Operational Analyses of Freeway Off-Ramp Bottlenecks

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October 24-25, 2019

Outline & Discussion

- 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

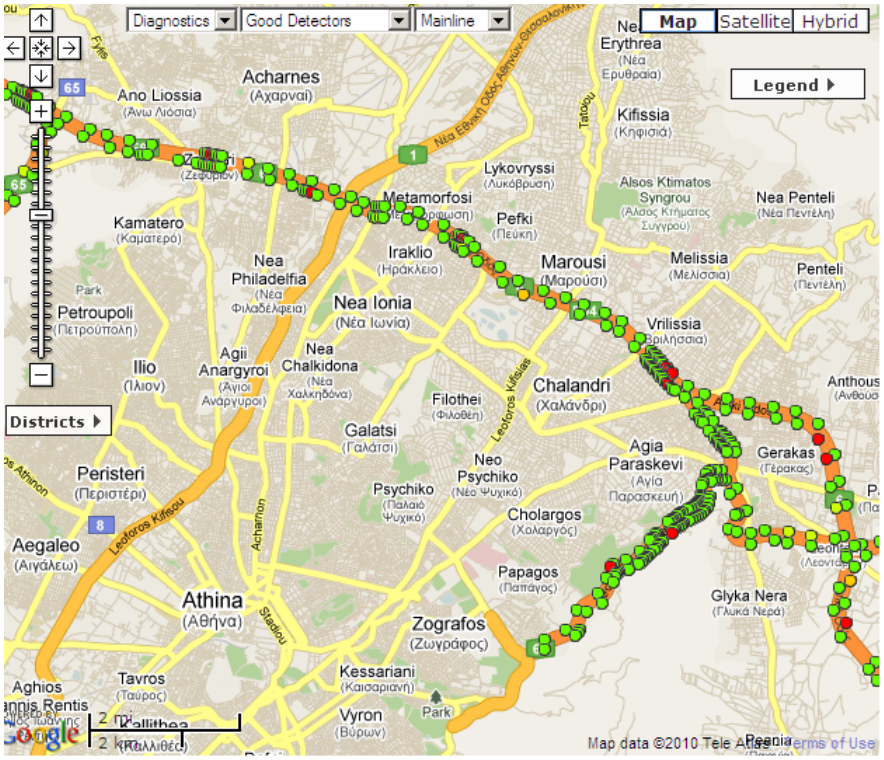
Attiki Odos (Attica Tollway): Overview

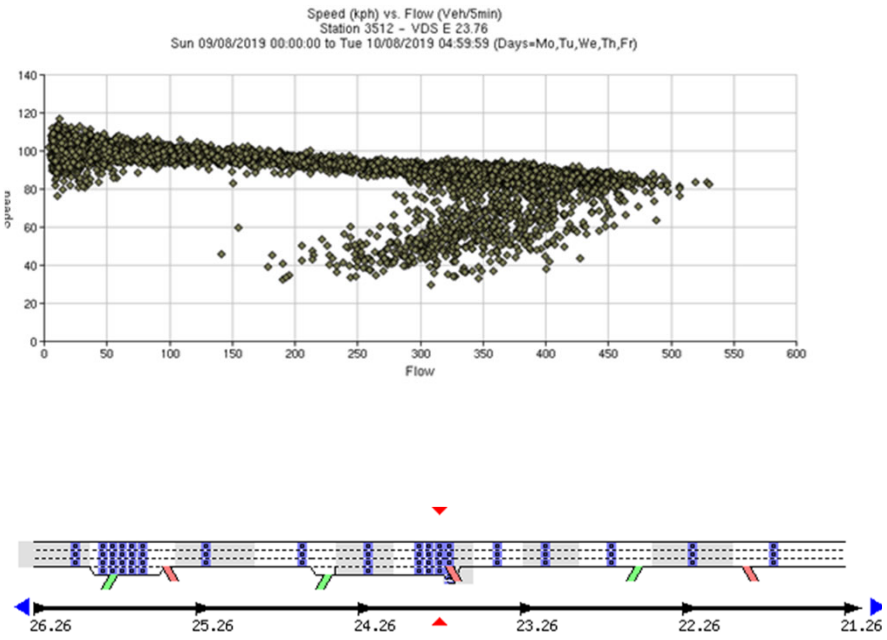
- **Total length** — **70 km (43,5 m)**
- **Toll Stations/Gates** — **39/195**
- **Interchanges** — **24**
- **Tunnels/Length** — **56/12.5 km (7.7 m)**
- **ADT** — **226.000 veh-entries / day**

