Module 7:

On-Road Mobile Source Emission Inventory Development

On-Road Vehicle Emissions

- Key source of urban, regional, and global air pollution
- Emissions cannot be measured from all vehicles
- A methodology is needed to accurately estimate present and future vehicle emissions in urban and national settings

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On-Road Mobile Source Definition

- Vehicles that operate on paved roadways, including:
  - Passenger vehicles, trucks and vans
  - Heavy duty trucks with trailers
  - Buses and motor homes
  - Taxis
  - Two and three-wheeled vehicles designed for on-road use

- May operate on any fuel, including petrol, diesel, propane, methanol, and electricity

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International Vehicle Emissions Model (IVE)

Model Overview

The International Vehicle Emissions (IVE) model is a computer model designed to estimate emissions from motor vehicles in developing countries. The model will help cities and regions develop emissions estimates to:

- Focus control strategies and transportation planning on those that are most effective;
- Predict how different strategies will affect local emissions; and
- Measure progress in reducing emissions over time. The model will include local air pollutants, greenhouse gas emissions, and toxic pollutants.

Note: The model most used in the U.S. is called MOBILE6. It is also developed by U.S. EPA and is tailored to U.S. vehicles, roadways, fuels, etc.

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On-Road Mobile Source Pollutants

- Pollutants of concern:
  - **CO**, O_3, **NO_x**, **SO_x**, **PM, Lead** and Contributors to criteria pollutants **VOC** and **NH_3**
- Other pollutants of concern include:
  - **1,3-Butadiene, Benzene, Formaldehyde, Acetaldehyde**, Several metal compounds and dioxin/furans
- Greenhouse Gases:
  - **CO_2, N_2O, CH_4**
- Pollutants in Bold are estimated in the IVE model

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Required Information for Estimating Mobile Source Emissions

I. Vehicle Emission Rates
  - Perform emissions tests
  - Use International Vehicle Emission (IVE) model emission rates

II. Vehicle Activity
  - Collect the amount of driving and starts
  - Collect the type of driving and starts

III. Fleet Distribution
  - Collect the quantity and type of vehicles

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Part I:

Understanding Mobile Source
Emission Rates

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Types of Mobile Source Emissions

- Evaporative Emissions:
  - VOC emissions from the petrol tank and hoses
- Crankcase Emissions:
  - VOC emissions from the engine
- Tailpipe Emissions:
  - From the engine exhaust

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Factors Affecting Evaporative Emissions

- Fuel Type and Volatility
- Ambient Temperature
- Engine and Tank technology

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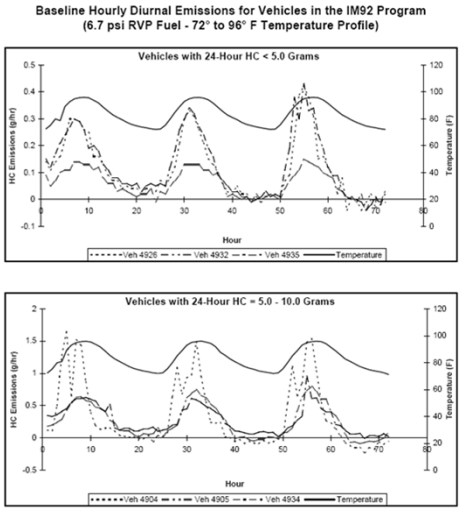
Diurnal Emissions



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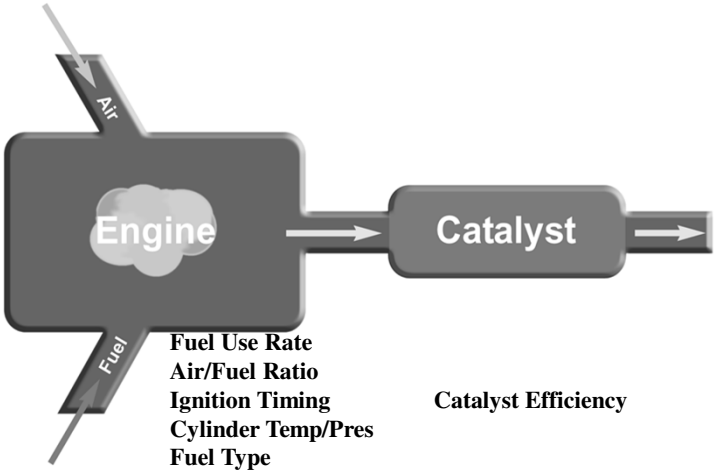
Factors Affecting Tailpipe Emissions



