Operational Analyses of Freeway Off-Ramp Bottlenecks

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• Application of HCM methodology for analysis of freeway weaving areas
• Case Study: active bottleneck in Attiki Odos
• Findings
• Ongoing research

• HCM under predicts the capacity and overestimates the density at the weaving test site
• Similar findings in other locations
• Proposed methodology modifications
• Ongoing research
  ▪ Relationship with other freeway facilities methodologies
  ▪ Impacts of Emerging Technologies
Attiki Odos (Attica Tollway): Overview

- Total length: 70 km (43.5 m)
- Toll Stations/Gates: 39/195
- Interchanges: 24
- Tunnels/Length: 56/12.5 km (7.7 m)
- ADT: 226,000 veh-entries / day
Field Data

Loop Detectors: 1,400 -- 1,500 ft (500 m)
Surveillance data: volumes, occupancy (density)

Freeway Performance Measurement (PeMS)

Video Cameras
PeMS Bottleneck Identification Algorithm*

- Sped Difference at Successive Loop Detectors

\[ v(x_j, t) - v(x_i, t) > 20 \text{ mph} \]

\[ v(x_i, t) < 40 \text{ mph} \]

- Duration filter: Minimum of 25 minutes of active bottleneck conditions during any 35 minutes

*TRR #1867, 2004
Test Site: Metamorfosis Interchange

Vehicle Speeds – AM Peak
HCM Methodology for Weaving Areas

a) Capacity:

\[ c_{IWL} = c_{IFL} - \left[ 438.2 (1 + VR)^{1.6} \right] + [0.0765 L_s] + [119.8 N_{WL}] \]

Min:

\[ c_{IW} = \frac{2,400}{VR} \quad \text{for} \quad N_{WL} = 2 \text{ lanes}, \quad c_{IW} = \frac{3,500}{VR} \quad \text{for} \quad N_{WL} = 3 \text{ lanes} \]

VR: weaving ratio

\( L_s \): length of weaving section

\( N_{WL} \): \# “weaving” lanes

b) Level of Service (LOS)--Density

# Lane changes for weaving & non-weaving veh \((L_s, N)\)

# Speeds of weaving & non-weaving veh

Segment density

<table>
<thead>
<tr>
<th>LOS</th>
<th>DENSITY (pc/mi/ln)</th>
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<tbody>
<tr>
<td>A</td>
<td>0-10</td>
</tr>
<tr>
<td>B</td>
<td>&gt;10-20</td>
</tr>
<tr>
<td>C</td>
<td>&gt;20-28</td>
</tr>
<tr>
<td>D</td>
<td>&gt;28-35</td>
</tr>
<tr>
<td>E</td>
<td>&gt;35-43</td>
</tr>
<tr>
<td>F</td>
<td>&gt;43</td>
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</table>
HCM Application: Test Site (1)

Measured Flows vs. HCM Predicted Capacities
Measured vs. HCM Predicted Densities (pc/m/l)
HCM Application: California Data*

16 Test Sites (64 data sets)
HCM over predicts section density by 23%

Measured vs. HCM Predicted Densities

*TRR #2483, 2015, pp.130-139
Queue Spillbacks at Off-Ramp Bottlenecks

Shorter weaving length
Through travel lanes affected by weaving maneuvers

Lane-by-Lane analysis
Adjust # Lane changes (shorter weaving length)

Capacity (pc/h):
\[ c = \frac{c_w}{N} \{ N_o + CAF \} \]

*NCHRP Project 15-57*
Inconsistencies in HCM Freeway Analyses Methodologies

Challenges:
Traffic Flow Relationships
Assessment of Design Improvements

*NCHRP Project 07-26
Looking Ahead*

Connected and Automated Vehicles (CAVs)

Capacity Estimates--Simulations

- Driver behavior
- Traffic stream configuration

<table>
<thead>
<tr>
<th>VR</th>
<th>%MPR 40</th>
<th>%MPR 60</th>
<th>%MPR 80</th>
<th>%MPR 100</th>
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<td>0.2</td>
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<td>1.15</td>
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<td>0.4</td>
<td>1.09</td>
<td>1.13</td>
<td>1.20</td>
<td>1.34</td>
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</tbody>
</table>

VR: weaving ratio, MFR: market penetration rate

*FHWA Pooled Fund Study Capacity Adjustment Factors for CAVs