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ECO-ITS: Intelligent Transportation System Applications to Reduce Environmental Impact

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Intelligent Transportation Systems: Targeted Benefits

- **Improving Safety:**
  - **reducing accidents**
  - **making accidents more survivable**
- **Improving Transportation Efficiency:**
  - **increasing throughput**
  - **reducing congestion**
  - **maximizing economic benefits**
- **Energy/Environment:**
  - **in-direct benefits of lower emissions and fuel savings**
  - **directed benefits to *target* lower emissions/fuel**

UCR Research Focus: ECO-ITS (since 2006)

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UC Riverside ECO-ITS Research:

Part 3: ***Real-Time Vehicle Environmental Information Research***

- **Quantify Energy/Emission Impacts of ITS Projects**
  - **developing new modeling methods**
  - **vehicle activity research using probe vehicles**
  - **real-time traffic data monitoring techniques**

Part 1: ***Arterial Roadway Energy/Emissions Estimation using Trajectory Reconstruction***

- **Dynamic ECO-Driving Research**
  - **en-route driving information**
  - **variable speed management – highways**
  - **variable speed management – signalized arterials**

Part 2: ***Dynamic ECO-Driving on Signalized Corridors***

- **ECO-Routing Research**
  - **light-duty vehicle implementation and testing**
  - **heavy-duty vehicles implementation**
  - **research on congestion and road grade effects**
  - **navigation mobility index development**

Part 1: Arterial Roadway Energy/Emissions Estimation using Trajectory Reconstruction

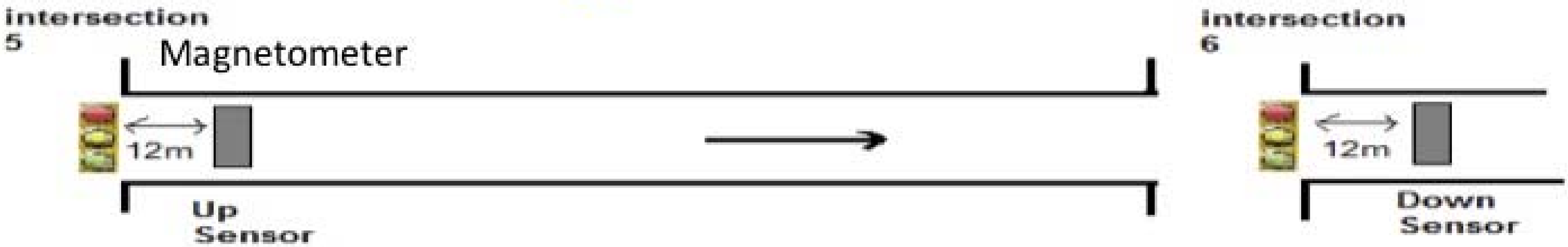
- **Objective**
  - **Estimate *traffic* emissions and fuel consumption along a signalized arterial using a travel time measurement system**
- **Modeling Approaches**
  - **Macroscopic:** flow × constant(link)
  - **Mesoscopic:** ∑ emissions(avg_speed)
  - **Microscopic:** ∑ emissions(second-by-second)

reference:

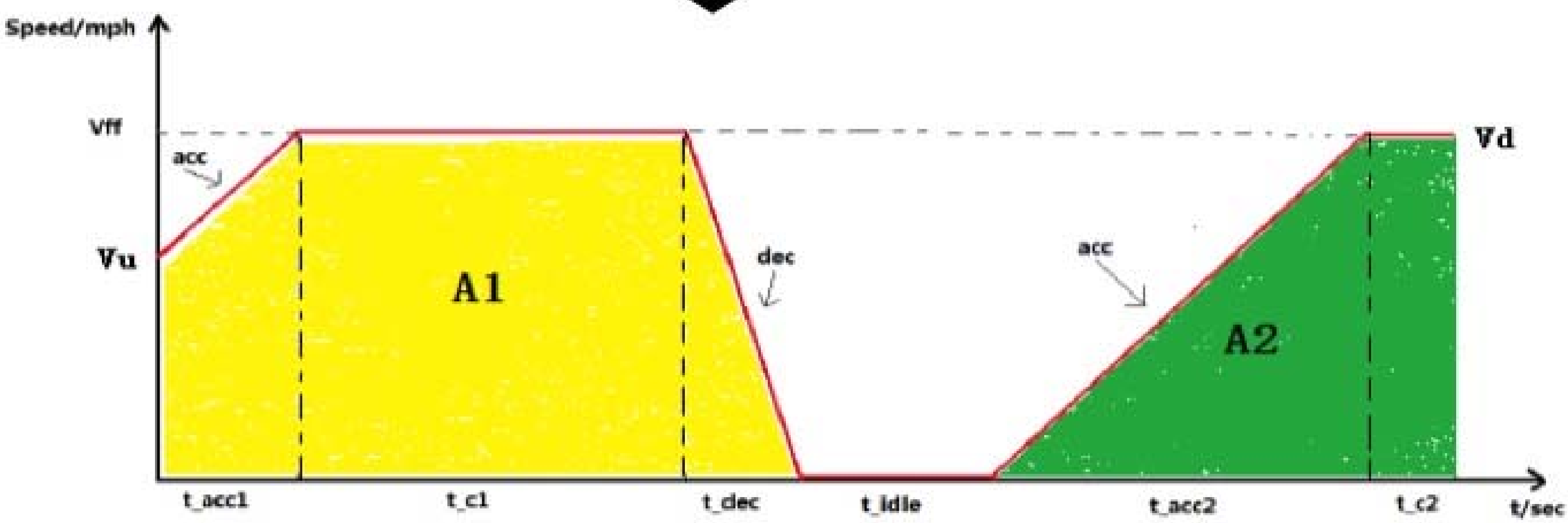
Q. Yang et al., "Arterial Roadway Energy/ Emission Estimation using Modal-Based Trajectory Reconstruction", *Proceedings of the IEEE Intelligent Transportation Systems Conference*, Washington, D.C., October, 2011.

