Identification and Characterization of Intersection and Interchange Bottlenecks

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Purpose and Scope

• Limitations of current tools/methods@VDOT
  – Deterministic models to complex simulations
  – 3 tools use probe-based speed data
  – Corridor-based approaches
  – Traffic volumes (delays), network effects, spillbacks, day-of-week and time-of-day aspects, reliability/variability, approaches@intersection
  – TMC vs. XD data

• Improve identification and characterization
  – Intersections and Interchanges
Objectives

• Fix/mitigate known limitations by developing new
  – Methodology
  – Performance measures
  – Visualizations, tools

• Also for this talk
  – Preliminary results
  – Resource needs, and challenges
  – Research questions
Methodology - overview

- Corridor vs. Nodes

<table>
<thead>
<tr>
<th>Ranking Method</th>
<th>Rank</th>
<th>Bottleneck Location</th>
<th>Impact (mile-minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranks of each approach among all</td>
<td>46</td>
<td>VA-244 W @ VA-120/S GLEBE RD</td>
<td>1475.12</td>
</tr>
<tr>
<td>identified link bottlenecks</td>
<td>68</td>
<td>VA-244 E @ VA-120/S GLEBE RD</td>
<td>1165.29</td>
</tr>
<tr>
<td></td>
<td>94</td>
<td>VA-120 S @ VA-244/COLUMBIA PIKE</td>
<td>902.95</td>
</tr>
<tr>
<td></td>
<td>123</td>
<td>VA-120 N @ VA-244/COLUMBIA PIKE</td>
<td>645.98</td>
</tr>
<tr>
<td>Rank of intersection among all clusters</td>
<td>13</td>
<td>Junction of VA-244 and VA-120 (combining all 4 approaches)</td>
<td>4189.34</td>
</tr>
</tbody>
</table>
Methodology

• Segments vs. Major/Minor intersections
  – AADT of at least 3 approaches > 10,000

• Strict vs. lazy queue methods
  – Access management; minor streets; run time
Inputs

• Probe-based speed data
• Volumes: Often only AADT available
  – Estimate for each 15-minute period using profile factors (TTI UMS and UMD RITIS)
• Posted Speed Limits; Reference Speeds
• Network attributes
Performance Measures

• DIVE (FHWA’s Congestion Bottleneck Identification tool)
  – Duration
  – Intensity
  – Variability
  – Extent
...Performance Measures

• $\text{Delay}_{\text{segment, time}} = (\text{addl. Travel time}) \times \text{volume}$
  – Additive measure for approach, intersection

• (methodology) What reference speed? 60% of
  – PSL
  – Vendor supplied reference speed
  – Overnight average speed

• VMT

• Queue length
  – Sum all approaches, for each time stamp
  – Max. bottleneck queue tracked
Performance Measures

• Spillback
  – Flag if all segments at an approach are congested
  – Count total spillback time intervals by approach, node

• Duration
  – If any approach is congested, node bottleneck

• Delay normalized by VMT, miles
  – For very short approaches
Study Network

Seven Corners and Tysons Corner
Preliminary Results

- Reference speed
- Time of day, Day of week heatmaps
- Cumulative distribution functions (CDFs)
## Preliminary Results

### Intersection Top N Bottlenecks (darker red by total delay)

<table>
<thead>
<tr>
<th>Int Id</th>
<th>Roads and directions</th>
<th># of Days</th>
<th>Avg. Duration per day (hrs.)</th>
<th># of Bottlenecks</th>
<th>Avg. Duration per Bottleneck (hrs.)</th>
<th>Total Duration</th>
<th>Avg. Delay per Bottleneck (veh. hrs.)</th>
<th>Total Delay (hrs.)</th>
<th>Total Spillbacks</th>
<th>Total VMT (1000's)</th>
<th>Avg. q_len_max</th>
<th>Delay per VMT (veh.min/veh. mi.)</th>
<th>Delay per Mile (veh.min/mi.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100687</td>
<td>I-66 E On Ram...</td>
<td>143</td>
<td>5.44</td>
<td>563</td>
<td>1.38</td>
<td>778</td>
<td>3.73</td>
<td>14.69</td>
<td>2,101.33</td>
<td>723</td>
<td>8.90</td>
<td>1.74</td>
<td>0.02</td>
</tr>
<tr>
<td>279272</td>
<td>I-495 Outer Lo...</td>
<td>104</td>
<td>3.79</td>
<td>140</td>
<td>2.82</td>
<td>394</td>
<td>10.90</td>
<td>14.67</td>
<td>1,525.06</td>
<td>1,323</td>
<td>23.23</td>
<td>1.29</td>
<td>0.03</td>
</tr>
<tr>
<td>279249</td>
<td>I-495 Inner Lo...</td>
<td>122</td>
<td>3.42</td>
<td>222</td>
<td>1.88</td>
<td>417</td>
<td>5.84</td>
<td>12.44</td>
<td>1,518.08</td>
<td>2,499</td>
<td>4.91</td>
<td>0.72</td>
<td>0.05</td>
</tr>
</tbody>
</table>