Field Data

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

Freeway Performance Measurement (PeMS)

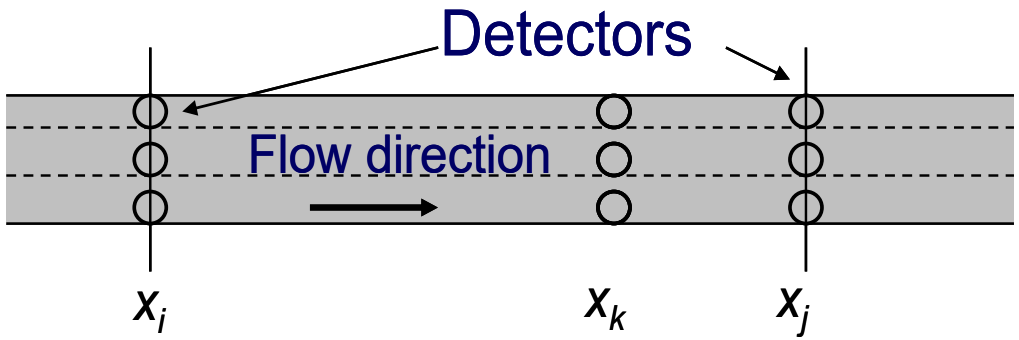




Video Cameras

PeMS Bottleneck Identification Algorithm*

- **Sped Difference at Successive Loop Detectors**

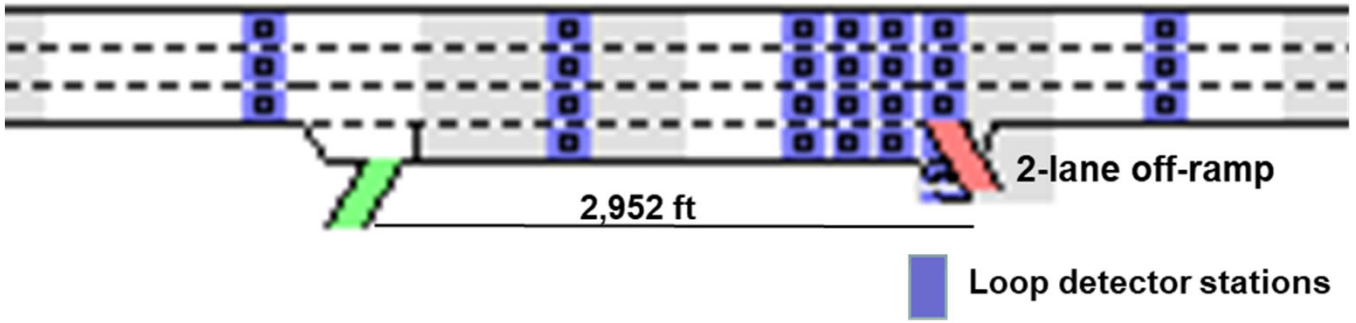


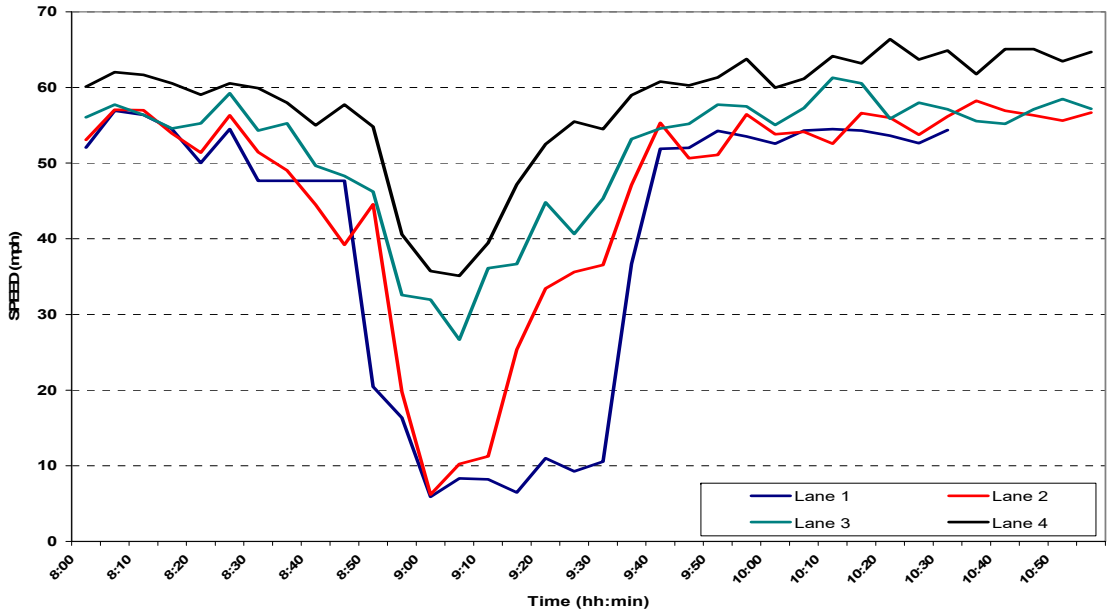
$v(x_j, t) - v(x_i, t) > 20$ mph
$v(x_i, t) < 40$ mph

- **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:

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

Min:

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

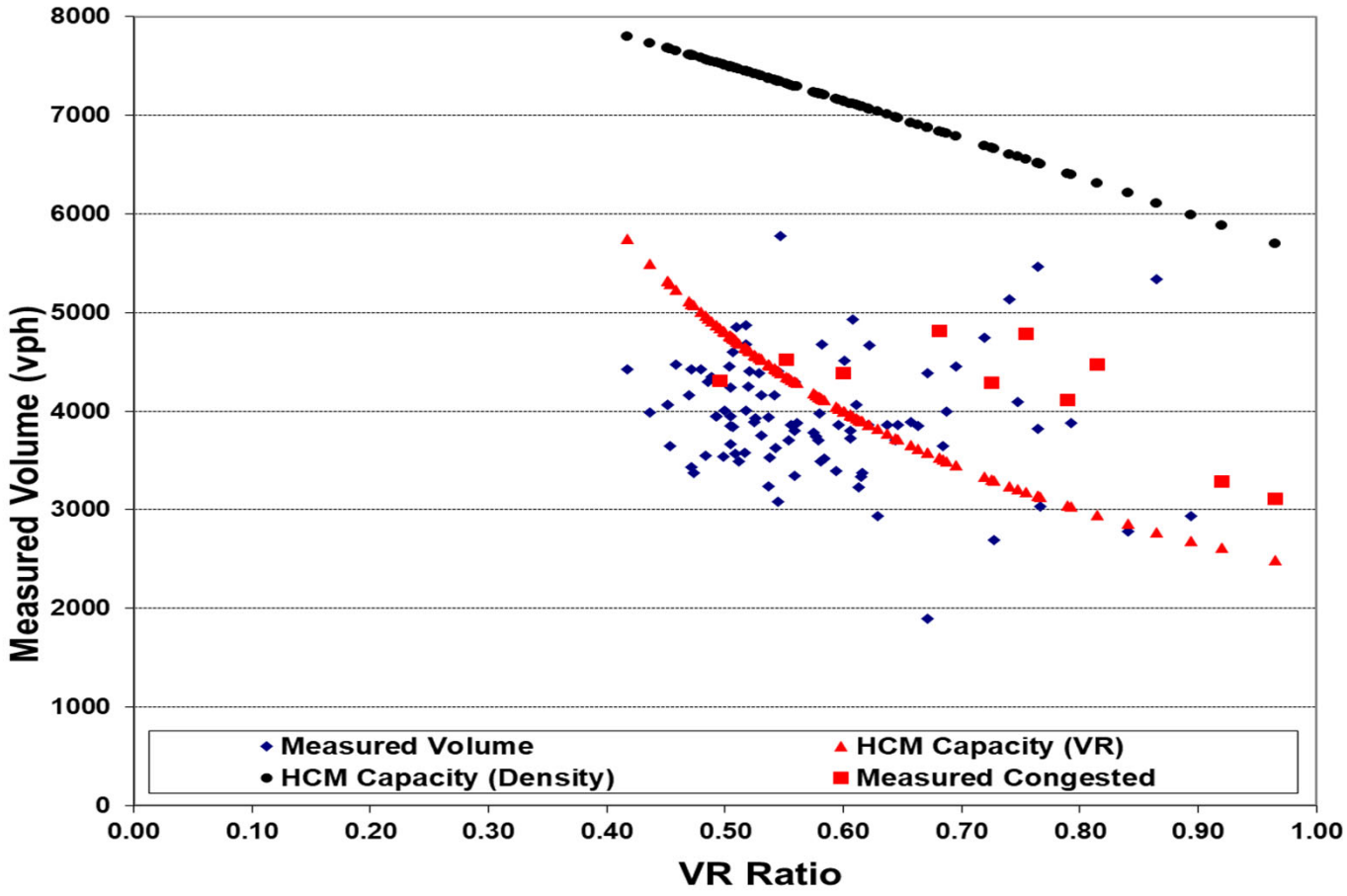
VR: weaving ratio
L_s: length of weaving section
N_{WL}: # "weaving" lanes

