Environmental Impact of Production-Ready Connected and Automated Vehicles (CAVs) on Arterials

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Introduction

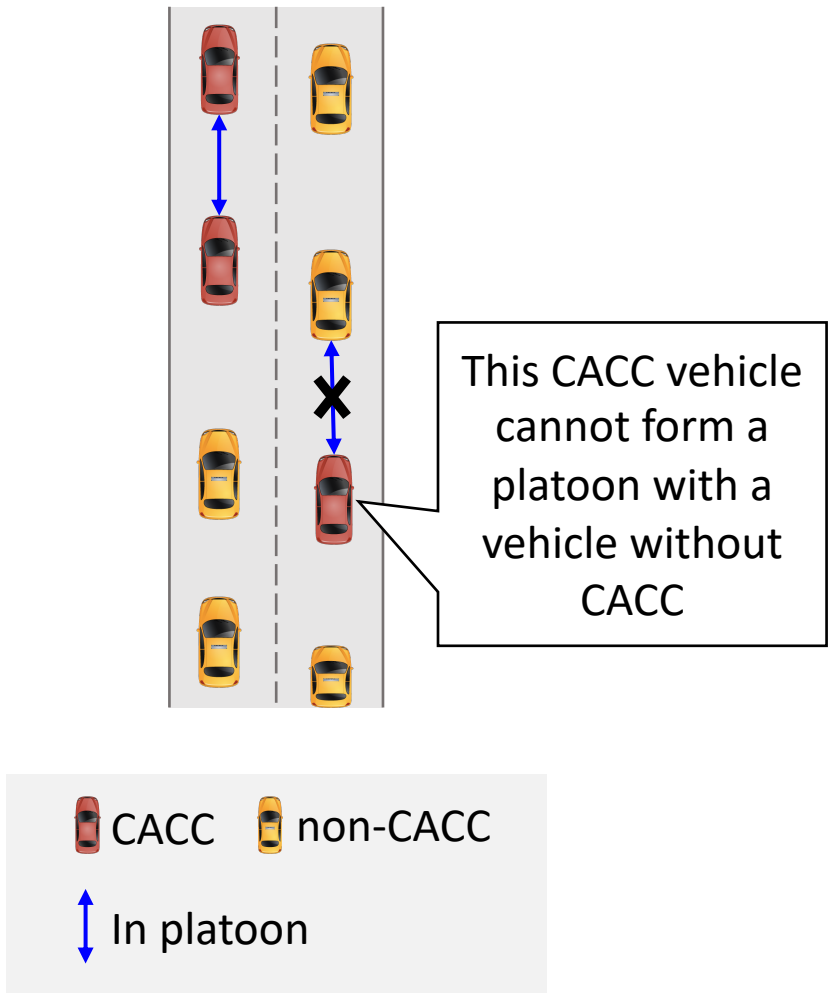
Commercially available automation in vehicles

- Adaptive Cruise Control (ACC)
  - Automatically maintain a desired speed and/or a safe following distance
  - A shorter detection range and a longer response time than human drivers
  - Can worsen the traffic stability
- Cooperative Adaptive Cruise Control (CACC)
  - Use Vehicle-to-Vehicle(V2V) communication and share information real-time
  - Multiple vehicles adjust speeds almost simultaneously in a string with shorter gaps
  - Potentially increase capacity and reduce fuel consumption and emissions.

Introduction

At the early stage of implementation

- Mixed traffic with human-driven vehicles, ACC vehicles, and CACC vehicles
- Sparse distribution of CACC vehicles
  - Less likely to find other CACC vehicles and form a string with shorter gaps
  - CACC vehicles will be operating in ACC mode



Research Objective

To examine how the effect of CACC vehicles on capacity, fuel consumption, and emissions at various market penetrations in an arterial corridor with multiple signalized intersections

Methodology

Overview

- Microscopic simulation
  - Mixed traffic with human-driven, ACC, and CACC vehicles
  - Various market penetrations of CACC vehicles
  - Output: the detailed trajectories of simulated vehicles
- Estimate the fuel consumption and emissions
- Estimate the bottleneck capacity

Methodology

Microscopic Simulation

PATH model, developed by UC Berkeley[1]

- Describes mixed traffic of human-driven, ACC, and CACC vehicles
- Integration of human-driven model (NGSIM oversaturated flow human driver model) and ACC/CACC model (calibrated with field data on CACC vehicle strings)

[1]X. Lu, X. D. Kan, and S. E. Shladover, "An Enhanced Microscopic Traffic Simulation Model for Application to Connected Automated Vehicles," 96th Annu. Meet. Transp. Res. Board, no. January, p. 20p, 2017.

Methodology

Analysis of Fuel Consumption and Emissions

Autonomie, developed by Argonne National Lab[2].

- Estimates the fuel consumption and emissions
- Based on simulation of powertrain dynamics for individual vehicles from the trajectory data
- Validated for several powertrain configurations and vehicle classes using field data.

