

US EPA ARCHIVE DOCUMENT

The MOVES Approach to Modal Emission Modeling

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EPA Office of Transportation & Air Quality
CRC On-Road Vehicle Emission Workshop
March 29, 2004

MOVES



Additional Collaborators

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MOVES2004 Emission Rate Sources

Pollutant/Process	Running	Start	Extended Idle	Well-To-Pump	Manufacture/Disposal
Total Energy	MSOD Second-By-Second Data	MSOD Bag Data	EPA Testing	GREET (version produced for EPA by Argonne National Lab)	
Petroleum Energy	Calculated from Total Energy				
Fossil Energy	Calculated from Total Energy				
Atmospheric CO₂	Calculated from Total Energy				
CH₄	MSOD Bag Data	Not Estimated			
N₂O	MSOD Bag Data	Not Estimated			
CO₂ Equivalent	Calculated from CO ₂ , CH ₄ , N ₂ O				

Modal Emission & Activity Approach

- **Applies only to running energy consumption for MOVES 2004**
 - Plan to use for HC, CO, PM, NOx, Toxics for later versions
- **Basis of MOBILE models is average speed**
 - Aggregate approach “averages out”
 - Appropriate for larger modeling domains
 - Does not separate out differences in acceleration
- **Transportation community has pushed for approach which accounts for speed & acceleration**
 - Intersection modeling, Hot-spot analysis, TRANSIMS
- **NRC recommended a modeling approach applicable to multiple analysis scales but internally consistent**₄

MOVES “Binning” Approach

- **Group activity and emissions into “Bins”**
 - Vehicle Specific Power (VSP) & Speed
 - VSP accounts for speed, acceleration, grade, road load
- **Any driving pattern can be modeled based on distribution of time spent in bins**
 - Adds major flexibility compared to MOBILE
- **Provides common emission rates for all scales**

Binning Approach - Background

- **Initially looked at binning by VSP only**
 - On-Board Shootout (CRC 2002)
 - NC State analysis of modal approaches (Frey, CRC 2003)
- **Concluded VSP alone not sufficient** (Koupal, CRC 2003)
 - Would produce bias at low and hi speeds
 - Initially proposed binning by VSP and average speed
- **Conducted further assessment to find improved binning approach**
 - “Engine Specific Power” (Nam, CRC 2003)
 - Revised binning assessment results presented today

Goals Of Binning Assessment

- **Improve prediction over VSP-only approach**
- **Define bins in such as way as to:**
 - Use readily-available activity parameters
 - Binning by RPM or engine friction fails this test
 - Allow bin definition based on what the vehicle is doing in that moment
 - Binning by average speed fails this test
- **Define common set of bins for all vehicles and pollutants**
- **Allow bins to be filled across a broad range of vehicles (source bins) using available data**

Binning Assessment

- **Chose instantaneous speed as second binning variable**
 - Also looked at RPM, acceleration
- **Used HTBR to show important VSP and speed breakpoints**
- **Assessed 5 different combinations of VSP & speed**
- **Decided on bin structure that performed well and could be filled with data from IM240 cycle**
 - Large portion of light-duty data for MOVES2004 will be from New York State I/M evaluation program (not an in-use I/M program)

“Bin Option 5” (17 bins)

Braking (Bin 0)			
Idle (Bin 1)			
VSP \ Speed	0-25_{mph}	25-50	>50
< 0 kw/tonne	Bin 11	Bin 21	
0 to 3	Bin 12	Bin 22	
3 to 6	Bin 13	Bin 23	
6 to 9	Bin 14	Bin 24	
9 to 12	Bin 15	Bin 25	
12 and greater	Bin 16	Bin 26	Bin 36
6 to 12			Bin 35
< 6			Bin 33

Binning Proof-Of-Concept

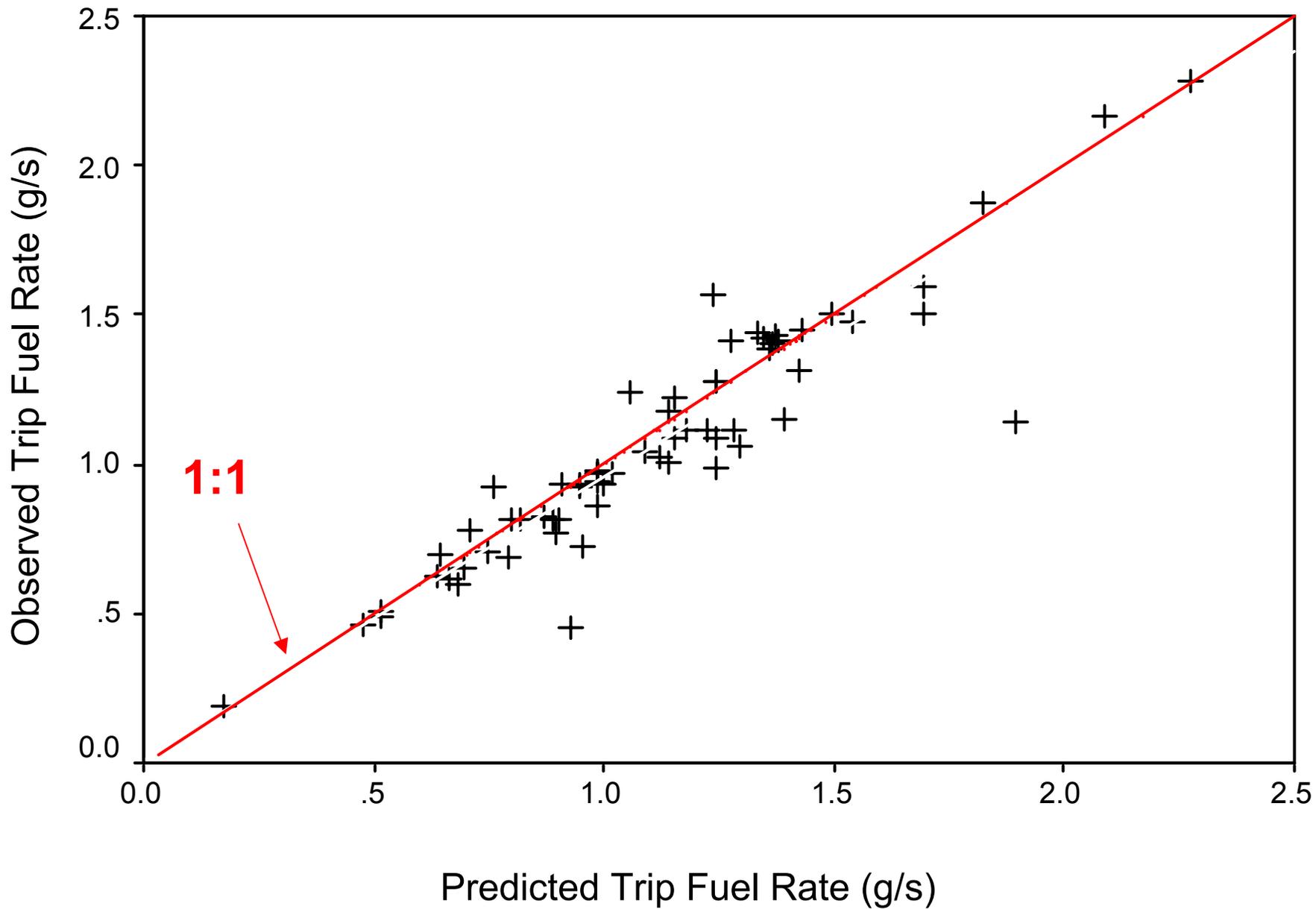
- **Can binning approach independently predict aggregate emission results?**
- **Analysis sample**
 - Light-duty: ARB UCC Dataset, EPA On-Board Shootout
 - Heavy-duty: CE-CERT Trailer Data, EPA Shootout
- **Random sample of trips removed**
- **Binned rates developed from remaining trips**
- **Emissions of removed trips independently predicted based on distribution of time in bins**