LOS	DENSITY (pc/mi/ln)
A	0-10
B	>10-20
C	>20-28
D	>28-35
E	>35-43
F	>43

b) Level of Service (LOS)--Density

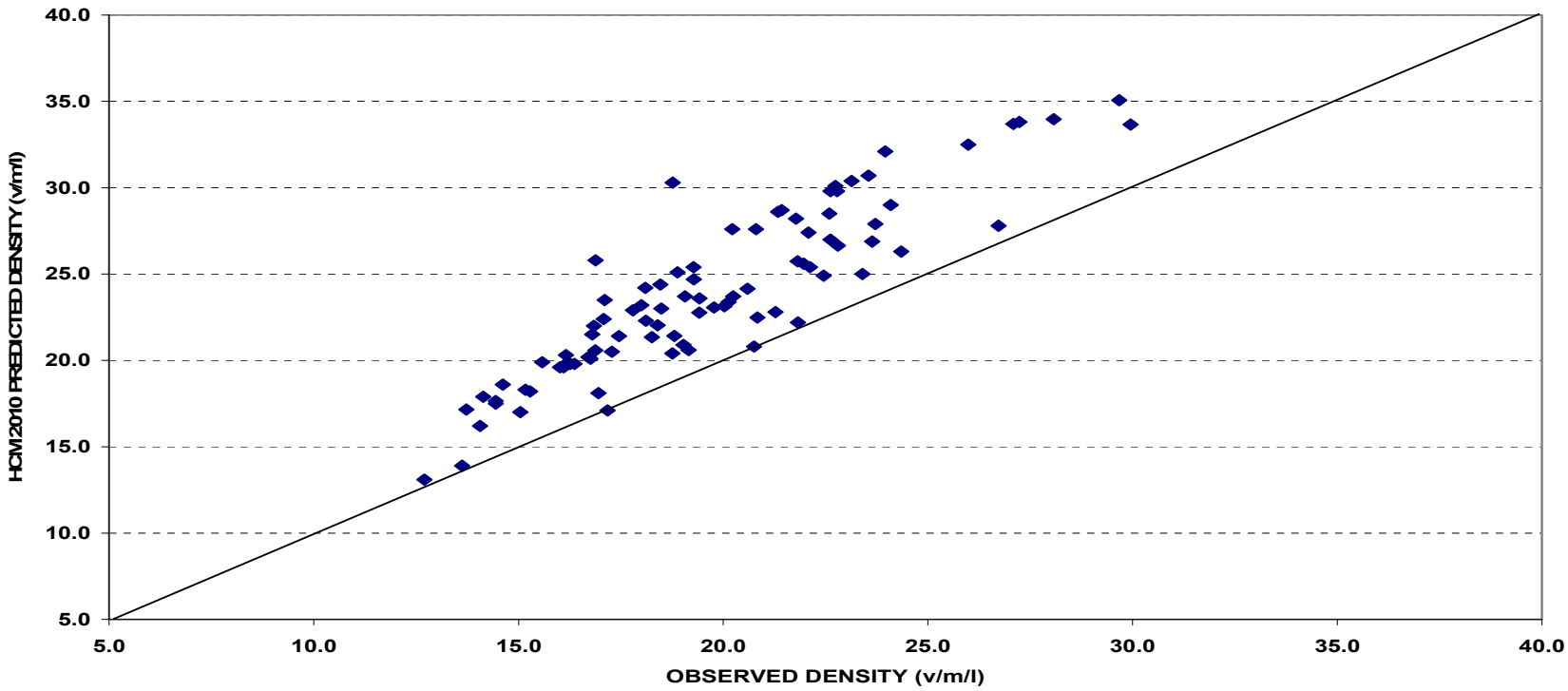
 # Lane changes for weaving & non-weaving veh (L_s,N)
 # Speeds of weaving & non-weaving veh
Segment density

HCM Application: Test Site (1)