Telegraph Road, Chula Vista, CA

Methodology:



Vehicle count, travel time, time stamp, $occupancy_{up}$, $occupancy_{down}$	$speed_{up}$, $speed_{down}$, queue length



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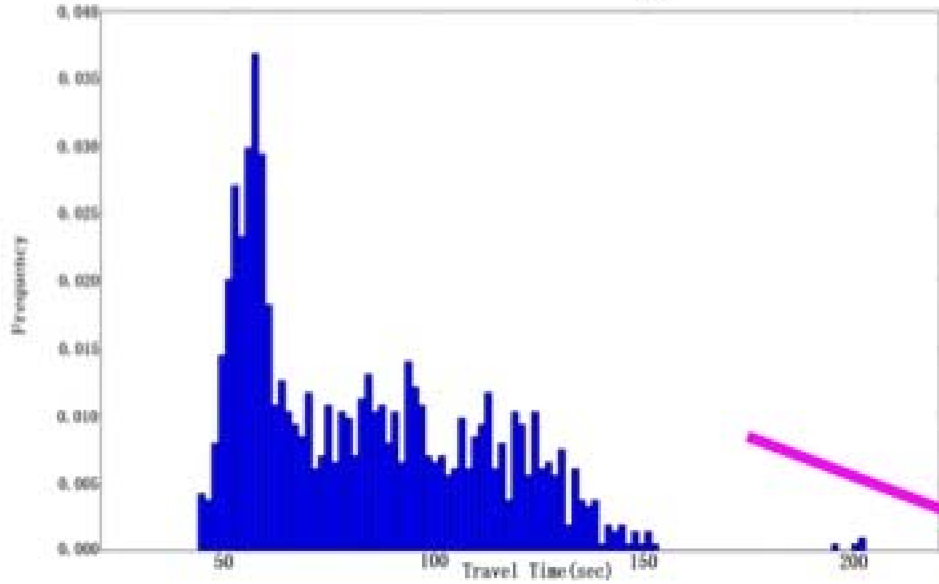
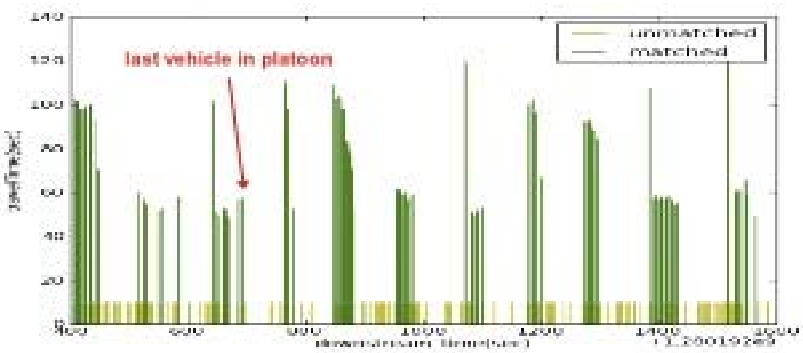
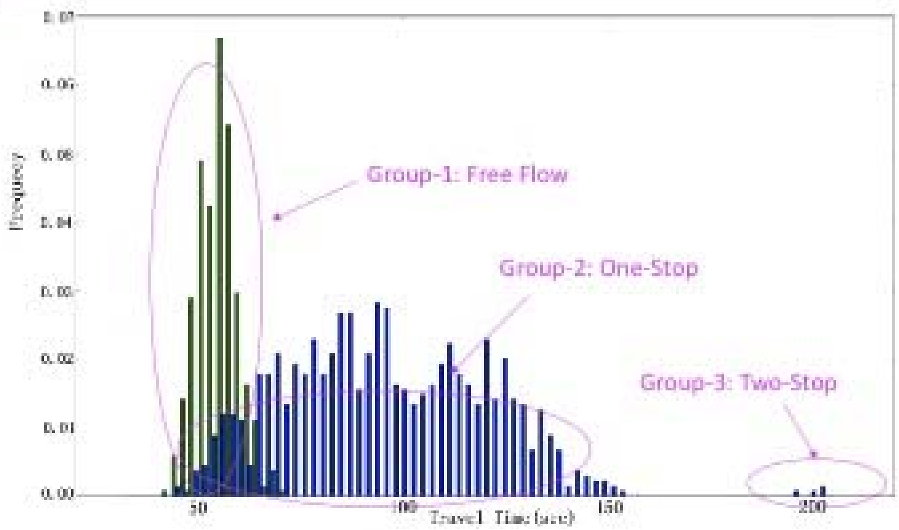
Travel Time Histogram







