

International Vehicle Emissions Model - IVE

Mauricio Osses

Department of Mechanical Engineering, University of Chile, Chile

James M. Lents, Nicole C. Davis, Richard M. Nikkila

International Sustainable Systems Research Center, USA

Eduardo Behrentz

Department of Civil and Environmental Engineering, Universidad de Los Andes, Colombia

Matthew J. Barth

Center for Environmental Research and Technology, University of California at Riverside, USA

Introduction

- As the economy of many countries improves, their vehicle fleets and the resulting pollutant emissions can be expected to increase.
- Developed nations have spent many millions of dollars to create methods for estimating the pollutant emissions from their on-road vehicle fleets.
- These methods are generally applicable only to the specific country for which they were created and modifications for use in other locations can be very time consuming and expensive.
- Developing countries usually do not have the funding to support the development of emission estimation methods.

IVE methodology

- A novel approach specifically designed for estimating vehicle emissions in international applications, so-called the *International Vehicle Emissions (IVE)* model, has been developed.
- The IVE model provides a much less expensive and time consuming alternative for developing countries to establish their on-road mobile emission inventory and, to assess the cost effectiveness of pollution management strategies.
- A user can use, or modify, activity data in the database. These include the percentage and types of engine technologies, engine size, acceleration-deceleration characteristics, average distance traveled per day and engine start-ups.

IVE Phase I: Traffic activity studies

Lima, Peru (December 2003);
Los Angeles, USA (2001);
Mexico City, Mexico (January 2004);
Santiago, Chile (December 2001, 2002);
Bogota, Colombia (January 2005)

Almaty, Kazakhstan (May 2003);
Nairobi, Kenya (March 2002);
Pune, India (March 2003);
Beijing, Shanghai, China (2004)



Vehicle Technology Distribution

A two-pronged effort –Parking lot surveys coupled with interviews at bus and trucking operations and, videotaping of traffic on streets.



IVE Phase I: driving composition



Video tape recording: 20 minutes, 7 times/day, 6 days = 14 hours \Leftrightarrow 42 hours

IVE Phase I: vehicle technology



Fuel type
Engine size
Model year
Manufacturer
Model
Mileage
A/C
Transmission
Catalytic
F/A system
Maintenance

IVE Phase I: driving patterns



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6th Open Meeting of the Human Dimensions of
Global Environmental Change

