International Vehicle Emissions Model - IVE

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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

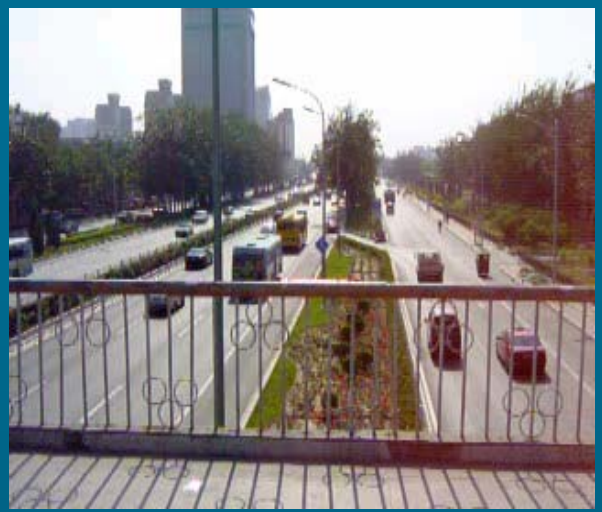
Lima, Peru (December 2003);
Los Angeles, USA (2001);
Mexico City, Mexico (January 2004);
Santiago, Chile (December 2001, 2002);
Bogota, Colombia (January 2005)

Almaty, Kazakhstan (May 2003);
Nairobi, Kenya (March 2002);
Pune, India (March 2003);
Beijing, Shanghai, China (2004)
Sao Paulo, Brazil (2004)
Istanbul, Turkey (2006)