Example Results:

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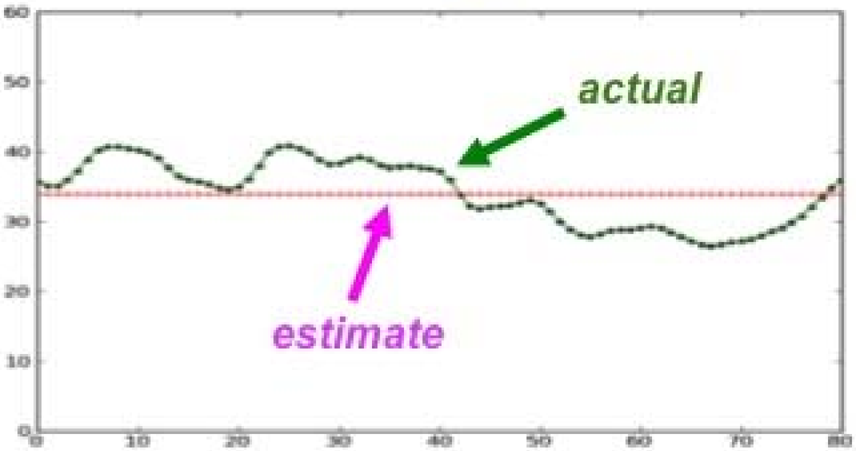
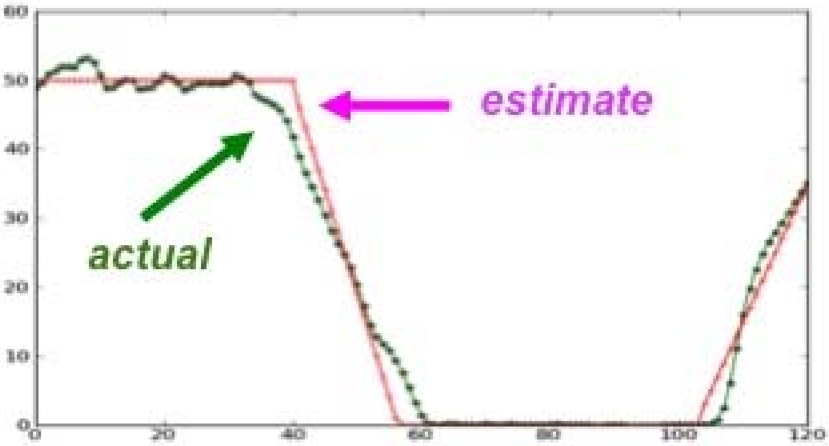
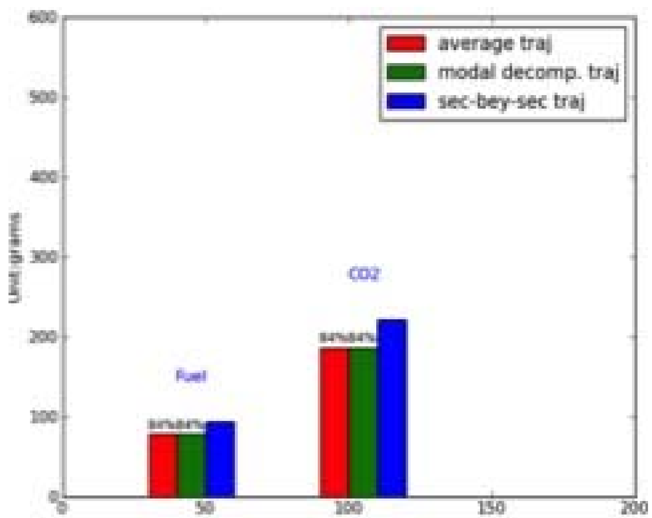
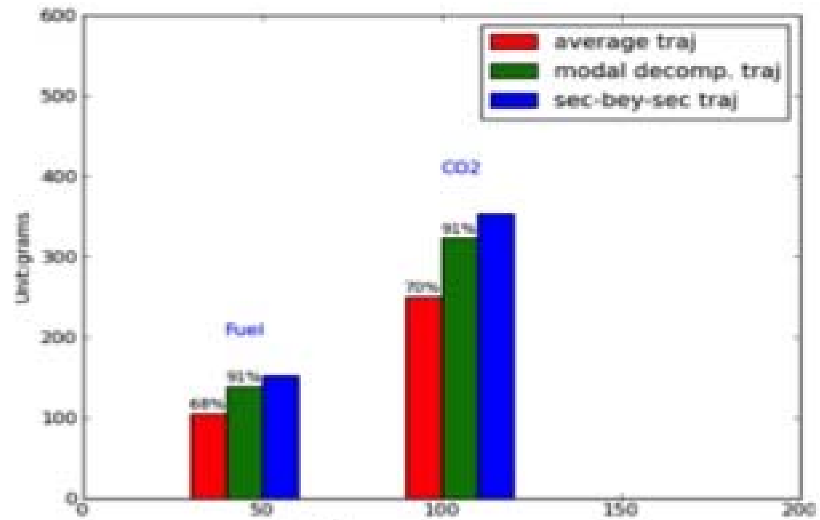