Measured Flows vs. HCM Predicted Capacities

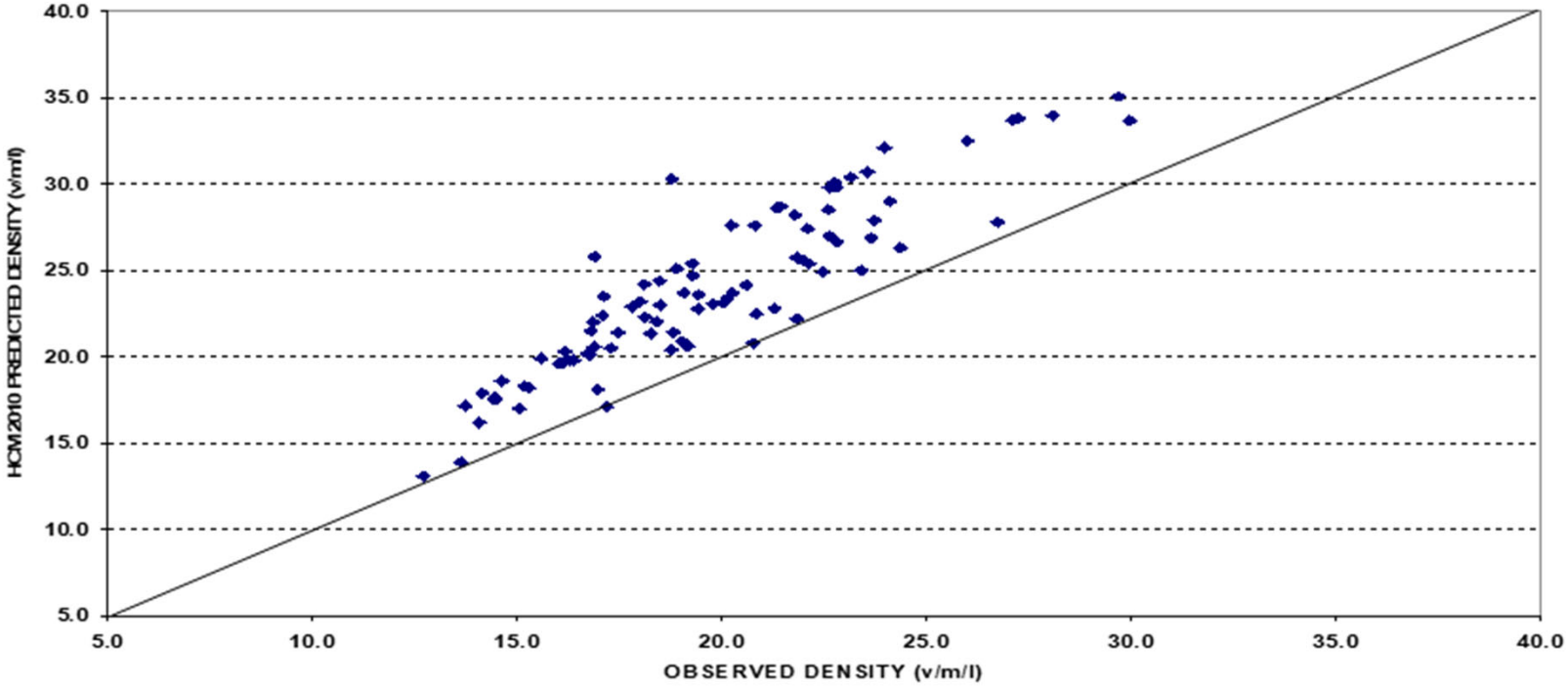
HCM Application: Test Site (2)



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%

