Vehicle Emissions Estimation Under Oversaturated Conditions Along Signalized Arterials

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Background

Vehicle emission methods have been based on:

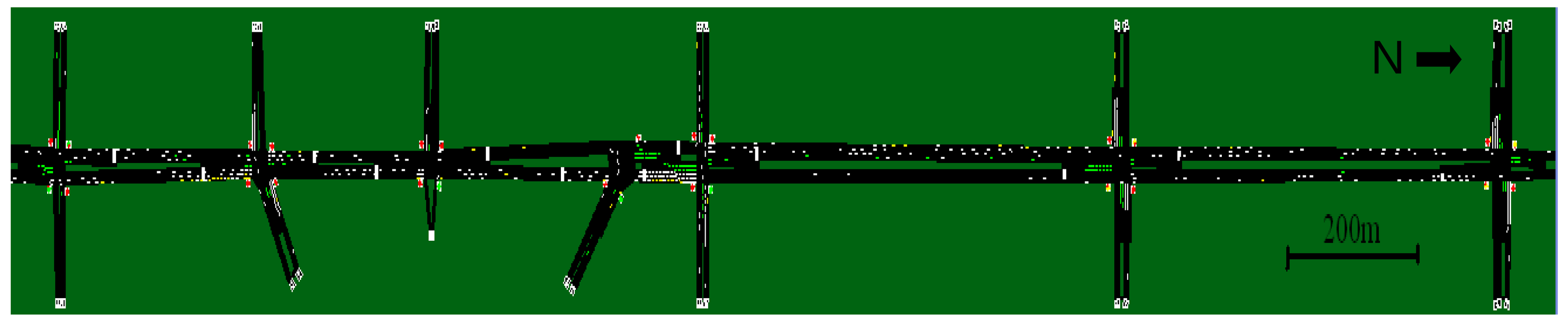
- Aggregate trip and vehicle miles traveled and aggregate measures of activity (*do not capture the contribution of different driving modes on emissions*),
- Empirical studies and field measurements (*expensive and time consuming*),
- Microsimulations (*time consuming and not easily transferable to other locations*).

Objective: *To develop an analytical model that estimates **vehicle activity**) for **oversaturated conditions** based on readily available **data from loop detectors** to be used for **improved emission estimates**.*

Test Site

Lincoln Avenue, between Fiji Way and Venice Boulevard

in the cities of Santa Monica & Los Angeles, CA



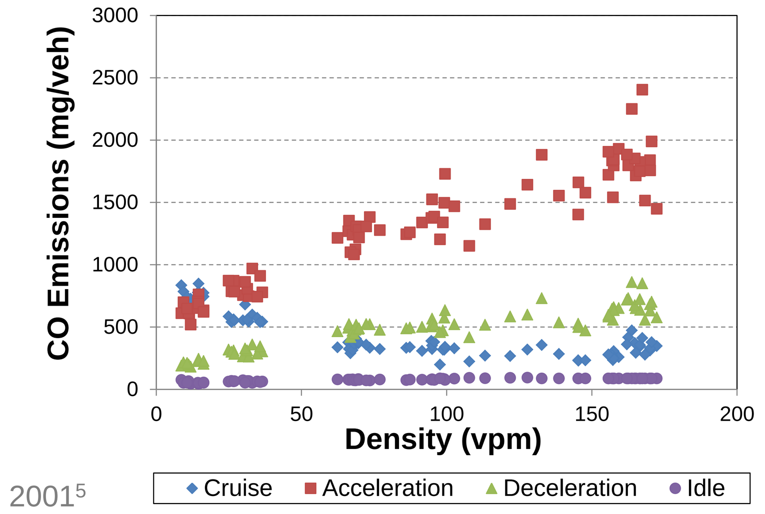
- 1.42miles (2.3km);
- Link lengths: 450-2,070ft (150-660m)
- 3 through plus turning lanes at each approach of the arterial
- Traffic responsive coordinated signal control
- System cycle lengths: 100-150sec.

Emissions Estimation

Emission Estimates (Percentages) for Lincoln Avenue—NB Direction*

	Cruise	Acceleration	Deceleration	Idle	Total
CO (gr)	4,430 (26.48%)	8,115 (48.51%)	3,057 (18.28%)	1,125 (6.73%)	16,727
HC (gr)	264 (14.52%)	804 (44.22%)	320 (17.60%)	430 (23.65%)	1,818
NO (gr)	550 (23.93%)	1,096 (47.69%)	480 (20.89%)	172 (7.48%)	2,298

Acceleration is responsible for emitting higher quantities of CO, compared to the other modes for a wide range of densities



*Emission rates per driving mode obtained by Frey et al., 2001[5]

Analytical Model

Extension of previously developed model for travel time estimation[1,2,3]

- based on kinematic wave theory,
- uses data from loop detectors (i.e., flow and occupancy) and signal settings (i.e., cycle length, green times, offsets),
- accounts for the temporal and spatial queues (e.g., queue delay, spillovers) and signal coordination.

