HCM CAV CAFS

Capacity Adjustment Factors for Connected and Autonomous Vehicles in the Highway Capacity Manual – Pooled Fund Study

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POOLED FUND STUDY OVERVIEW

**Objectives:**
Develop highway capacity adjustments for CAVs at different levels of volume and market penetration

**Agent-Based Approach:**
Vehicle and driver behavior fully customizable for simulation scenarios

**Project Milestones**
- Freeway Models (Spring 2019)
- Intersection Models (Fall 2019)
- Arterial Models (Spring 2020)
AV - CV - CAV

Signals from GPS (global positioning system) satellites are combined with readings from tachometers, altimeters and gyroscopes to provide more accurate positioning than is possible with GPS alone.

Lidar (light detection and ranging) sensors bounce pulses of light off the surroundings. These are analysed to identify lane markings and the edges of roads.

Radar sensors monitor the position of other vehicles nearby. Such sensors are already used in adaptive cruise-control systems.

Ultrasonic sensors may be used to measure the position of objects very close to the vehicle, such as curbs and other vehicles when parking.

Video cameras detect traffic lights, read road signs, keep track of the position of other vehicles and look out for pedestrians and obstacles on the road.

The information from all of the sensors is analysed by a central computer that manipulates the steering, accelerator and brakes. Its software must understand the rules of the road, both formal and informal.

Source: The Economist

Image Credit: The Economist
CONNECTED AND AUTONOMOUS VEHICLES (CAVS)
... THE PROBLEM WITH MOST CAV STUDIES
... at 70 mi/h travel speed

- **2,400 pc/h/ln**
  - $\rightarrow$ 1.5 seconds $\rightarrow$ 154 feet

- **3,600 pc/h/ln**
  - $\rightarrow$ 1.0 seconds $\rightarrow$ 103 feet

- **7,200 pc/h/ln**
  - $\rightarrow$ 0.5 seconds $\rightarrow$ 51 feet
What is Capacity?

- The inverse of following headway
- Function of:
  - Perception-Reaction Time
  - Physics
  - Level of Stress
- Lower at bottlenecks than basic segments
CAV ADOPTION TIMELINE

- **U.S. Light Duty Fleet Turnover Rate**: 14.8 years

- **Technology availability**:
  - Partial Automation (Levels 1-2): 2017-2019
  - Conditional Automation (Level 3): 2020 (limited operational design domains)
  - High/Full Automation (Levels 4-5): 2025-2030

- **Market Penetration**:
  - Once technology is perfected, it will take another 13 years for 50% market penetration and 27 years for 90% market penetration
If they follow previous vehicle technologies autonomous vehicles it will take one to three decades to dominate vehicle sales, and one or two more decades to dominate vehicle travel, and even at saturation a significant portion of vehicle travel may continue to be human operated, indicated by the dashed lines.

CLOSER THAN WE THINK ... MAYBE NOT
ASSUMPTIONS

- Headways and Oscillation
- Platooning
- Cooperation
- Market Penetration
- Number of Lanes
- Volume Mix
### Modeling Framework (Freeways)

<table>
<thead>
<tr>
<th>Basic Freeway Segments</th>
<th>Freeway Merge Segments</th>
<th>Freeway Weaving Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Lane vs. 3-Lane Segment</td>
<td>With and without Advanced Merge</td>
<td>With and without Advanced Merge</td>
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<tr>
<td>ACC Only vs. CACC (platooning)</td>
<td>Market Penetration Rate</td>
<td>Market Penetration Rate</td>
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<td>Market Penetration Rate</td>
<td>Volume Balance</td>
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<tr>
<td>Parameter Sensitivity</td>
<td>Weaving Intensity</td>
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Draft Results
Freeways
Basic Freeway Segments ➔ Effects of Market Penetration

Steady Increase in Capacity with Increasing Market Penetration
Basic Freeway Segments \( \rightarrow \) Platooning Effects (Intra-platoon Gap)

Capacity function of “Intra-Platoon Gap” Setting

\( \rightarrow \) Average Distribution Used for Results
Basic Freeway Segments

2-Lane vs. 3-Lane

Capacity follows same trends for 2-lane and 3-lane Segments
Basic Freeway Segments

ACC vs. CACC

Capacity significantly lower with ACC (Autonomous Vehicles without Platooning)
Basic Freeway Segments → Varying Base Capacity

Capacity converges at same point, despite varying calibrated base capacities (e.g. bottleneck capacities)
Freeway Merge Segments ➔ Effects of Platooning

Platooning is essential to achieve merge area capacity benefits with CAVs.
Freeway Weaving Segments

Effects of Volume Ratios without Advanced Merge

Capacity decreases with higher volume ratio

MPR effects consistent across VRs (similar slopes)
HCM

» Implementation
### Draft CAF Tables - Basic Segments

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<th>Base Capacity (pc/h/ln)</th>
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## Draft CAF Tables – Merge Segments

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## Draft CAF Tables - Weaving Segments

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Closing Thoughts

- CAVs will likely increase capacities, but
  - ... not as soon as you may think
  - ... not as much as media may suggest

- Actual capacity is a function of many factors and assumptions

- Planning-level estimates can help inform decision-making, but agencies should understand modeling assumptions

- Dedicated CAV-Only Facilities may happen sooner
QUESTIONS AND DISCUSSION