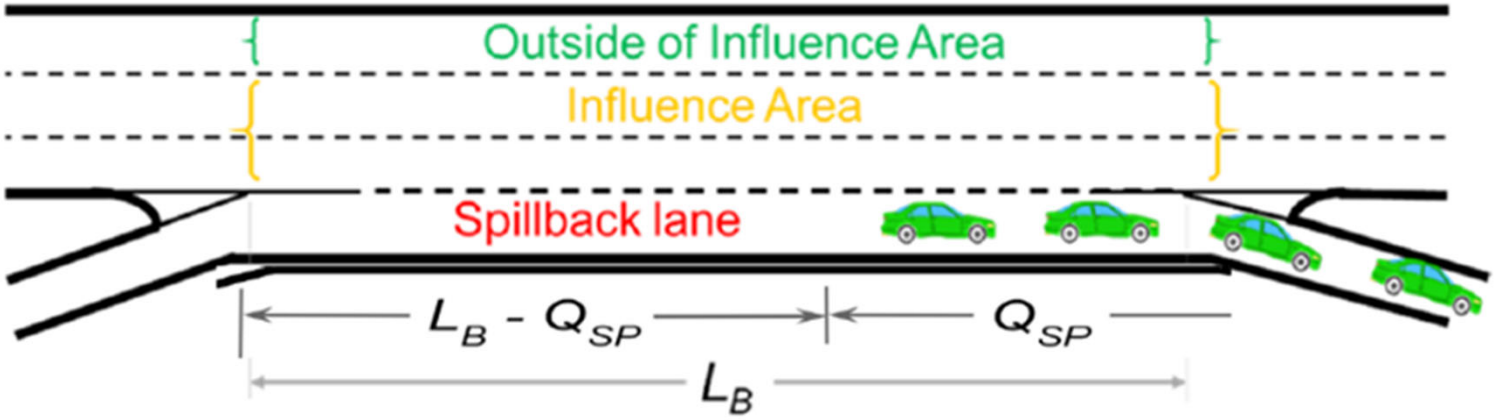


Measured vs. HCM Predicted Densities

**TRR #2483, 2015, pp.130-139*

Toward an Improved Method* (1)

