SYSTEMATIC REVIEW AND META-ANALYSIS OF ADAPTIVE CRUISE CONTROL APPLICATIONS:
Operational and Environmental Benefits

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INTRODUCTION

There is a rapidly growing body of research on the potential impacts of connected and automated vehicles (CAVs), particularly studies on the impacts of adaptive cruise control (ACC) and cooperative adaptive cruise control (CACC).

Despite the burgeoning research field, there is little consensus on the magnitude of operational and environmental benefits from ACC and CACC systems. This poster provides a systematic review of ACC and CACC studies along with a meta-analysis of key parameters.

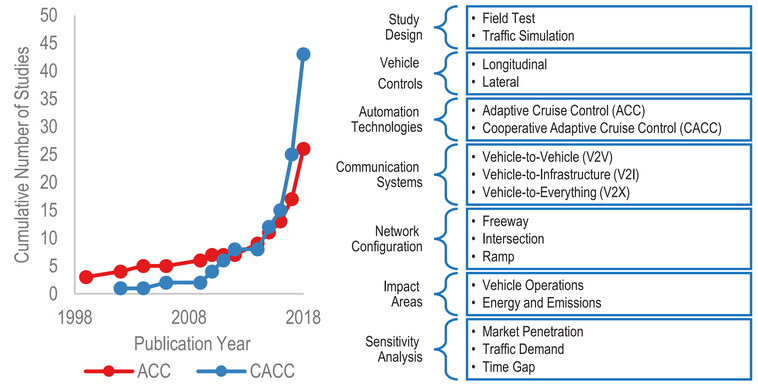

Figure 1. (left) a cumulative plot of the relevant publications for ACC (n=26) and CACC (n=43) by year, and (right) a list of the major fields considered and some common tags in the systematic review

SYSTEMATIC REVIEW

We reviewed 67 CAV impact studies that presented the following:

A. Quantifiable impacts to vehicle operations, fuel use, and/or emissions, and
B. Cooperative and adaptive cruise control technologies only.

STUDY DESIGN

Studies of passenger vehicles on freeways were given preference, though a few heavy-duty applications as well as some intersection networks were included. Given these filters, we manually added multiple keyword tags, such as "CACC", "V2V", and "freeway" for each study and tracked them in a reference management software system.

Out of the ACC and CACC impact studies reviewed, a large majority were simulations. Field testing of these systems did not begin until roughly 10 years ago and are greatly lagging behind simulation-only studies. It may not be feasible to evaluate global objectives such as highway capacity and fleet fuel efficiency without higher adoption.

TIME GAPS

The time gap between the lead and following vehicle in a string is a critical component for determining system performance. Our review was almost exclusively of constant time gap regulation. Shorter gaps result in larger capacity improvements and more fuel efficient behavior. Given the high sensitivity, we have compared time gaps for ACC, CACC, and manual driving below across studies selected in our meta-analysis.

CAPACITY IMPROVEMENTS

Notably, several studies showed decreases in capacity under ACC driving. The same decreased capacities were not present for CACC scenarios, which would suggest that those ACC applications were suffering from extended time gaps and/or reduced string stability. When present, the capacity improvements for ACC was generally more modest than CACC.

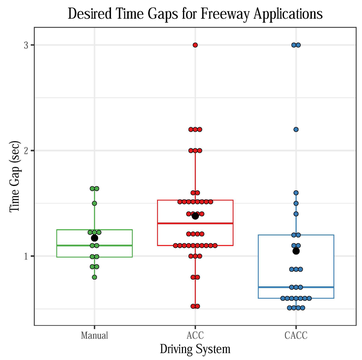

Figure 2. Meta-analysis of reported following time gaps for ACC (n=42), CACC (n=27), and manual (n=13) driving on freeways (boxplots present the 25th, 50th, and 75th percentile, black dots represent mean gaps)

FUEL SAVINGS

Although we only found four ACC studies assessing fuel consumption, two were field tests that show fuel savings. CACC applications with V2I communications at intersections showed promising fuel savings, but results were not as impressive on highways.

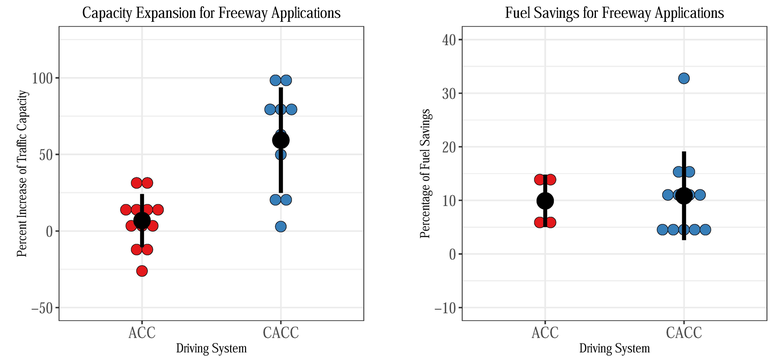

Figure 3. (left) meta-analysis of maximum reported capacity improvements for ACC (n=12), CACC (n=10) systems on freeways, and (right) maximum reported fuel savings for ACC (n=4) and CACC (n=12) systems on freeway (black dots represents means with whiskers of one standard deviation)

CONCLUSIONS

Our meta-analyses of maximum capacity improvements and fuel savings against manual driving suggests that:

- CACC systems will perform better on average than ACC systems due to shorter time gaps and more stable strings,
- Longer time gaps and lack of connectivity for ACC translate to less pronounced capacity improvements than CACC, and
- Real-world fuel consumption and emissions testing could confirm environmental benefits.

If anything, this meta-analysis brings together the adaptive cruise control literature that suggests the benefits of pairing vehicle automation and connectivity are greater than automation alone.

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FOR MORE INFORMATION

See TRB Paper 19-04981 at amonline.trb.org, visit its.dot.gov, or contact Andrew Eilbert (andrew.eilbert@dot.gov).

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