Fuel Use Rate
Air/Fuel Ratio
Ignition Timing
Cylinder Temp/Pres
Fuel Type

Catalyst Efficiency

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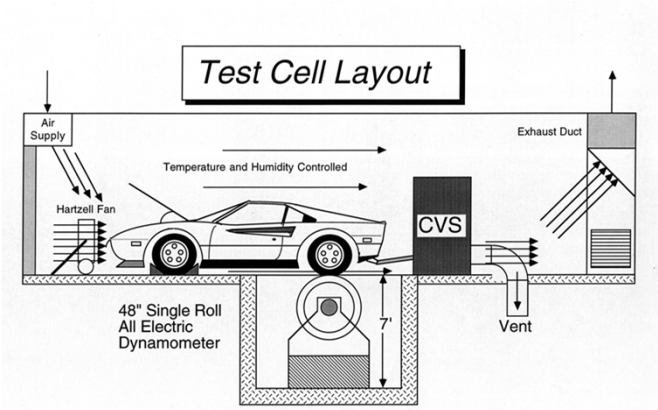
Dynamometer



Road Load Force = Tire Rolling Losses + Wind Resistance + Grade + Inertia
= A + B*V + C*V^2 + D*W + Mass* dV/dt

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Dynamometer

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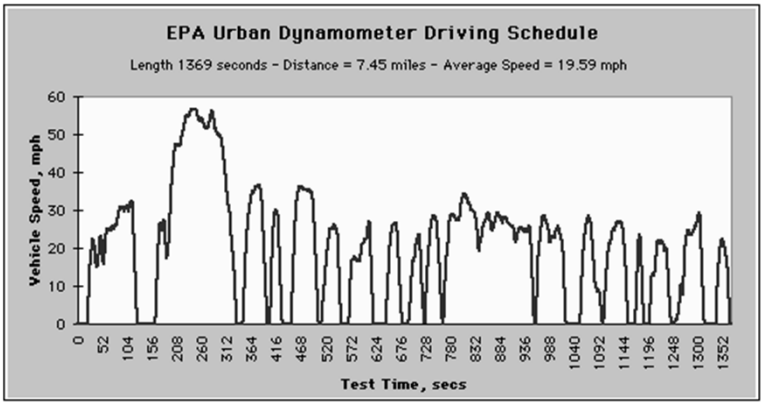
Driving Cycles



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Tailpipe Control

- Air pump
  - Adds combustion air to tailpipe
- 2-Way Catalyst (CO/VOC Control)
  - Catalyst design and active metal content
- 3-Way Catalyst (CO/VOC/NO_x Control)
  - Catalyst design and active metal content
- Location of Catalyst near engine
  - Heats catalyst faster to provide emissions control sooner
- Pre-capture pollutants during first few minutes of vehicle operation
  - Captures pollutants until catalyst is hot

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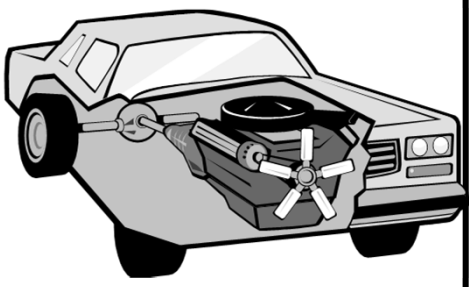
Engine Technology

- Ignition Type and Compression Ratios
  - Spark ignition, compression ignition, high or low compression ratios
- Air Fuel Control
  - Carburetor, Single-Point or Multi-Point Fuel Injection
  - Oxygen Sensor/Computer
- Ignition Control
  - Mechanical, Computer