[2]Islam, E., Moawad, A., Kim, N., & Rousseau, A., 2017. An Extensive Study on Sizing, Energy Consumption, and Cost of Advanced Vehicle Technologies (No. ANL/ESD-17/17). Argonne National Lab (ANL), Lemont, IL (United States).

Methodology

Experiment Setup

- Aimsun to emulate an arterial network traffic at capacity
  - CACC penetration rates = [0, 25, 50, 75, 100%]
- Estimate the capacity of a major bottleneck in the network
- Estimate the fuel consumption, and emissions

Methodology

San Pablo Network in Berkeley, California

- 3.25-km section in Berkeley, California
  - 2 lanes per direction
  - 10 signalized intersections
  - Speed limit of 50 km/hr.
- Evening peak congestion (4:30 - 5:30 PM) in the north-bound traffic
- Calibrated traffic demand and signal timing plan

Fig. 1. San Pablo Network

Results

Highlights

Low CACC penetration (≤25%)	• Lower capacity and higher fuel consumption and emissions • Why? CACC vehicles revert to ACC mode due to the low probability of forming a string and operate with limited detection range and response latency.
As penetration increases (>25%)	• Traffic capacity increases and fuel consumption • Why? CACC vehicles easily form multi-vehicle strings.

Results

Traffic Flow

Fig. 2. validates the traffic simulation. The contour shows that a bottleneck forms at the intersection of San Pablo Avenue and University Avenue.

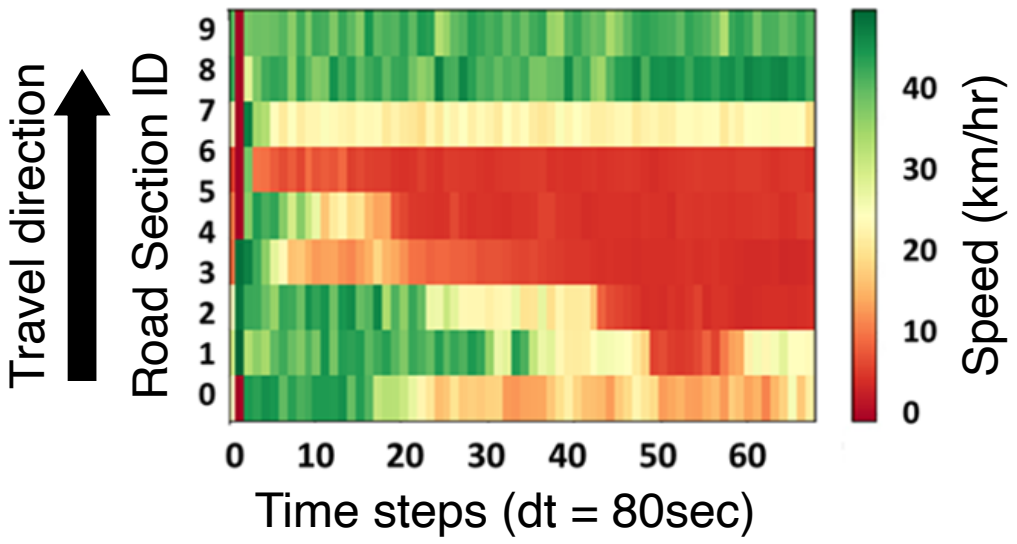


Fig. 2. Speed Contour at Major Bottleneck (25% CACC)

Results

Traffic Flow

- At low penetration of CACC vehicles (25%), capacity is lower compared to the case with no CACC vehicles.
- As the penetration increases, the capacity increases.