IVE Phase I: cold start emissions



Set-up procedure



Measurement process

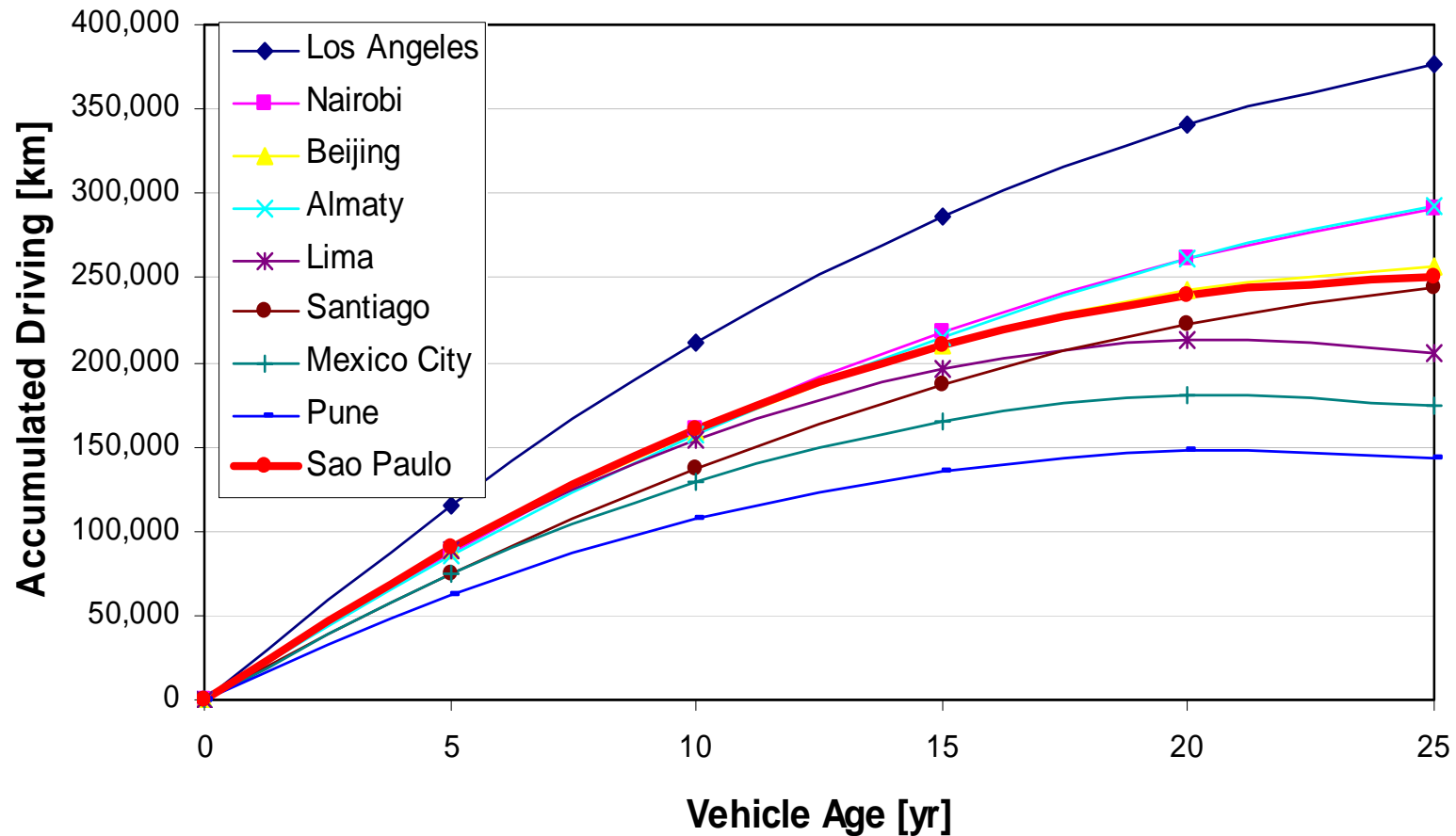


Downloading data

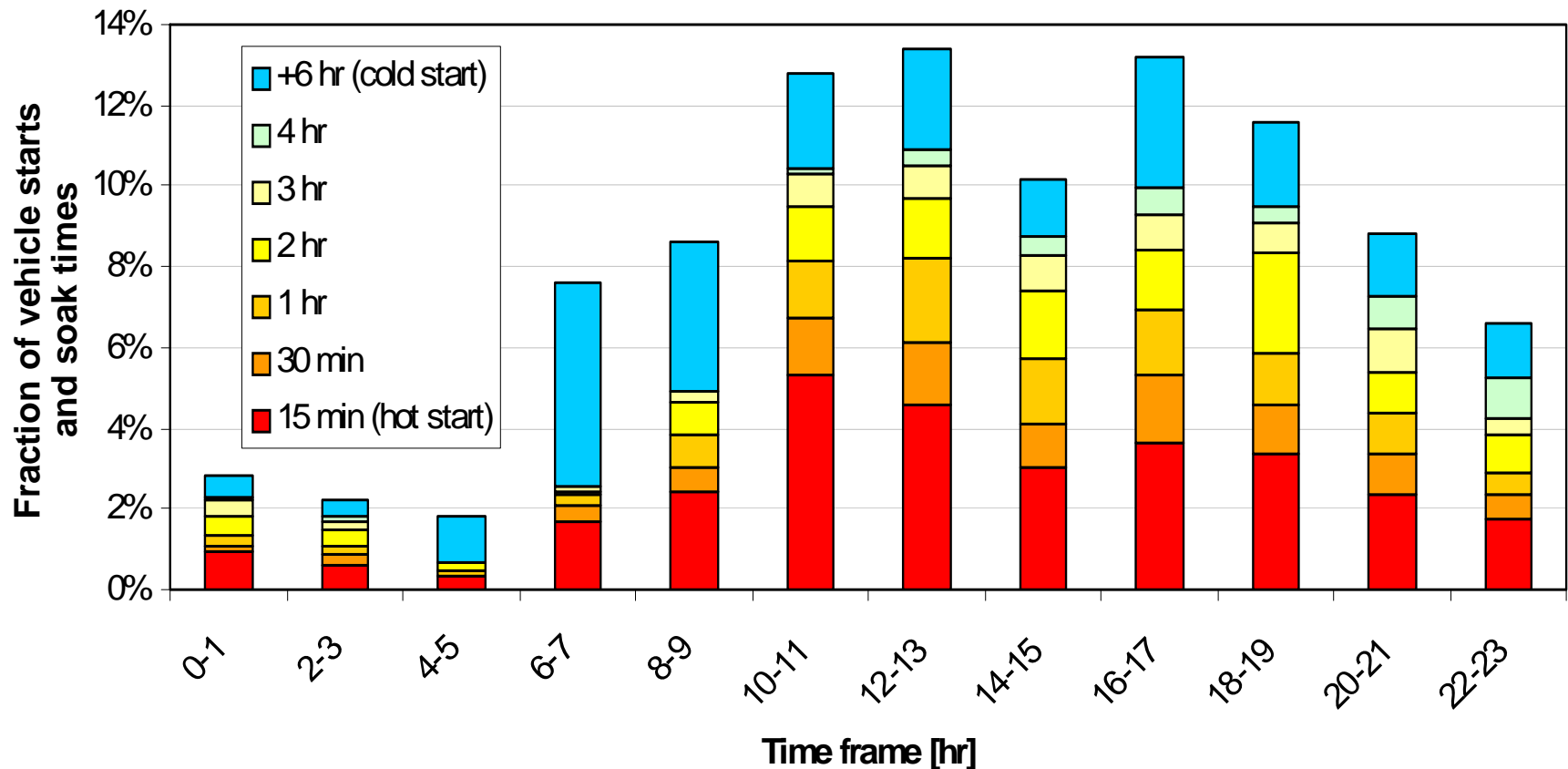
Results: dynamic fleet composition

City, Country	Pass Car	TAXI	2W	3W	BUS	TRUCK	N-M
Almaty Kazakhstan	83%	0%	0%	0%	12%	5%	1%
Bogotá Colombia	44%	32%	5%	0%	15%	5%	0%
Lima Peru	52%	25%	1%	0%	17%	5%	0%
Los Angeles USA	95%	0%	0%	0%	1%	4%	0%
Mexico City Mexico	74%	15%	2%	0%	3%	5%	0%
Nairobi Kenya	88%	1%	2%	0%	4%	5%	1%
Pune India	12%	0%	55%	13%	1%	1%	17%
Santiago Chile	79%	8%	1%	0%	6%	6%	0%
São Paulo Brazil	75%	5%	10%	0%	5%	5%	0%