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)

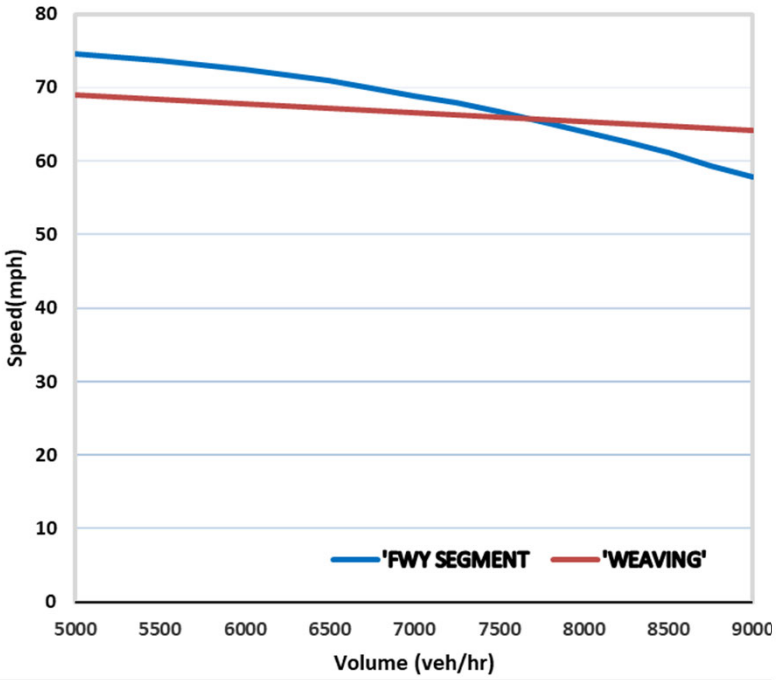
Capacity (pc/h): $$c = \frac{c_w}{N}\{N_O + CAF\}$$

**NCHRP Project 15-57*

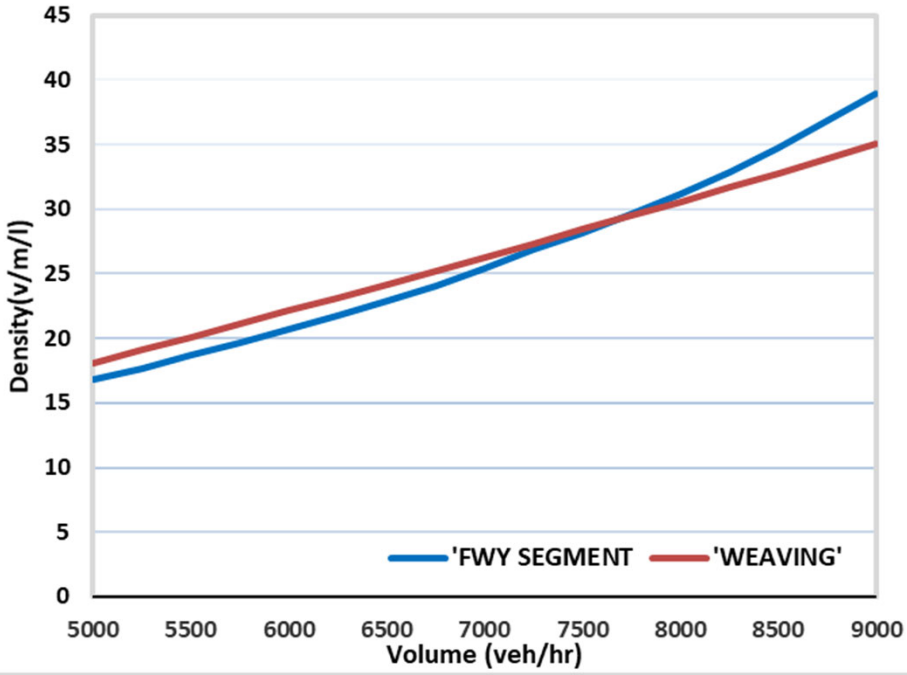
Toward an Improved Method* (2)

