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Vehicle Automation and its Role in Energy and Emissions

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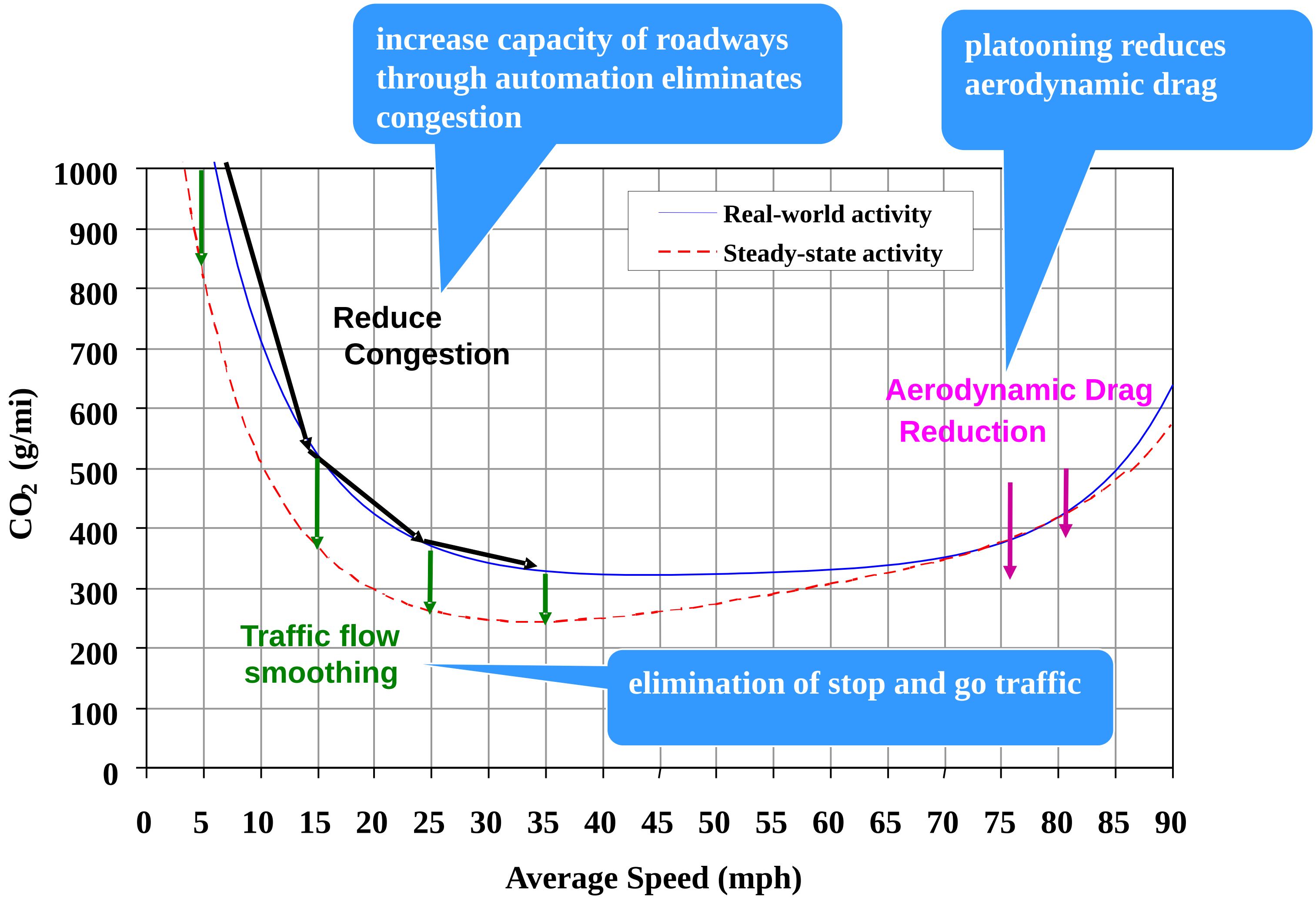
Approaches to Minimize Energy and Emissions Impacts of Transportation:

- **Build cleaner, more efficient vehicles:**
  - **make vehicles lighter (and smaller) while maintaining safety**
  - **improve powertrain efficiency**
  - **develop alternative technologies (e.g.,hybrids, fuel-cell, electric vehicles)**

- **Develop and use alternative fuels:**
  - **Bio and synthetic fuels (cellulosic ethanol, biodiesel)**
  - **electricity**
- **Decrease the total amount of driving: VMT reduction methods**
- **Improve transportation system efficiency through automation**

Three regimes on how to reduce on-road energy and emissions through automation



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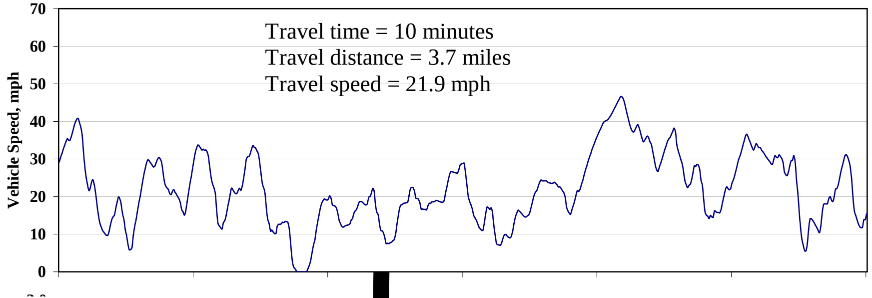
Modeling Methodology:

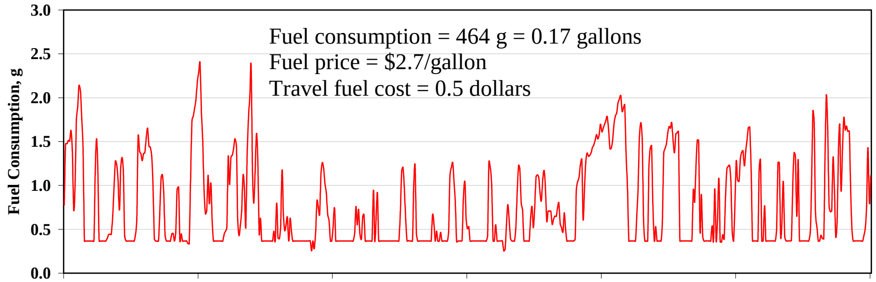


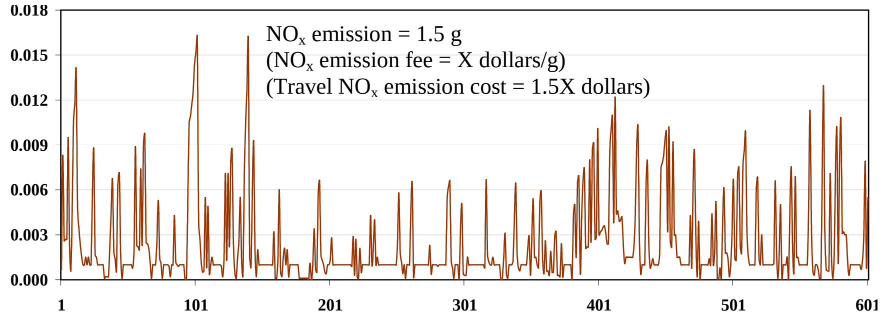
vehicle activity

(velocity trajectory and grade if available)