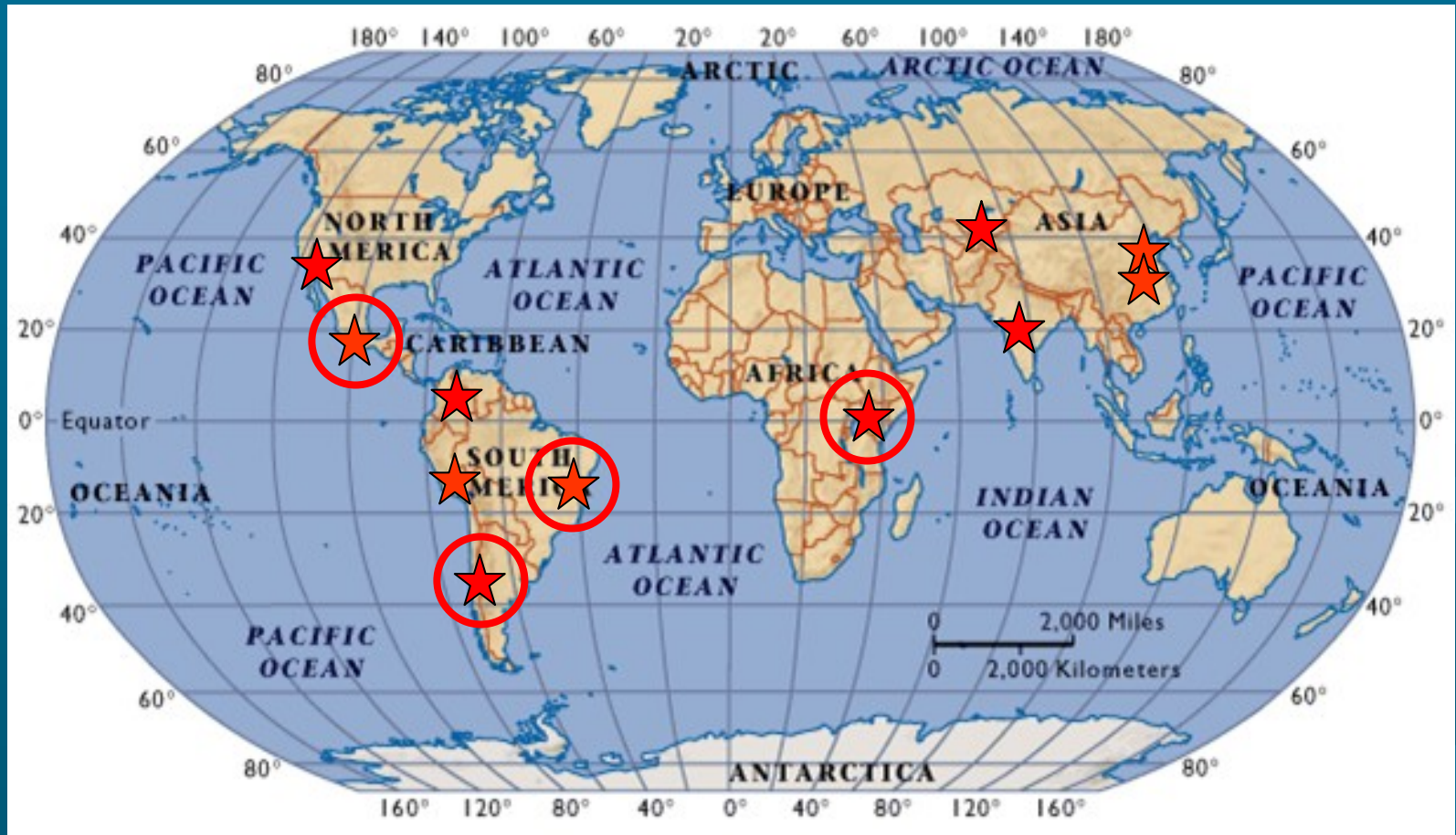
Results: Accumulated driving



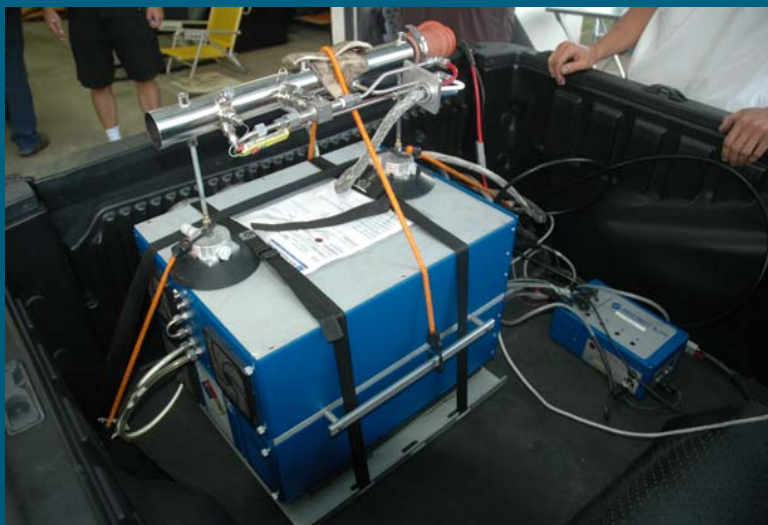
Results: cold starts in Sao Paulo



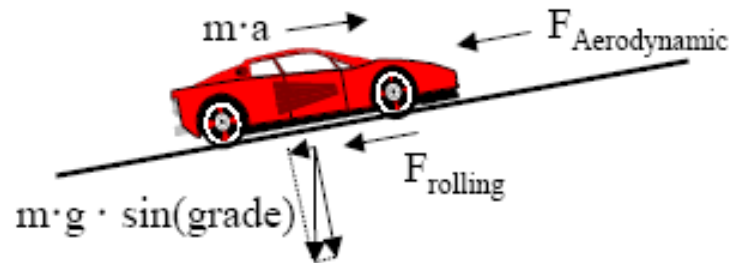
IVE Phase II: Real-world emissions



IVE Phase II: real-world emissions



Vehicle Specific Power (VSP)



$$\text{VSP} = \frac{\text{Power}}{\text{Mass}} = \frac{\frac{d}{dt}(E_{\text{Kinetic}} + E_{\text{Potential}}) + F_{\text{Rolling}} \cdot v + F_{\text{Aerodynamic}} \cdot v + F_{\text{internal friction}} \cdot v}{m} =$$

$$\approx v \cdot a \cdot (1 + \epsilon_i) + g \cdot \text{grade} \cdot v + g \cdot C_R \cdot v + \frac{1}{2} \rho_a C_D \frac{A}{m} (v + v_w)^2 \cdot v + C_{\text{if}} \cdot v$$

