Micro-Simulation of Truck Platooning with Cooperative Adaptive Cruise Control: Model Development and a Case Study

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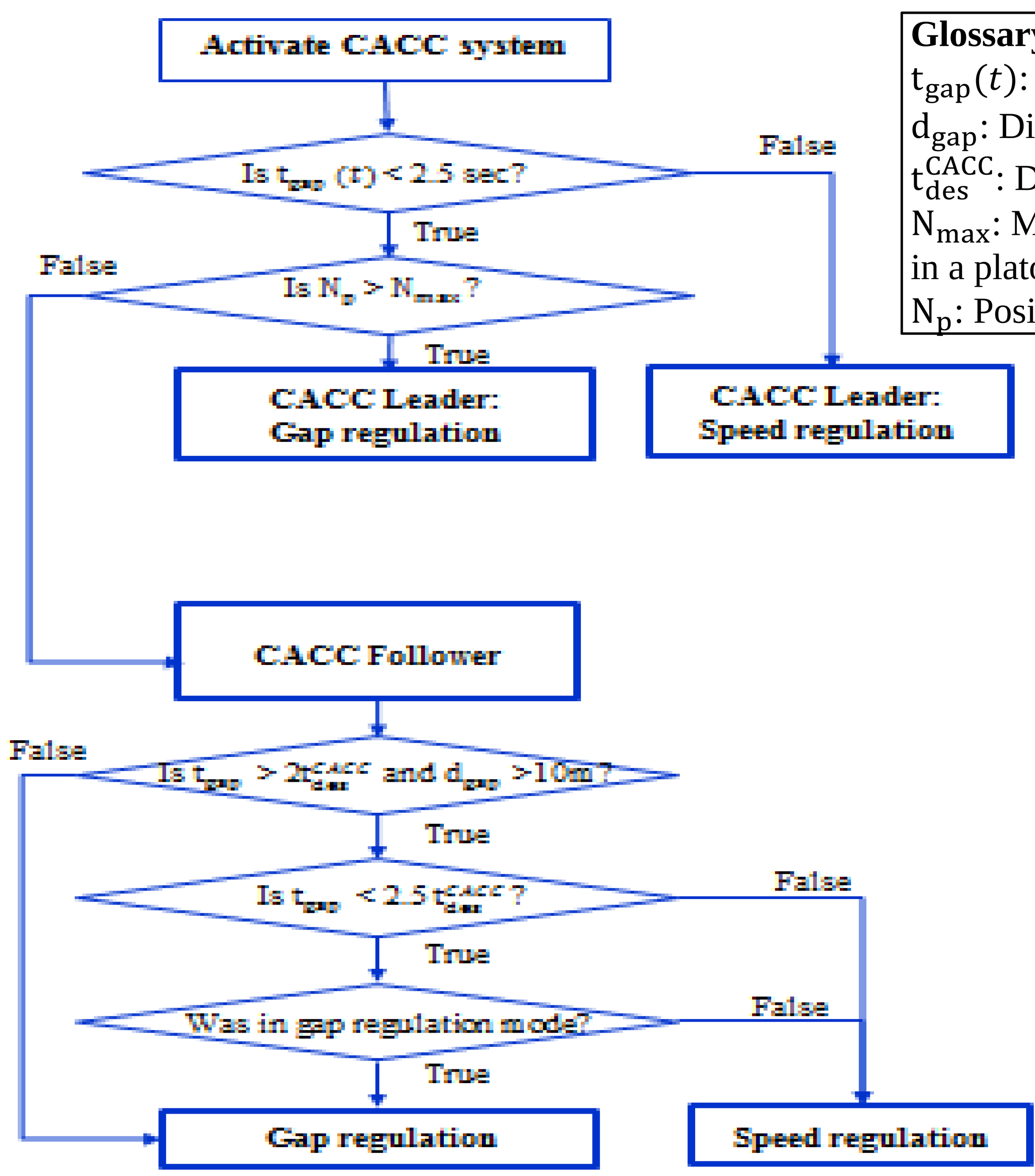
ABSTRACT

- Objective: Developed a micro-simulation model of heavy truck CACC when trucks share a freeway with manually driven passenger cars.
- Car following models: Developed for CACC, ACC, and CC
- Other behavioral models: Implemented lane changing, lane change cooperation, lane use restrictions, and switch from automated mode to manual mode
- Case study: Calibrated Aimsun model for a 15-mile corridor
  Studied effect of penetration rate on speed and VMT

MECHANISM OF AUTOMATIC VEHICLE FOLLOWING



Glossary:
$t_{gap}(t)$: Time gap at time t
d_{gap}: Distance gap
t_{des}^{CACC}: Desired time gap in CACC
N_{max}: Maximum number of vehicle in a platoon
N_p: Position in platoon

CAR FOLLOWING MODEL

$$a_{target}(t) = Max\big(b_f, Min(a_F(t), a_m(t), a_G(t))\big)$$

b_f: Max braking rate
$a_F(t)$: Acc. rate to reach free flow speed
$a_G(t)$: Gipps deceleration component
$a_m(t)$: Acc. rate for a given driving mode. For manual mode, the Newell model is used. For automated modes the following models are used.