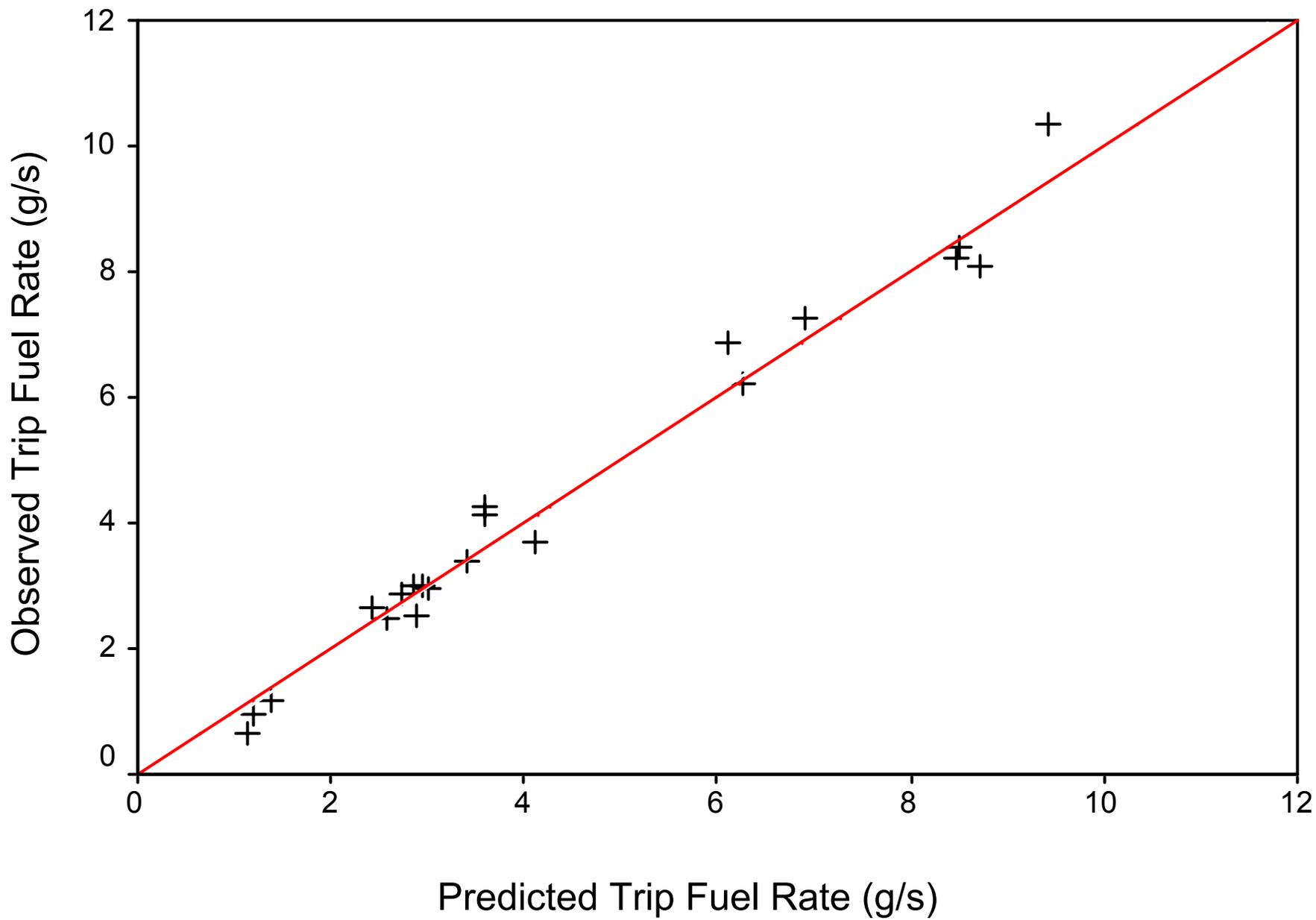
Validation Results: Bin Option 5 and VSP-Only Approaches

Percent Difference From Observed Average Trip Fuel/Emission Rates

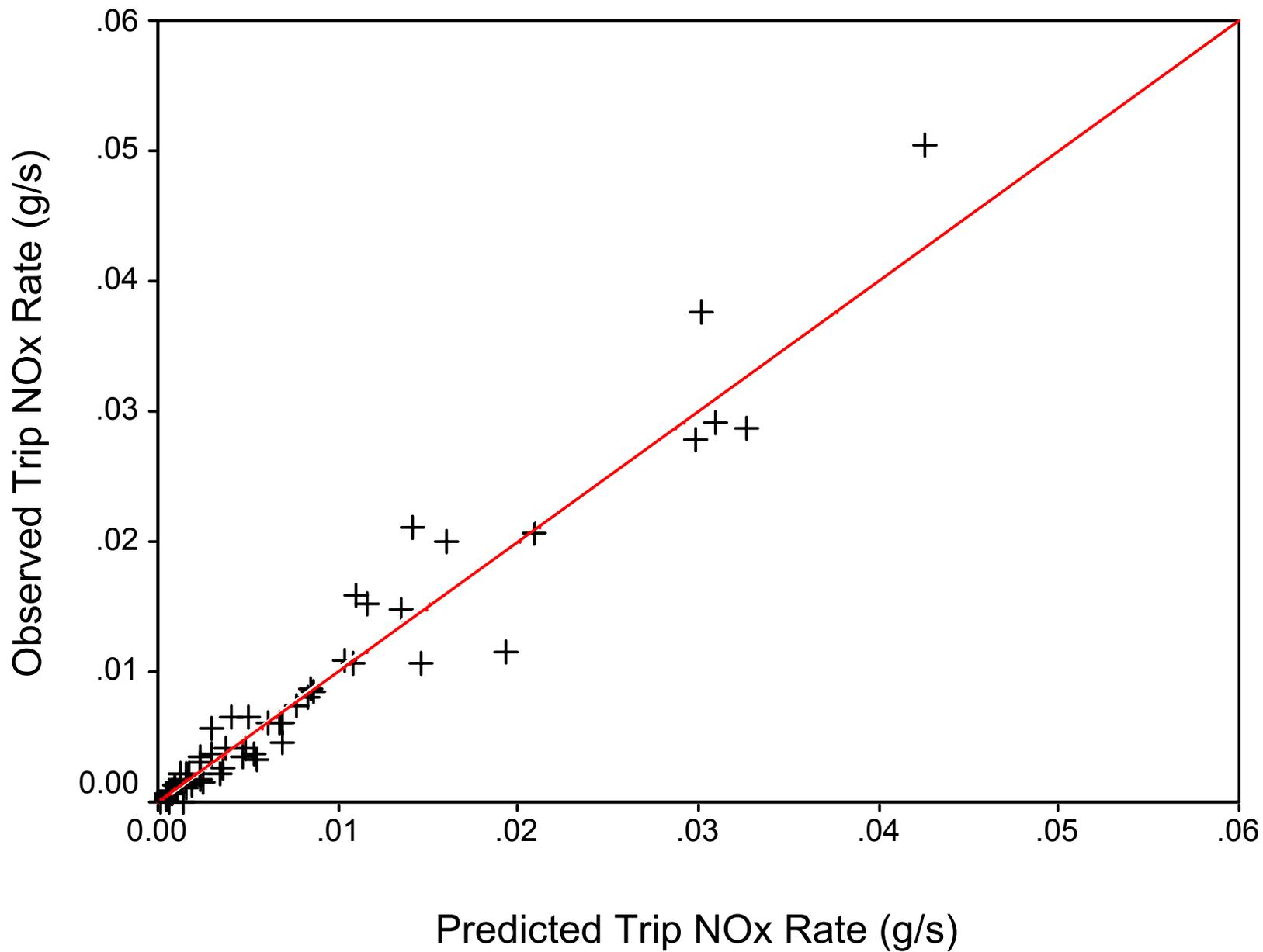
All Trips								
Light-Duty					Heavy-Duty			
	Fuel	HC	CO	NOx	Fuel	HC	CO	NOx
VSP	9%	1%	6%	5%	1%	15%	13%	-3%
BO5	4%	1%	3%	-3%	-1%	10%	14%	-4%
Trips w/ Average Speed < 30								
Light-Duty					Heavy-Duty			
	Fuel	HC	CO	NOx	Fuel	HC	CO	NOx
VSP	22%	14%	8%	14%	10%	36%	25%	19%
BO5	8%	6%	4%	-7%	0%	23%	21%	7%
Trips w/ Average Speed > 30								
Light-Duty					Heavy-Duty			
	Fuel	HC	CO	NOx	Fuel	HC	CO	NOx
VSP	-1%	-6%	6%	1%	-6%	-15%	-4%	-16%
BO5	1%	-2%	3%	-1%	-2%	-9%	3%	-11%