Inconsistencies in HCM Freeway Analyses Methodologies

HCM Speed (mph)



HCM Density (v/m/l)

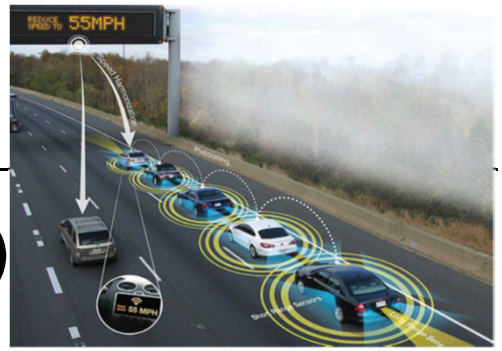


Challenges:

- Traffic Flow Relationships
- Assessment of Design Improvements

**NCHRP Project 07-26*

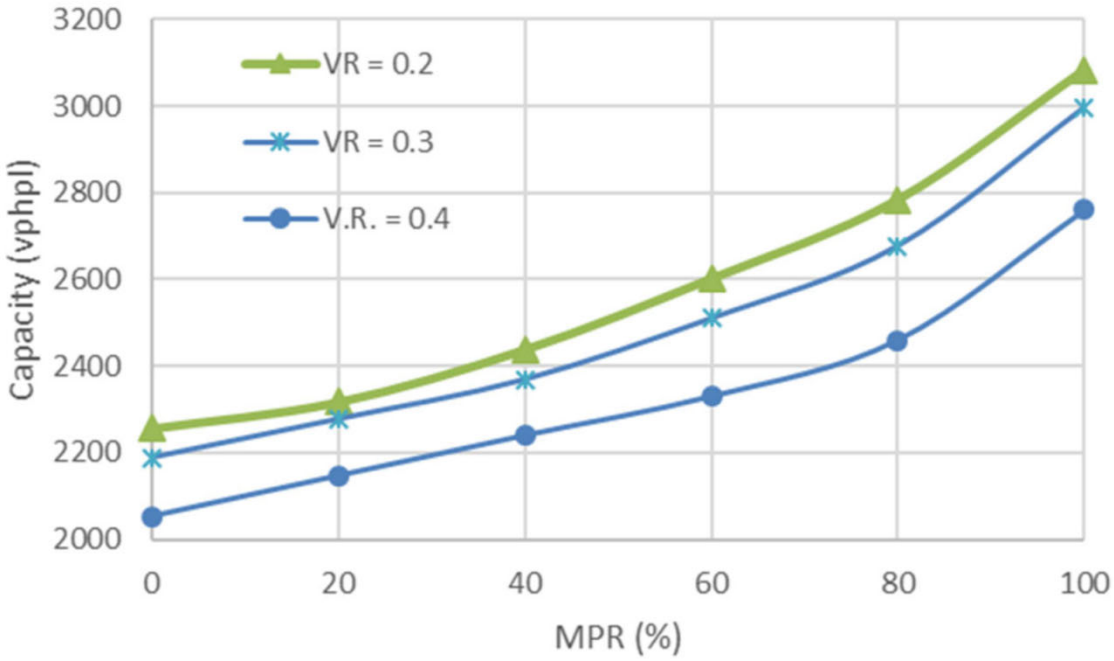
Looking Ahead*



Connected and Automated Vehicles (CAVs)

Capacity Estimates--Simulations

- Driver behavior
- Traffic stream configuration



VR	%MPR			
	40	60	80	100
0.2	1.08	1.15	1.23	1.37
0.3	1.08	1.15	1.23	1.37
0.4	1.09	1.13	1.20	1.34

VR: weaving ratio, MFR: market penetration rate

******FHWA Pooled Fund Study Capacity Adjustment Factors for CAVs*