Based on:
 José Luis Jiménez, PhD Thesis
 Aerodyne Research and MIT Chemical Engineering

Vehicle Specific Power (VSP)

For typical U.S. light - duty vehicles and light - duty trucks (better estimates of the resistance coefficients should be used when available):

$$\text{VSP} = \frac{\text{Power}}{\text{Mass}} \approx 1.1 \cdot v \cdot a + 9.81 \cdot \text{grade} \cdot v + 0.213 \cdot v + 0.000305 \cdot (v + v_w)^2 \cdot v$$

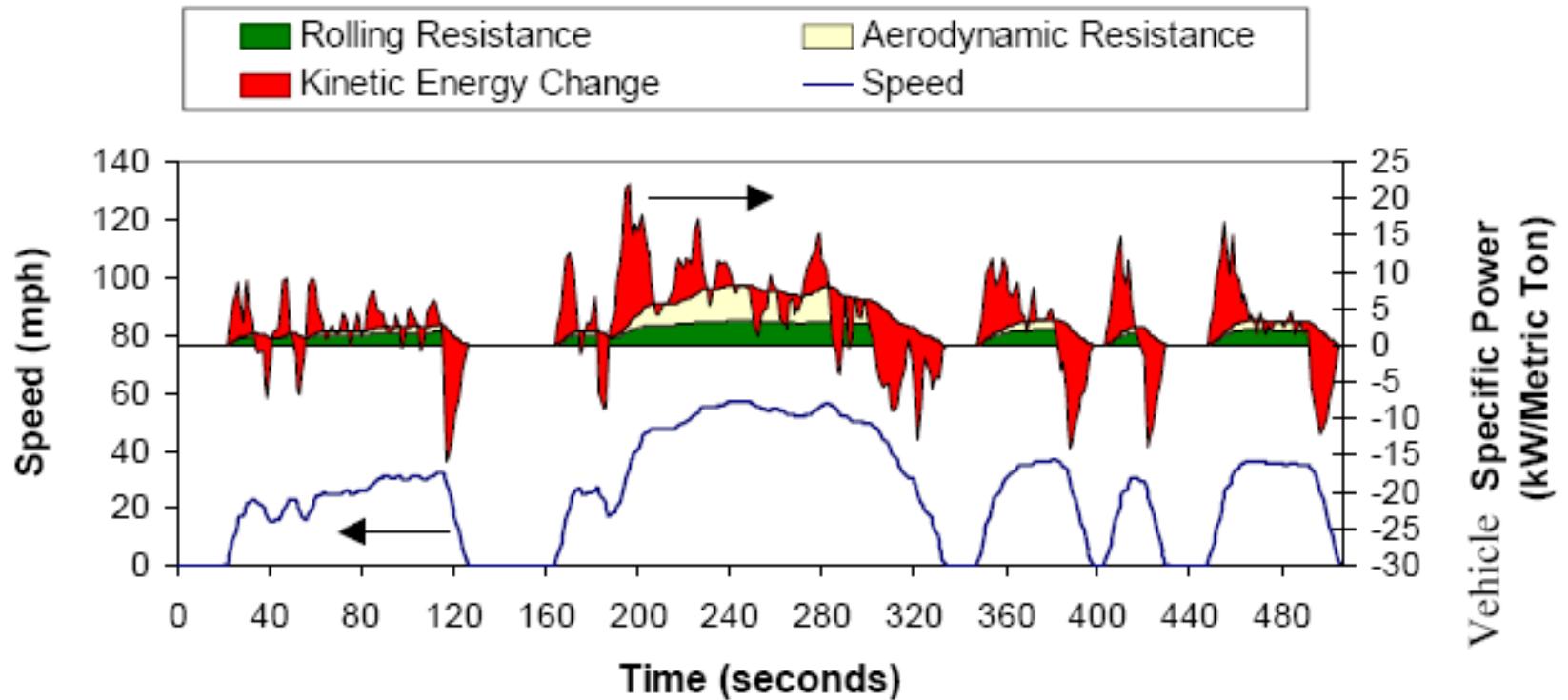
with VSP in kW/Metric Ton, v (speed) and v_w (headwind into the vehicle) in m/s, a (acceleration) in m/s^2 , grade defined as vertical rise/horizontal distance

$$\text{VSP} = \frac{\text{Power}}{\text{Mass}} \approx 0.22 \cdot v \cdot a + 4.39 \cdot \text{grade} \cdot v + 0.0954 \cdot v + 0.0000272 \cdot (v + v_w)^2 \cdot v$$