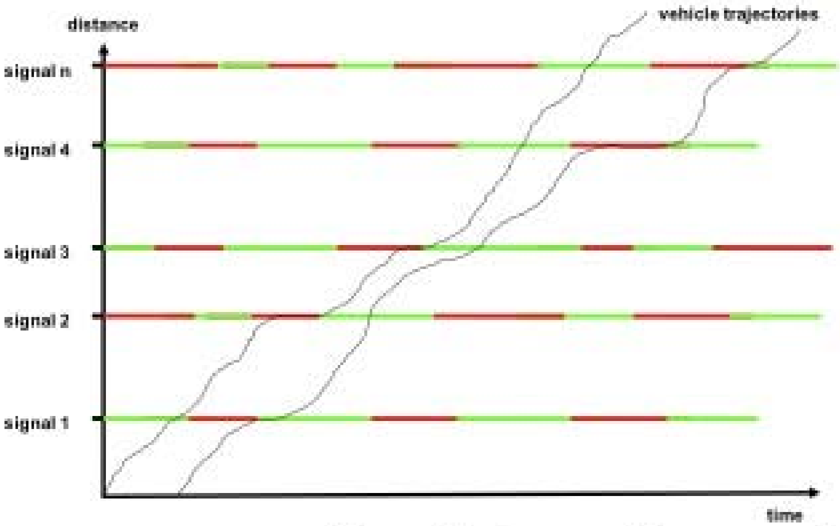
No modeling benefit



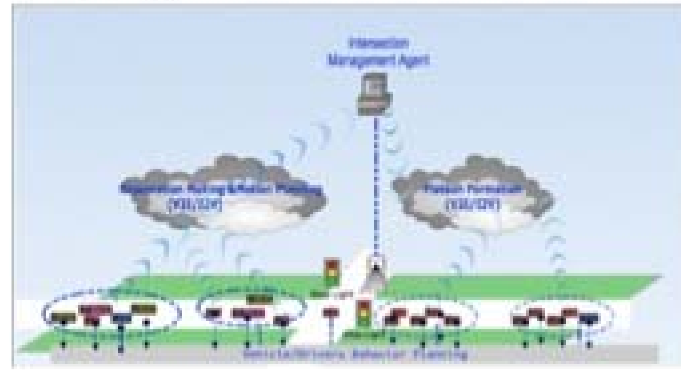
70% → 91% improvement

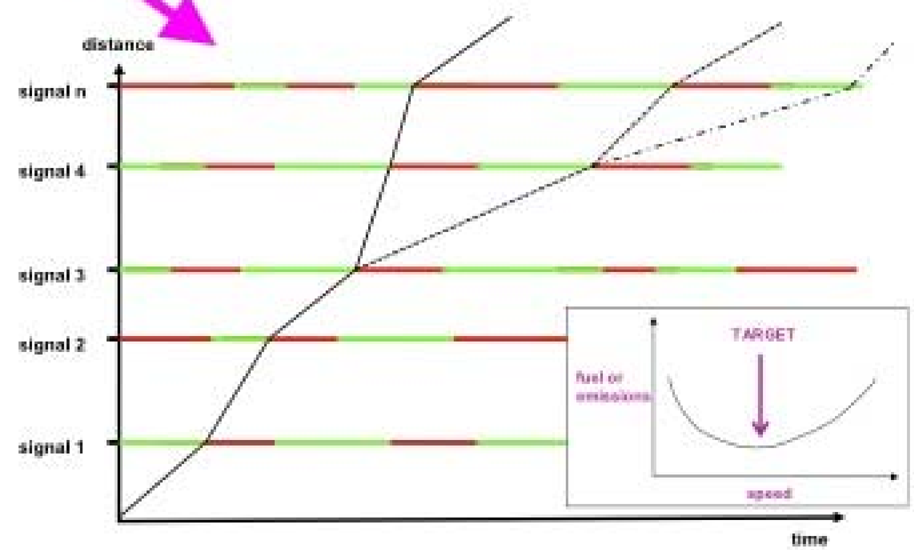
Overall: ***new method typically has 10% error***
old method typically has 40% error

Part 2: Dynamic ECO-Driving on Signalized Corridors (a.k.a. "ECO-Signals")