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

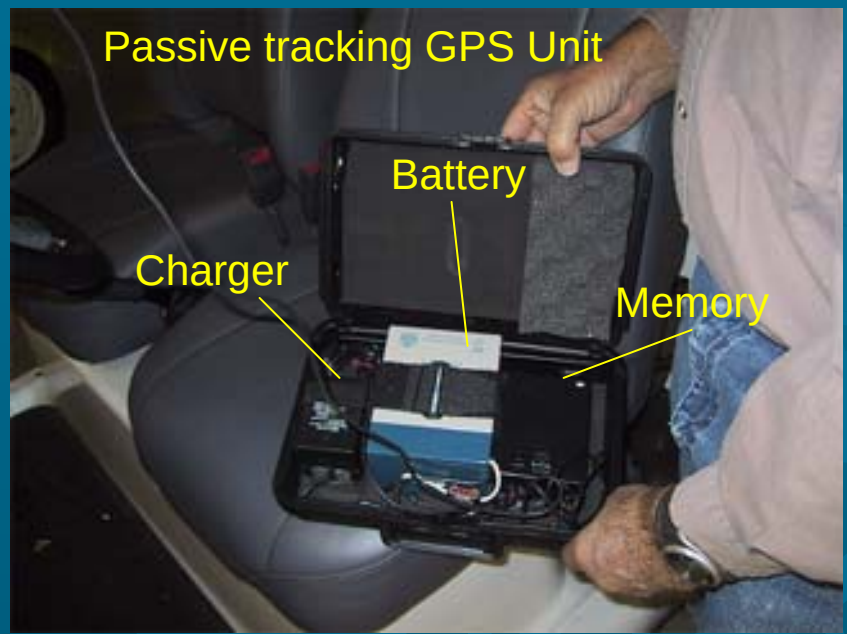


Video tape recording: 20 minutes, 7 times/day, 6 days = 14 hours ⇔ 42 hours

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



IVE Phase I: cold start emissions

Set-up procedure

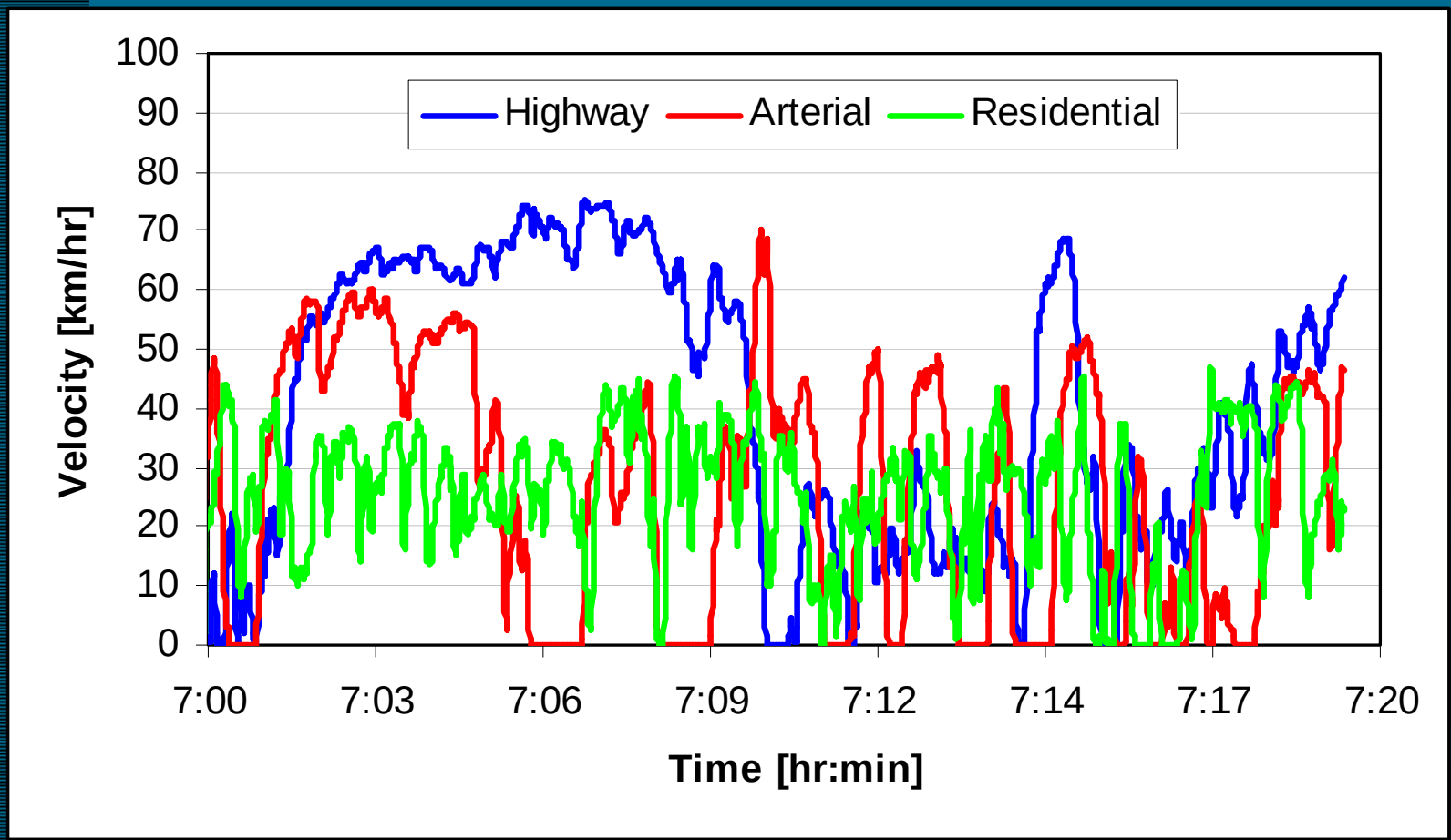
Measurement process

Downloading data

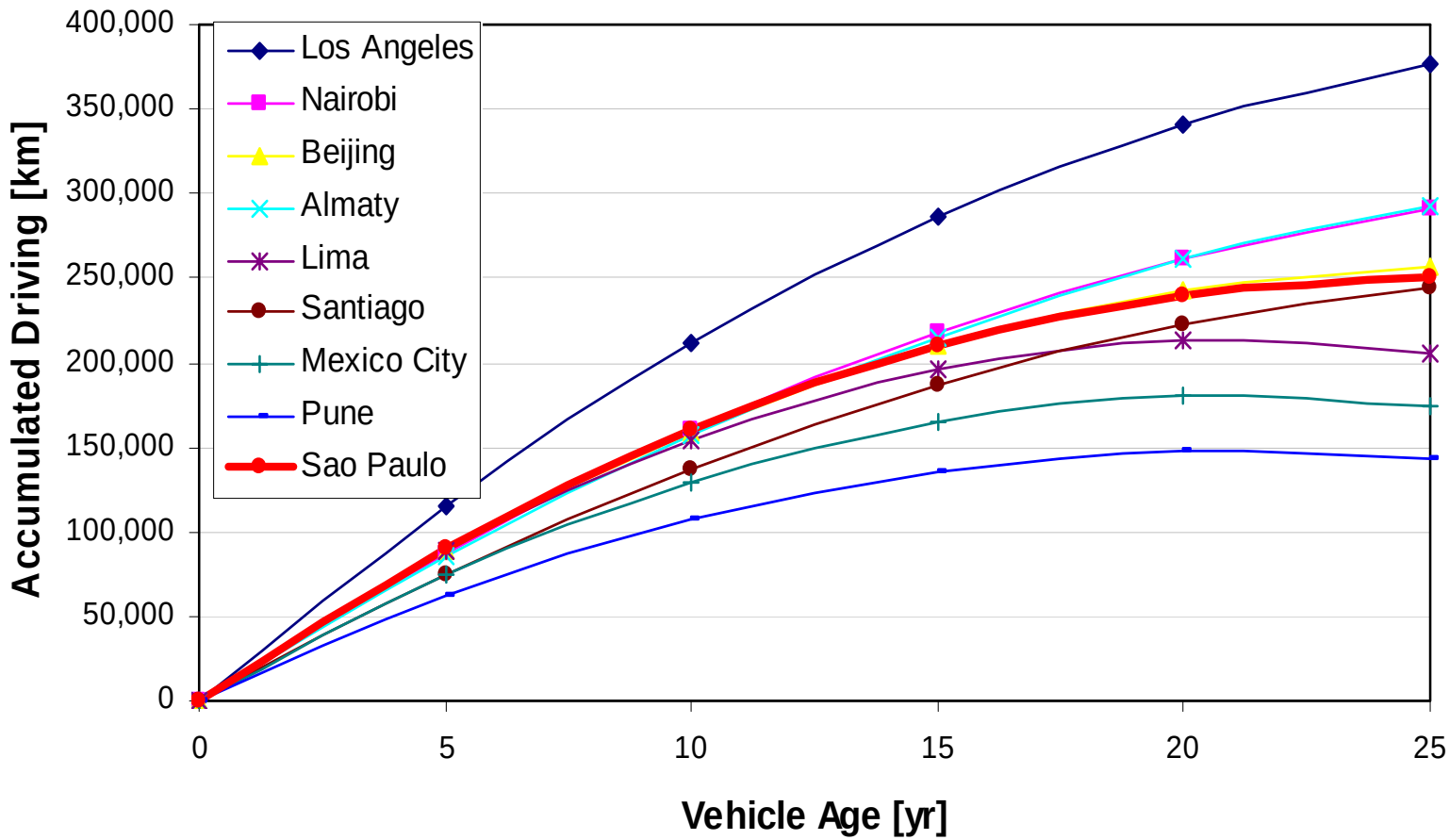
Results: dynamic fleet composition

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%

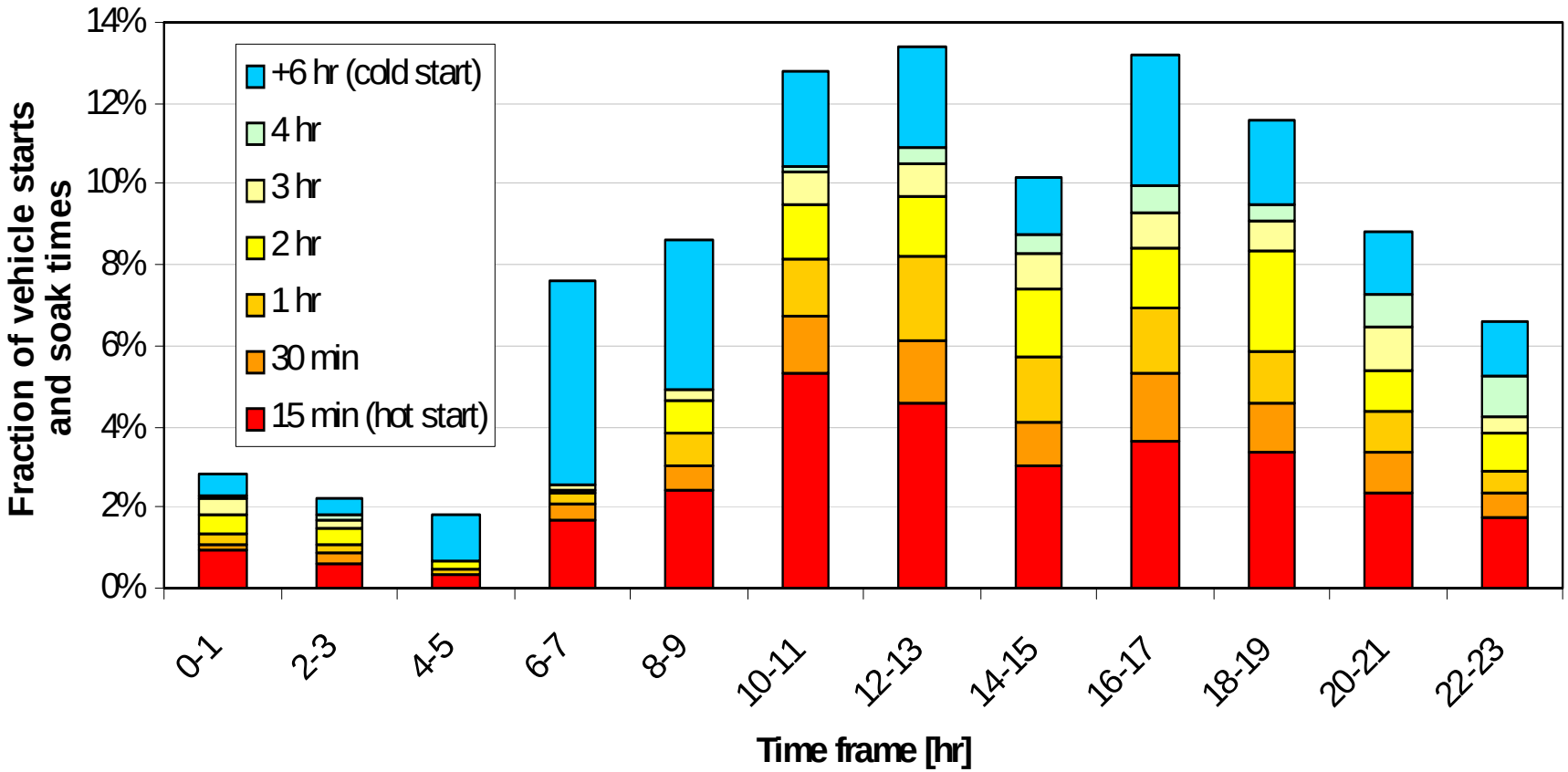
Average Passenger Car Speeds on São Paulo Roads



Results: Accumulated driving



Results: cold starts in Sao Paulo



Introduction

- In most cities motor vehicle traffic is a major source of air pollution. The production of a reliable estimate of emissions for mobile sources is thus complex and most developing countries do not have the resources to properly develop emissions estimates
- Therefore, it is necessary to quantify mobile emission levels as accurately as possible with appropriate spatial and temporal resolution, for both local and global pollutants, and taking into consideration future trends in urbanization and vehicle technologies

Establishment of base year emissions

Generation of Data

- Emission Factors
- Mileage
- Traffic Data
- Traffic Structure
- Auxiliary Data

Processing of the Data Base

- Parameter definition and differentiation
- Data base definition
- Developement of methodologies
  - Cold Start
  - Evaporation
  - Projection of traffic data
  - geografic / time scale resolution

Application

- National and local environmental politics
- Standard of Immission Protection
- Construction of Traffic Plans
- Environmental Assessment Studies

Maintainance and Update

differentiate data according to necessities

integrate data bases and methodologies

harmonize further fields of application

Vehicle emission measurement

vehicle emissions

hot exhaust

cold start

evaporative

$$E_t = E_{he} + E_{cs} + E_{ev}$$

vehicle activity level

emission factors

correction factors

$$VA \times EF \times CF$$

- On-road vehicle emissions are made up of a great number of pollutants which originate from various processes. In addition to these processes, it is possible to distinguish running/start, evaporative and other emissions which are not directly related to the vehicle
- Running emissions can be calculated as the product between vehicle activity level and emission factors, where each element depends on several factors

Vehicle emissions measurement methods

vehicle activity level

emission factors

correction factors

$$E_{he} = VA \times EF \times CF$$

Transportation models
- Micro-mezo-macro scale
- Static or dynamic modeling

Real traffic data collection
- Total vehicle counts (24 hours)
- Fleet composition
- Vehicle technology
- Real-time speed recordings

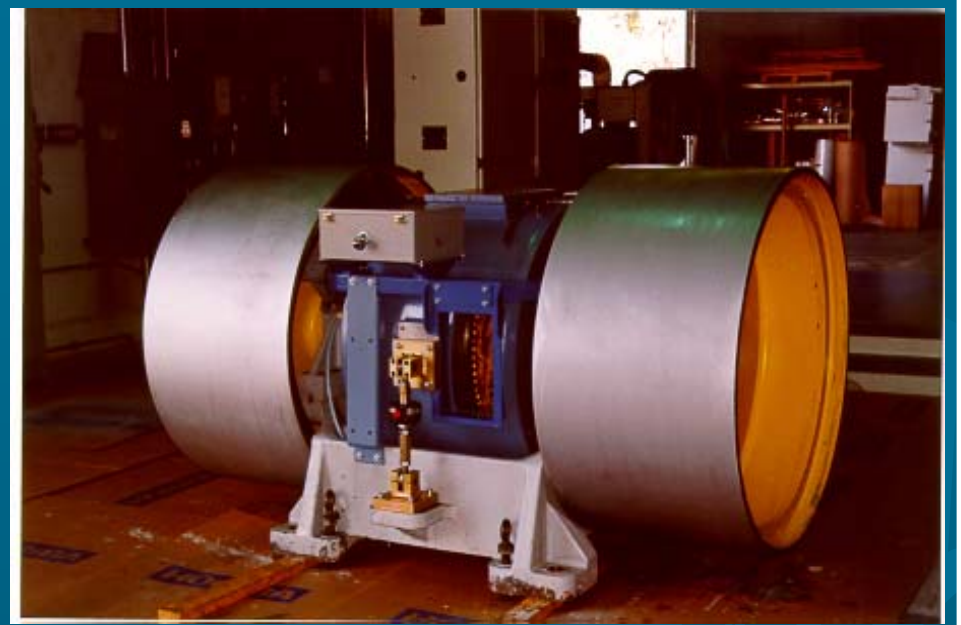
Traffic network
- Digitized road network
- GIS support

Emission models
- Existing emission factors

Experimental emission factors
- Dynamometer measurements
- On-board measurements (OBM)

Correction factors
- Fuel composition effect
- Mileage deterioration factor
- Gradient effect
- I/M and enforcement
- Driving patterns
- Altitude, weather

Chassis dynamometer testing



The most realistic standardized method to measure exhaust emissions from actual vehicles is by the use of an emission laboratory equipped with chassis dynamometer, following specified test procedures.

For testing of light duty vehicles, emission laboratories have been in use in Europe, Japan and the U.S. since the 1960´s, while for heavy duty vehicles the test resources have been very limited due to high costs for a laboratory and in addition lack of stringent emission regulations for heavy vehicles.

On-Board Measurement, OBM

- Regardless the high level of detailed specification for tests carried out in emission laboratories, it will never full replicate in-use operating conditions
- A further alternative is to use a system for measurement of the emissions from vehicles when they are used under normal operating conditions on the road, so called on-board measurement (OBM)
- However, one method can not replace the other; rather they are good complements for a full verification of the actual emissions emitted
- In the future OBM will play an even more important role for measurement of the emissions from especially heavy duty vehicles
- Programs are under development both in Europe and in North America to validate different OBM systems

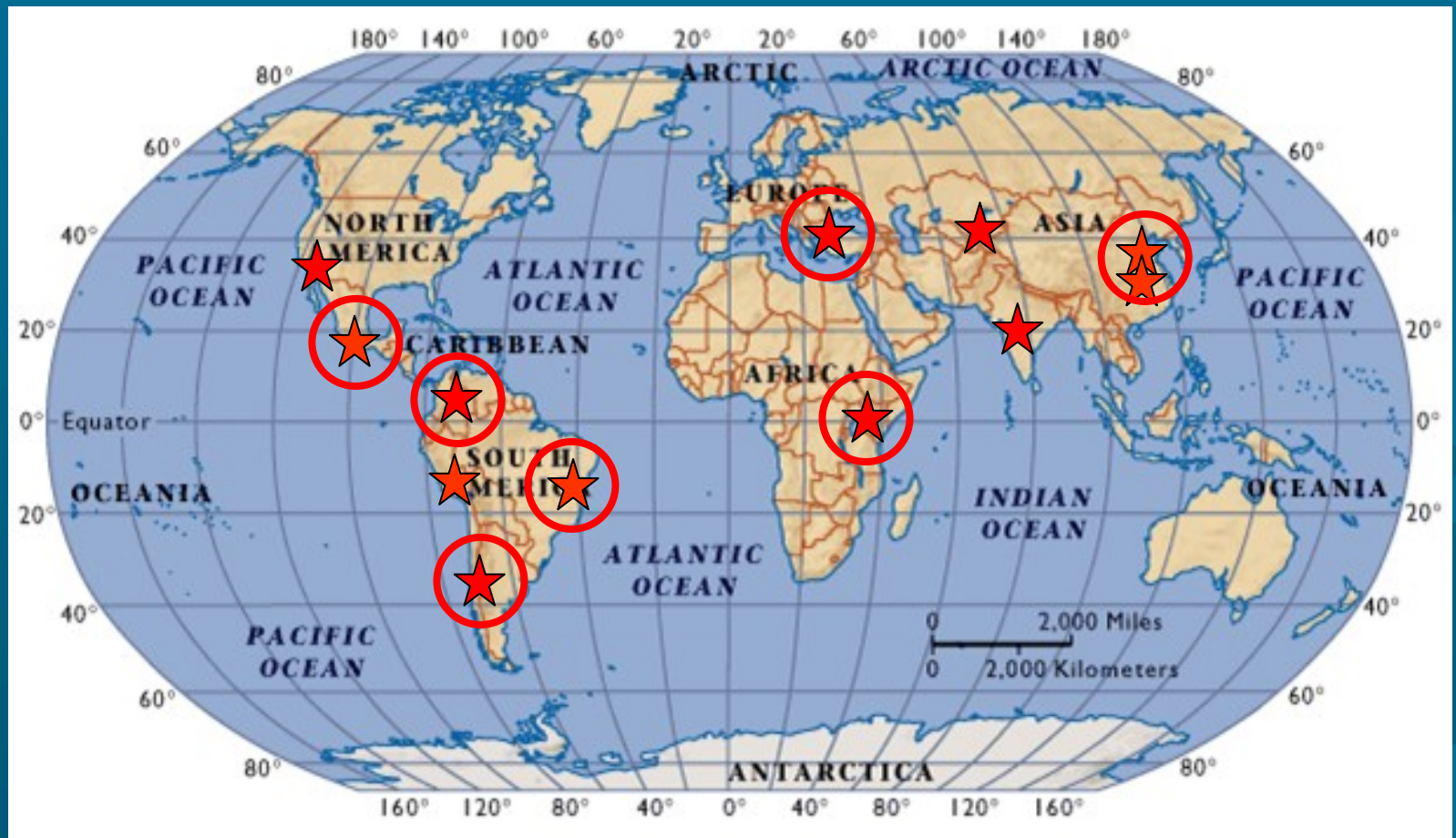
Portable Emission Measurement Systems, PEMS

- Portable emission measuring system (PEMS) are used on a vehicle to measure real-time emissions, collecting continuous exhaust emission rate data along with data on vehicle operating conditions and location
- They are designed for rapid installation in vehicles for in-use exhaust measurements
- There are commercial PEMS-gas units offered by Horiba, Sensors Inc., Clean Air Technologies and Galio Industrial Development Co.; as well as several research units that measure regulated gaseous emissions
- In general, these units have shown to be in good agreement with conventional measurement methods when tested under controlled laboratory conditions
- With the commercialization of PEMS units for gaseous regulated pollutants, there is a strong possibility that there will be a very large increase in real-world vehicle emissions data in the near future

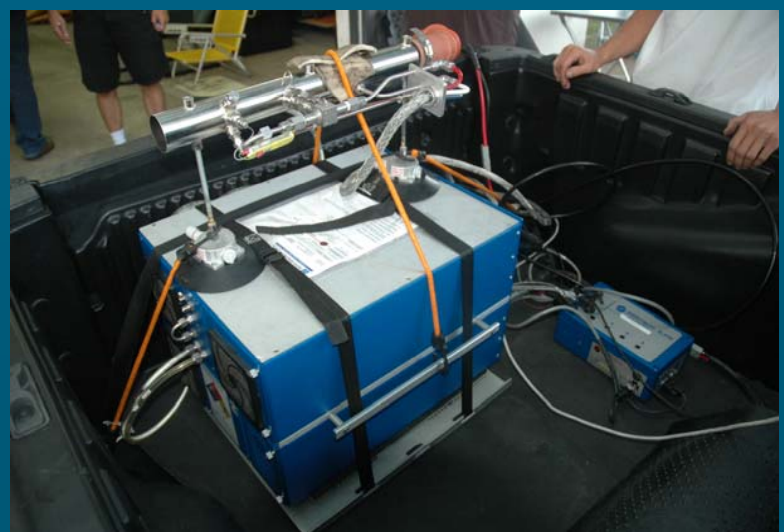
Mass Particulate Matter PEMS

- While optical methods of measuring PM have been used in PEMS units, it has been a research objective to have continuous PM mass measurements
- Proper sampling of vehicle exhaust is a challenge for on-board PM PEMS measurement
- Research needs to continue on the development of PEMS-based PM measurement capability and, as a second priority, other HAPs
- There are some commercial units available by Dekati Ltd., Sensors Inc., TSI, Cambustion and Argonne National Laboratory, as well as research units still under development for particle size distribution, but successful PEMS-PM mass measurement had not been yet reported