Comprehensive Modal Emissions Model

calibration parameters



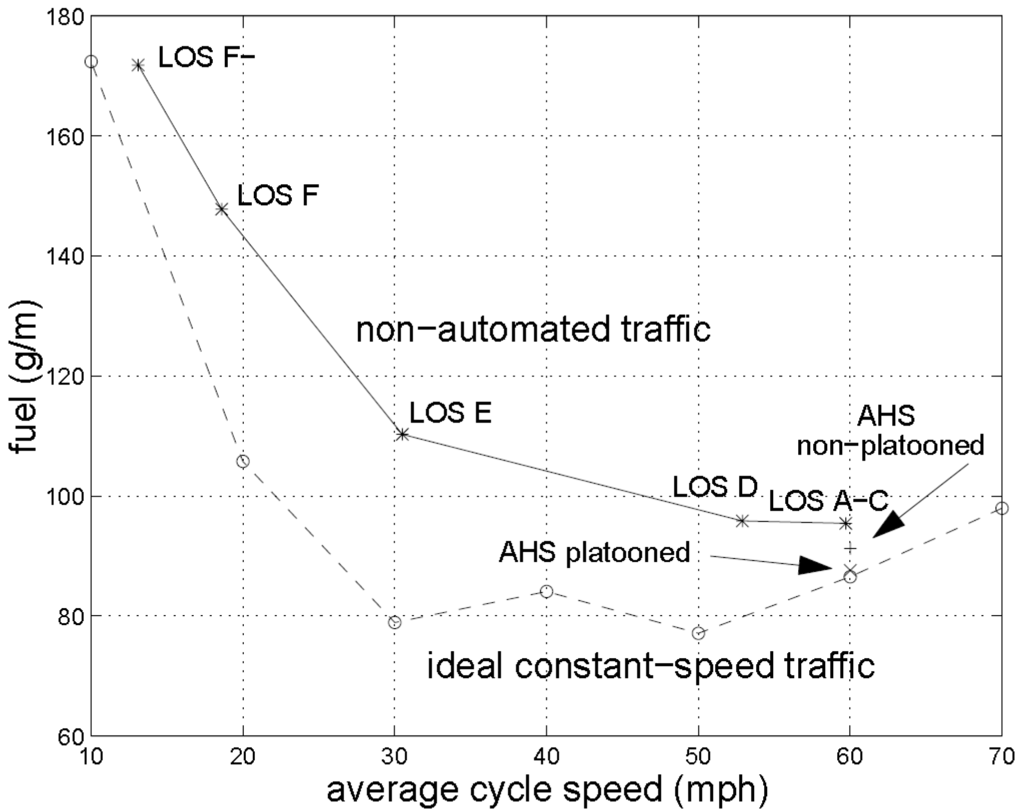


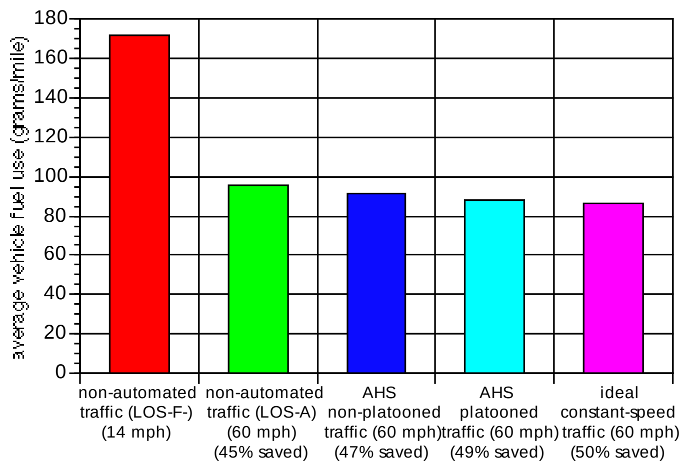
fuel consumption

emissions

Initial Energy and Emissions Analysis of Automated Highway Systems:

- sponsored by NAHSC/PATH
- CO_2 and fuel are linearly related
- used energy/emissions model with typical driving activity





reference:

M. Barth, "An emissions and energy comparison between a simulated automated highway system and current traffic conditions," *Proceedings of the 2000 IEEE Intelligent Transportation Systems Conference*, Dearborn, MI, Oct. 2000