time-distance diagram of disorganized traffic through corridor



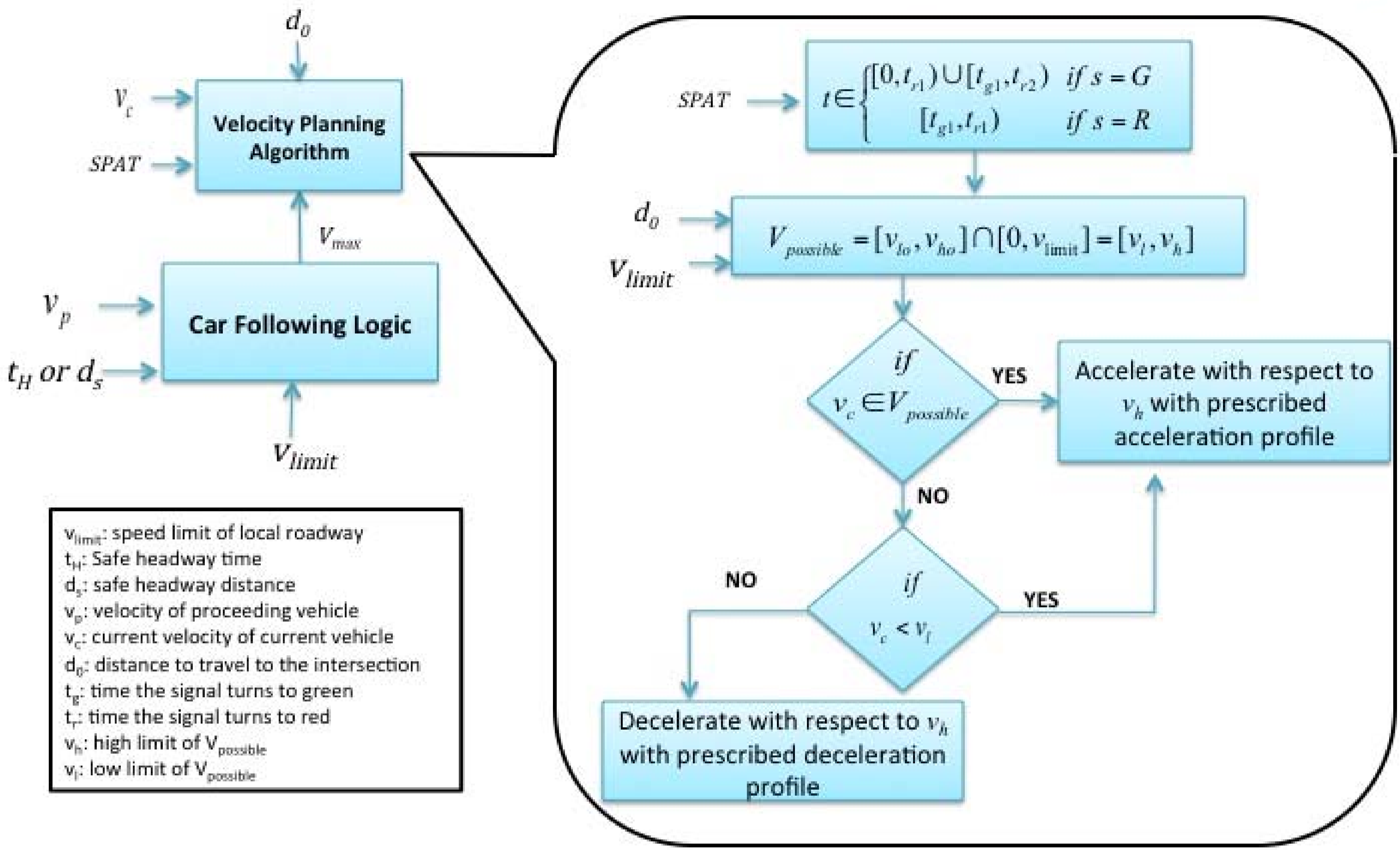


time-distance diagram of organized traffic through corridor using SPaT

references:

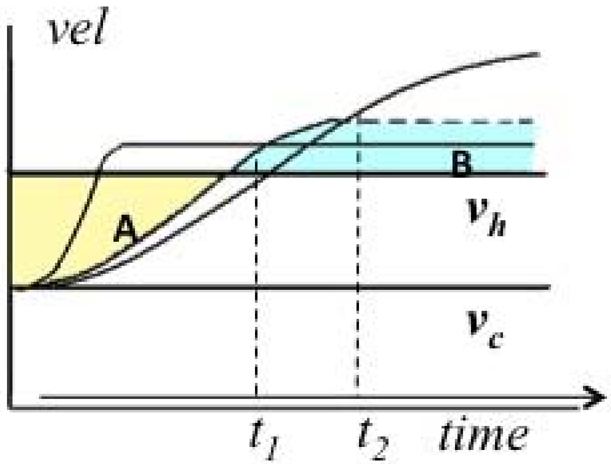
M. Barth et al., "Dynamic ECO-Driving for Arterial Corridors", *Proceedings of the 2011 IEEE Forum on Integrated Sustainable Transportation (FISTS)*, Vienna, Austria, June, 2011.