IVE Phase II: Real-world emissions



IVE Phase II: real-world emissions



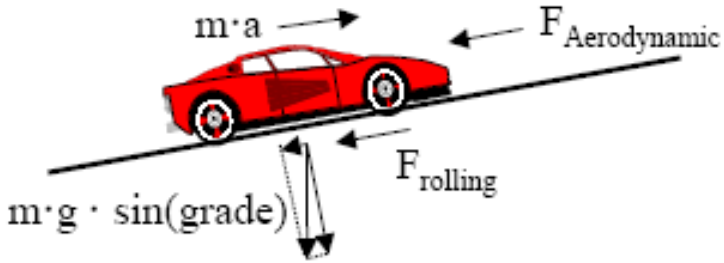
Metodología VSP-IVE

- **VSP: Vehicle Specific Power**
- **PSV: Potencia eSpecífica Vehicular**
- **IVE: International Vehicle Emissions**
- **MOVES: MOtor Vehicle Emission Simulator**

"To keep pace with new analysis needs, modeling approaches, and data, the EPA's Office of Transportation and Air Quality (OTAQ) is developing a modeling system termed the **MO**tor **V**ehicle **E**mission **S**imulator (MOVES). This new system will estimate emissions for on-road and nonroad sources, cover a broad range of pollutants, and allow multiple scale analysis, from fine-scale analysis to national inventory estimation. When fully implemented MOVES will serve as the replacement for MOBILE6 and NONROAD. The new system will not necessarily be a single piece of software, but instead will encompass the necessary tools, algorithms, underlying data and guidance necessary for use in all official analyses associated with regulatory development, compliance with statutory requirements, and national/regional inventory projections. This project was previously known as the New Generation Mobile Source Emissions Model (NGM)"

Fuente: www.epa.gov

Vehicle Specific Power (VSP)

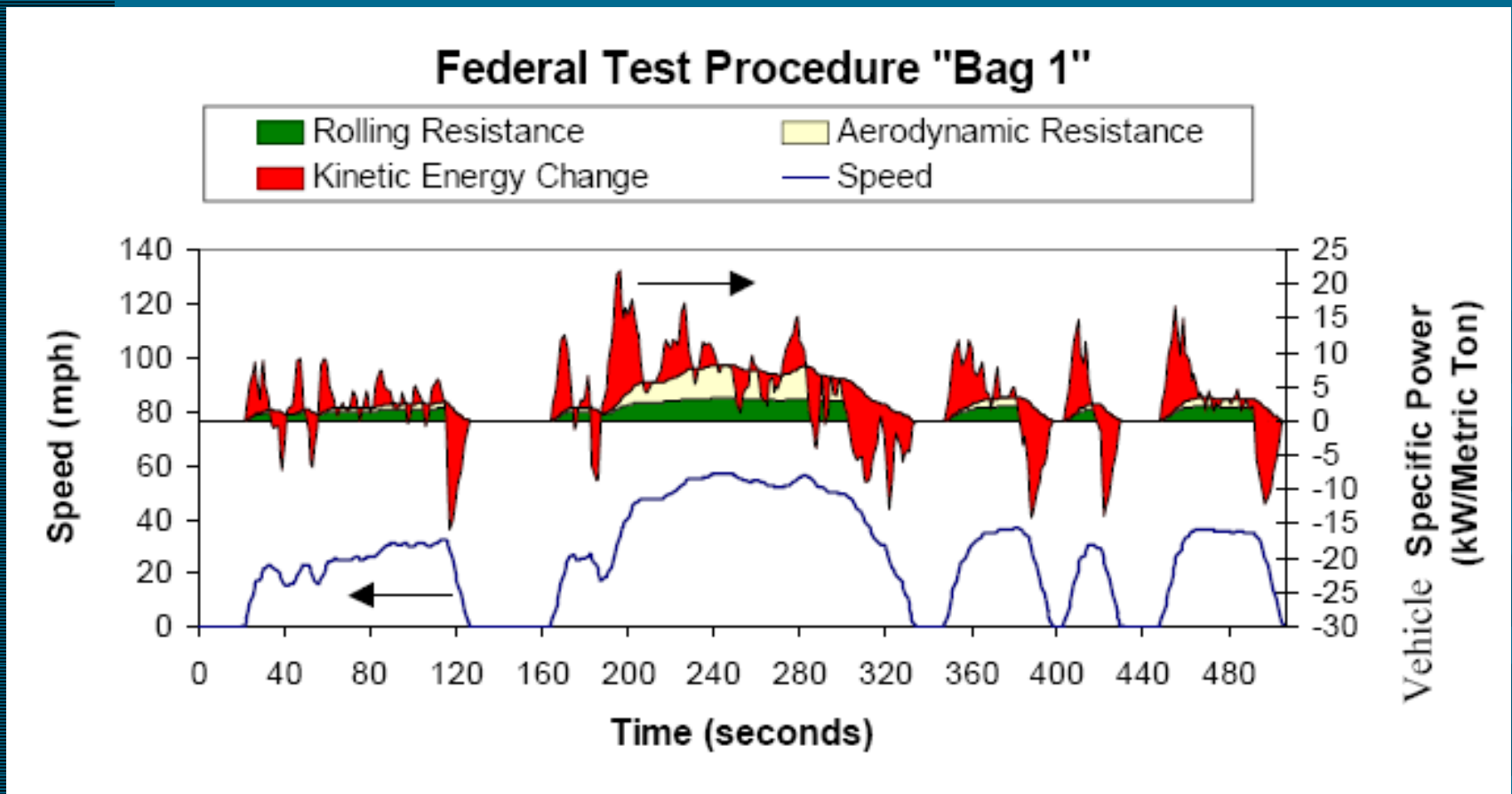


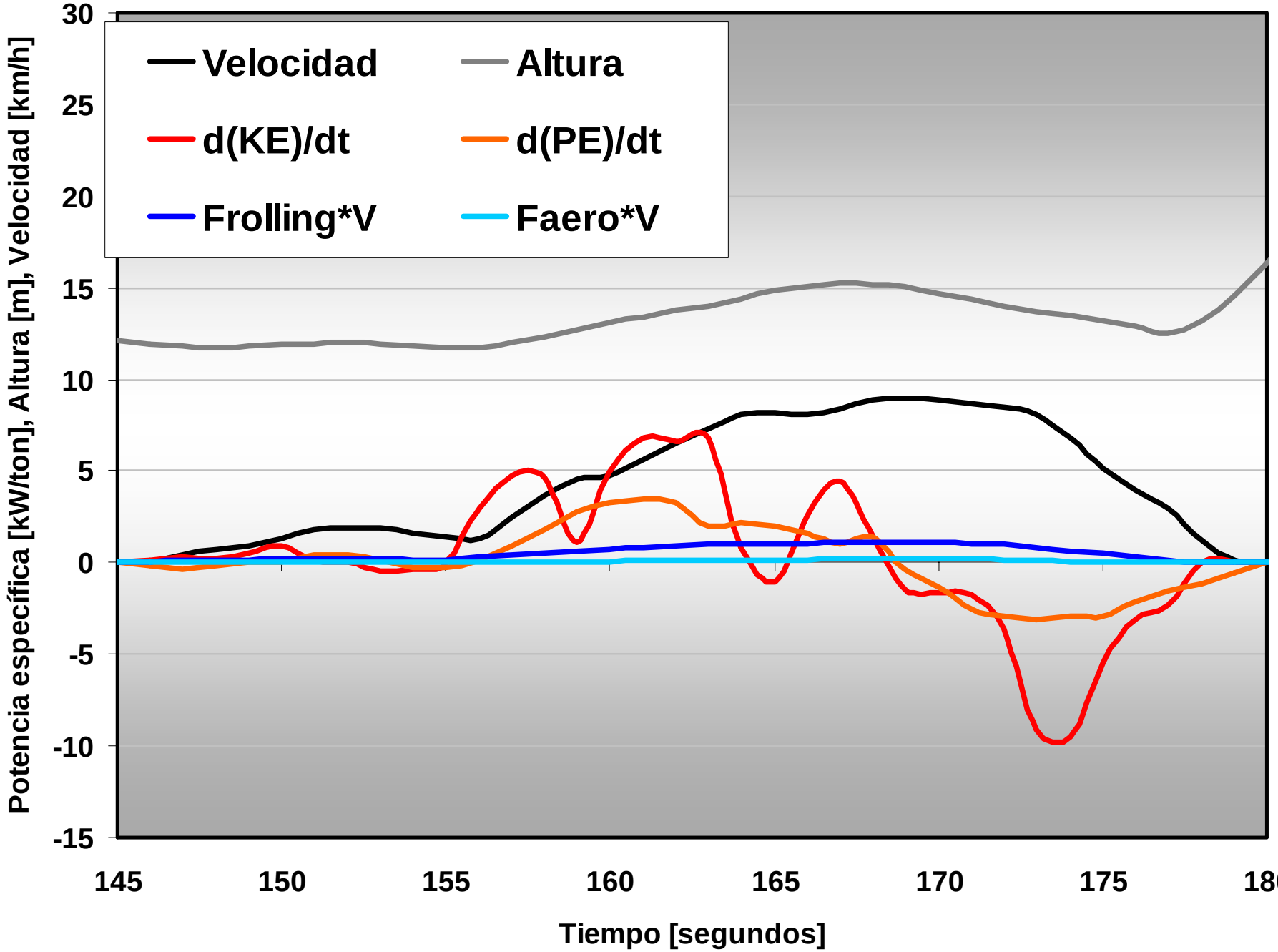
$$VSP = \frac{\text{Power}}{\text{Mass}} = \frac{\frac{d}{dt}(E_{Kinetic} + E_{Potential}) + F_{Rolling} \cdot v + F_{Aerodynamic} \cdot v + F_{internal\ friction} \cdot v}{m} =$$

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

Trabajo original: “Understanding and Quantifying Motor Vehicle Emissions with Vehicle Specific Power and TILDAS Remote Sensing”, José Luis Jiménez-Palacios, Tesis Doctoral, Department of Mechanical Engineering, Massachusetts Institute of Technology, February 1999

VSP in Emissions Certification Cycles




Velocidad
Altura
d(KE)/dt
d(PE)/dt
Frolling*V
Faero*V
Potencia específica [kW/ton], Altura [m], Velocidad [km/h]
30
25
20
15
10
5
0
-5
-10
-15
145
150
155
160
165
170
175
180
Tiempo [segundos]

$$VSP\left(\frac{kW}{Ton}=\frac{W}{kg}=\frac{m^2}{s^3}\right)=v\left[1.1\cdot a+9.81\cdot\sin\left(\tan^{-1}(grade)\right)+0.132\right]+0.000302\cdot v^3$$

Bin	VSP (kW/Ton)	
	Lower	Upper
0	-80.0	-44.0
1	-44.0	-39.9
2	-39.9	-35.8
3	-35.8	-31.7
4	-31.7	-27.6
5	-27.6	-23.4
6	-23.4	-19.3
7	-19.3	-15.2
8	-15.2	-11.1
9	-11.1	-7.0
10	-7.0	-2.9
11	-2.9	1.2
12	1.2	5.3
13	5.3	9.4
14	9.4	13.6
15	13.6	17.7
16	17.7	21.8
17	21.8	25.9
18	25.9	30.0
19	30.0	1000.0

"VSP is broken into 20 groups varying from quick stops, to slow and moderate stops, idle, low, medium, and high accelerations"