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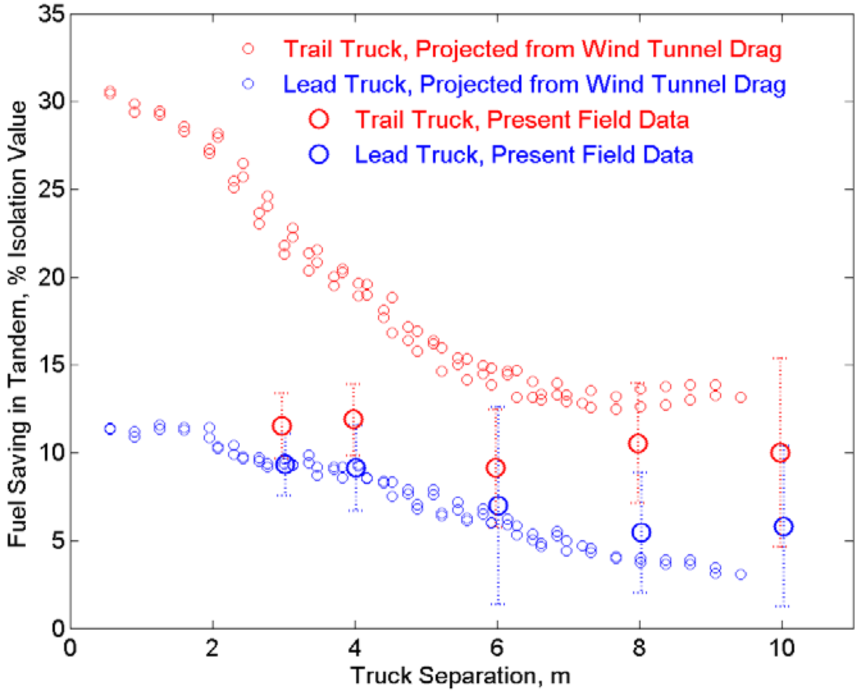
Fuel Saved by Trucks Driving in Close-Formation Platoons (PATH et al., 2003)



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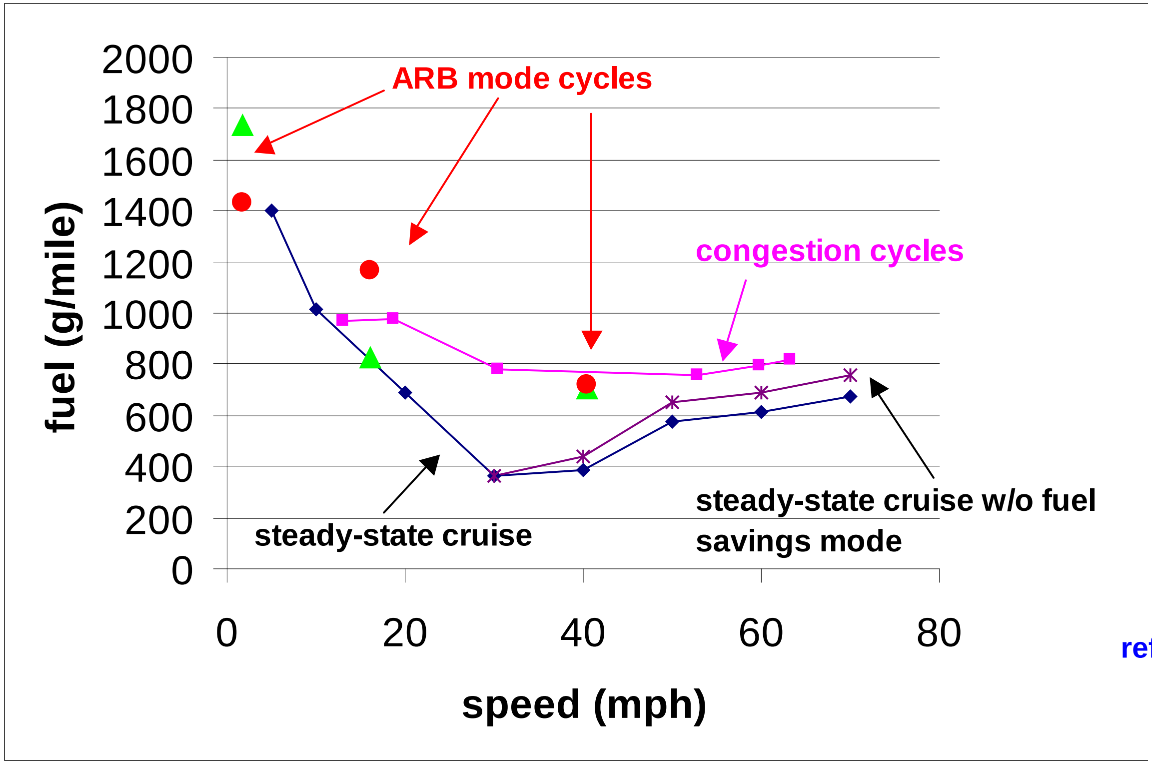
Energy and Emissions Analysis of Heavy Duty Trucks:

- **sponsored by PATH, U.S. EPA, CARB**
- **CO_2 and fuel are linearly related**
- **measured (and modeled) energy/emissions of heavy duty trucks**



Follow Truck raw data			
spacing	Avg CO2 gm/s	Avg NOx gm/s	Avg fuel gm/s
inf M	33.44	0.2004	10.57
10 M	30.91	0.1975	9.78
8 M	30.78	0.1938	9.74
6 M	29.58	0.1926	9.36
4 M	27.50	0.1982	8.70

reference:

M. Barth, "Development of a Heavy-Duty Diesel Modal Emissions and Fuel Consumption Model", *PATH Technical Report for MOU-4215*, September, 2004.

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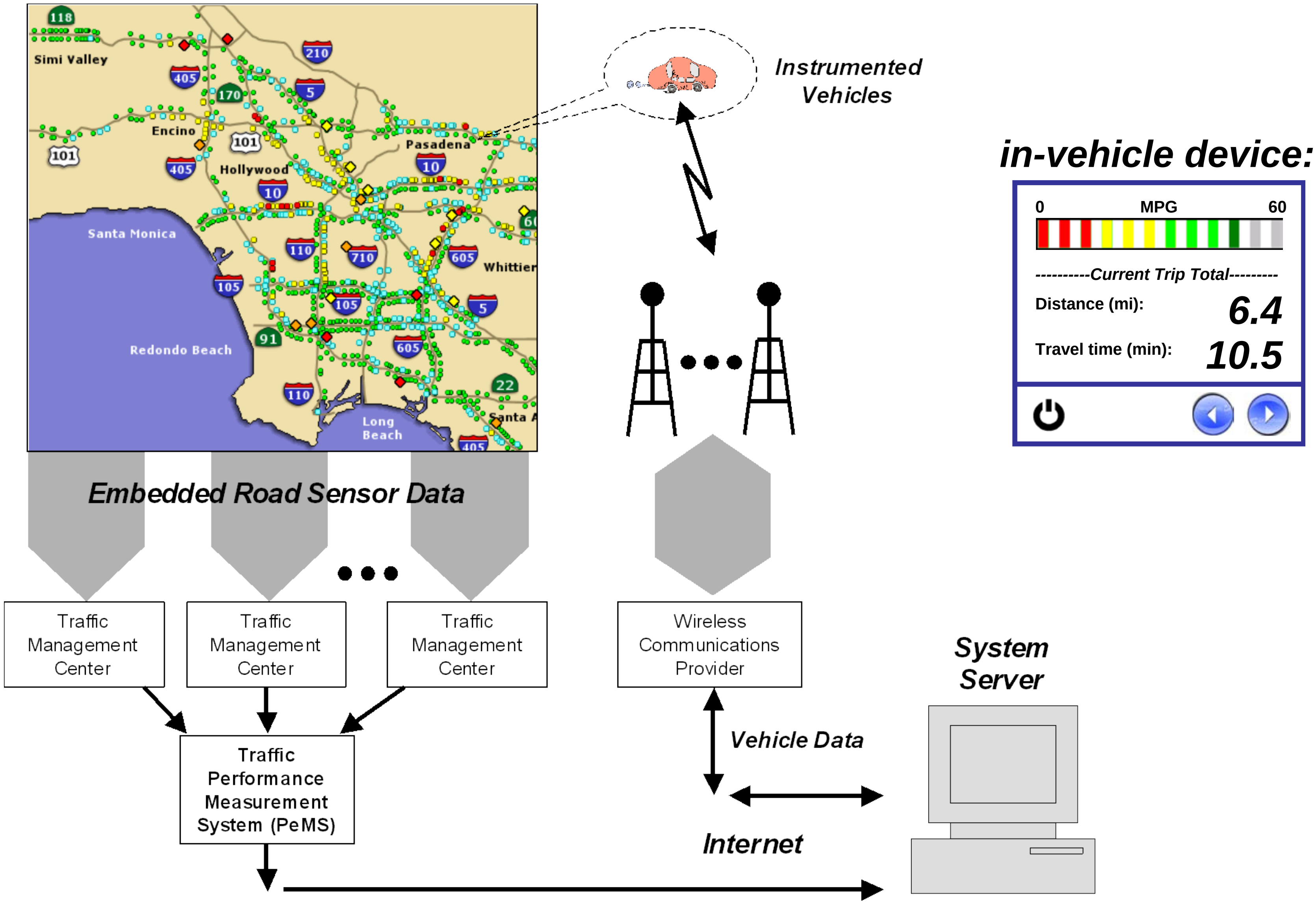
