MOVES2010: Information for Transportation Modelers

Transportation Research Board
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MOVES

What is MOVES2010?

- **Motor Vehicle Emission Simulator**
- **Estimates emissions & energy use from mobile sources**
  - Emissions used for inventories and air quality models
  - Accounts for changing standards, local conditions, etc.
  - Updates required by Clean Air Act
- **Highway version released December 2009**
  - Replaces MOBILE6.2 as EPA's official car & truck emissions model for SIPs and conformity determinations

MOVES – Primary Users

- **U.S. EPA**
  - Uses MOVES to estimate emission results of proposed rules, other policies.
  - Uses MOVES when creating national inventories of air pollutants
- **States**
  - **Must** use MOVES to model effects of “State Implementation Plans” (SIPs) required by Clean Air Act.
- **Cities**
  - **Must** use MOVES to model effects of transportation plans to demonstrate “transportation conformity” with SIPs.
- **Others**
  - Will use MOVES to model policy impacts.
  - Will use MOVES in vehicle emission research.

Why MOVES?

- **Under development since 2000**
- **Developed in response to National Academy of Science recommendations**
- **Replaces existing MOBILE6.2 model and expands capabilities**
  - Estimates energy consumption & GHGs
  - Allows project-level modeling
- **New state-of-the art software framework**
  - MOBILE6 code built on 1978 design & code
  - MOVES uses Java & MYSQL code & MYSQL database
  - Now easily incorporates data from variety of sources

MOVES

MOVES is Based on Latest Data

- **Light duty emissions based on review of millions of measurements of cars and light trucks**
  - Landmark study of gasoline PM in Kansas City
  - First use of portable emission measurement systems (PEMs) to capture on-road heavy-duty truck emissions
  - Much of the car and light truck data came from Inspection/Maintenance programs
- **Heavy duty emissions based on substantial new data**
  - Data from more than 400 in-use trucks
    - M6 only had engine data from certification tests
  - Includes data on HD extended idle (“hotelling”) and crankcase ventilation
  - Better information on speed effects and vehicle deterioration

New Features Since Draft MOVES2009

- Added SO2, NH3, NO2 & NO
- On-the-fly fuel adjustments
- Improved fuel importer
- External looping tool
- Road grade for project level
- Run-time speed improvements
- JAVA 6 & MySQL updates
- Improved installer tool
- Converters to help translate MOBILE6 inputs to MOVES
- Improved interface
  - IM Editor
  - Pollutant/Process screen
- Importer for daily VMT
- Improved Project Level Calculations
- Expanded Lookup Table
  - Now for evap & starts too
- Rate of Progress Calculation tool

MOVES

Major changes to Defaults Since Draft MOVES2009

- Exhaust emission rate improvements
- Fuel effect updates
- Updated VMT and LD vehicle sales
- New default driving cycles
- Improved gas/diesel mix
- Removed most alt fuel options
  - Clearer message on lack of alt fuel emissions data
- Motorcycle emissions and activity

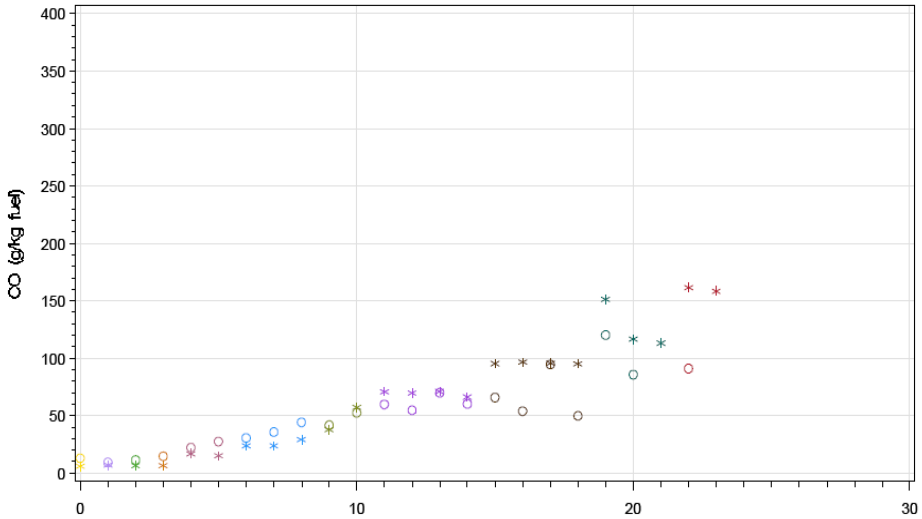
MOVES Validation

MOVES Results	Compared Against Independent Data
Light-duty gasoline exhaust rates	Atlanta Remote Sensing Data Chicago I/M and Remote Sensing Data EPA In-Use Verification Program Kansas City Gasoline Vehicle Program
Light-duty evaporative rates	CRC E-77
Heavy-duty diesel emission rates	CRC E-55 (NOx) Purdue / Borman Expressway Data (PM)
Energy consumption	FHWA Fuel Sales data