Desaceleración

Ralentí

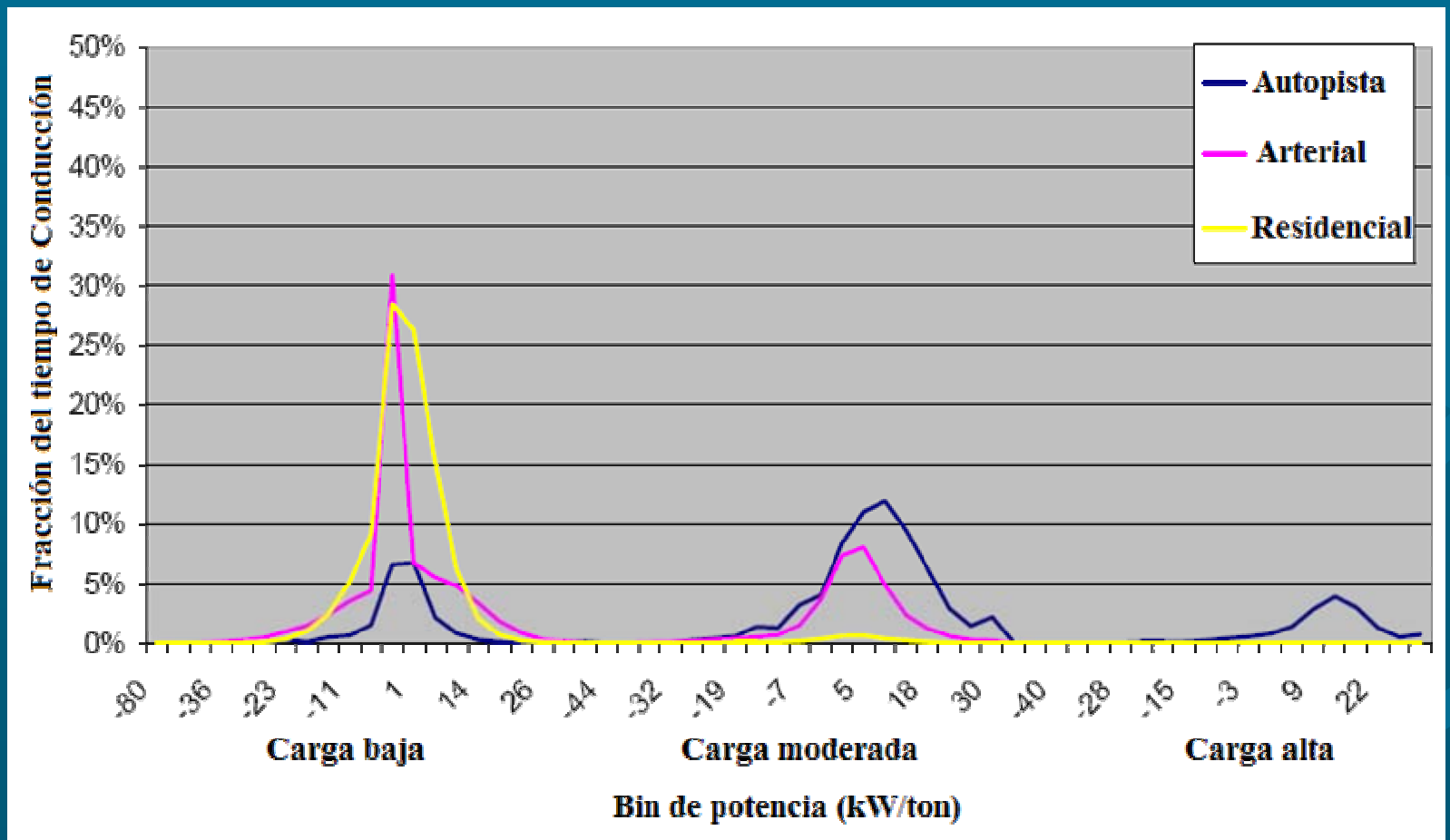
Aceleración

20 bins y 3 niveles de carga

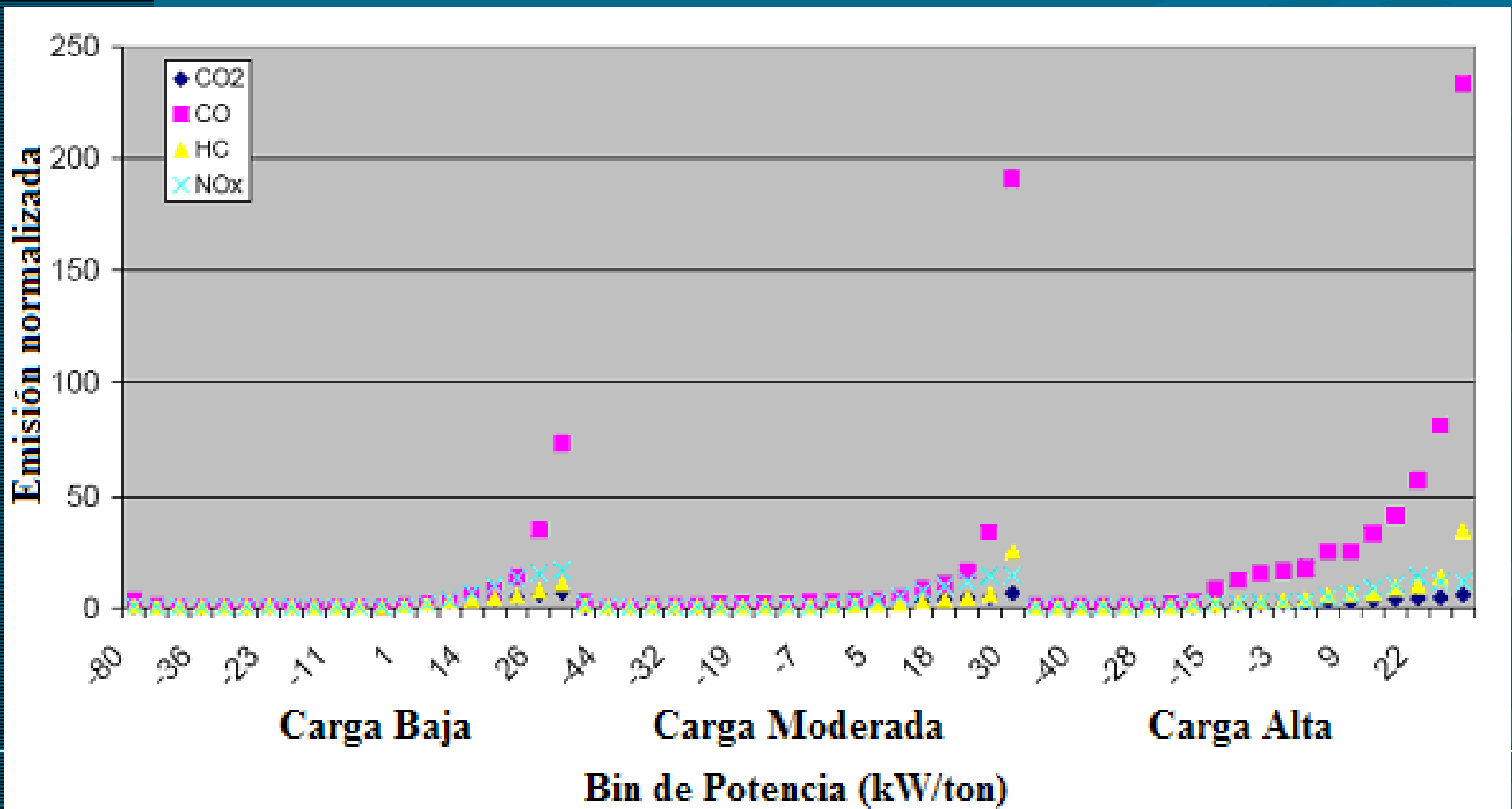
"A second parameter used is called Stress, which is primarily impacted by estimated engine RPM and secondarily by power load on the vehicle in the most recent 15 seconds of driving. Stress is broken into 3 categories and further improves vehicle emission estimates"

Bins	Engine stress (unitless)	
	Lower	Upper
0 to 19	-1.6	3.1
20 to 39	3.1	7.8
40 to 59	7.8	12.6