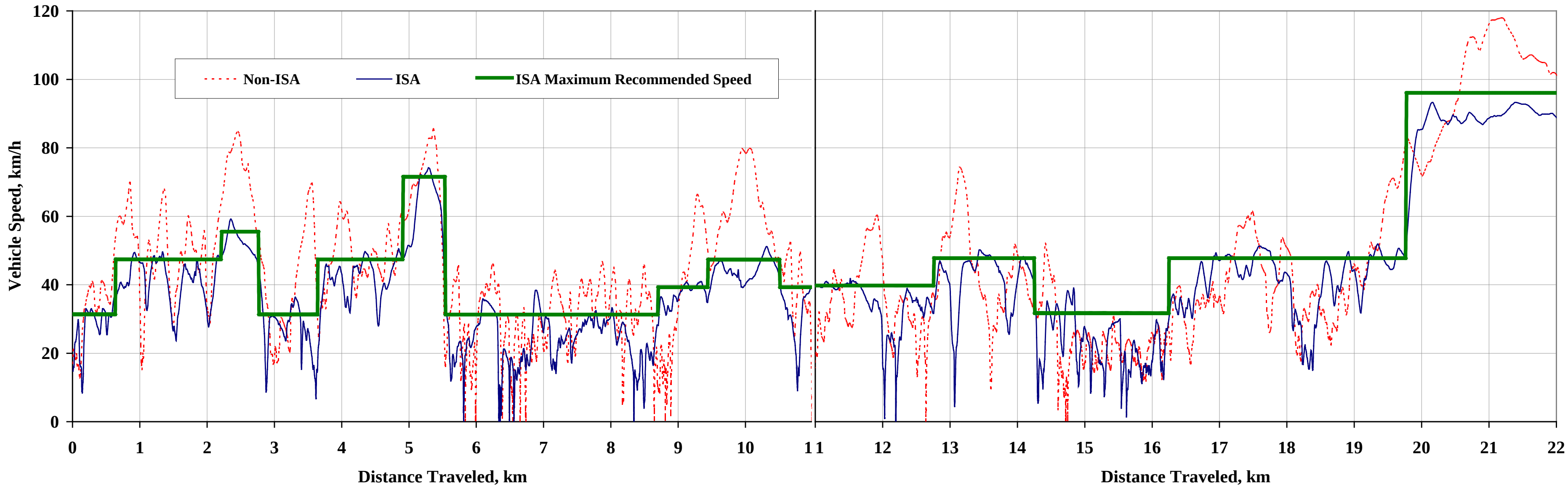
System Architecture of Dynamic Eco-Driving



Dynamic Eco-Driving Field Experiments: Example Results



same travel time results:

Energy/Emissions	Non-ISA	ISA	Difference
CO_2 (g)	5439	4781	-12%
CO (g)	97.01	50.47	-48%
HC (g)	3.20	1.90	-41%
NO_x (g)	6.28	3.97	-37%
Fuel (g)	1766	1534	-13%

reference:

M. Barth and K. Boriboonsomsin (2008) “Energy and Emissions Impacts of a Freeway-Based Dynamic Eco-Driving System”, in press, *Transportation Research Part D: Environment*, Elsevier Press, August, 2008.