Car Following Model (Cont.)

For Cruise Control (CC) mode:

$$a_m(t+1) = 0.3907(v_{ref}(t) - v(t))$$

$v_{ref}(t)$: Reference speed
$v(t)$: Speed of the subject vehicle

For Adaptive CC (ACC) mode:

$$a_m(t+1) = 0.0561[d(t) - t_{des}^{ACC} v(t)] + 0.3393[v_{prec}(t) - v(t)]$$

$d(t)$: Distance gap
t_{des}^{ACC}: Desired time gap, selected to be 2.2 sec
$v_{prec}(t)$: Speed of the preceding vehicle

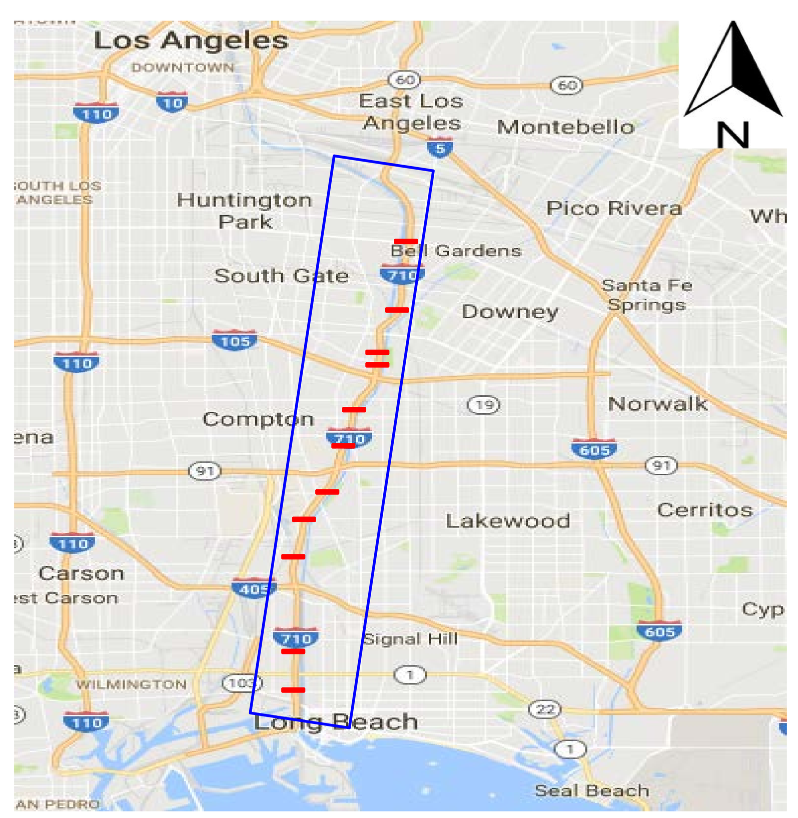
For Cooperative ACC (CACC) mode:

$$a_m(t+1) = 0.0074\,[d(t) - t_{des}^{CACC} v(t)] + 0.0805\,[v_{prec}(t) - v(t) - t_{des}^{CACC} a(t)]$$