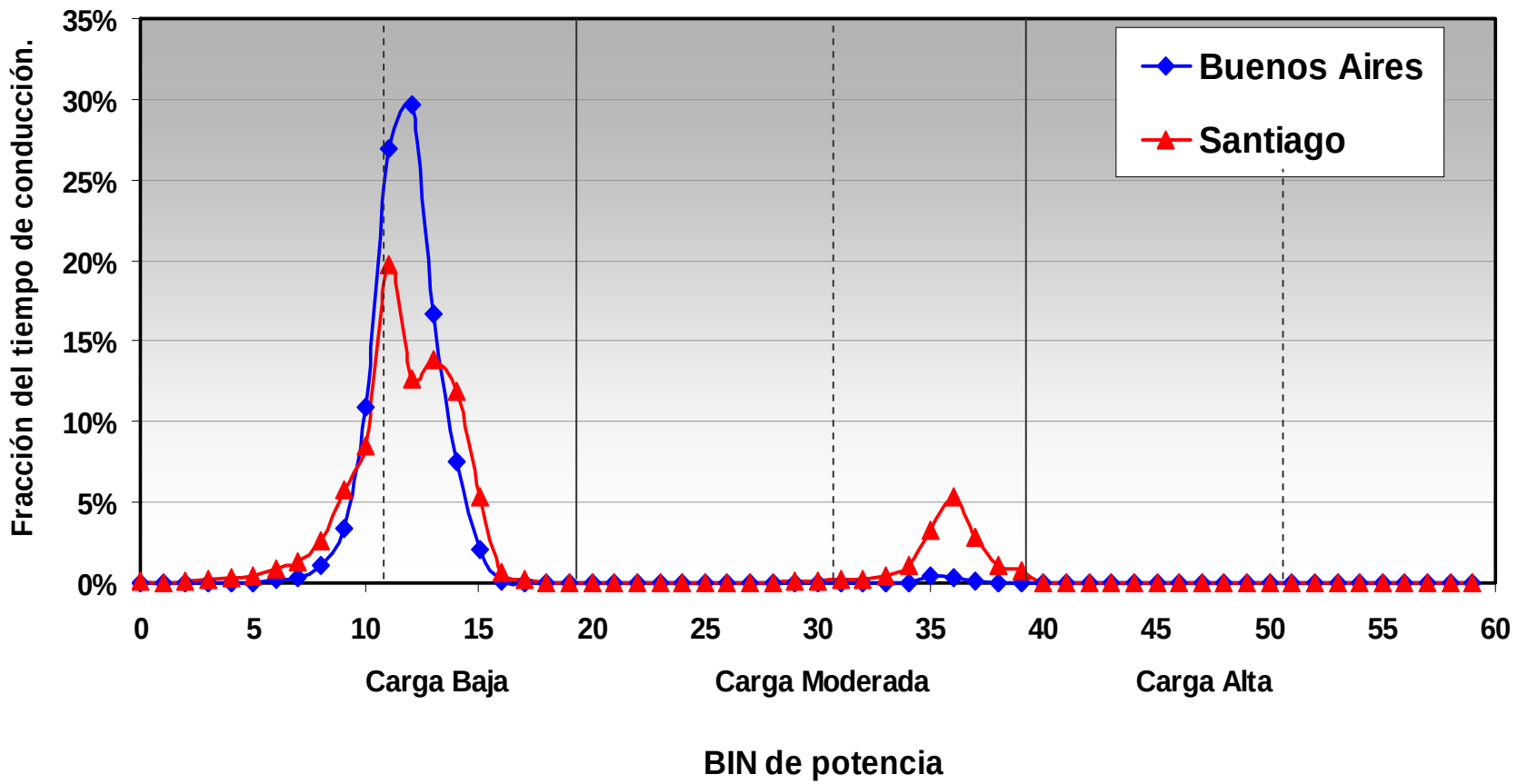
60 Niveles - bins - de potencia

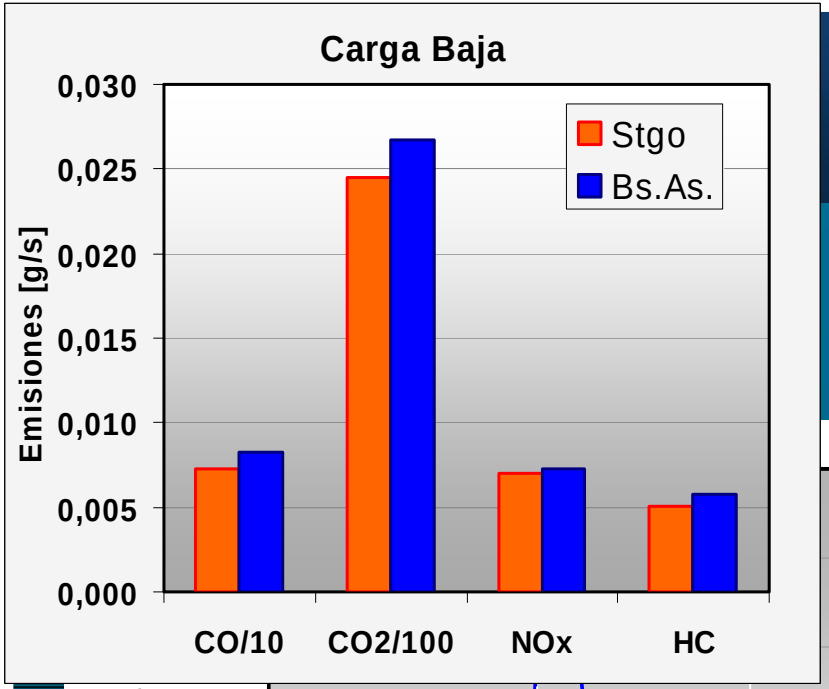


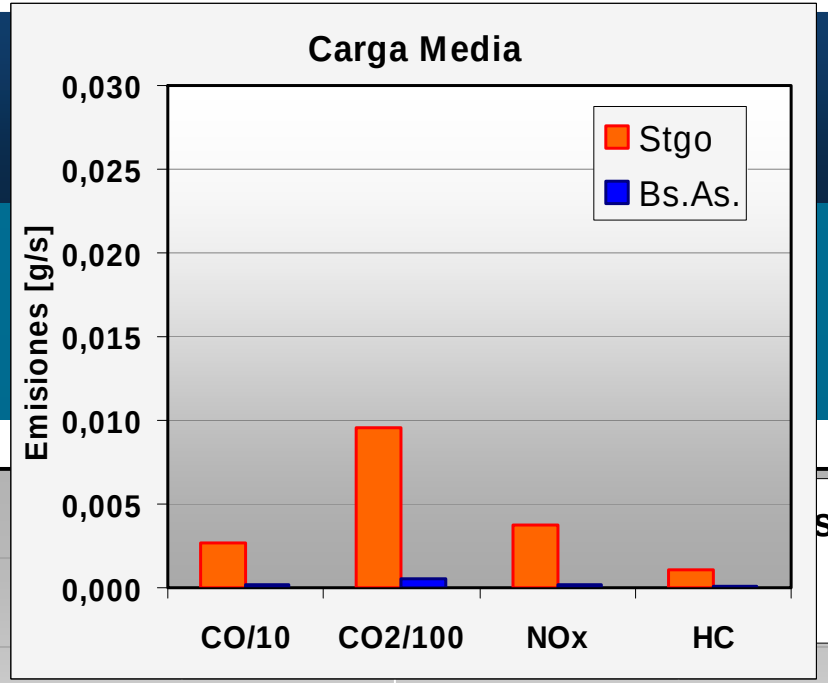
- Existen Emisiones en base a bins para cada tecnología
- Definir ruta y recorrerla con vehículo instrumentado
- Generar Histograma de PSV para dicho recorrido
- Histograma + emisiones individuales = emisiones totales

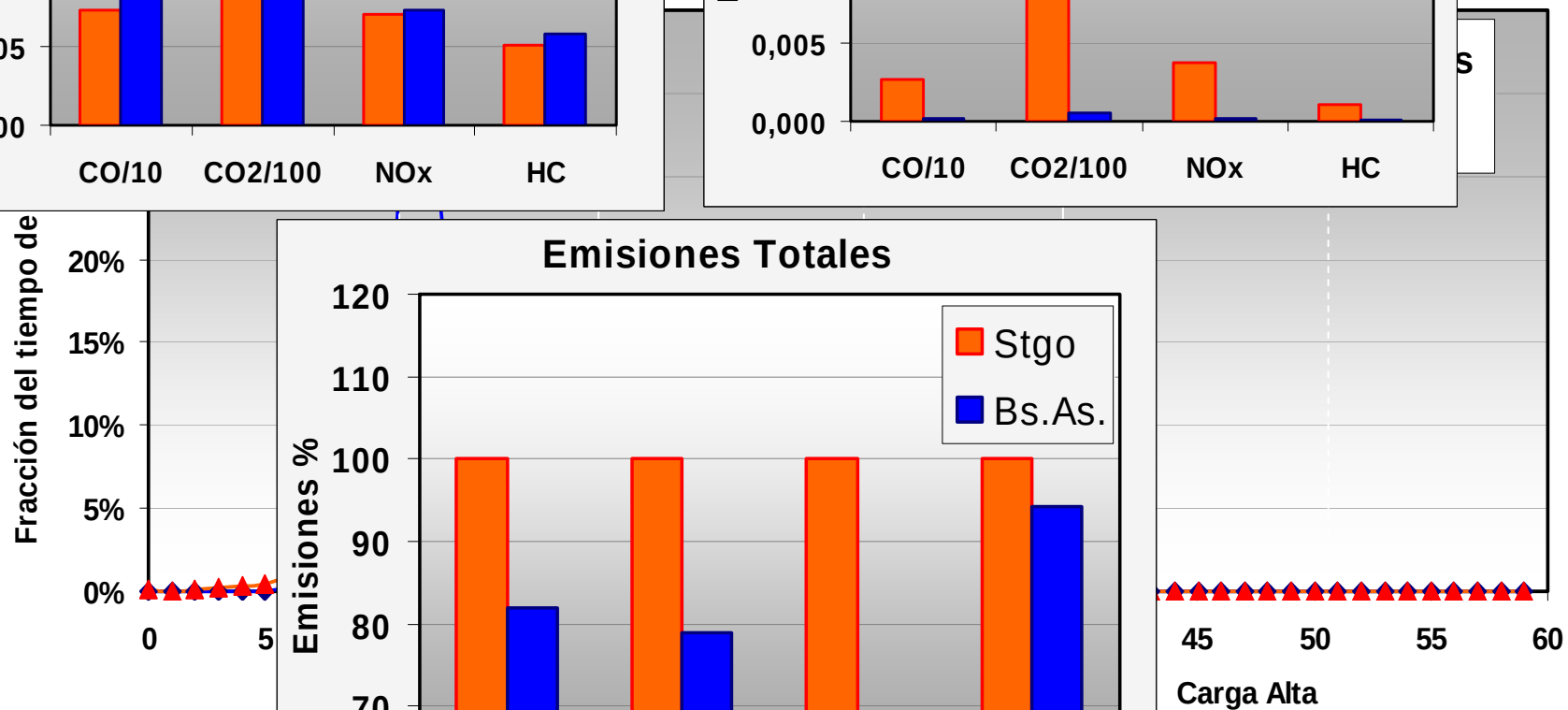


Fracción de tiempo según PSV



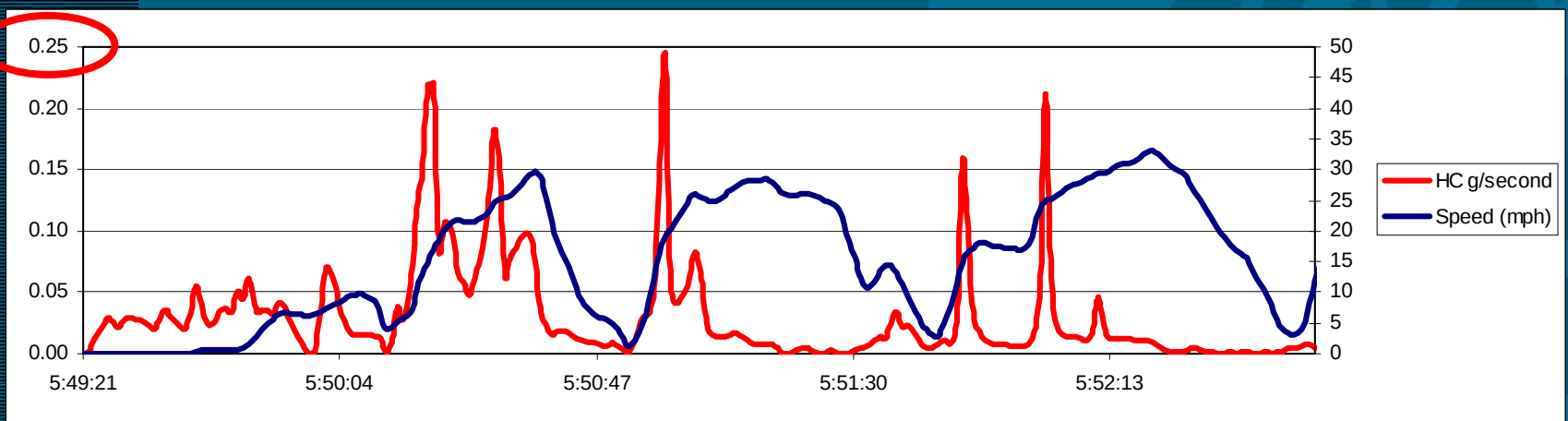

Carga Baja
Emisiones [g/s]
0,030
0,025
0,020
0,015
0,010
0,005
0,000
Stgo
Bs.As.
CO/10
CO2/100
NOx
HC


Carga Media
Emisiones [g/s]
0,030
0,025
0,020
0,015
0,010
0,005
0,000
Stgo
Bs.As.
CO/10
CO2/100
NOx
HC