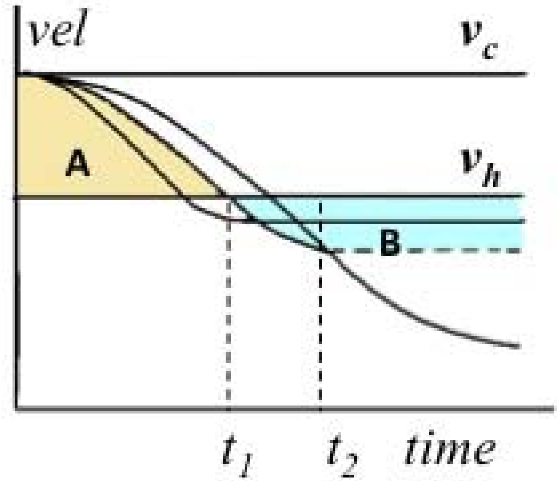
H. Xia et al., "Indirect Network-wide Energy/Emissions Benefits from Dynamic ECO-Driving on Signalized Corridors", *Proceedings of the 2011 IEEE Intelligent Transportation Systems Conference 2011*, Washington, DC; Oct. 2011



Arterial Velocity Planning Algorithm

Acceleration/Deceleration Trajectories Design





v_c: current velocity of the vehicle
v_h: high limit of $V_{possible}$
v_l: low limit of $V_{possible}$
$V_{possible}$: possible constant speeds for vehicle to travel through the intersection ahead without idling

$$a = \frac{1}{2}\left(-s\left(\frac{\pi}{2} - Ts\right) + \sqrt{s^2\left(\frac{\pi}{2} - Ts\right) - 4s^2\left(\frac{\pi}{2} - 1\right)}\right) \qquad v_d = v_h - v_c$$

$$v = \begin{cases} v_{max} - v_d \cos(st) & for\ t = 0\ to \dfrac{\pi}{2s} \\ v_{max} - v_d * \dfrac{s}{a} * \cos a\left(t - \dfrac{\pi}{2s} + \dfrac{\pi}{2a}\right) & for\ t = \dfrac{\pi}{2s}\ to (\dfrac{\pi}{2a} + \dfrac{\pi}{2s}\ ) \\ v_{max} + v_d * \dfrac{s}{a} & for\ t = (\dfrac{\pi}{2a} + \dfrac{\pi}{2s}) to \dfrac{d}{v_{max}} \end{cases}$$

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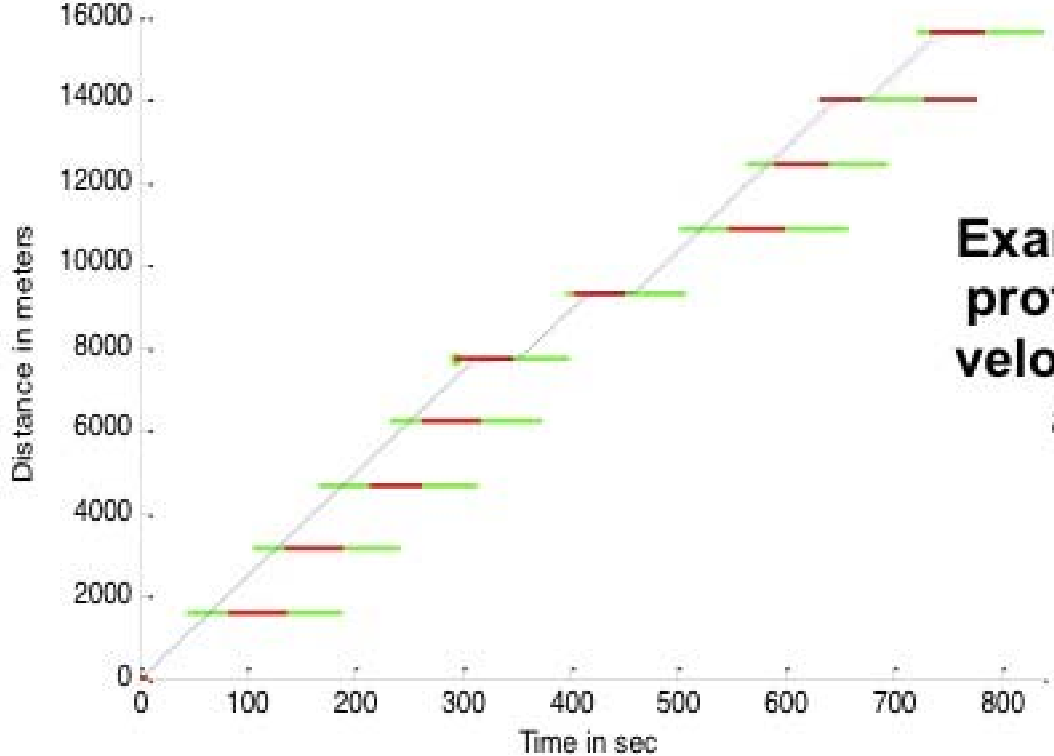
Results:



Example velocity profile using the velocity planning algorithm

passenger car	Without		With		Diff. in Avg.
	Avg.	*S.D.*	*Avg.*	*S.D.*	
Fuel (g/mi)	170.1	4.7%	150.8	5.4%	-11.3%
CO_2 (g/mi)	439.3	4.0%	388.0	9.6%	-11.7%
TTPM (sec/mi)	123.4	1.4%	127.6	2.6%	+3.4%