Per-Trip Results for BO5 In Following Slides

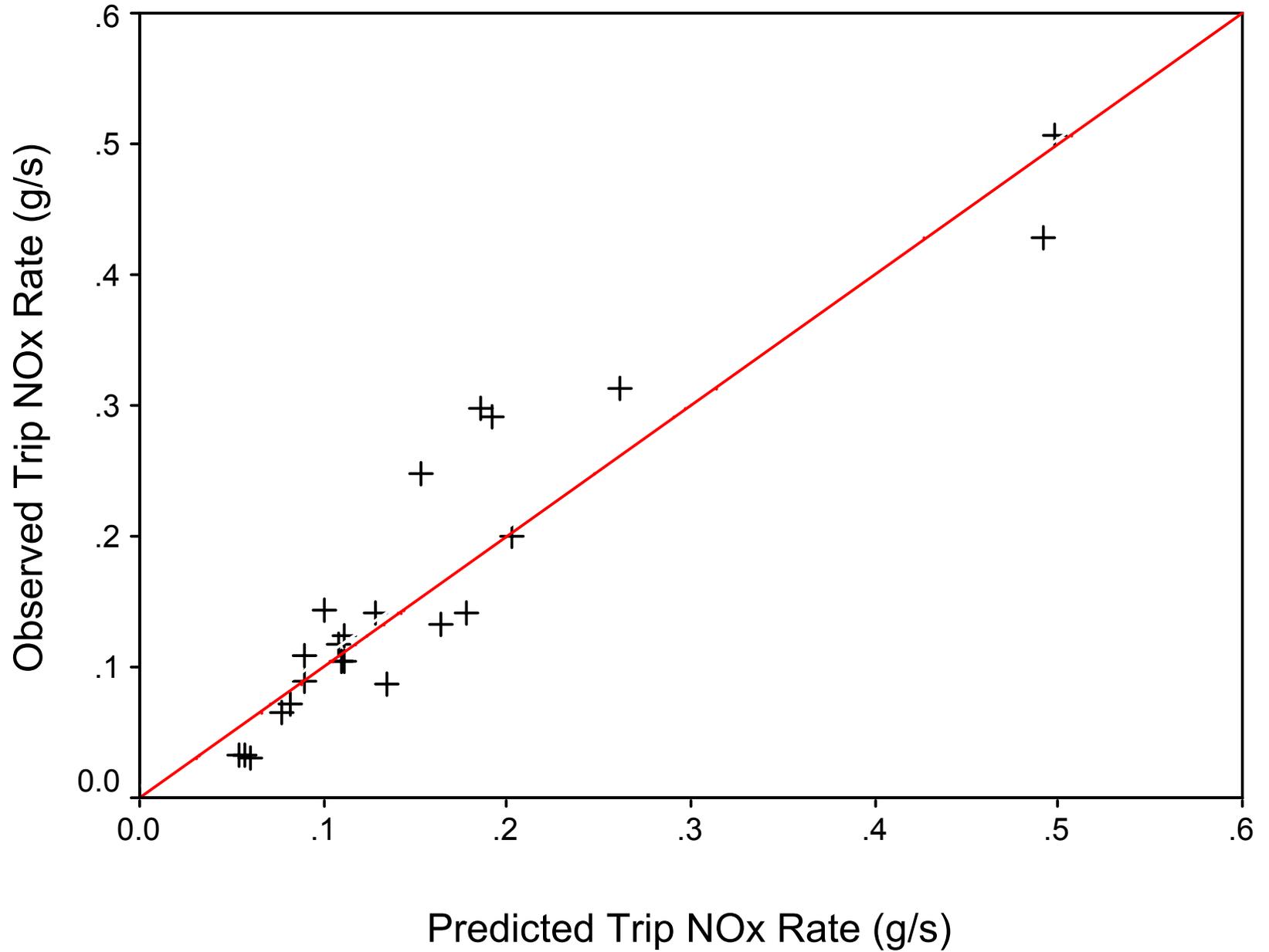




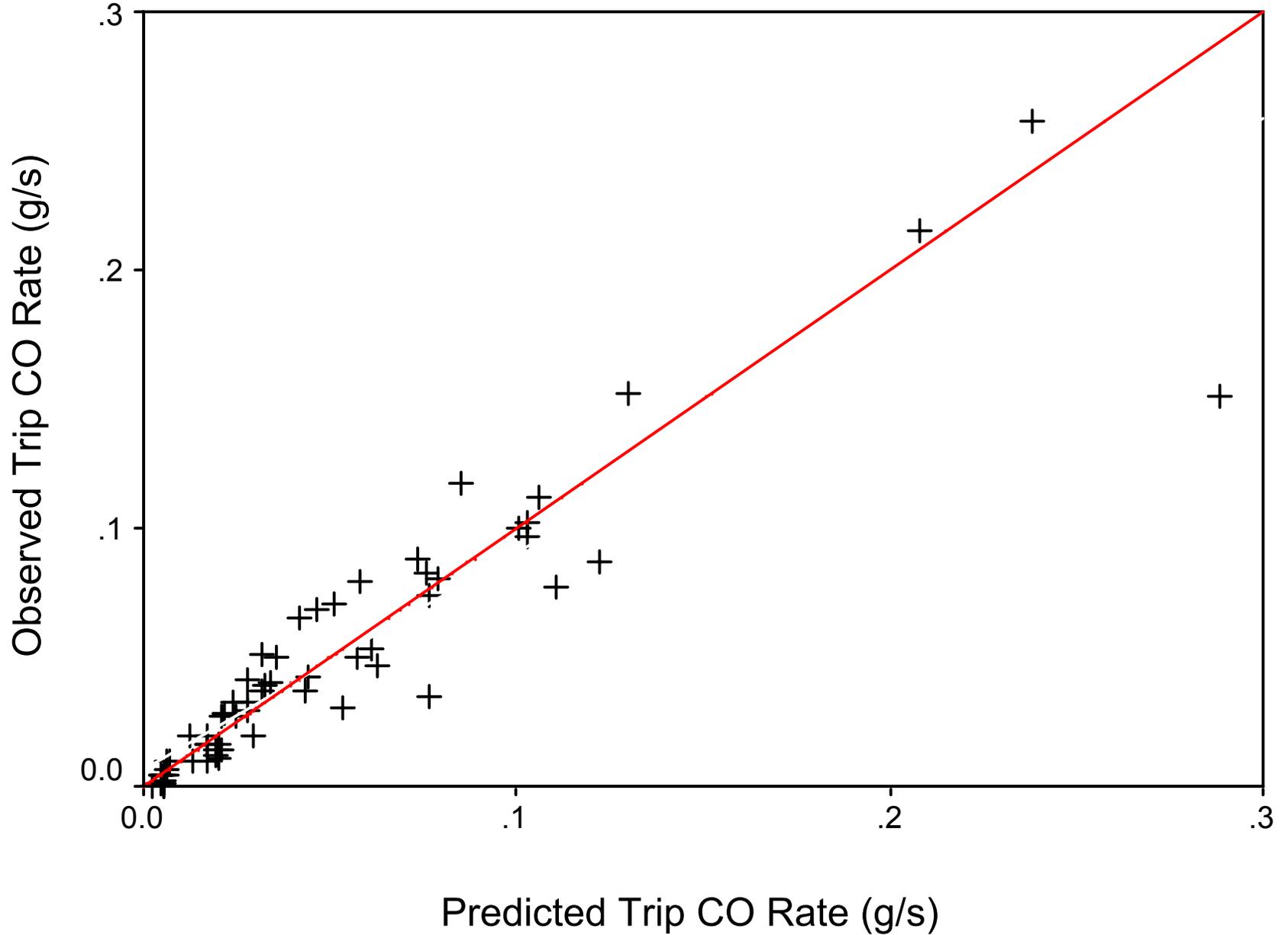
Light Duty NOx



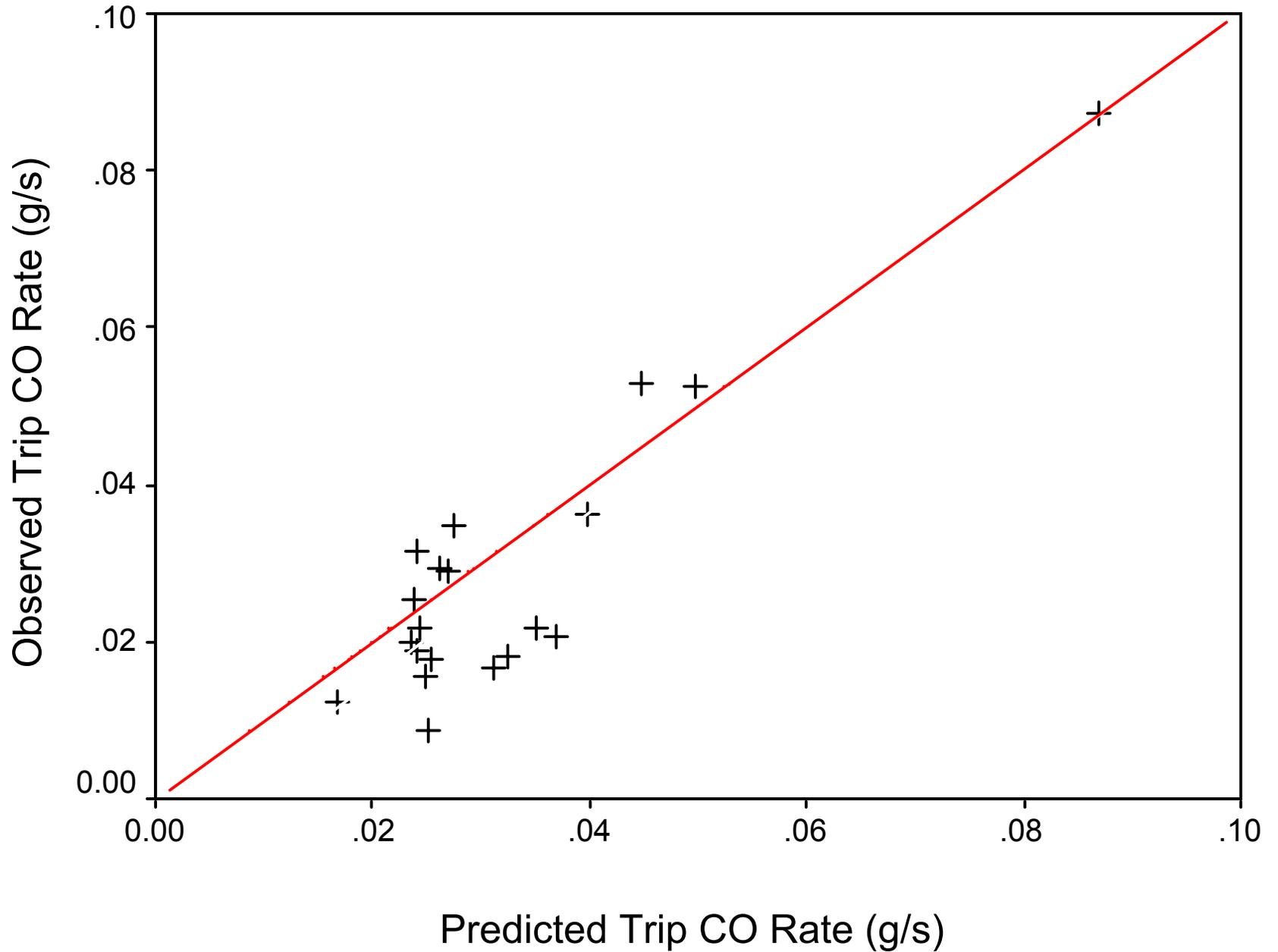
Heavy Duty NOx



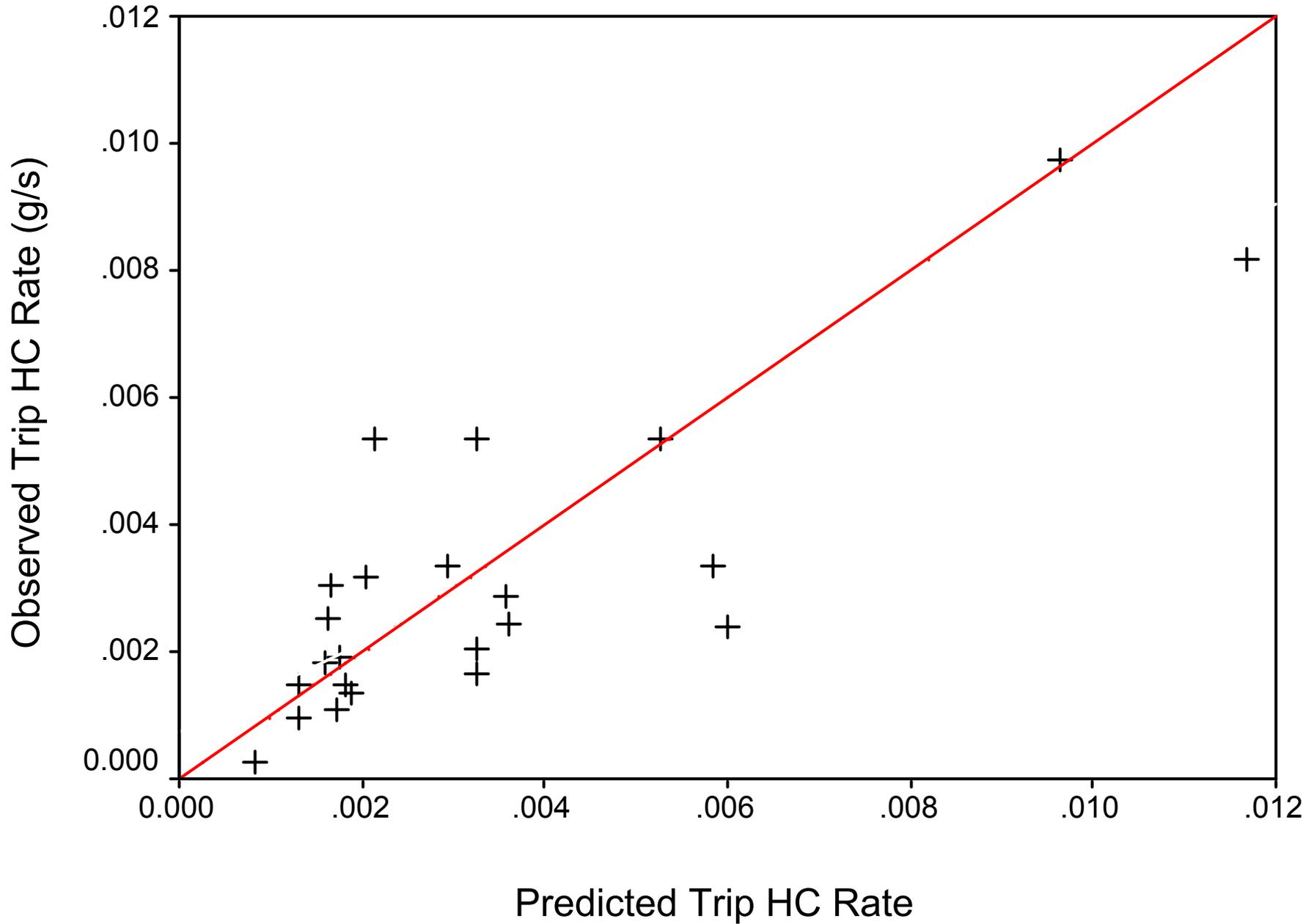
Light Duty CO



Heavy Duty CO

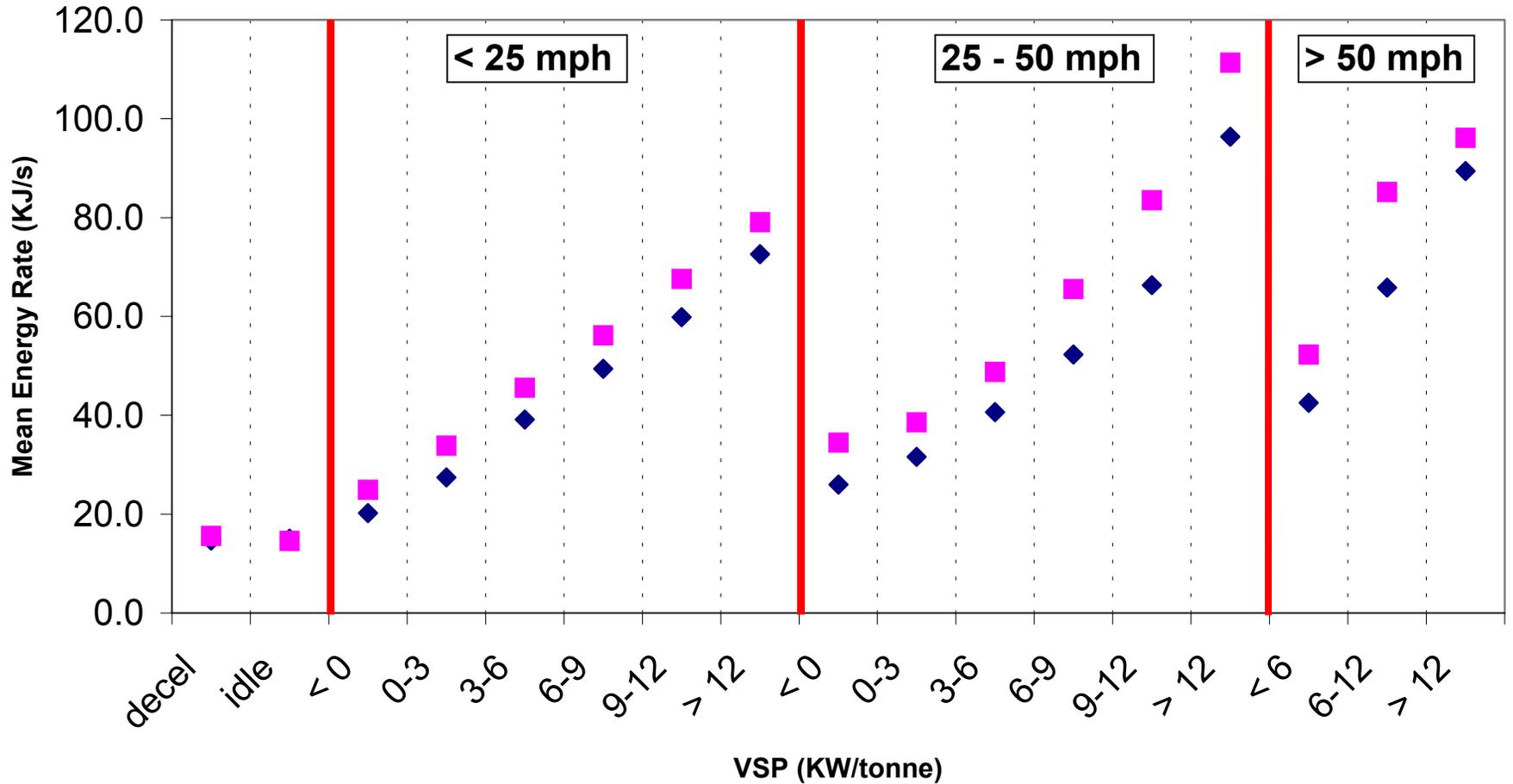


Heavy Duty HC



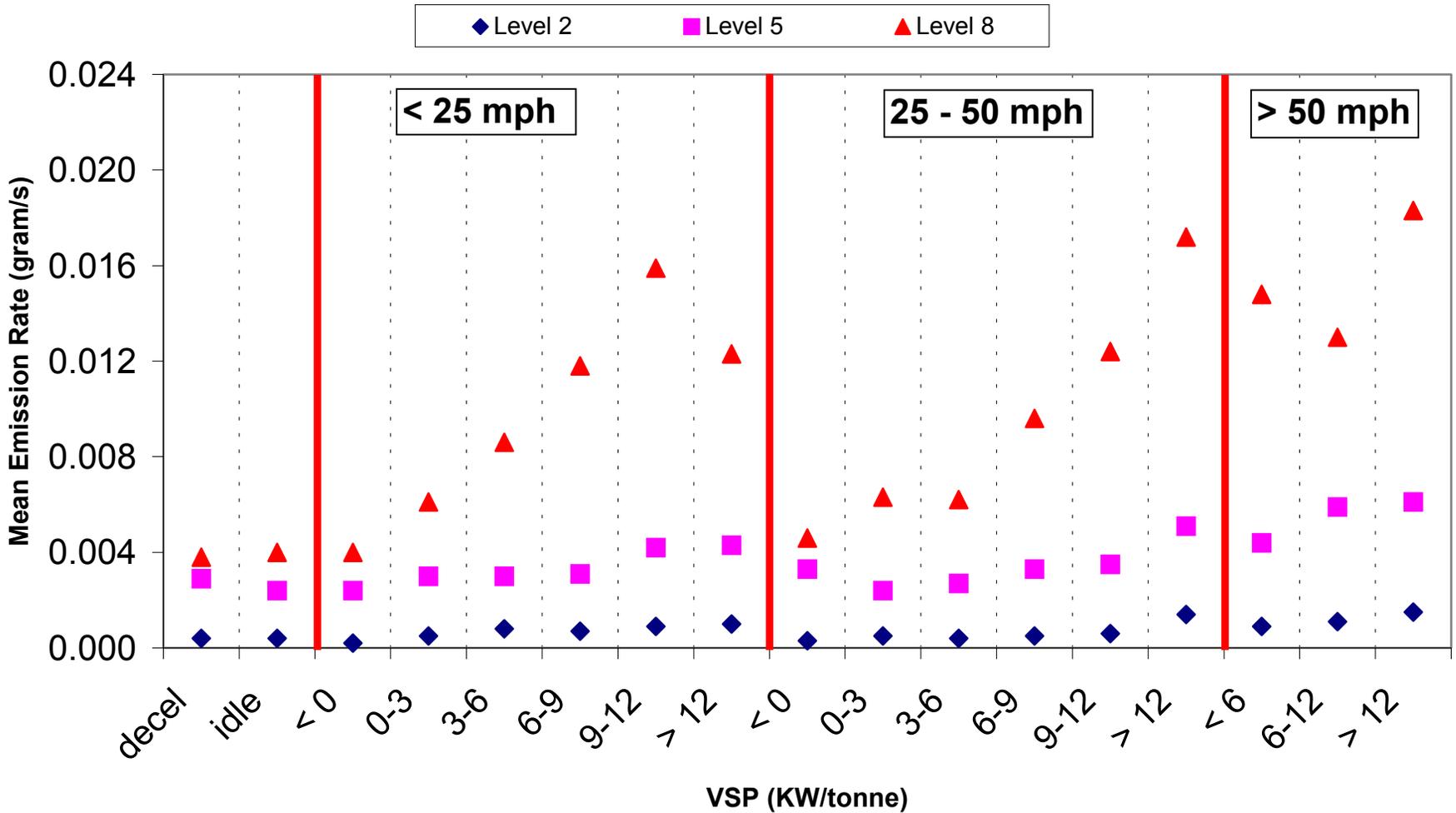
Energy Consumption Rates By Bin

Source Bin: Gasoline / 86-90 MY / 2.0-2.5 liter



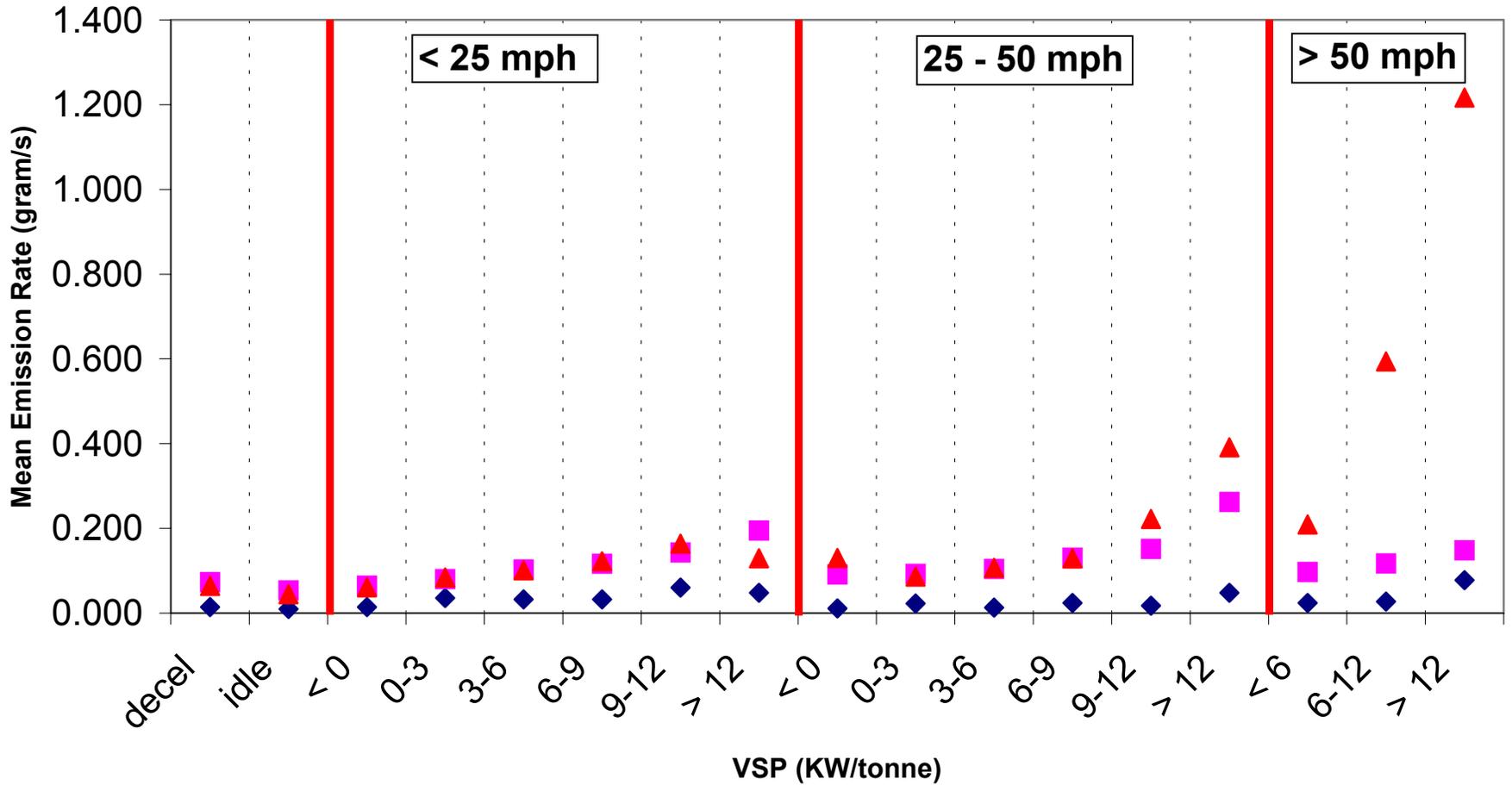
HC Emission Rates By Bin