### Int approach Top N Bottlenecks

<table>
<thead>
<tr>
<th>Int Approach Id</th>
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<th>Approach Name</th>
<th># of Days</th>
<th>Avg. Duration per day (hrs.)</th>
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<th>Total Spillbacks</th>
<th>Avg. Max. Q Length (mi)</th>
<th>Delay per VMT (veh.min/veh. mi.)</th>
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<tr>
<td>10.</td>
<td>100687</td>
<td>2</td>
<td>I-66 EB</td>
<td>141</td>
<td>4.87</td>
<td>458</td>
<td>1.50</td>
<td>698.75</td>
<td>4.57</td>
<td>14.95</td>
<td>2,093.34</td>
<td>2,07</td>
<td>10.92</td>
<td>0.02</td>
</tr>
</tbody>
</table>

### CDF - Int, weekday, Hour

<table>
<thead>
<tr>
<th>Int Id</th>
<th>Sun</th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
<th>Sat</th>
</tr>
</thead>
<tbody>
<tr>
<td>100079</td>
<td>0K</td>
<td>2K</td>
<td>4K</td>
<td>6K</td>
<td>0K</td>
<td>2K</td>
<td>4K</td>
</tr>
</tbody>
</table>

### Intersection map - Delay (size) and VMT (color intensity)

### Total Delay Heatmap by Intersection (X-axis); Date/Time (Y-axis) (Full day)

### Total Delay Heatmap by Int/Approach (X-axis); Day of Week/Time of Day (Y-axis) (Full day)

- Sun
- Mon
- Tue
- Wed
- Thu
- Fri
- Sat
Preliminary Results

Intersection Top N Bottlenecks (darker red by total delay)

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<tr>
<td>263990</td>
<td>VA-650/Gallos Rd S8</td>
<td>147</td>
<td>7.45</td>
<td>1,789</td>
<td>0.61</td>
<td>1,096</td>
<td>0.29</td>
<td>515.42</td>
<td>4,685</td>
<td>0.41</td>
<td>0.77</td>
<td>0.04</td>
<td>2.97</td>
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<tbody>
<tr>
<td>263990</td>
<td>26. 263990</td>
<td>3</td>
<td>147</td>
<td>5.11</td>
<td>1.454</td>
<td>0.52</td>
<td>751.75</td>
<td>0.15</td>
<td>219.83</td>
<td>67</td>
<td>0.42</td>
<td>0.22</td>
<td>0.04</td>
<td>2.75</td>
</tr>
</tbody>
</table>

CDF - Int, weekday, Hour

Int Id | Sun | Mon | Tue | Wed | Thu | Fri | Sat
|------|-----|-----|-----|-----|-----|-----|-----
| 263990 | 0   | 50  | 100 | 0   | 50  | 100 | 0

Intersection map - Delay (size) and VMT (color intensity)

Total Delay Heatmap by Intersection(X-axis); Date/Time(Y-axis) (Full day);

Total Delay Heatmap by Int/Approach(X-axis); Day of Week/Time of Day (Y-axis) (Full day)
Preliminary Results

- Delay by day of week, hour
Preliminary Results

Intersection map - Total delay (size) and Total Delay (color intensity). AM peak: 5:00-11:00; PM peak: 14:00-20:00.
Resource Needs, Challenges

• Conflation!! Conflation!! Conflation!!
  – Manual work – nodes, approaches, segment order; data availability; PSL; AADT

• Cluster/one node– NOVA network, 7 months
  – 5.5 hours for strict queue method (require large memory, one node (16 cores), and 62GB memory per core)
  – Less than 1 hour for lazy queue method (one node (20 cores), and 10GB memory per core)
Current Status and Next Steps

• Expert validation
• Ongoing iterative improvements

• Corridor performance
  – US-50/1 as a whole, along with its side streets
• Nodes with diverging travel paths
• Super nodes for interchanges, alternative intersections
Acknowledgements

• Expert reviewers, advisors:
  – Mena Lockwood, Terry Short, Sanhita Lahiri, Terrell Hughes, Katie McCann, Mike Fontaine
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Research Questions

• Which performance measures are more useful for which applications?
• Arterial speed data quality (turning movements; slow speeds vs. bike/ped)
• Detailed traffic volumes
• Conflation!! – access density, schools
Questions, Comments