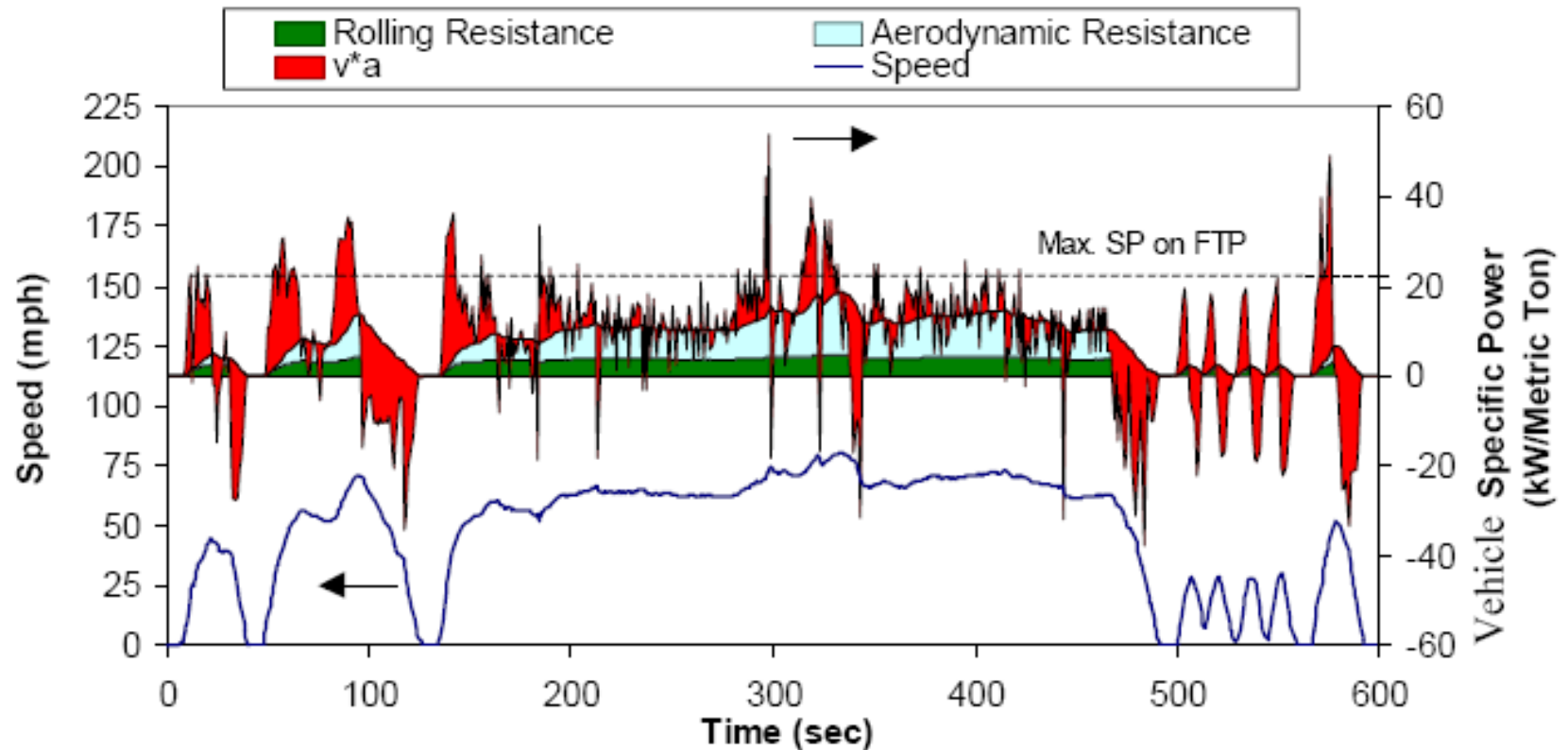
(VSP in kW/Metric Ton, v and v_w in mph, a in mph/sec)

VSP in Emissions Certification Cycles

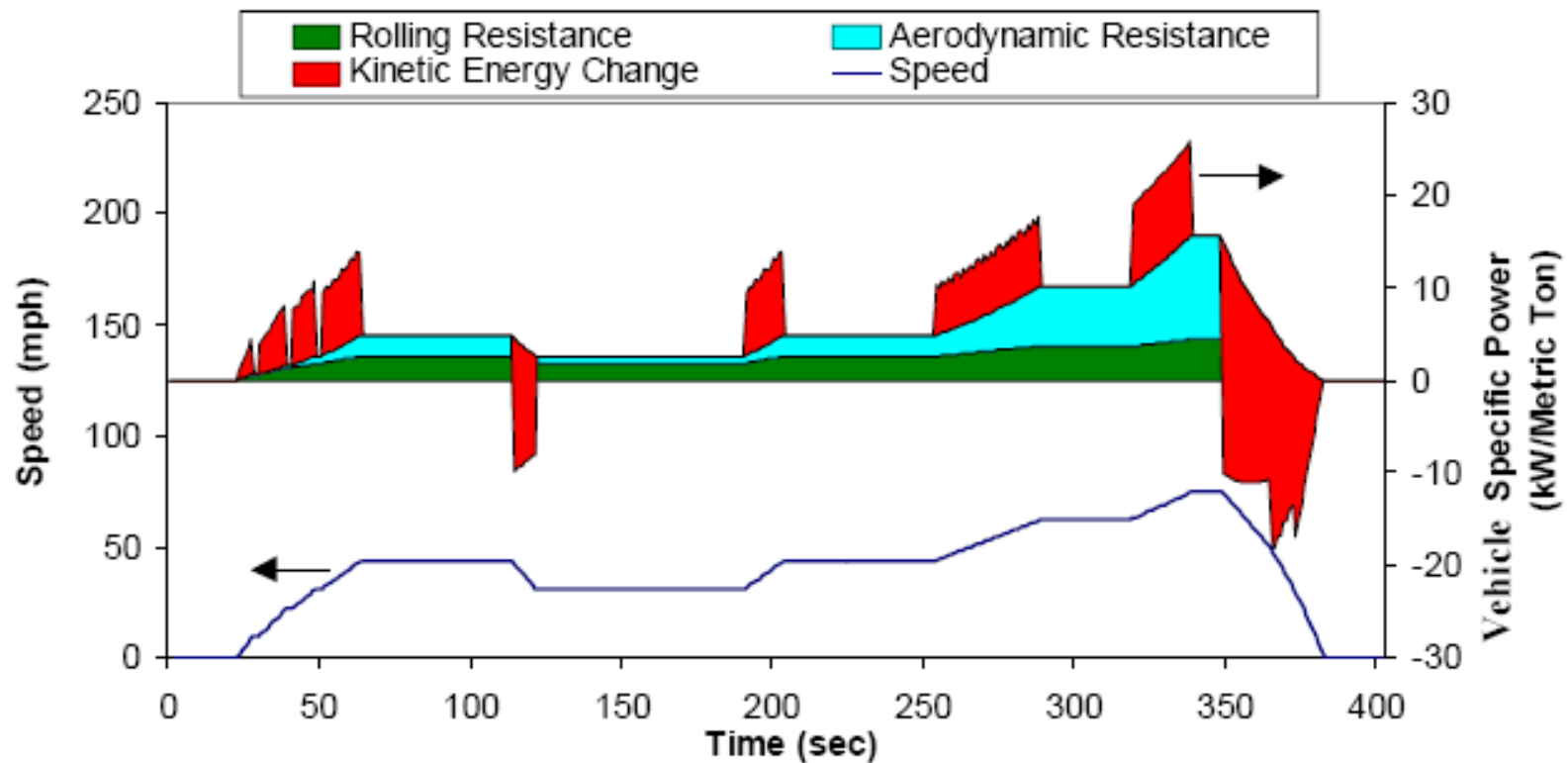
Federal Test Procedure "Bag 1"