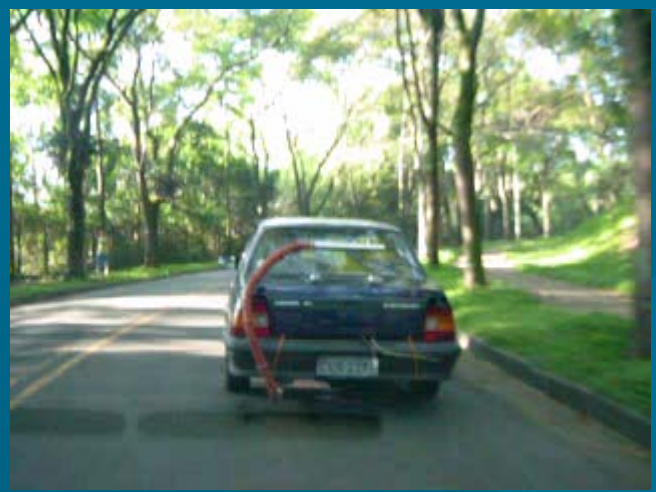

Fracción del tiempo de
20%
15%
10%
5%
0%
0
5
45
50
55
60
Carga Alta

Emisiones Totales
Emisiones %
120
110
100
90
80
70
60
Stgo
Bs.As.
CO
CO2
NOx
HC

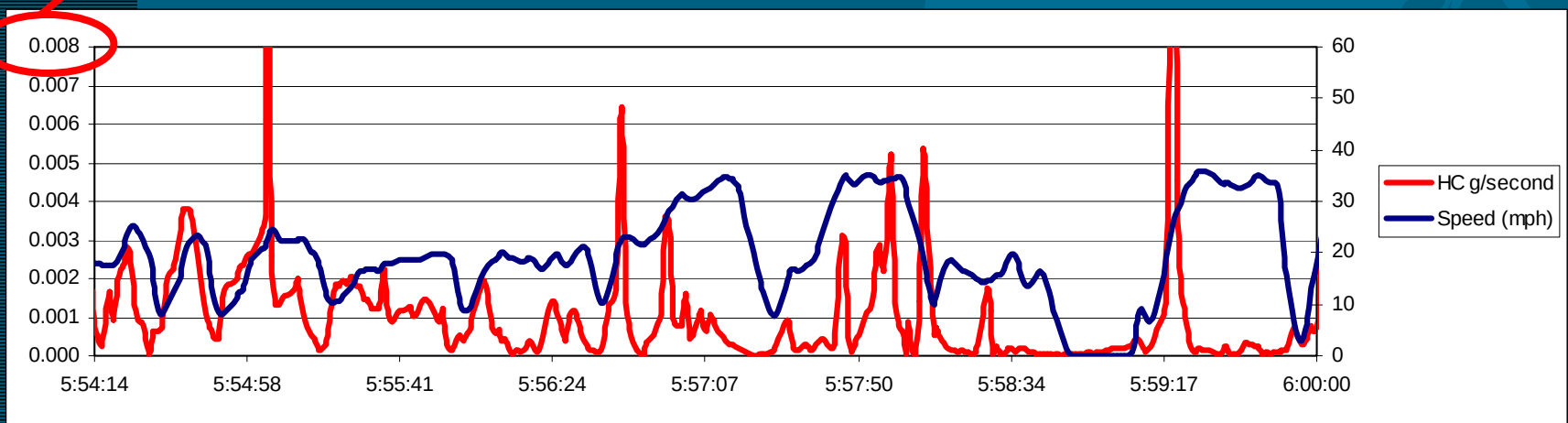
Start Emissions



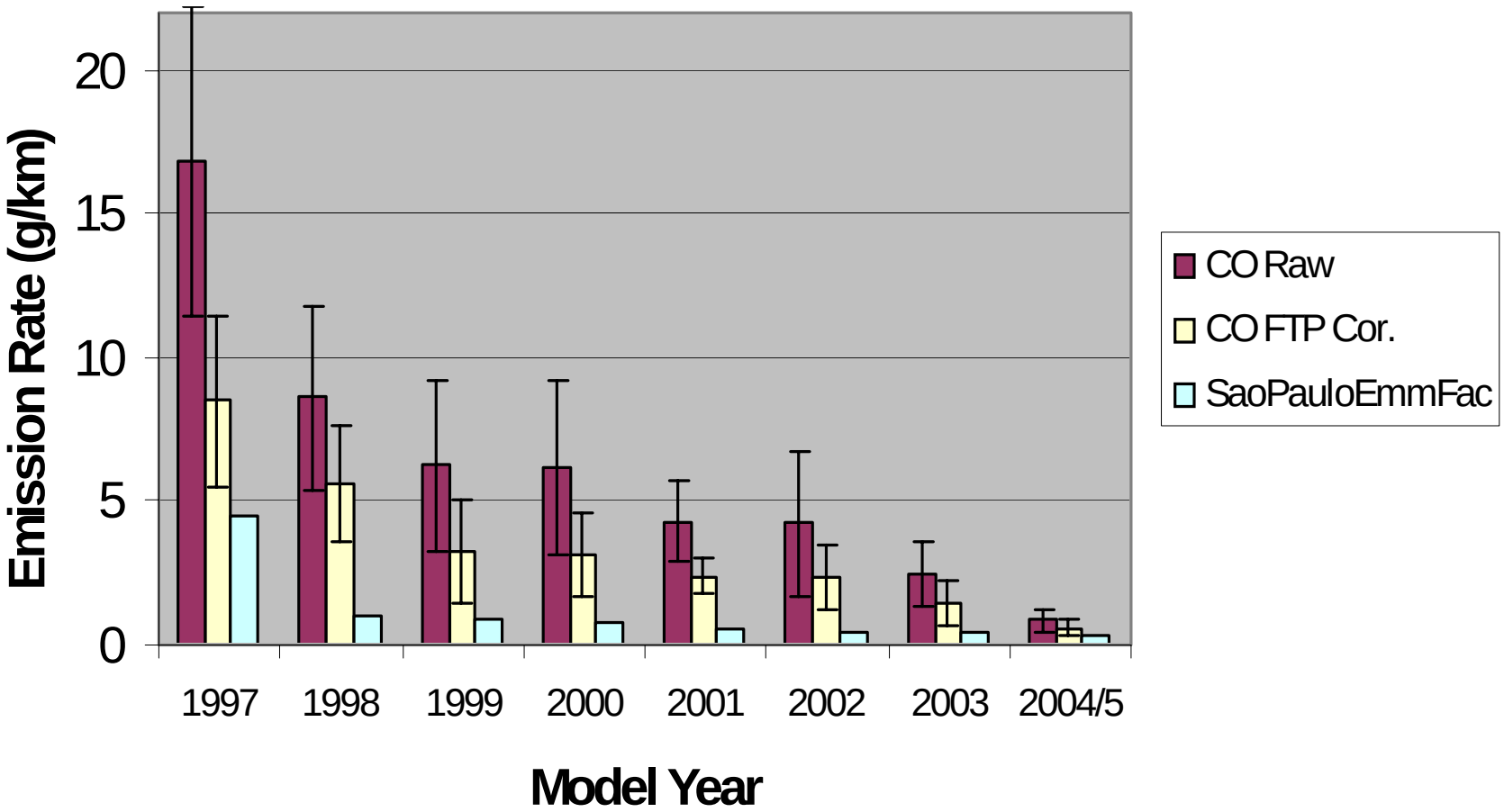
Running Emissions



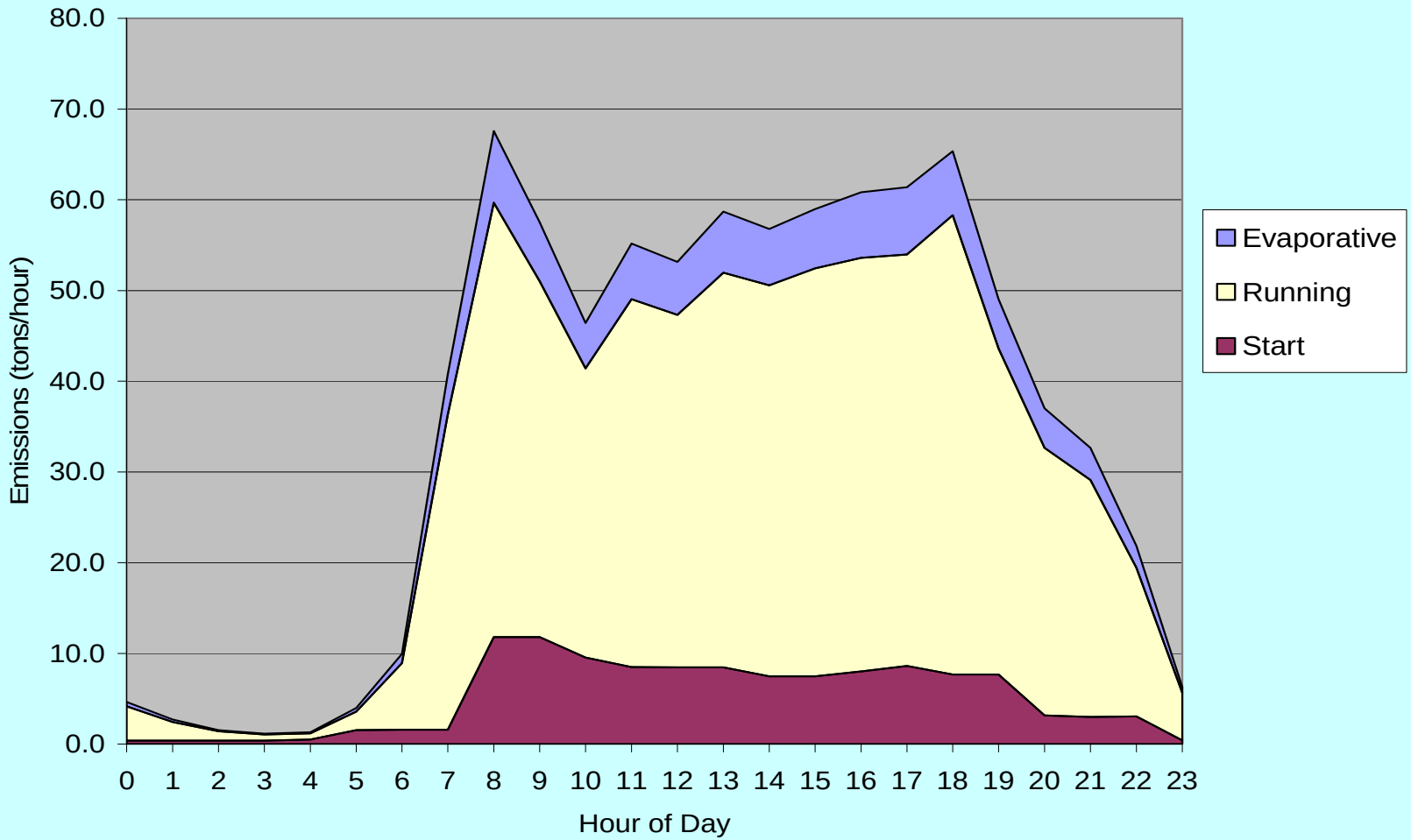
Start-up scale: 0.25 g/sec



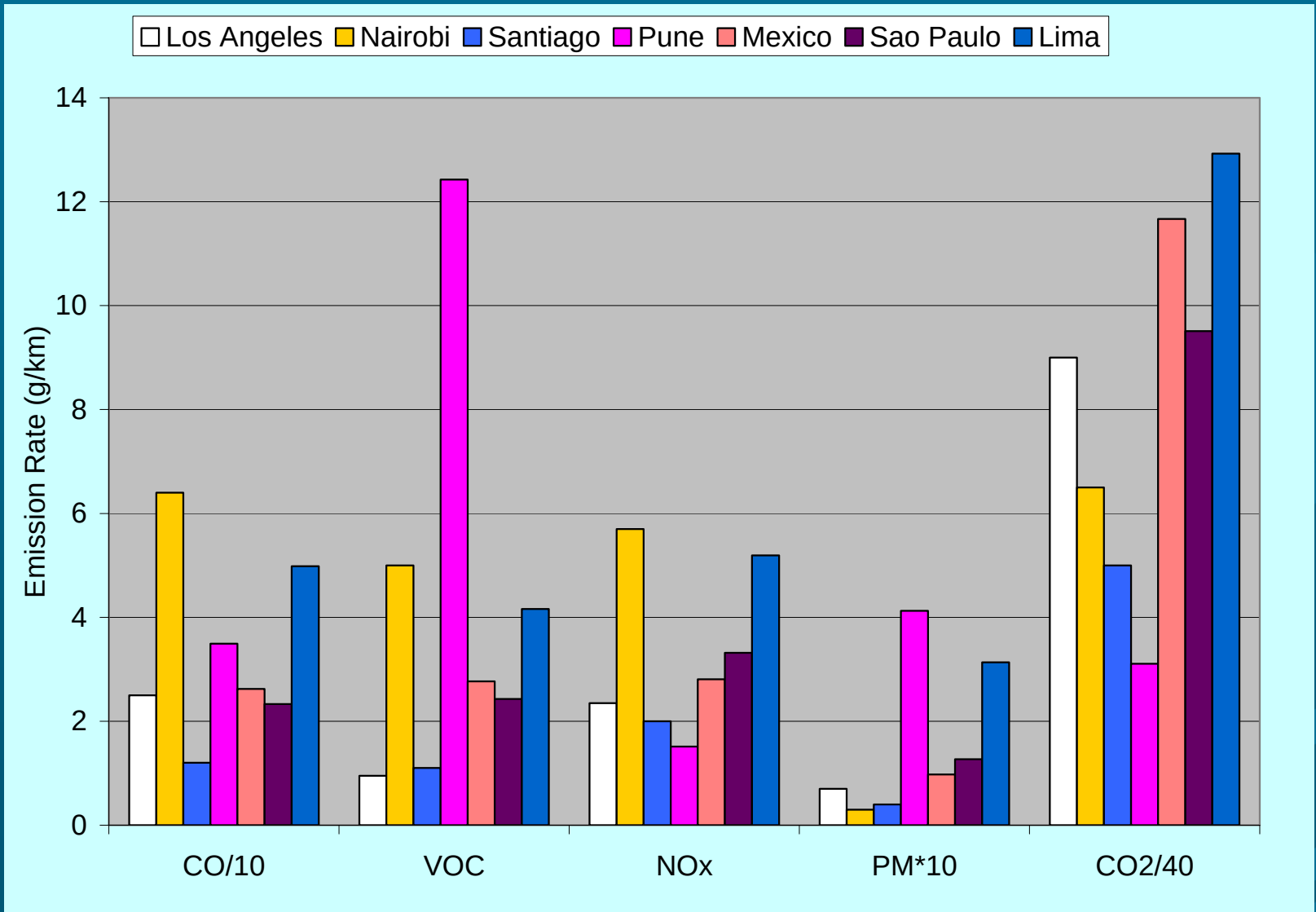
CO Emissions (preliminary)



Results: Temporal distribution (IVE)