Source Bin: Light-Duty/86-90 MY



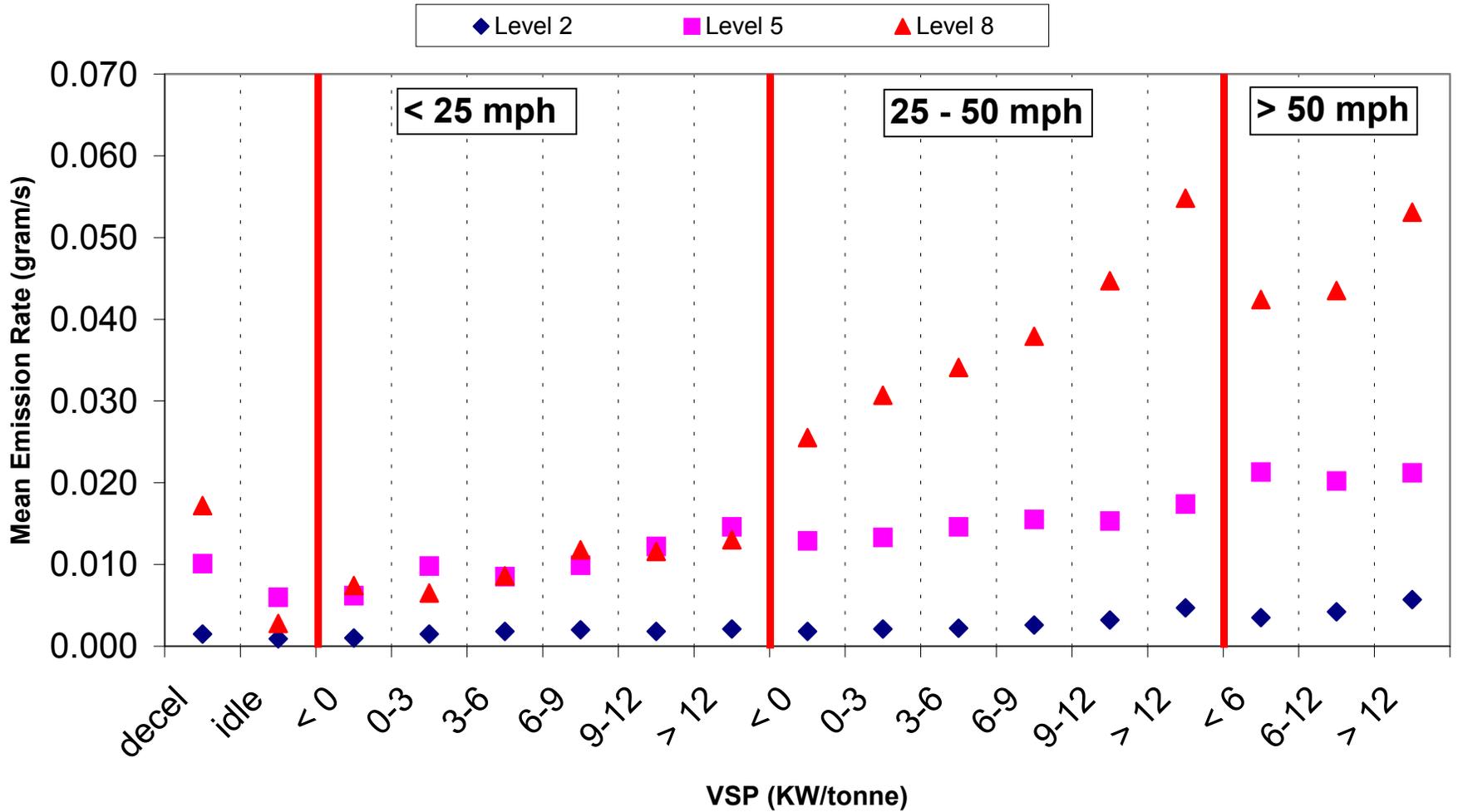
CO Emission Rates By Bin

Source Bin: Light-Duty/86-90 MY



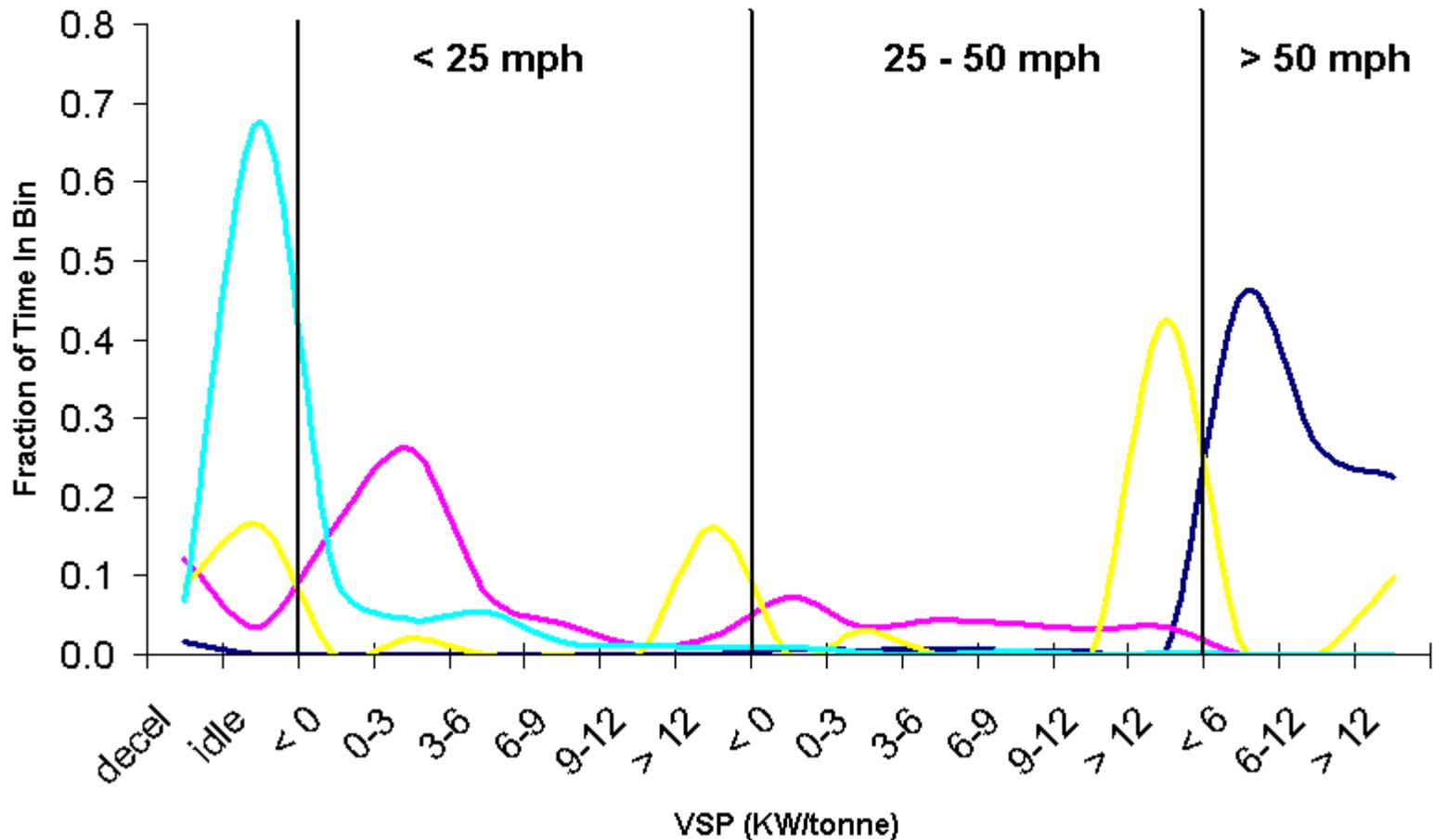
NOx Emission Rates By Bin

Source Bin: Light-Duty/86-90 MY

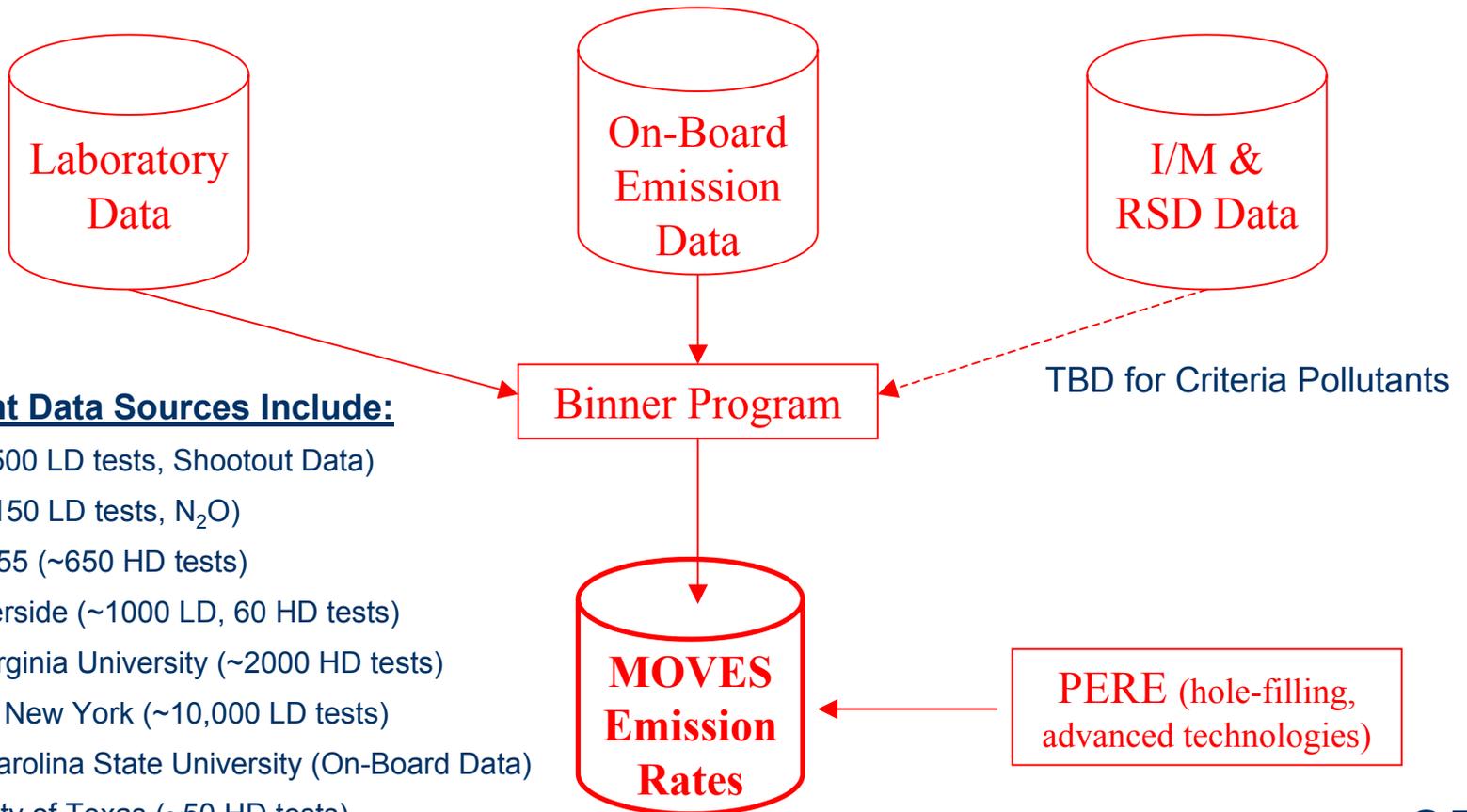


Distribution of Time By Bin

- Uncongested Freeway
- Congested Freeway
- Moderate Speed Arterial
- New York City Bus



Binning Approach Broadens Data Sources



First-Pass Binner Results

- **Percent of 1999 fleet covered by second-by-second data, by source use type:**