VSP in US06 Driving Cycle



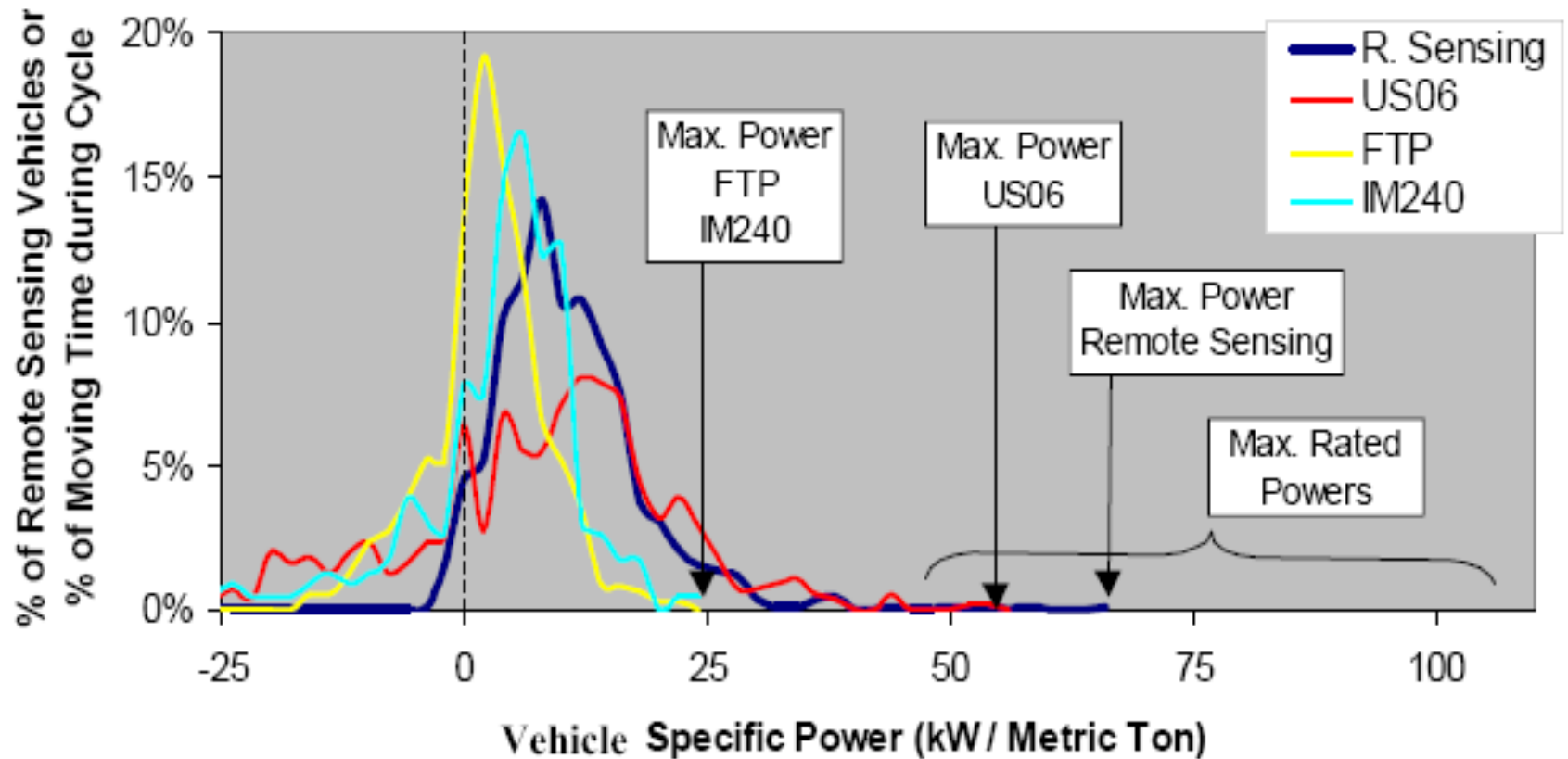
VSP in European ECE2 Cycle



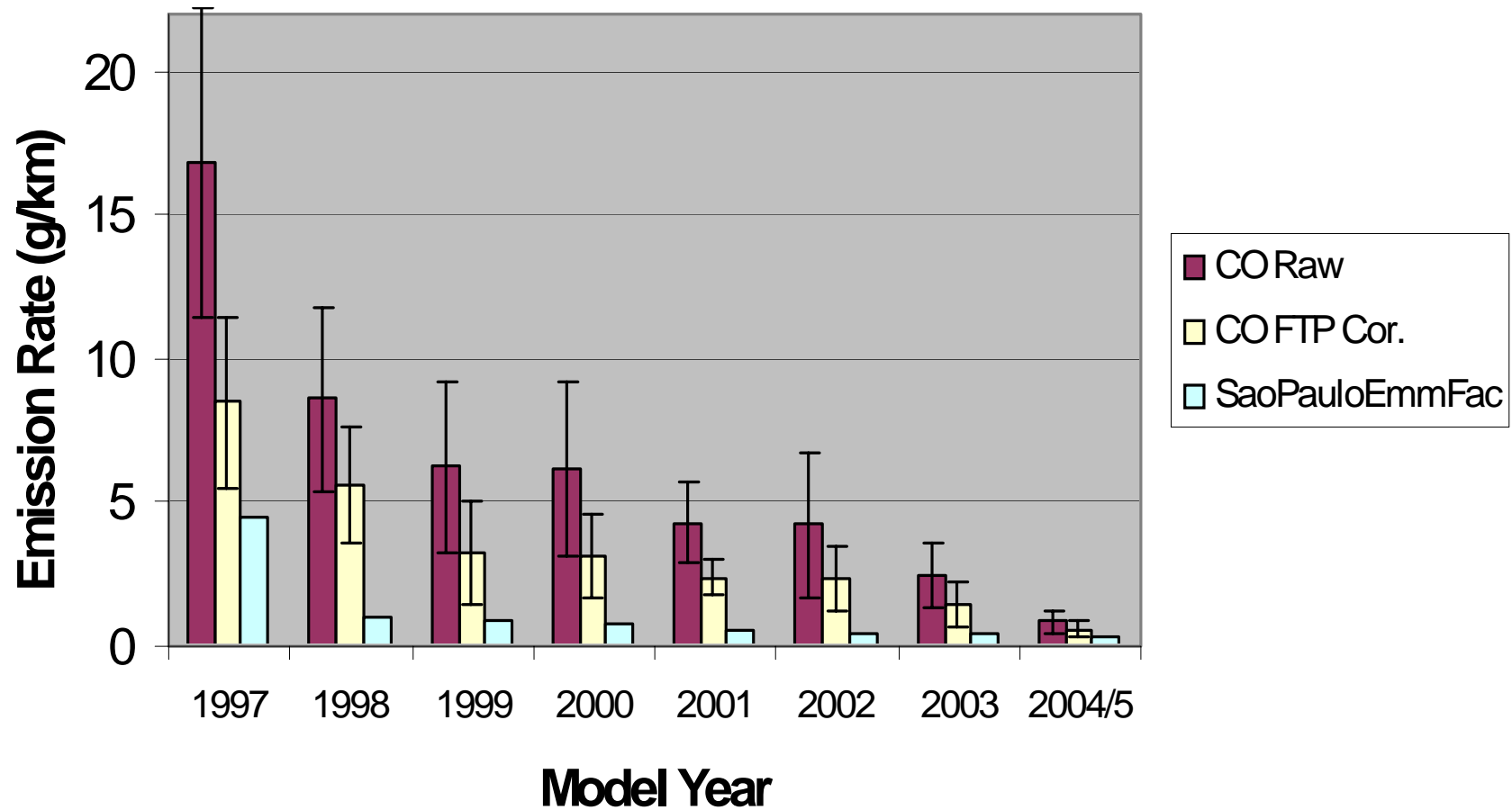
VSP Levels of Various Activities

<u>Activity</u>	<u>VSP (kW/ Metric Ton):</u>
• Max. Rated Powers	44 - 112
• 0 to 60 mph in 15 seconds	33
• 60 mph up a 4% grade	23
• Maximum in FTP/IM240	23
• Rem. Sensing site means	10 -15
• Average in IM240	8
• ASM 5015	6
• ASM 2525	5