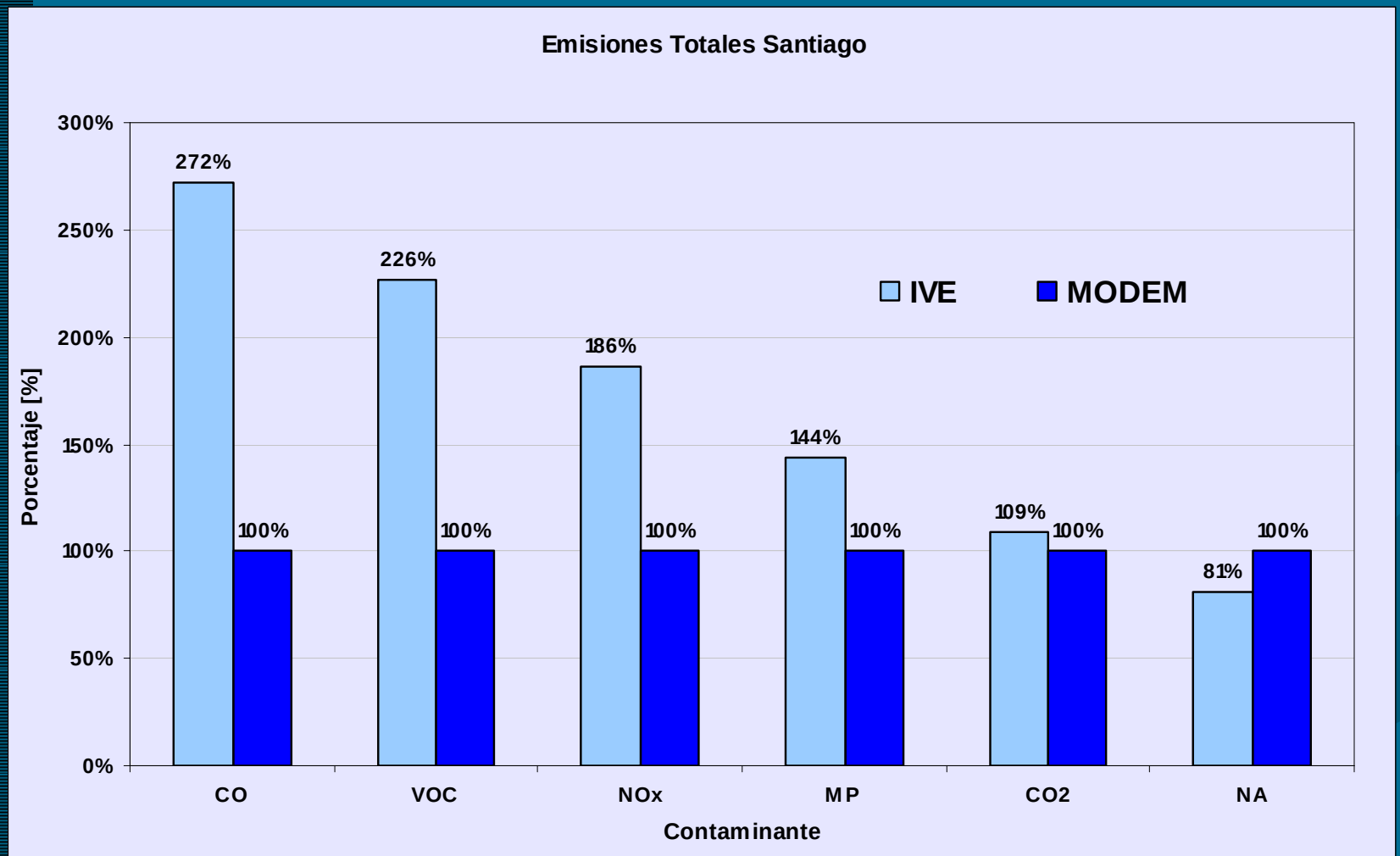
Results: inter-city comparison



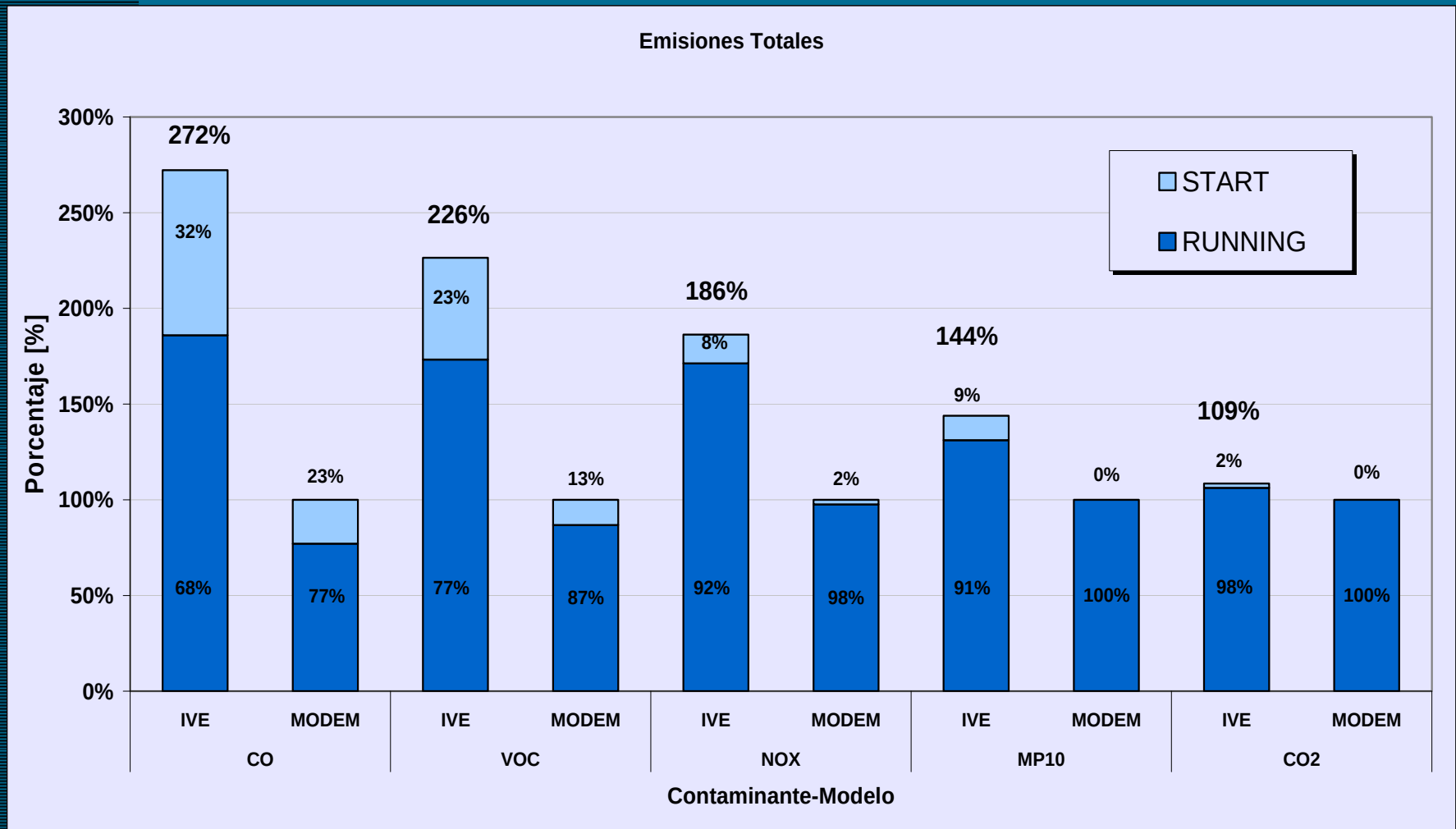
Conclusions

- 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**

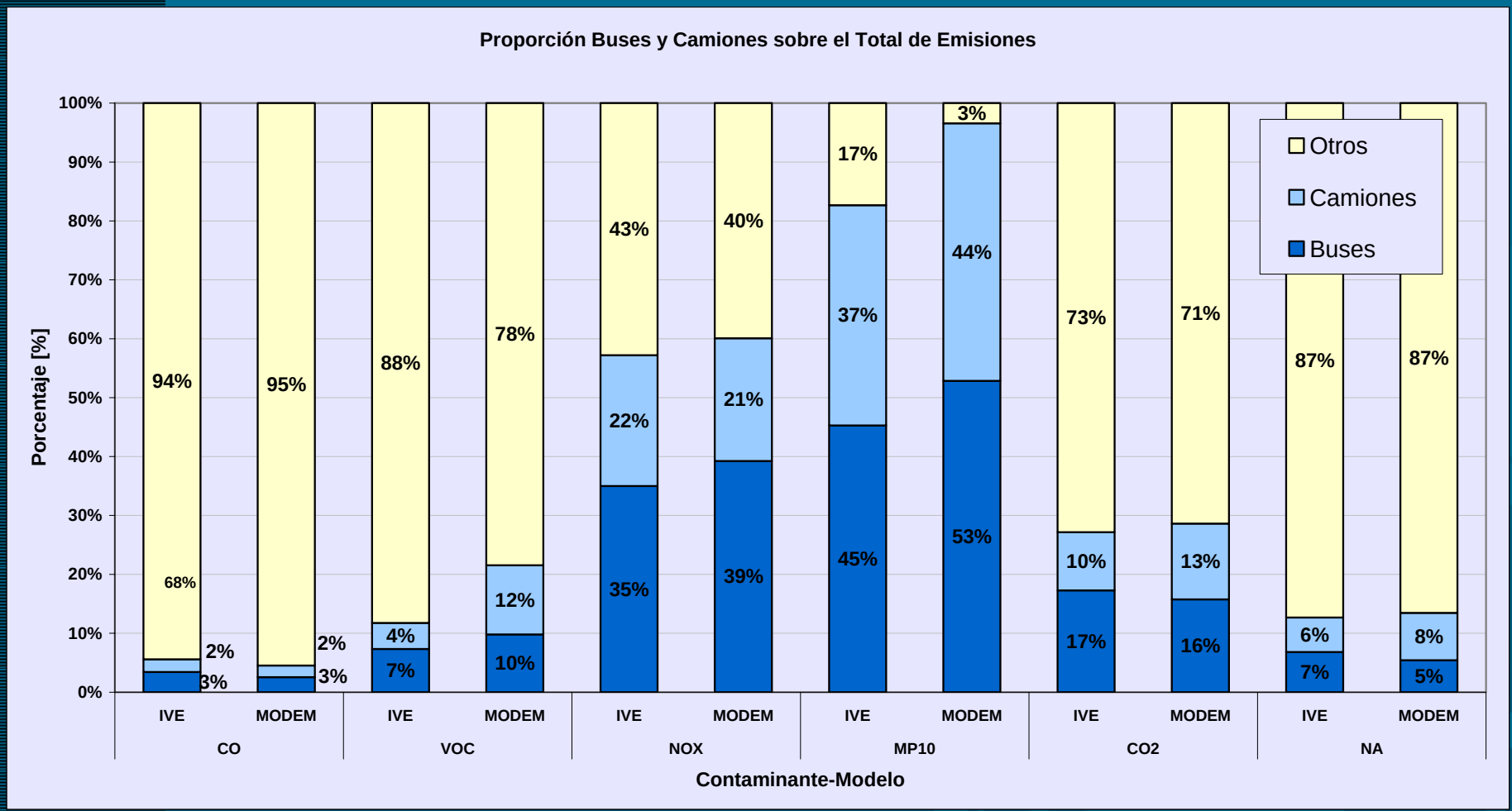
Comparación IVE-2004 MODEM-2000



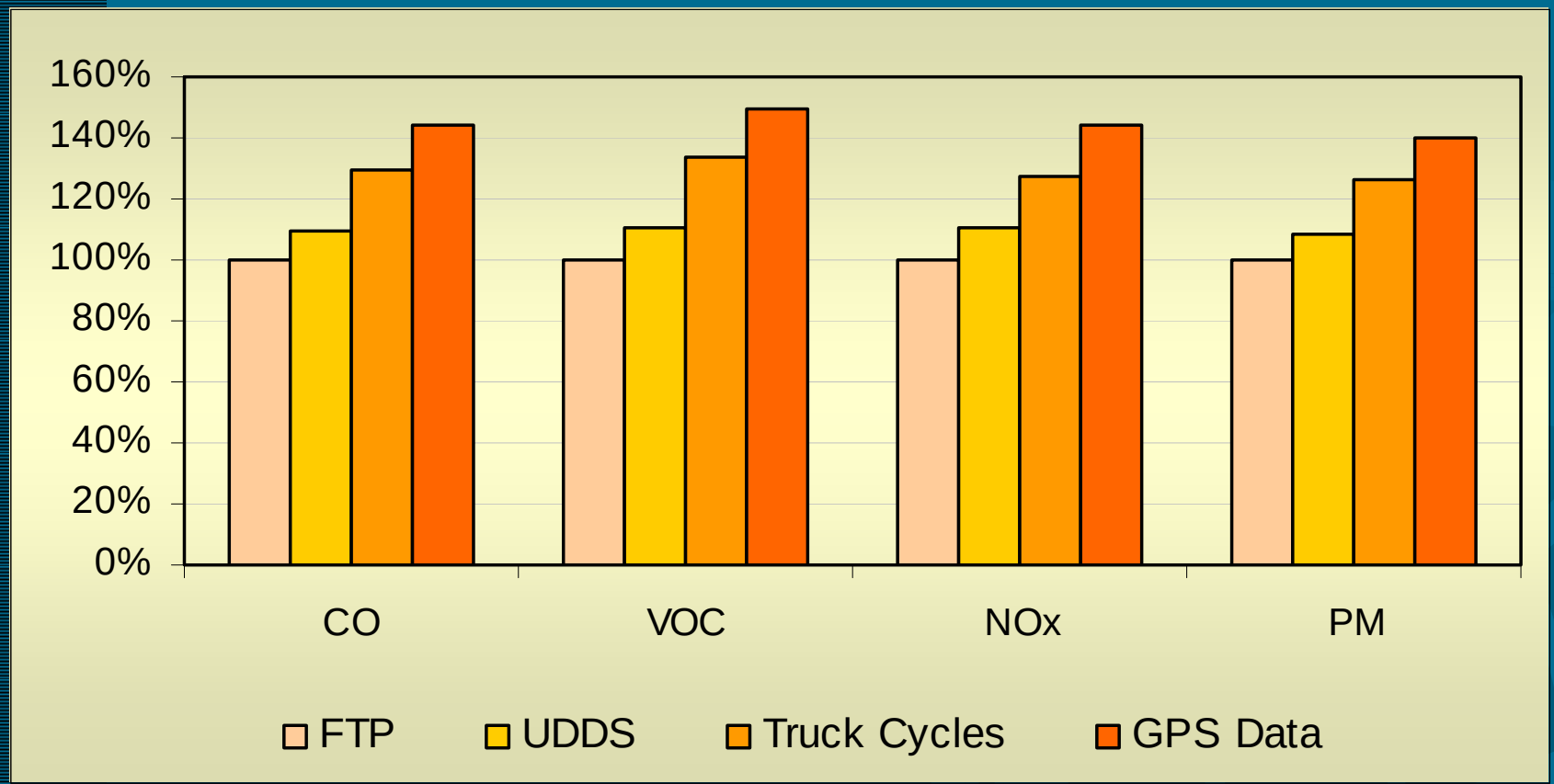
Partidas en frío y emisiones en caliente