Time spent accelerating

$$t_{acc} = N_{s,C} t_1 = \sum_i \left(\frac{n^i_{s,C}}{q^i_C} + b^i_C \right) t_1$$

Time spent decelerating

$$t_{dec} = N_{s,C} t_2 = \sum_i \left(\frac{n^i_{s,C}}{q^i_C} + b^i_C \right) t_2$$

Time spent cruising

$$t_{cr} = \frac{L - L_{acc} - L_{dec}}{v_f}$$

Time spent idling

$$t_{idle} = \bar{t}_C - t_{cr} - t_{acc} - t_{dec}$$

$N_{s,C}$: average number of stops of vehicle in cycle C

v_f : free flow speed

$t_1(t_2)$: time it takes to accelerate (decelerate) from speed zero to v_f (v_f to zero)

$n^i_{s,C}$: number of vehicles stopped in link i during cycle C

q^i_C : discharged flow from link i during cycle C

b^i_C : binary variable with value equal to 1 if $L^i_{q,C} > 0.9L_i$ and 0 o.w.

$L_i; L^i_{q,C}$: length of link i; queue length on link i during cycle C

$L_{acc}(L_{dec})$: corridor length traveled in acceleration (deceleration)

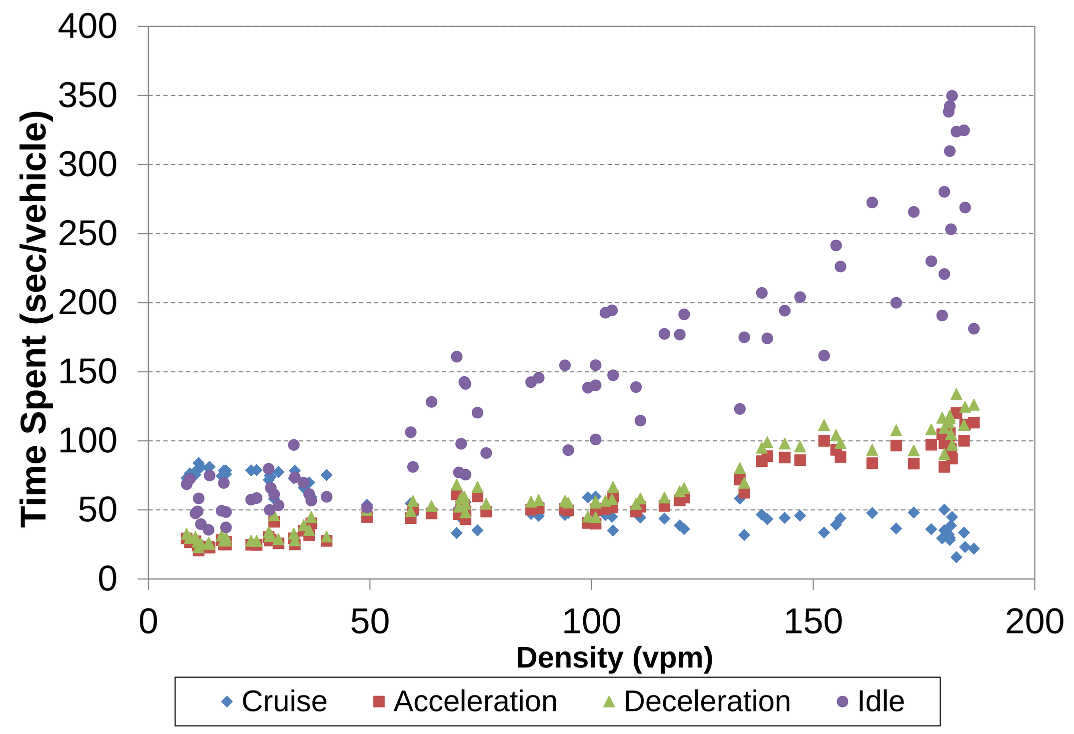
L : total length of the corridor under consideration