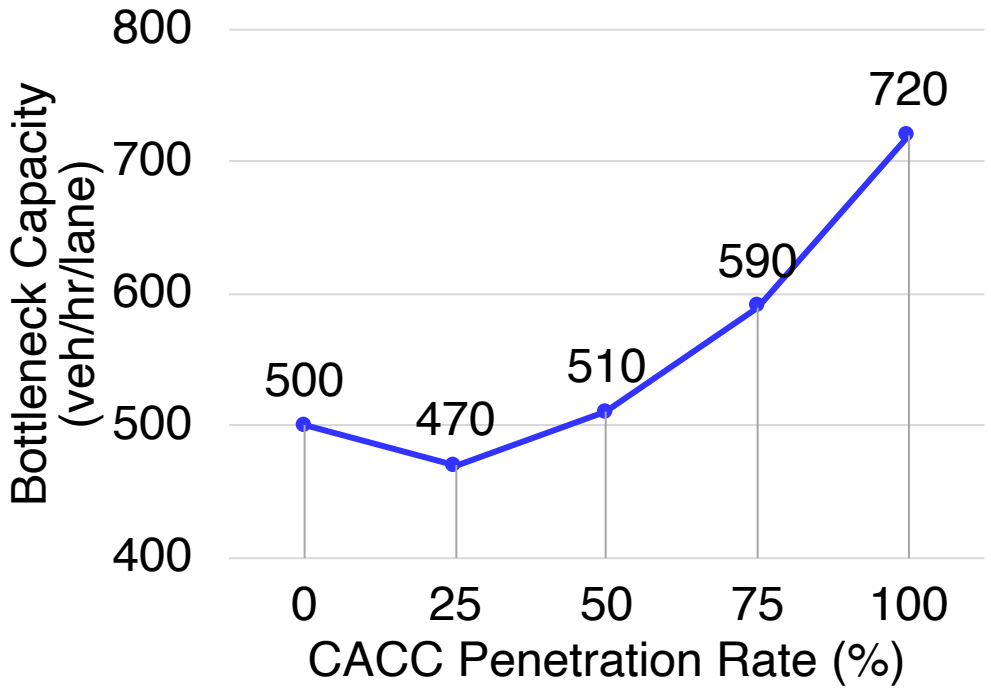


Fig. 3. Bottleneck Capacity at Various CACC Penetration Rates

Results

Environmental Impact

- At low penetration of CACC vehicles (25%), the fuel consumption and emission increase.
- As penetration increases, the fuel consumption and emissions decrease significantly.

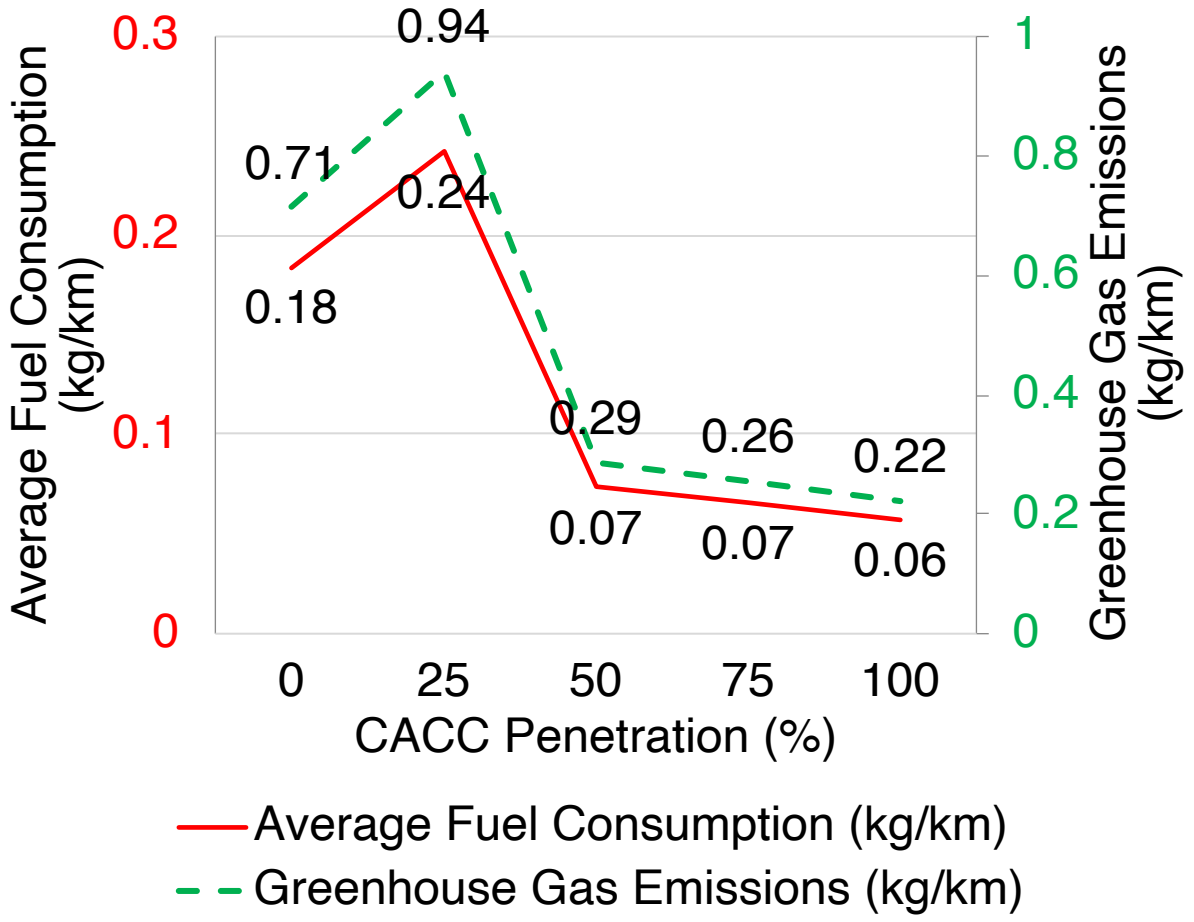


Fig. 4. Average Fuel Consumption and Greenhouse Gas Emissions at Various CACC Penetration Rates

Future Work

- Field tests to study the characteristics of production ACC and CACC vehicles
- More accurate estimate of the traffic and environmental impact that connected and automated vehicles could bring

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