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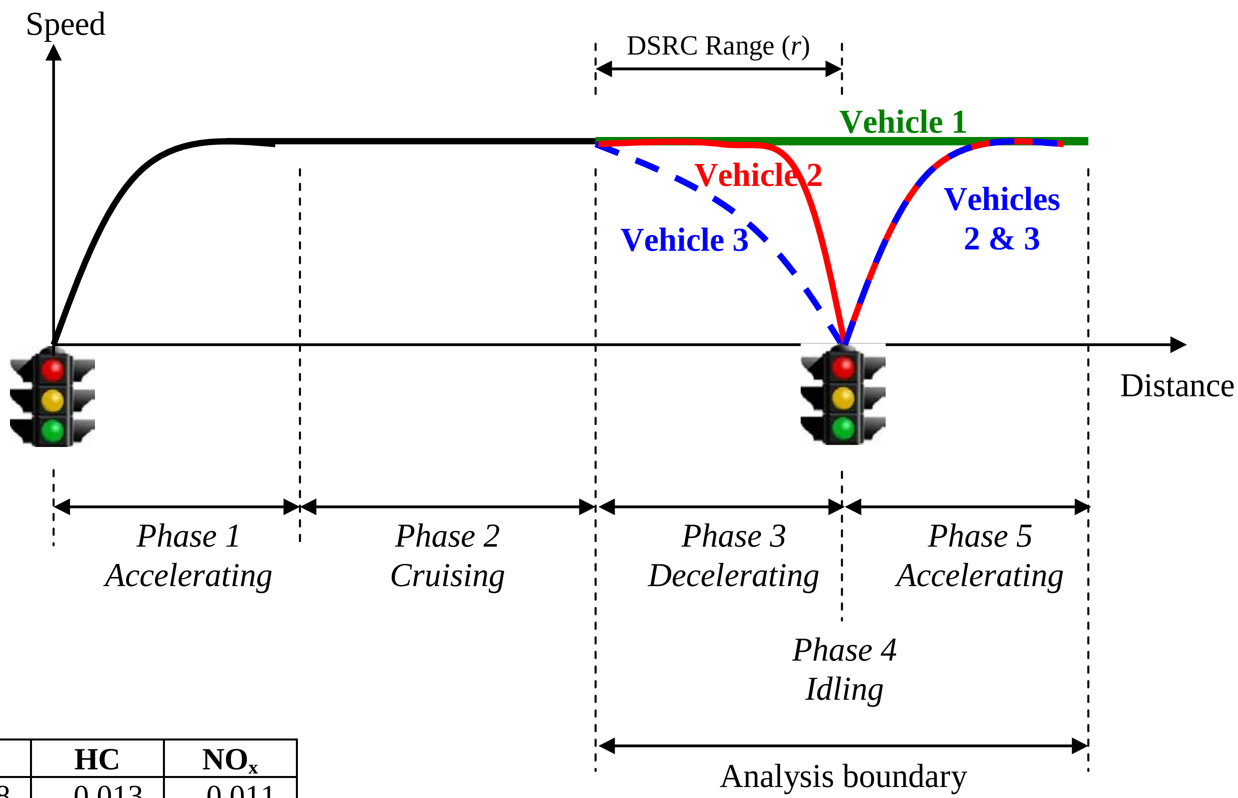
Single Intersection Optimization with Signal Phase and Timing Information

advanced signal information can help reduce intersection-influenced fuel consumption by 14% for cars and 12% for trucks