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Fuel Quality Improvements That Can Reduce Emissions

- Eliminate lead (Pb)
  - Reduces public lead exposure
  - Allows for use of 3-way catalytic control
- Reduce sulfur
  - Reduces public exposure to sulfur oxides and resulting particulate matter
  - Increases catalyst efficiency
- Improve combustion qualities of fuel
  - Modify mixture of hydrocarbons in the fuel, Use easier to combust fuel (ethanol, natural gas)
  - Pre-mix fuel for 2-stroke to reduce oil in fuel
  - Add water to diesel fuel to improve combustion (lowers power)
- Lower oxygen demand of the fuel
  - Add oxygen containing organics such as ethanol

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Base Emission Rates

- Taken from MOBILE6 data, extensive measurements made at CE-CERT, and some internationally provided data
- Base emission rate for each technology and for each pollutant (~19,000 Base emission rates)
- Stored in IVE model as grams/kilometer traveled

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Emissions Divided into Two Categories

- Start-up emissions
  - Excess emissions beyond normal hot-running emissions that occur while engine is warming up
  - Occur typically in the first 200 seconds of vehicle operation
- Running emissions
  - Those emissions that occur during vehicle operations including idle
  - There are both running and start-up emissions during the first 200 seconds of vehicle operation

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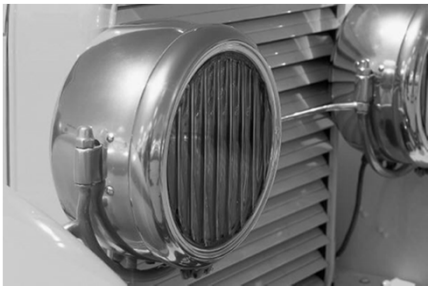
Start-Up Emissions



- Depend on temperature of engine and catalyst at start
  - Time since engine last started
  - Air temperature at the time of start
- Proximity of catalyst to engine
  - Impacts the time required to heat up catalyst. (included as an engine technology)

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Driving Pattern Impacts

- Vehicle response to driving patterns varies depending on vehicle technology
- The key is how vehicle fuel demand, air/fuel, and ignition timing respond to driving patterns
- Air/fuel and ignition timing may be purposely adjusted to compensate for high power demand situations

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Running Emissions

- Are dependent on "driving factors" that are based on vehicle speeds. These factors have been distilled from vehicle test programs, using speed as a surrogate for driving patterns.
- Also considers "local effects" due to road grade and air conditioning usage.

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Correction Factors

- IVE model contains 500,000 correction factors used to consider:
  - Inspection/maintenance programs
  - Relative humidity
  - Fuel types
  - Driving patterns
  - Etc.

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Part II:

Vehicle Activity Data

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Vehicle Activity Inputs

- Driving pattern distribution
- Total amount of driving
- Soak pattern distribution
- Total amount of start-ups
- Separate distribution required for 'multi-stop' vehicles
- Distribution can be average for an entire day or hourly

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Vehicle Activity Collection

- A substantial amount of driving data (second-by-second velocity information) is necessary to estimate the driving distribution (percentage of driving in each driving bin)
- Data on the time of day and engine soak period necessary to estimate soak bin percentage for each vehicle type
- Computer programs process collected data into usable files

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Estimating Overall Driving

- The amount of driving in a city or area must be estimated, by one or a combination of the following:
  - Collecting vehicle counts on a representative set of roadways,
  - Using registration and sales data, and
  - Inspection and maintenance or other form of odometer reading
- The number of vehicles and the average driving per vehicle will yield an approximate estimate of vehicle kilometers traveled in an area
- Many times, multiple estimates can be made and used for cross-checking

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Part III:

Fleet Distribution

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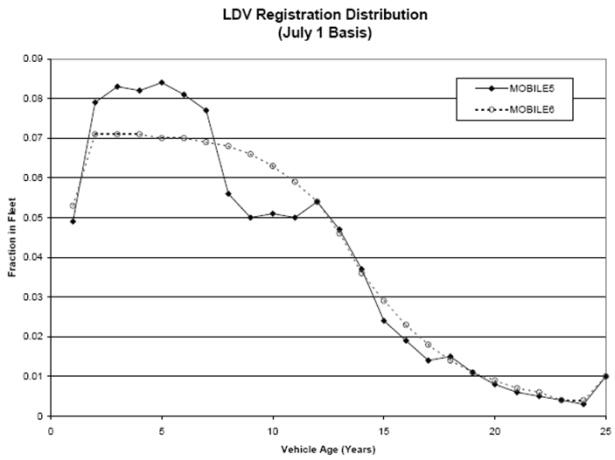
LDV Registration Distribution



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Fleet Technologies

- The IVE model allows selection of up to 1,243 technologies categorized by vehicle type, size, fuel type, age and emissions control technology
- At least 1,000 vehicles should be surveyed in each area to identify an accurate fleet profile
- The fleet VKT (as opposed to registration) should be used to calculate the fleet distribution
- In many instances, the on-road fleet distribution is significantly different than registration data

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Vehicle Technology Classifications

Vehicle Class	Fuel and Engine Type	Fuel Delivery	After Control Devices
Light Duty Vehicles	Petro 2-cycle	Carburated	None
Medium Duty Vehicle	Petro 4-cycle	Single Port fuel Injected	Catalyst (2 way)
Heavy Duty Trucks	Diesel	Multi-port fuel injected	Catalyst (3 way)
2 and 3 wheeled vehicles	Methanol	Direct Injection	Particulate Trap
	Ethanol	Exhaust Gas Recirculation	
	Propane	Standard based controls (Euro, Tier, SULEV)	
	Hybrid		
	Electric		

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Video Taping of Traffic

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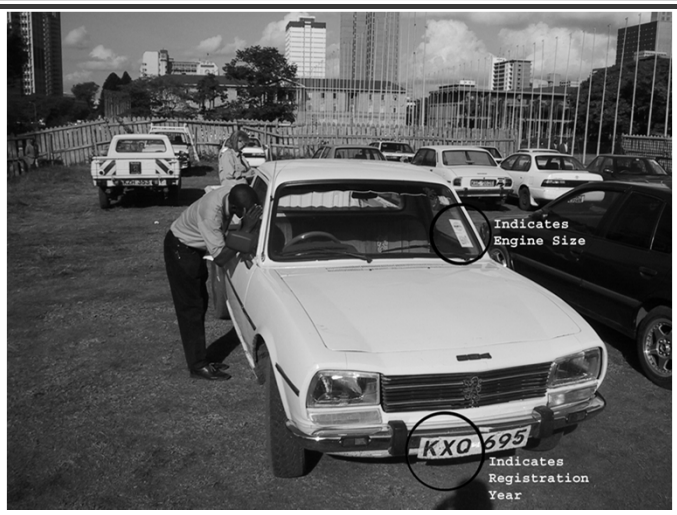
Parking Lot Surveys



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International Vehicle Emissions Model

Design And Measurements

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Estimating On-Road Emissions using the IVE Model

- All on-road emissions can be estimated using the International Vehicle Emissions (IVE) model
- Based on international data, and on the latest information from the U.S. MOBILE6 and CARB EMFAC2002 models
- Predicts emissions for most pollutants and global warming, and toxic pollutants
- Predicts emissions from over 1,370 different vehicle types

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Existing General Vehicle Emission Models

- Existing models designed for specific use in U.S., Europe, and California
- Inaccurate if applied directly to other international situations
- The International Vehicle Emissions (IVE) model designed specifically for use in developing nations

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IVE Model Uses 3 Key Input Files

- Location file describes applicable
  - Altitude, road grade(optional), temperature, humidity
  - Diesel and petrol fuel quality
  - Driving and start patterns and amounts
- Fleet file describes applicable
  - Distribution of vehicle technologies (2 × 1,243)
  - Allows normal use and multi-stop vehicles
- Country adjustment file describes applicable
  - Adjustments to base emission factors