Energy and Emissions Comparison

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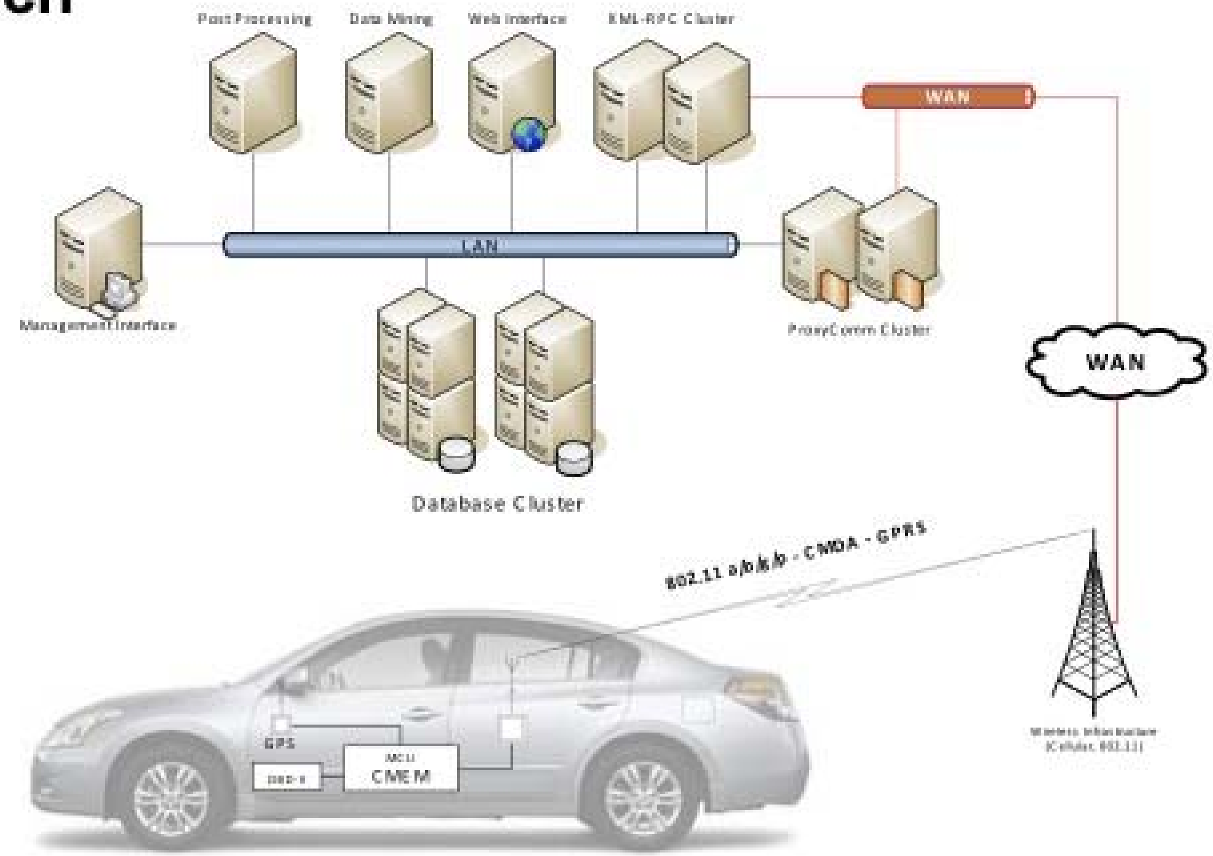
Part 3: Real-Time Vehicle Environmental Information Research



Concept of
Mobile Energy/Emissions Telematic System (MEETS)

UC Riverside ECO-Friendly Intelligent Transportation System (ECO-ITS) Test Bed Vehicle