LD Validation Example

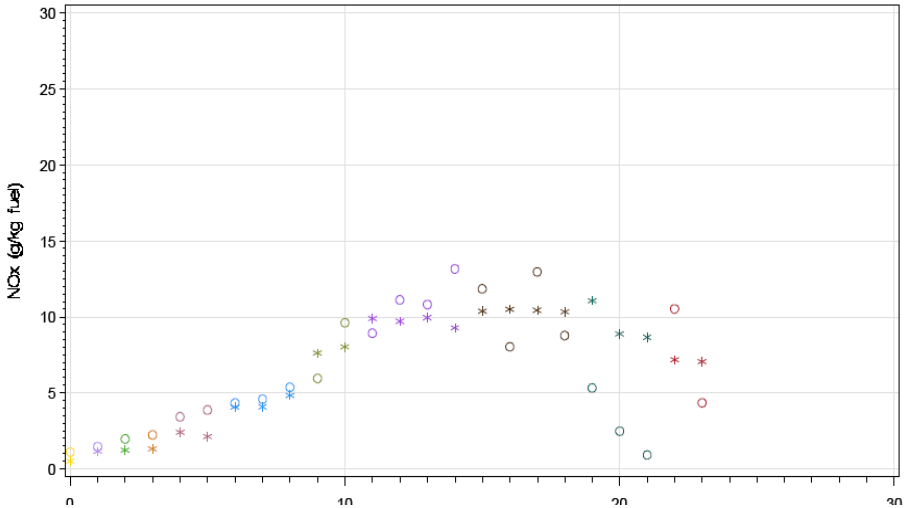
2004 LDV

Chicago RSD (circle), MOVES (star)
revised rates 111309



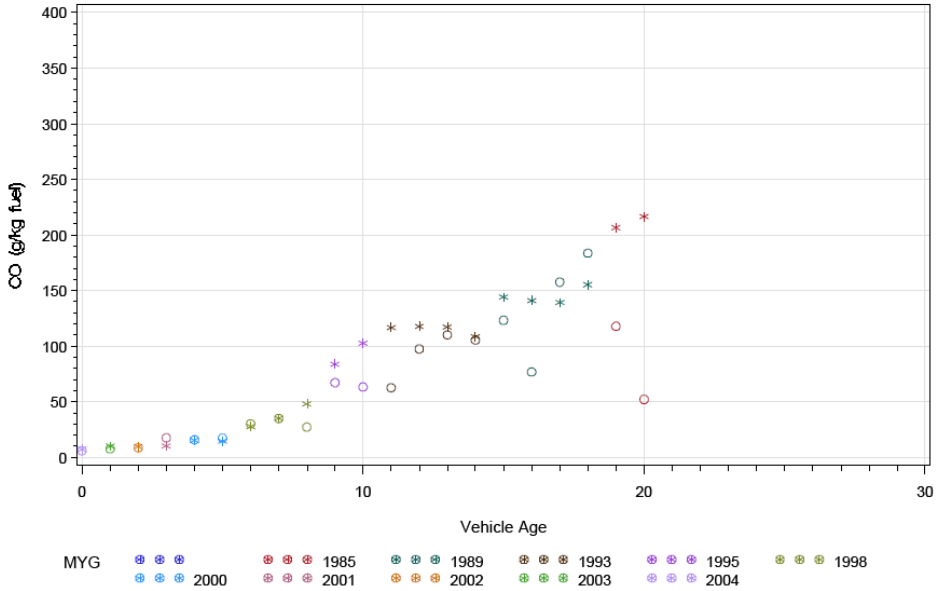
2004 LDV

Chicago RSD (circle), MOVES (star)