t_{des}^{CACC}: Desired time gap, evenly distributed between 1.2 sec and 1.5 sec

CASE STUDY: I-1710 NB

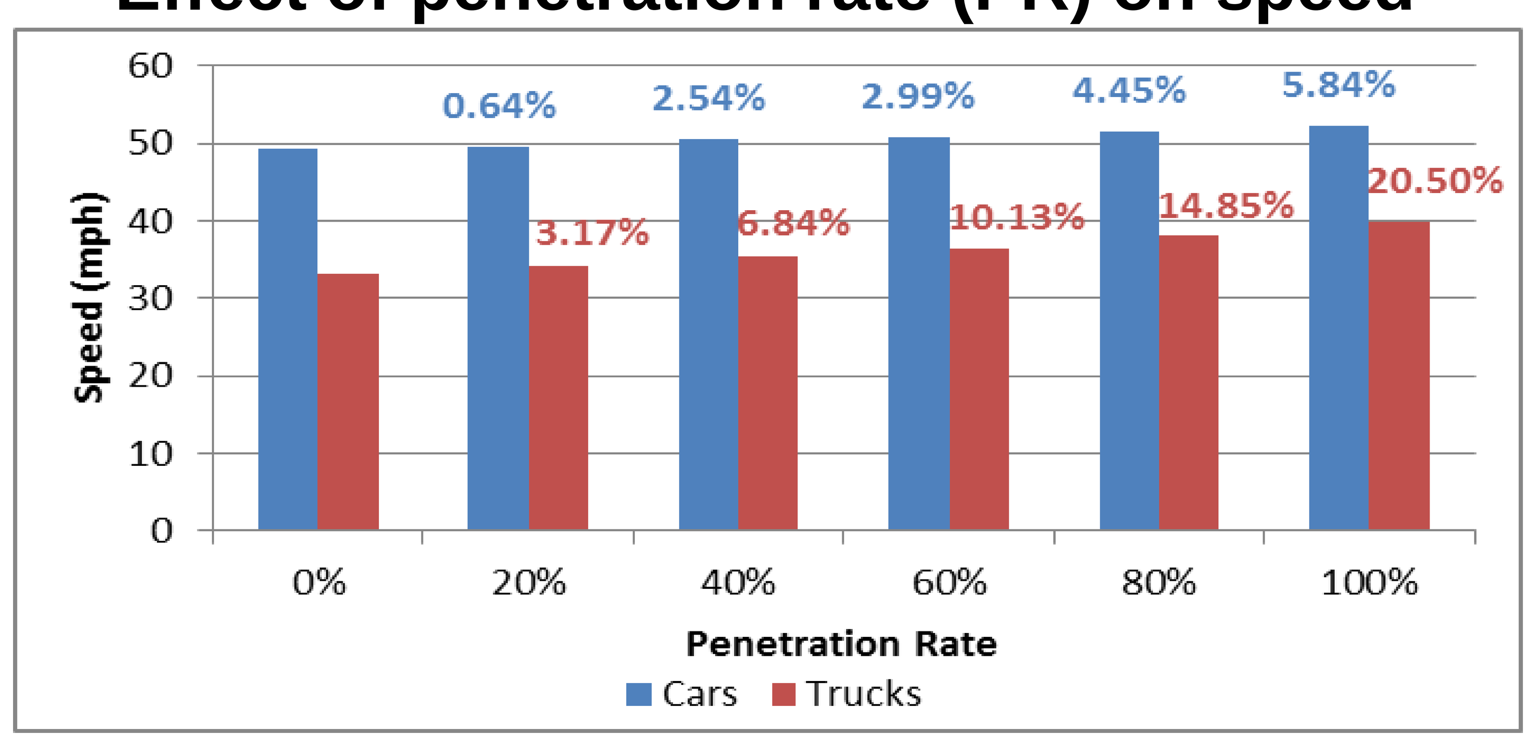
15-mile corridor with loop detector locations



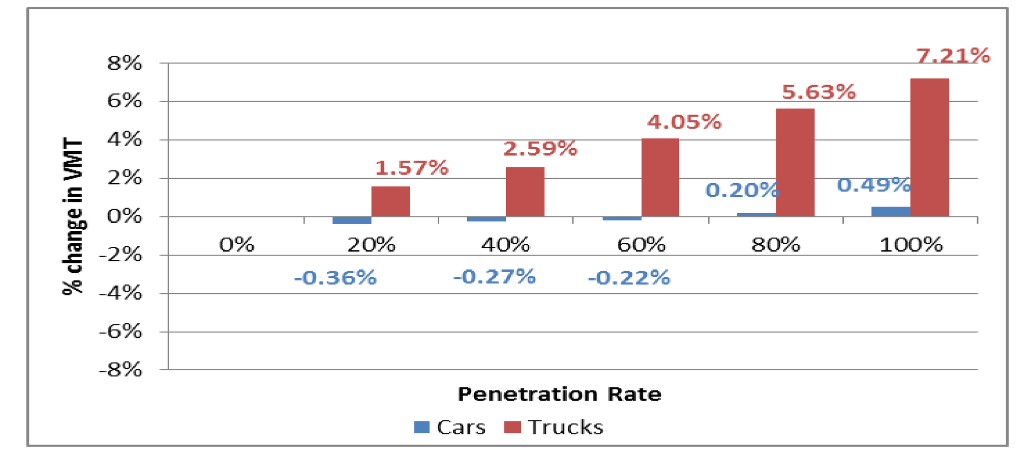
Calibrated parameters

Parameter	Calibrated value
Reaction time	1.3 sec
Gap for manual trucks	2.4 sec
Gap for manual cars	1.25 sec
Theta in Gipps model	$0.2 * \tau_r$
Max Acc. for cars	$2.5\ m/s^2$
Max Dec. for cars	$3\ m/s^2$
Min. speed difference to consider friction	10 m/s