Passenger car: 98%

Passenger truck: 93%

Light commercial truck: 87%

Single Unit Short-haul: 65%

Single Unit Long-haul: 65%

Refuse Truck: 86%

Motorhome: 58%

Combination Short-haul: 36%

Combination Long-haul: 24%

Urban bus: 99%

School bus: 84%

Interstate bus: 100%

Motorcycles: 0%

Filling Holes

- **Energy (and eventually emission) rates needed for:**
 - Current fleet bins not adequately covered by available data
 - Advanced technologies
- **Hole-filling approaches investigated:**
 - Interpolation with surrounding bins
 - Derive binned rates from bag data
 - **Use PERE to generate binned data**
 - Presentation: “Advanced Technology Vehicle Fuel Consumption Modeling using PERE”
 - Poster: “Medium and Heavy Duty Diesel Vehicle Emissions Modeling Using a Fuel Consumption Methodology”
- **Bins making up very small percentage of a source type (< 1%) will use nearest “filled” bin**

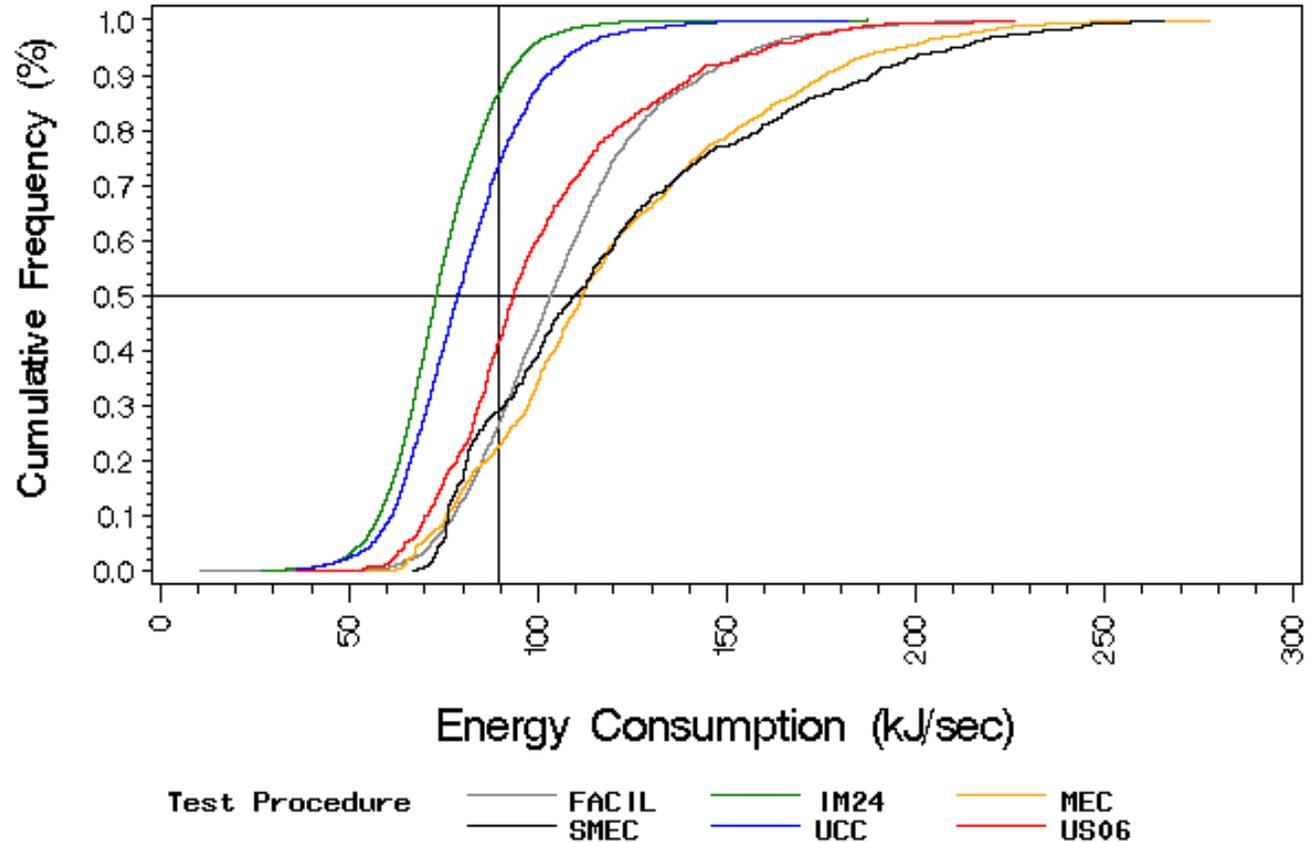
Assessing Data Within A Bin

Source Bin: Gasoline / 86-90 MY / 2.0-2.5 liter / 2500-3000lbs
Operating Mode Bin: VSP > 12 kw/tonne Speed > 50 mph

16,159 seconds of data

Breakdown by cycle:

FTP	1 %
UCC	9 %
IM240	51 %
LA92	3 %
Facility	15 %
US06	4 %
MEC/SMEC	17 %



opMode 38

For More Detail See Poster: "Mean Energy Consumption Rates within the MOVES Modal Framework"

Looking Ahead - Criteria Pollutants

- Are higher VSP bins needed, i.e. for CO?
- High emitters
 - What is a high emitter?
 - A vehicle that has high emissions all the time?
 - A vehicle that has high emissions intermittently?
 - A vehicle that has high emissions only in certain modes?
 - How should a high emitter be defined?
 - Based on aggregate emissions?
 - Within each operating mode?
 - Are we characterizing high emitters or high emissions ?
 - What data should be used?

Summary

- **Emission rates under development for all pollutants/processes in MOVES2004**
- **Modal binning approach has been developed for running total energy and as prelude for other pollutants; validation looks good**
- **Binning program “Data Crank” will enable easy updates of emission rates with new data**
- **Existing data covers large portion of fleet; PERE will be used to fill remaining holes**