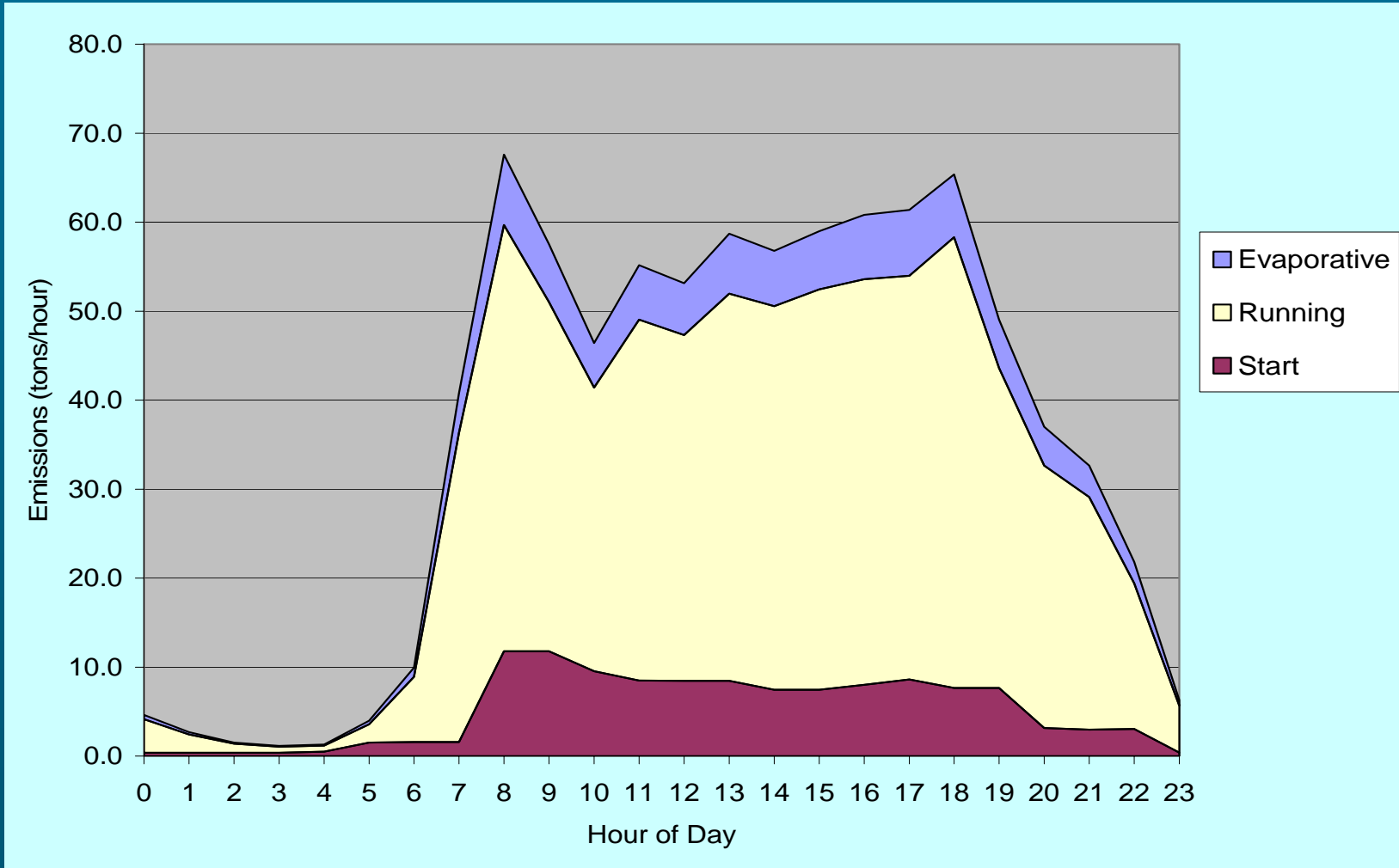
Use of VSP Distributions



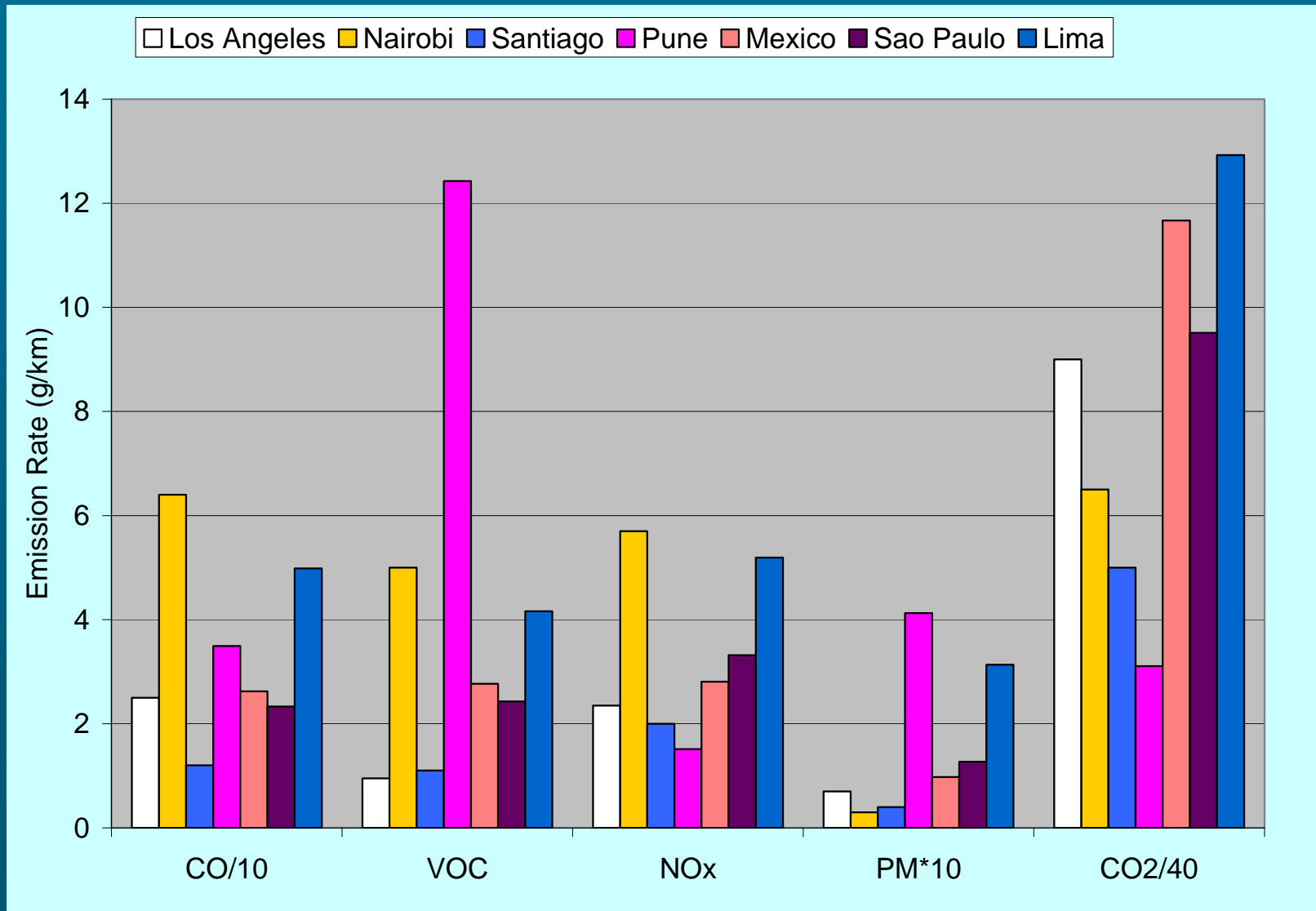
CO Emissions (preliminary)



Results: Temporal distribution (IVE)



Results: inter-city comparison



Conclusions

- Our goal has been to develop vehicle activity data as well as emission data for as many areas in the world as funding will allow. Each new input into the database results in the model having increased utility to a larger number of developing nations.
- At the same time, in each location where we gather information, we make an effort to train local individuals on the operation of the model and the methodology to collect the needed input data.
- Once an area has developed their on-road mobile source inventory, the IVE model can then be used to assess the emission benefits of various pollutant control strategies. Once the benefits are known, the strategies can be ranked by cost-effectiveness to insure the area realizes the greatest health/environmental benefit at the least cost.
- Further information available at: <http://www.issrc.org>