td>
<td>4</td>
<td>2</td>
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<td>MD-08</td>
<td>MD-140</td>
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<td>12</td>
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</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>
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<tbody>
<tr>
<td>&lt;= 1 signal per mile</td>
<td>1 to 2 signals per mile</td>
<td>&gt;= 2 signals per mile</td>
</tr>
<tr>
<td>AADT &gt; 40,000 vpd (2-way)</td>
<td>AADT 20K to 40K vpd (2-way)</td>
<td>AADT &lt; 20K (2-way) - low volume</td>
</tr>
<tr>
<td>Limited curb cuts</td>
<td>Moderate number of curb cuts</td>
<td>Substantial number of curb cuts</td>
</tr>
<tr>
<td>Principal Arterials</td>
<td>Minor Arterials</td>
<td>Major Collectors</td>
</tr>
<tr>
<td>Likely to be accurate...</td>
<td>Possibly accurate, test ...</td>
<td>Unlikely to be accurate...</td>
</tr>
</tbody>
</table>

- Data quality most correlated to signal density
- Consistently over-reporting speed in congestion
  - As probe data improves, delay will increase
- Other issues / challenges:
  - Challenged by queuing, multi-cycle failures
  - Follows faster mode in bi-modal traffic
  - Insensitive to signal timing changes
- Anticipated improvement...
  - Increased probe density
  - Point pair processing (true travel time sampling)
## Arterial Probe Data Recommendations

<table>
<thead>
<tr>
<th>RECOMMENDED</th>
<th>SHOULD BE TESTED</th>
<th>NOT RECOMMENDED</th>
</tr>
</thead>
</table>
| • <= 1 signal per mile  
  • AADT > 40,000 vpd (2-way)  
  • Limited curb cuts  
    Principal Arterials  
    Likely to be accurate... | • 1 to 2 signals per mile  
  • AADT 20K to 40K vpd (2-way)  
  • Moderate number of curb cuts  
    Minor Arterials  
    Possibly accurate, test ... | • >= 2 signals per mile  
  • AADT < 20K (2-way) - low volume  
  • Substantial number of curb cuts  
    Major Collectors  
    Unlikely to be accurate... |

- Data quality most correlated to signal density
- Consistently over-reporting speed in congestion
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Full Report posted to the I-95 Corridor Coalition Website
Recent Result - 2014 into 2015

- US 1 Northern Part
  - Beltway to Joplin Triangle
  - >36K AADT, 2.8 signals per mile
  - 79 Slowdowns observed from Dec 4-18, 2014
    - 41% Fully Captured
    - 43% Partially Capture
    - 16% Failed to Capture

- US 1 Southern Part
  - Joplin Triangle to Fredericksburg, VA
  - >20K AADT, 1.3 signals per mile
  - 18 Slowdowns observed from Dec 4-18, 2014
    - 28% Fully Captured
    - 0% Partially Capture
    - 72% Failed to Capture
Recent Result - 2014 into 2015

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    - 43% Partially Capture
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  - Joplin Triangle to Fredericksburg, VA
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    - 28% Fully Captured
    - 0% Partially Capture
    - 72% Failed to Capture

Contact Masoud Hamedi for most current validation results
Shifting Gears -
Measuring Arterial Performance
Arterial Performance Measures

- Previously too costly to measure, could only model
- Technology has enabled first generation system wide measurement
  - Re-identification data
  - High-Resolution Controller data
- Significant opportunity - significant challenges
  - Identify key measures that span the agency
  - Common language, lexicon, tools
  - Bridge culture divide between traffic, planning and operations
# Technologies Enabling Arterial Management Systems

## Re-identification

- Direct samples vehicle travel time (5% for BT, >15% with WiFi)
- Works best at corridor level
- Independent of Signal System
- Provides top-level user experience information

## High-Res Signal Data

- Logs *all* actuation and phasing information
- Applied per intersection
- Integrated with Signal System
- Provides detailed intersection operation analysis
- Multiple intersection data infers corridor performance

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Both enabled by consumer wireless communication and big data processing.

Available Now - Multiple Vendors - Cost Effective

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

- **Travel Time & Travel Time Reliability**
  - Based on directly measured travel time using re-identification
  - Future may include outsourced probe data and connected vehicles
  - Based on the statistical distribution (CFDs) of travel time

- **Percent Arrivals on Green - reflects quality of progression**
  - Based on High-Res Data
  - Purdue Coordination Diagram tools

- **Capacity Utilization at Intersections**
  - Based on High-Res Data
  - Frequency of split or phase failures
  - Based Green Occupancy Ratio / Red Occupancy Ratio
Travel Time and Travel Time Reliability

- Based on direct measures of travel time
- Emphasized quality of corridors
- Directly reflects traveling public
  - Measures efficiency & travel predictability
- Can be applicable to other modes of travel
  - Freeway, transit, air, etc.