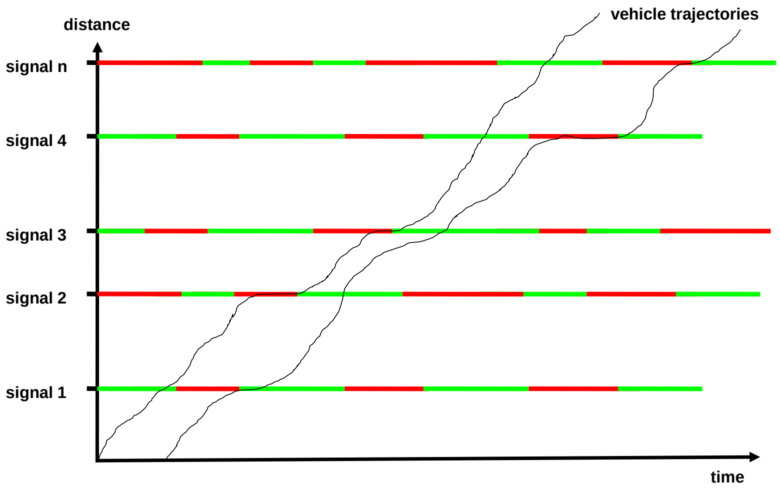


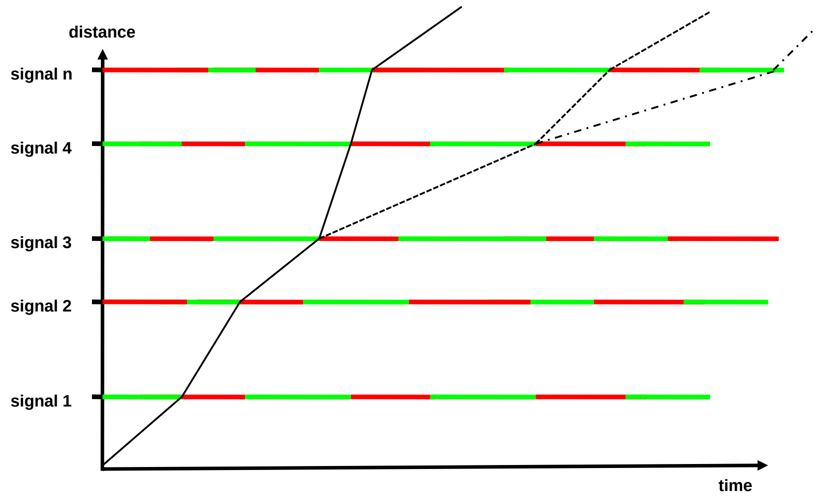
LDV24	Fuel	CO_2	CO	HC	NO_x
Vehicle 1	27.8	87.5	0.378	0.013	0.011
Vehicle 2	70.6	222.4	0.990	0.045	0.063
Vehicle 3	64.5	203.1	0.873	0.034	0.067
% 3 vs 2	*-8.7*	*-8.7*	*-11.8*	*-24.8*	*+6.4*
(2-1)	42.9	134.9	0.612	0.032	0.052
(3-1)	36.7	115.6	0.496	0.021	0.056
% (3-1) vs (2-1)	*-14.3*	*-14.3*	*-19.0*	*-34.7*	*+7.8*

reference:

M. Li et al., “Traffic Energy and Emission Reductions at Signalized Intersections: A Study of the Benefits of Advanced Driver Information”, *submitted to International Journal on ITS*, January, 2009.

Dynamic Eco-Driving on Signalized Corridors





LDV24	**Without**		**With**		**% Diff. in Avg.**	***p*-value of *t*-test**
	Avg.	*S.D.*	*Avg.*	*S.D.*		
Fuel (g/mi)	118.3	13.2	103.8	9.3	-12.3	8.7E-06
CO_2 (g/mi)	371.0	41.2	318.8	25.3	-14.1	3.2E-07
TT (sec)	456.7	60.7	451.9	56.9	-1.06	0.635

references:

S. Mandava et al., “Arterial Velocity Planning based on Traffic Signal Information under Light Traffic Conditions”, 2009 *IEEE Intelligent Vehicle Systems Conference*, October, 2009.

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.

Summary and Conclusions:

- **automation can have a significant impact on environment/energy through better vehicle control, better traffic operations, and better information systems**

Vehicle Systems:

- **Automation (lateral and longitudinal control, platooning, etc.)**
- **Closed loop systems: Smart Engines, HEV energy management**

Traffic Operations:

- **congestion mitigation**
- **smoother traffic flow**

Information Systems:

- **Environmental Friendly Navigation**
- **Dynamic Eco-Driving**
- **Speed Management Systems**

- **Energy/Emissions Savings: Each automation strategy can potentially save 5 – 15%; all strategies can be additive for greater savings**