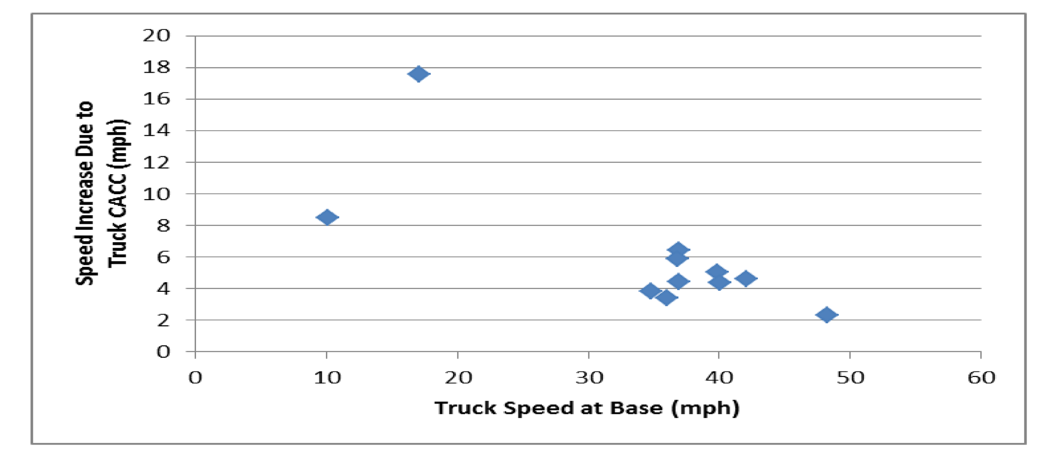
Effect of penetration rate (PR) on speed



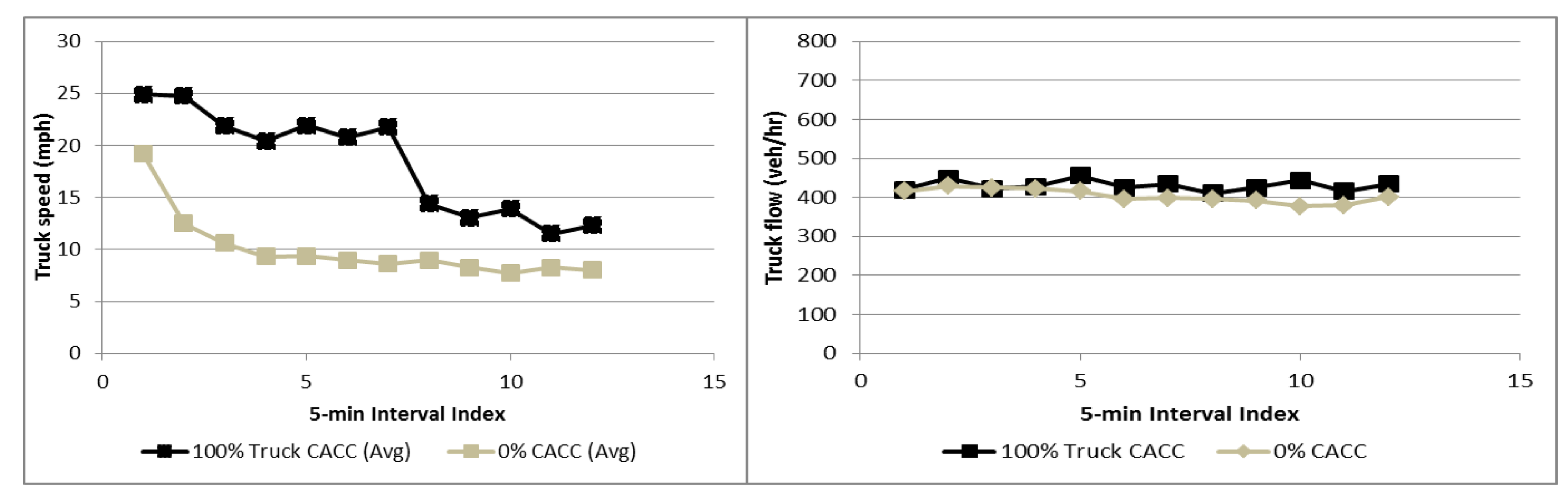
Effect of PR on VMT



Effect of 100% PR on speed at detector locations:



Traffic dynamic at the most congested detector:



CONCLUDING REMARKS

- Developed a framework to simulate automated truck platoon, manual passenger cars and manual trucks
- Comparison of 0% penetration rate vs. 100%:

For trucks: Speed and VMT increased by 20.5 % and 7.2%, respectively
For cars: Speed increased by 5.8%; marginal effect on VMT

ACKNOWLEDGMENT

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