<table>
<thead>
<tr>
<th>Car</th>
<th>MAC address</th>
<th>Entry Time hh:mm:ss</th>
<th>Exit Time hh:mm:ss</th>
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</thead>
</table>
Sample Data
US-1, PA

- North of Philadelphia
- Southbound
  - 1.2 miles, 6 (3/3) lanes
  - AADT >24K
  - 4 signalized intersection
  - 45 mph speedlimit
- Date collected Dec 3-17, 2013
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

- BlueTooth
- VPP
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>Percentile</th>
<th>VPP</th>
<th>BT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTI</td>
<td>1.00</td>
<td>1.42</td>
</tr>
<tr>
<td>PTI</td>
<td>1.24</td>
<td>2.99</td>
</tr>
<tr>
<td>80th</td>
<td>1.24</td>
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<tr>
<td>90th</td>
<td>1.98</td>
<td>2.07</td>
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<tr>
<td>95th</td>
<td>1.98</td>
<td>2.38</td>
</tr>
<tr>
<td>99th</td>
<td>2.46</td>
<td>5.96</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Percentile</th>
<th>VPP</th>
<th>BT</th>
</tr>
</thead>
<tbody>
<tr>
<td>10th</td>
<td>0.00</td>
<td>1.82</td>
</tr>
</tbody>
</table>

Travel Time (minutes) vs. Hour of Day

Travel Time (minutes) vs. Percentile
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

- BlueTooth

Hour of Day
Travel Time (min)

Hour of Day
Travel Time (min)

CDF -- Focus Hour : 8AM to 9AM

Percentile
Travel Time (minutes)

Percentile
Travel Time (minutes)

VPP

BlueTooth

<table>
<thead>
<tr>
<th>VPP</th>
<th>1.08</th>
<th>1.25</th>
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<tbody>
<tr>
<td>PTI</td>
<td>1.43</td>
<td>1.72</td>
</tr>
<tr>
<td>BTI</td>
<td>1.32</td>
<td>1.37</td>
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<tr>
<td>25th</td>
<td>2.55</td>
<td>3.60</td>
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<tr>
<td>50th</td>
<td>2.67</td>
<td>3.87</td>
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<tr>
<td>75th</td>
<td>3.03</td>
<td>4.08</td>
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<tr>
<td>95th</td>
<td>3.53</td>
<td>5.29</td>
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<tr>
<td>IQR</td>
<td>0.48</td>
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Travel Time Distribution

Comparative CFD

Travel-time Minutes

Before
After
Example from Freeways ... Impact of the ICC
Impact on travel time A -> E

CFD View
Impact on travel time A -> E

CFD View

95th Percentile

Median

Travel Time (Minutes)
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

- 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

THIS IS CONNECTED INFRASTRUCTURE!!!!!!
Percent Arrivals on Green

Purdue Coordination Diagram

Purdue Univ.
Percent Arrivals on Green Purdue Coordination Diagram

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
Adequate Intersection Capacity
Movement Capacity Analysis (ROR - GOR)

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

Purdue Univ.
Adequate Intersection Capacity - 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)

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

Pavement Management Systems
Arterial Management Systems

Challenges / Benefits to Arterial Performance Measures

- Standardize performance
  - Performance Levels (Good, Mediocre, and Ugly)
  - Communicate efficiently with management and public
- Created a common lexicon/language & bridge disciplines
- Systematic approach
  - Link performance to budget/funding
  - Long term performance tracking
- External Pressure Points
  - Extend ITS operations to signalized arterials
  - Energy efficiency, GHG emissions on roadways
Final Thoughts on Arterials

- **Arterial Performance Measures**
  - We can now measure - not model
  - Enable by Re-identification and Hi-Res Controller Data

- **Key Measures**
  - **Travel time** (Median of CFD)
  - Travel-time reliability
  - Percent Arrivals on Green
  - Adequate Intersection Capacity

- Challenges include bridging culture and language barriers of traffic, ops, planning - and management.

- These Enable **Performance Management** of Arterials

Nov 10 - Arterial Performance Measure Workshop
And beyond ... Volume Data Everywhere

- I95 Corridor Coalition to accelerate availability of real-time volume estimates from probe data
  - Volume estimates for all roadways, every 15 minutes
  - CONOPS - 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 with UMD CATT, National Renewable Energy Lab, INRIX, HERE, TomTom, and I95 Corridor Coalition members
- Contact Reuben Juster (rmjcar@umd.edu)
Thank You!

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Stanley.young@nrel.gov