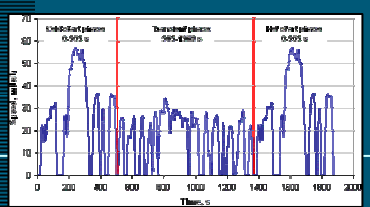


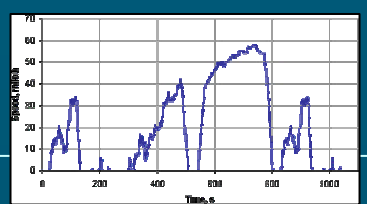
Responsabilidad de buses y camiones

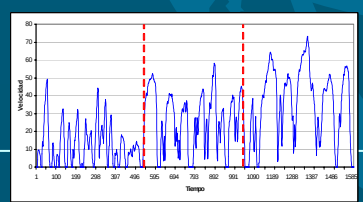


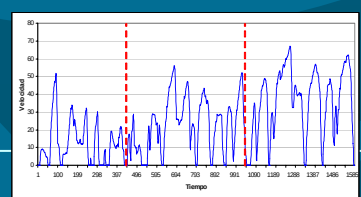
Comparación de ciclos transientes












3 PORTAL NORTE
SALIDA
A011
TransMilenio


TAXI


BUSSCAR
RENCA
LO ESPEJO


COMPRAS

OBM & PEMS


Total 2.3E+2 ug/
DMMvi 1.1
12:55:28 PM: Initialising
12:55:33 PM: AutoCalibration OFF
12:56:00 PM: Charger voltage alarm
SENSOR
Tech-PC

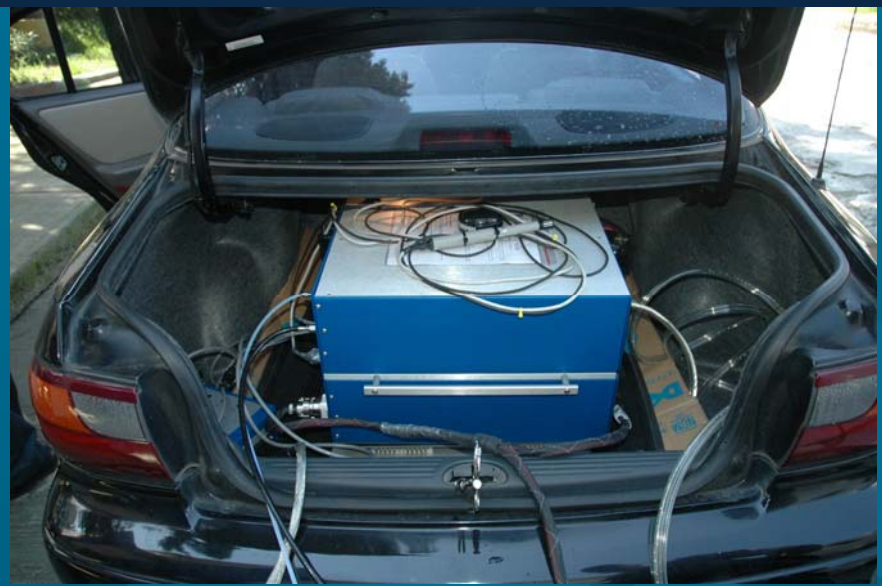
IVE Sao Paulo

THE WILLIAM AND FLORA HEWLETT FOUNDATION

CETESB

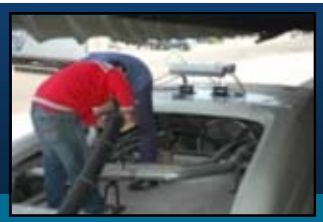
IVE Mexico City

THE WILLIAM AND FLORA HEWLETT FOUNDATION



IVE Nairobi





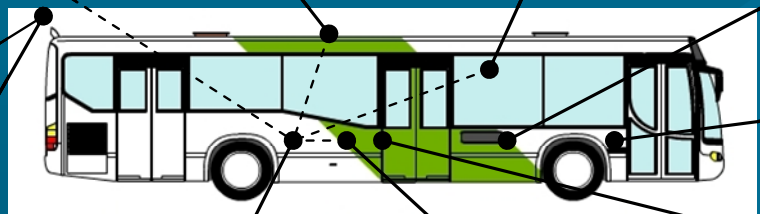

Medición de posición y velocidad instantánea por segundo con GPS

Medición de humedad relativa y temperatura ambiente

Transporte de gases a temperatura controlada, 200ºC

Sistema de dilución con filtro HEPA para aire ambiente

Sistema de medición de flujo y muestreo de gases



Equipo generador para equipos eléctricos con soporte de batería

Bus cargado con sacos de arena (50% de su capacidad de pax)

Bomba de vacío para muestreo de material particulado, 10 l/m

Sistema de análisis y adquisición de datos para gases

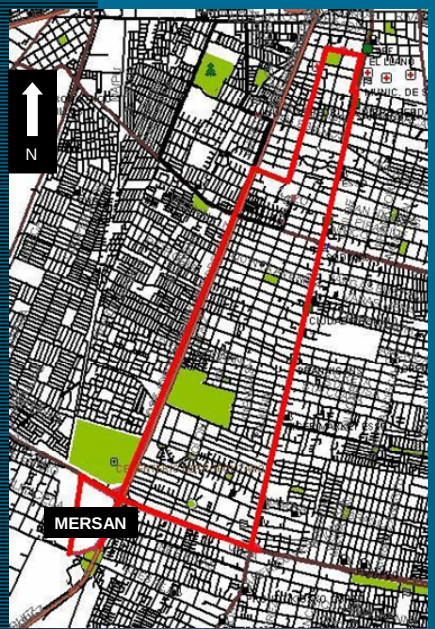
Sistema de medición y adquisición de datos para partículas

Computador de apoyo para unidad de medición de gases

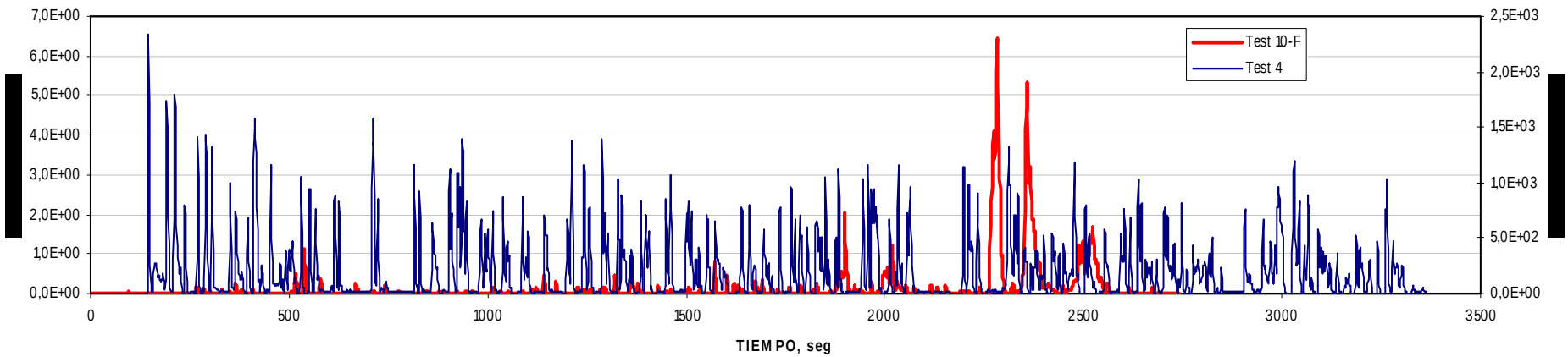
Computador de apoyo para unidad de medición de partículas



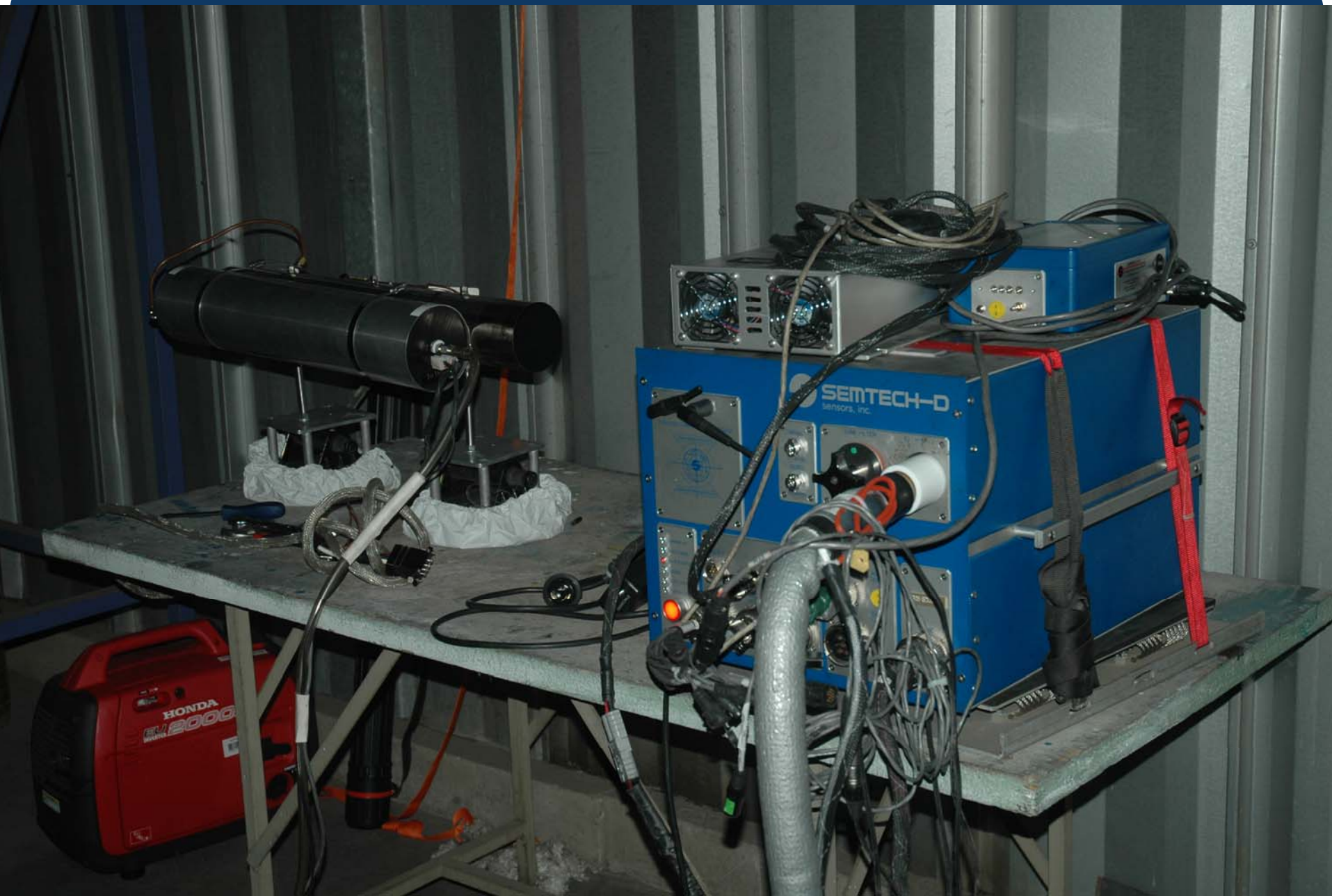


Tipo de bus	Estándar de emisión	Nº de buses
Convencionales	Euro-I	2
	Euro-II	3
	Euro-II con filtro	3
	Euro-III	2
Transantiago	Volvo B9SALF	3
	Volvo B9SALF con filtro	1
	Volvo B7RLE	6
	Volvo B7RLE con filtro	5
	Total de buses	**25**




LAND ROVER
SEATECH


SEMTECH-D
sensors, inc.
HONDA
EU2000


Crédito
Los Héroes
600 222 77 77
LOS HEROES
ZN626
7008
3791
VOLVO
ZN 51 61


VOLVO


Estimado Estudiante:
A contar del
lunes 19 de Junio,
el beneficio de
tarifa rebajada
se otorgará a aquellos estudiantes
que presenten el
pase escolar vigente (BIP)
entregado por el
Ministerio de Educación.
Si su pase presenta inconvenientes, llame a nuestra
línea gratuita 800 387700.
El conductor no está autorizado
a transportar pasajeros que no paguen
la tarifa correspondiente.
SUBUS


DAY
vitamina.
4550
NA 8534


NUEVO
Gato
890
3776
VOLVO
B7R
ZN 5374
7047
ZN-53-74


SENSOR Tech-PC
Home
System Setup
Status
Test
Data Analysis
Activity Logs
Tech Support
Test Setup
Data Files
Data Table
Graph
Emissions
Bench Display
Road Test
Drive Cycle
READY
Dekati Mass Monitor Software
Setup
Measurement
Instrument status
Total Mass [ug/m³]
Clear
Total 2.0E+2 ug/
DMMvi 1.1
12:55:28 PM: Initialising
12:55:33 PM: AutoCalibration OFF
12:56:00 PM: Charger voltage alarm


LAND ROVER
SEMTECH-D