revised rates 111309



2004 LDT

Chicago RSD (circle), MOVES (star)
revised rates 111309



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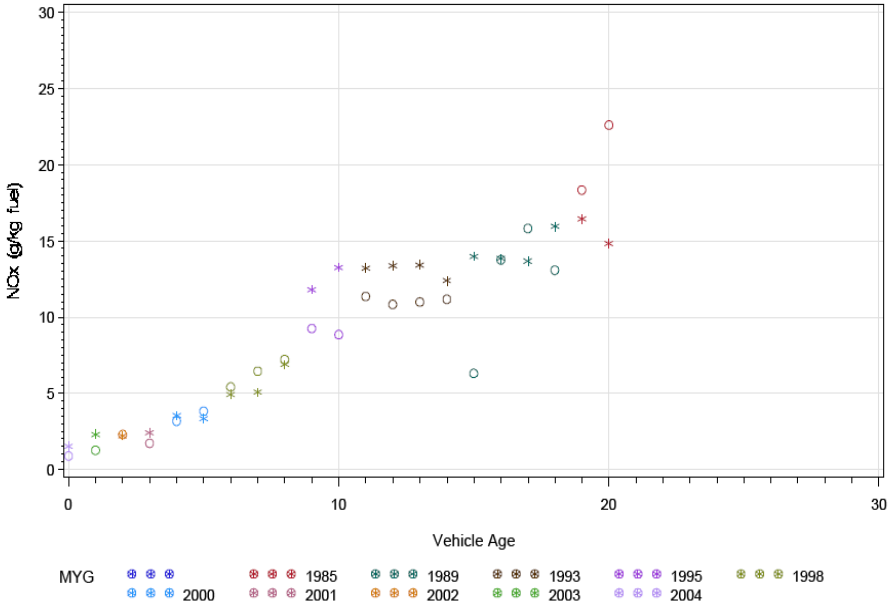
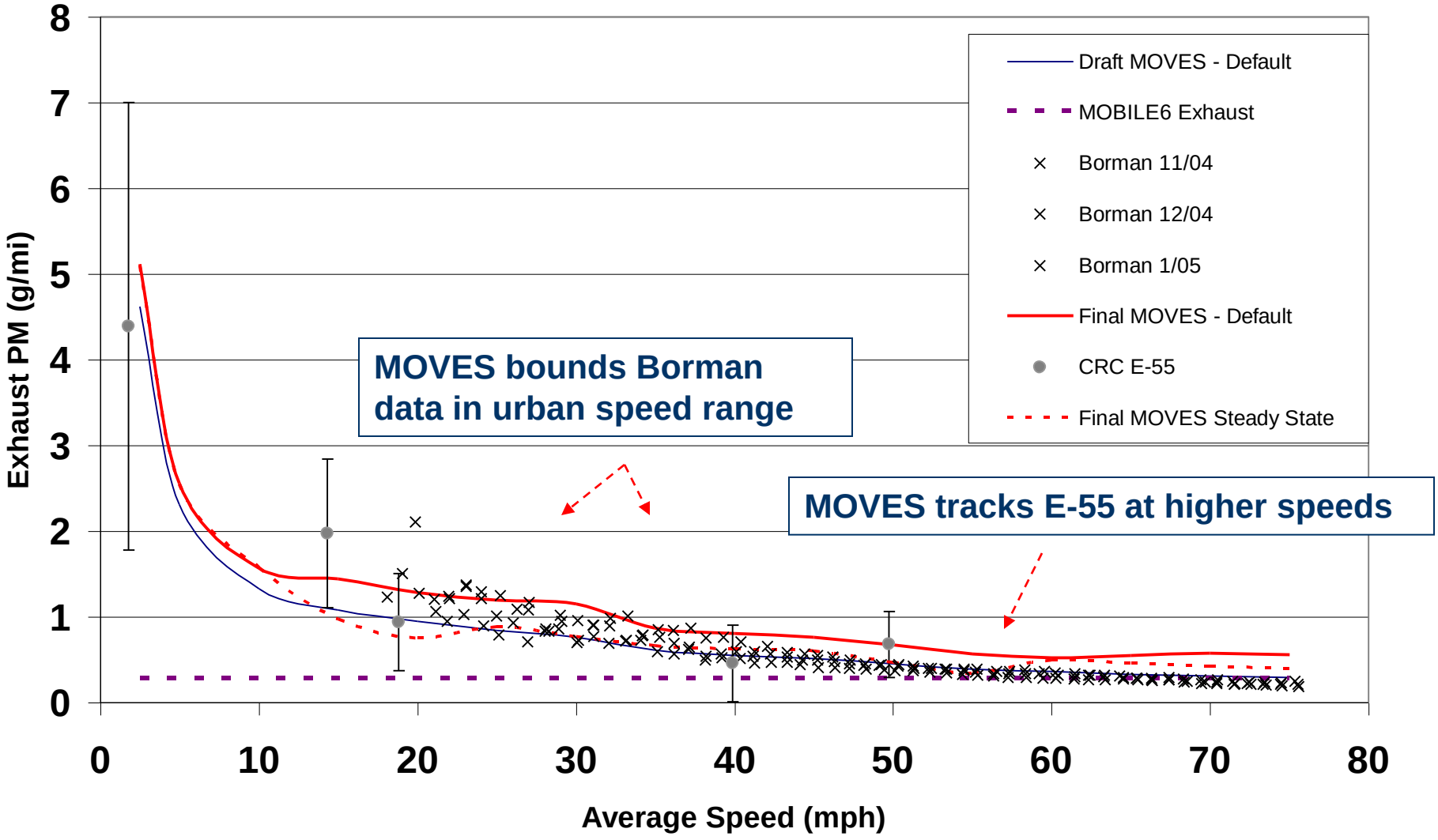