$\bar{t}_C$: average travel time in cycle C

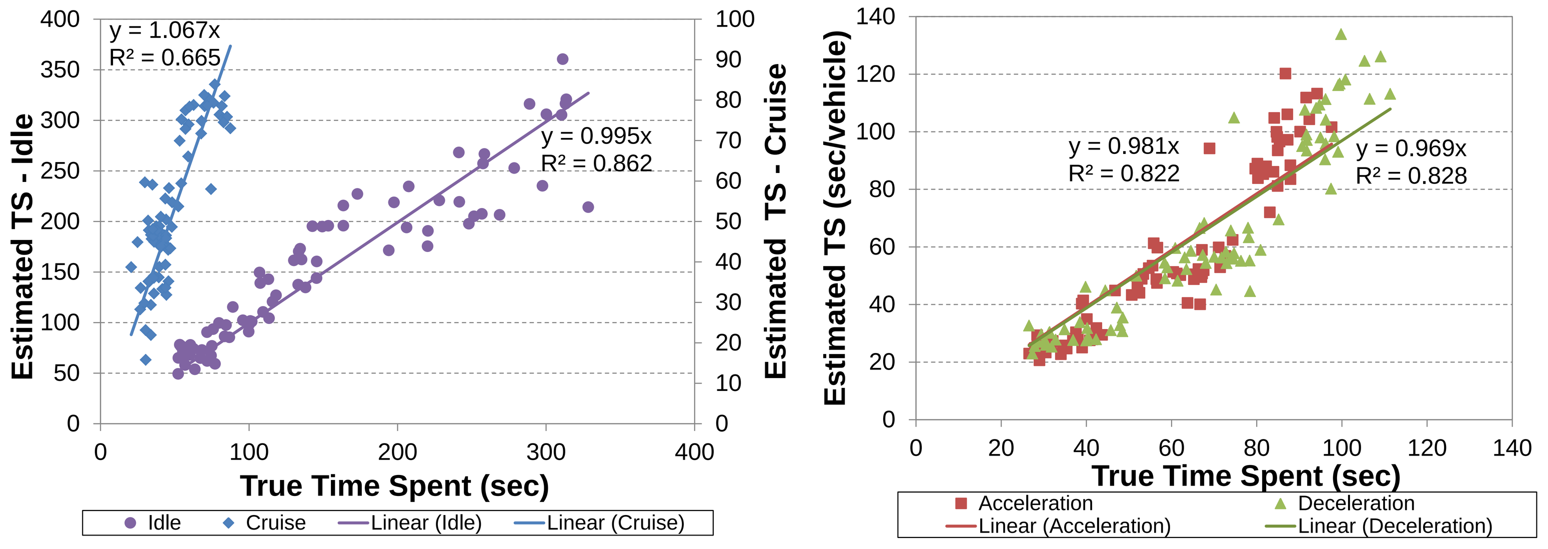
Simulation Experiments

- 4 hours of simulation in CORSIM
- Time dependent demand
- Focused on northbound direction
- Trajectory data file read by Vehicle Trajectory Analysis for Performance Evaluation (VTAPE) Program[4]

Well-defined relationship between driving mode and average density for a wide range of demand profiles



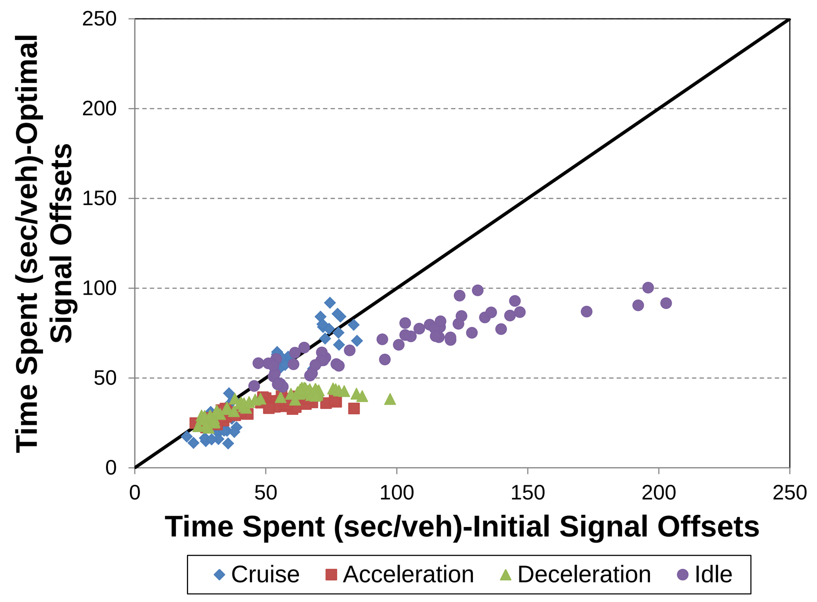
Analytical Model Application



Comparison of Estimated and Simulated Time Spent (TS) per Cycle per Driving Mode

Offset Optimization

For NB direction of Lincoln Avenue using SYNCHRO software



Optimal offsets result in:

- significant reduction in time spent idling, accelerating, decelerating
- 8% reduction in travel time
- 20% reduction in delay
- 15% reduction of emissions

Discussion

- An analytical model to ***estimate the time spent per driving mode at signalized arterials*** is developed.
- The model based on data commonly provided by **system loop detectors** and the **signal settings**.
- Comparison with simulated data shows that it accurately estimates the time spent per driving mode for a wide range of operating conditions
- The model can be used along with emissions factors per driving mode to estimate emissions and evaluate the performance of emission reduction and signal control strategies.

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4. Courage, K., (2010), Vehicle Trajectory Analysis for Performance Evaluation (VTAPE), Preliminary Documentation, Version 1.10, University of Florida.
5. Frey, H., N. Rouphail, A. Unal, and J. Colyar, (2001), Emission Reduction Through Better Traffic Management: An Empirical Evaluation Based Upon On-Road Measurements, Report No. FHWA/NC/2002-001, North Carolina Department of Transportation, USA.