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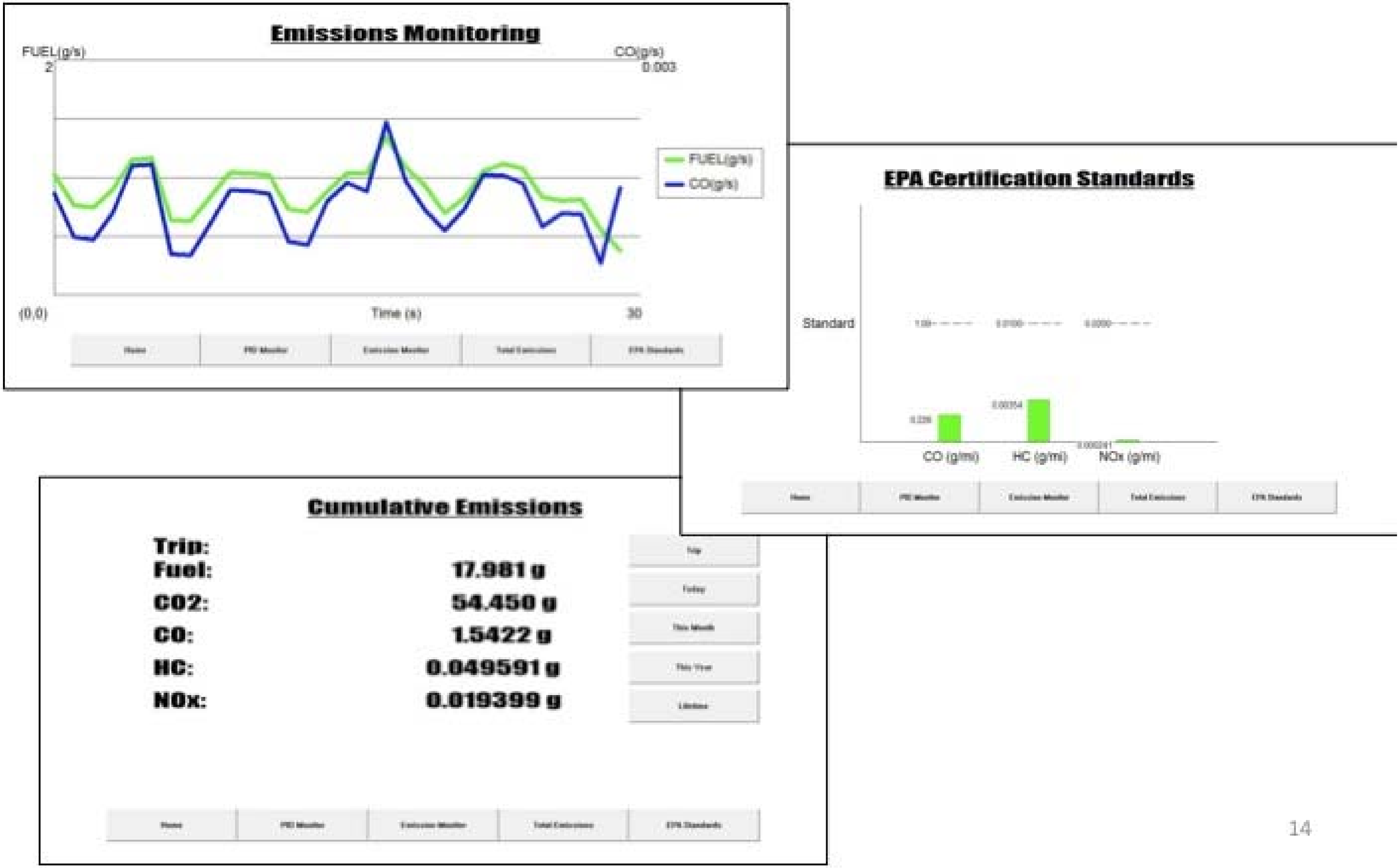
Example screenshots of MEETS on-board application



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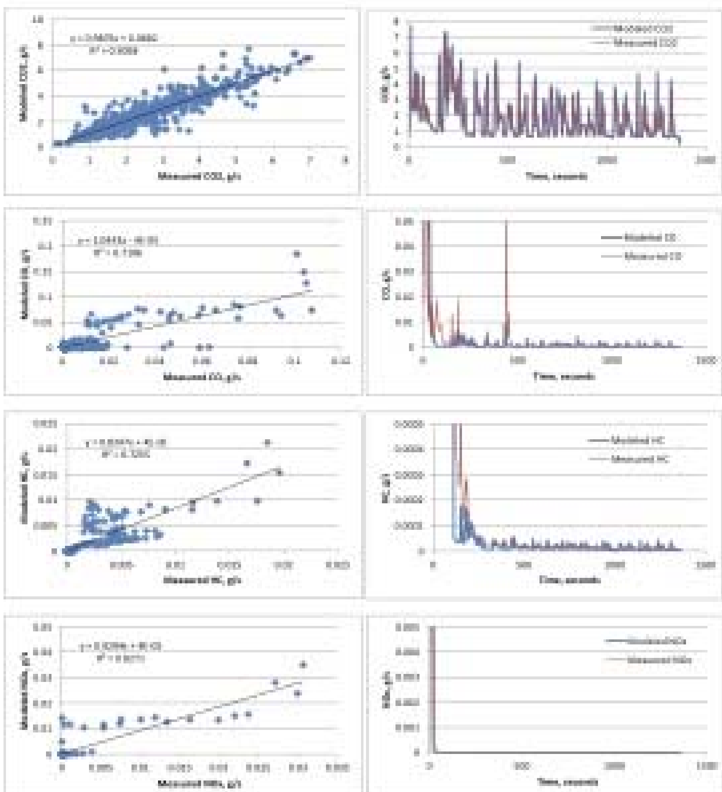
Comparison between total modeled (by MEETS) and measured emissions

	CO2 (g/s)	CO (g/s)	HC (g/s)	NOx (g/s)
Measured	2398.656	3.295	0.514	0.250
Modeled	2434.401	3.388	0.483	0.287
% Difference	1.5	2.8	-5.9	14.6



second-by-second regression plots between modeled (by MEETS) and measured emissions

Conclusions

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- Signalized corridor traffic energy/emissions estimation: new sensors and methods are coming on-line to better estimate traffic activity, including energy and emissions.
- Better quantification is necessary to properly evaluate a variety of ITS programs targeted at signalized corridors.
- ECO-SIGNALS: have greater potential to reduce fuel consumption and emissions compared to a synchronized signal approach.
- ECO-SIGNAL future: categorization and progression: *advanced signal control, I2V-based communications, both I2V & V2I communications together, network equilibration*
- On-Board Energy/Emissions Estimation:
  - Less expensive compared to on-board measurement devices (e.g., PEMS)
  - Can be used for on-board feedback to drivers
  - Can be used for estimating energy/emissions from traffic