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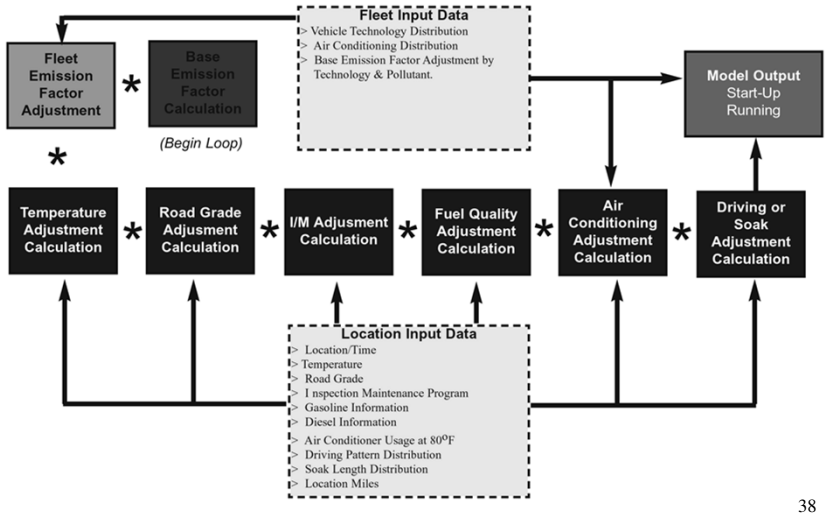
IVE Model Calculation Process



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Model Calculation Process Allows

- Single or multiple times of day
- Single or multiple locations or links in an urban area
- Use of local emission factors
- Setup of independent adjustment calculations for each technology and pollutant

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Location Page

- Specifies data pertaining to the immediate location including:
  - General Information such as average altitude, type of I/M program if any, fraction of persons using a/c at 80° F, fossil fuel characteristics
  - Hourly (or daily) data including driving patterns, average speeds, travel distance or time, temperature, humidity, start patterns, number of starts

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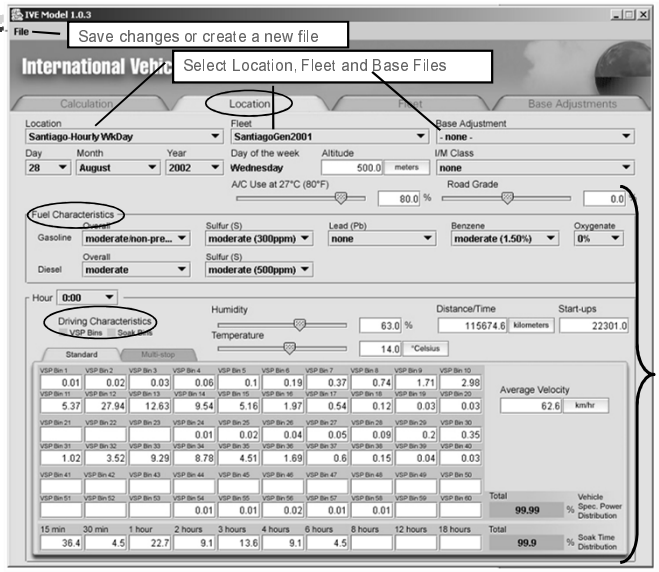
Location Page



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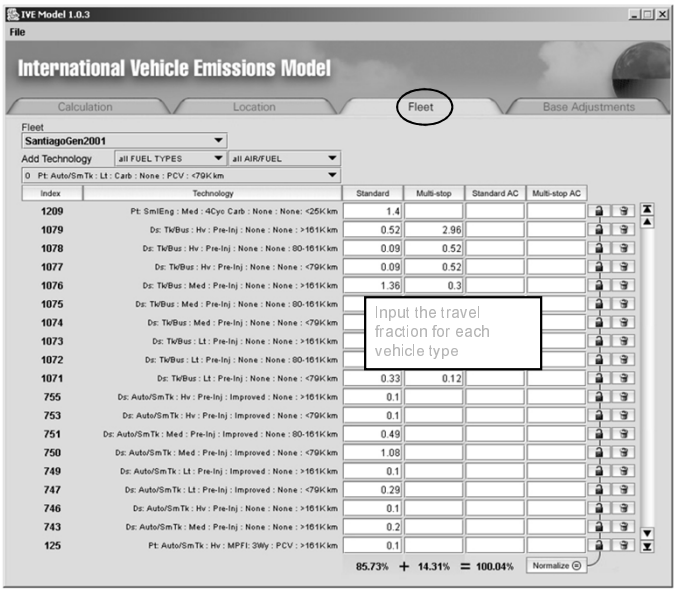
Fleet Page



