Car-following Characteristics of Adaptive Cruise Control from Empirical Data
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OBJECTIVES AND METHODS

BACKGROUND

Automated vehicles will affect capacity
- Alt's drive differently than humans, yet car-following models are based on observed human behavior.
- Transportation agencies need car-following models for computer-controlled driving

Adaptive cruise control (ACC) systems are an early form of automation.
- The models used in ACC on production vehicles are industry trade secrets. Most literature estimates automated vehicle behavior.
- Car-following models should be derived from or calibrated to observed behavior of ACC systems.

OBJECTIVES

- Establish a car-following model that reflects the behavior of a production vehicle with adaptive cruise control
- Provide guidance for modeling a vehicle with adaptive cruise control using commercial microscopic simulation software

DATA COLLECTION

Vehicle
- 2017 Audi Q7
- ACC headways of 1, 1.3, 1.8 (default tested), 2.4, and 3.6 seconds
Sensor
- Laser scanner for measuring gap to lead vehicle
- Smartphone GPS for speed and acceleration, vehicle, 3x/second

Vehicle speed
- Laser scanner for measuring speed

INTELLIGENT DRIVER MODEL COMPARISON

ACC CHARACTERISTICS RELEVANT TO CAR-FOLLOWING

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>Desired distance between two stationary vehicles.</td>
<td>3.5 m (2)</td>
</tr>
<tr>
<td>D</td>
<td>Desired time gap between two vehicles.</td>
<td>The minimum desired time gap between two vehicles.</td>
</tr>
<tr>
<td>q</td>
<td>Jam distance</td>
<td>The shortest distance between two vehicles where a vehicle will accelerate to a leading vehicle.</td>
</tr>
<tr>
<td>v</td>
<td>Vehicle speed (km/hr)</td>
<td>50</td>
</tr>
<tr>
<td>a</td>
<td>Acceleration</td>
<td>The acceleration when starting from standstill.</td>
</tr>
<tr>
<td>b</td>
<td>Oscillation during acceleration</td>
<td>The oscillation during acceleration.</td>
</tr>
<tr>
<td>c</td>
<td>Value closer to zero result in more sensitive reactions to changes in lead vehicle speed. Using default value as recommended in the literature (5, 6).</td>
<td>0.35 m/s</td>
</tr>
<tr>
<td>j</td>
<td>Desired deceleration</td>
<td>The desired deceleration when following distance exceeded 1.9 s at speeds of 15, 30, 45, and 60 mph, resulting in a T-1.3 seconds.</td>
</tr>
<tr>
<td>l</td>
<td>Maximum jerk over 1 s</td>
<td>The maximum jerk over 1 second.</td>
</tr>
<tr>
<td>r</td>
<td>Limits the jerk during the first time step while a vehicle is in the free regime.</td>
<td>0.17 m/s^3</td>
</tr>
<tr>
<td>E</td>
<td>Enhanced model to reduce hard braking</td>
<td>Variable value.</td>
</tr>
<tr>
<td>t</td>
<td>Average time between lead vehicle movement and ACC vehicle movement</td>
<td>1.59 s</td>
</tr>
<tr>
<td>T</td>
<td>Time between lead brake light off and ACC vehicle movement</td>
<td>2.48 s</td>
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MODELING

The models used in ACC on production vehicles are industry trade secrets. Most literature estimates automated vehicle behavior.

The desired gap between two stationary vehicles. Acceleration starting from standstill: 0.57 m/s^2

Field Test – Hard Braking Event

- Position vs. time for vehicles and models in the test scenarios.
- Speed vs. time for vehicles and models in the test scenarios.

RECOMMENDATIONS

- Accelerations and speeds of unaccelerated car-following from standard.

CONCLUSIONS

- Four attributes of production ACC measured from field data: standstill distance (3.5 m), startup time (1.59 s), accelerations (Table 2), and decelerations (effective maximum of 3.0 m/s^2).
- Sample parameters for the Wiedemann 99 car-following model were provided based on the empirical data and the literature, allowing realistic modeling of ACC and automated vehicles in the VISSIM microscopic simulation software.
- Production ACC system compared to IDM intelligent Driver Model (over a 30-second sequence exhibited in a speed range from 22.5 m/s to 5 m/s, the most drastic deceleration of an ACC vehicle analyzed in the following literature). The ACC vehicle showed less severe deceleration when encountering congestion, allowing headways of 1.3 seconds before decelerating compared to IDM’s 3 second headway.

ACKNOWLEDGMENTS

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REFERENCES