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Applying Technology Specific Emission Rates in the IVE model

- Base emission rates in the IVE model are from the Running LA4 cycle and from U.S. vehicles
- For users with local data, they are encouraged to apply their own emission rates

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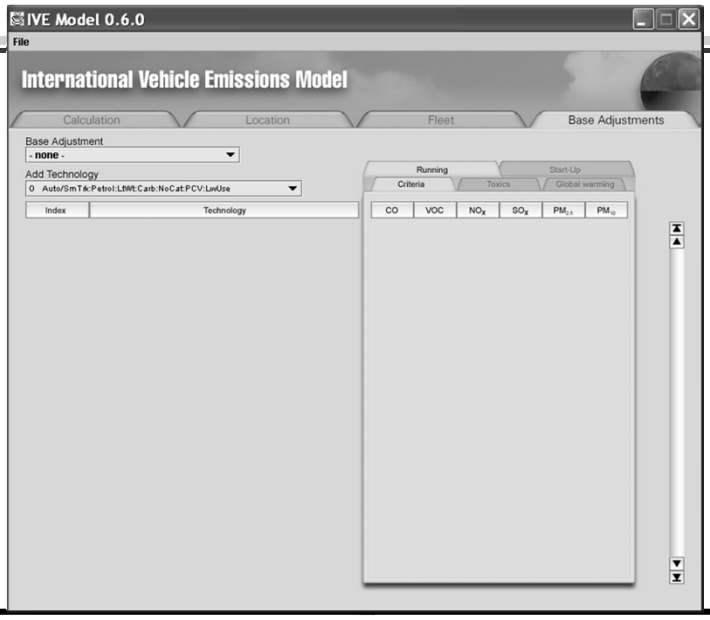
Base Adjustment Page



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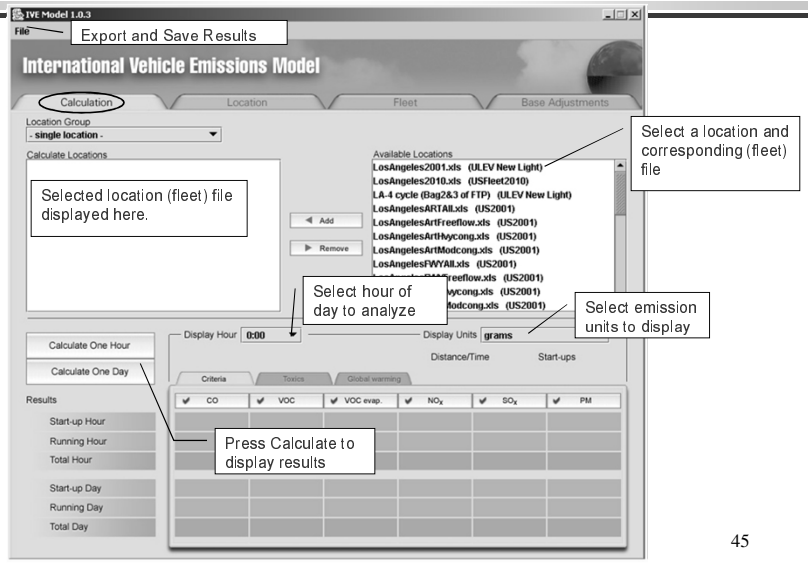
Calculation Page



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Summary: On-road Mobile Sources

- Estimating on-road mobile source emissions requires three components:
  - Vehicle emission rates
  - Vehicle activity
  - Fleet distribution
- The IVE model has been designed as a tool to aid in developing accurate inventories and can be used initially with only minimal inputs and advanced as necessary

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Questions
or
Comments?

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