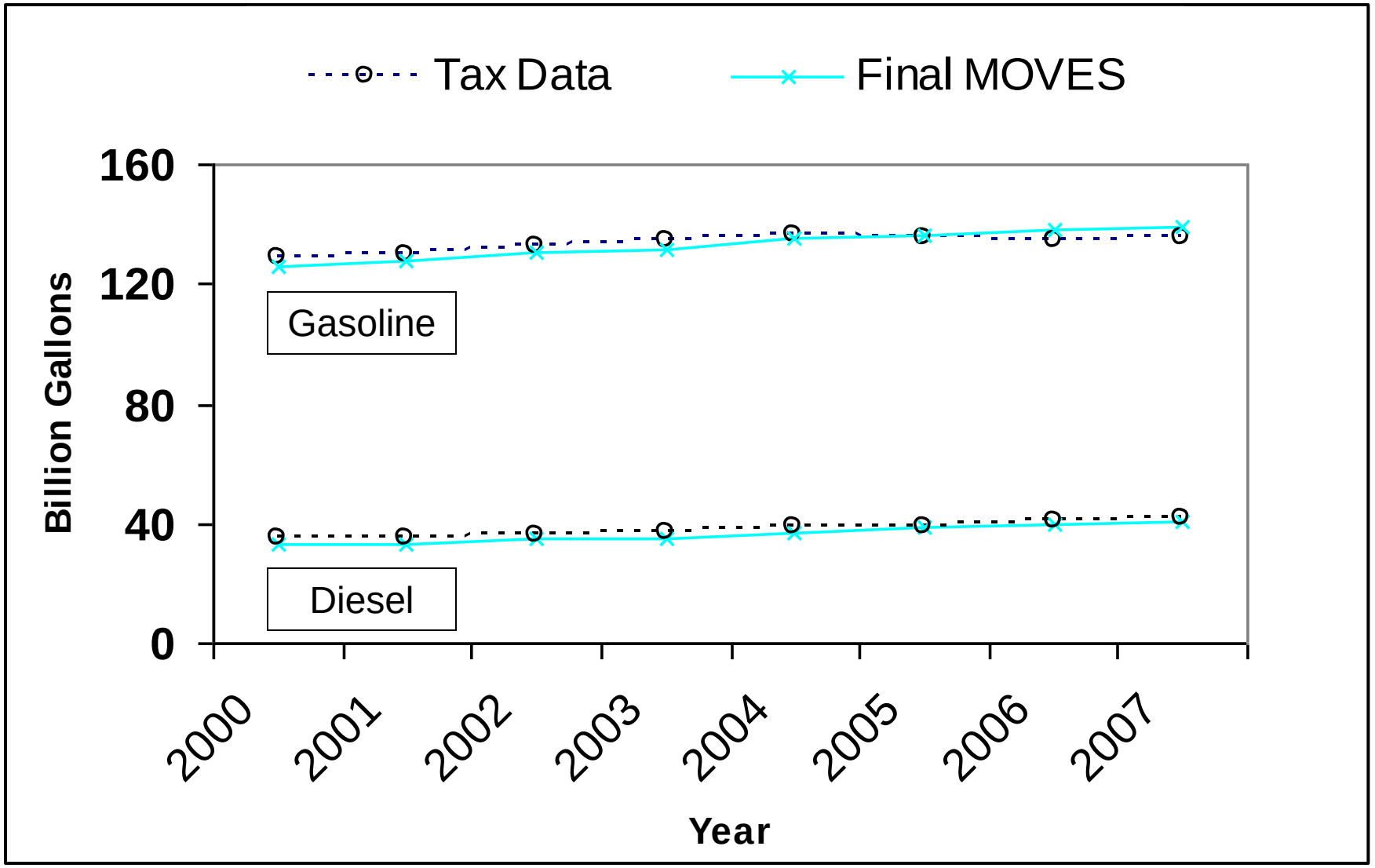


MOVES Calendar Year 2005 HDD Exhaust PM2.5

independent verification vs. Borman Expressway Monitoring Results



National Fuel Consumption Comparison

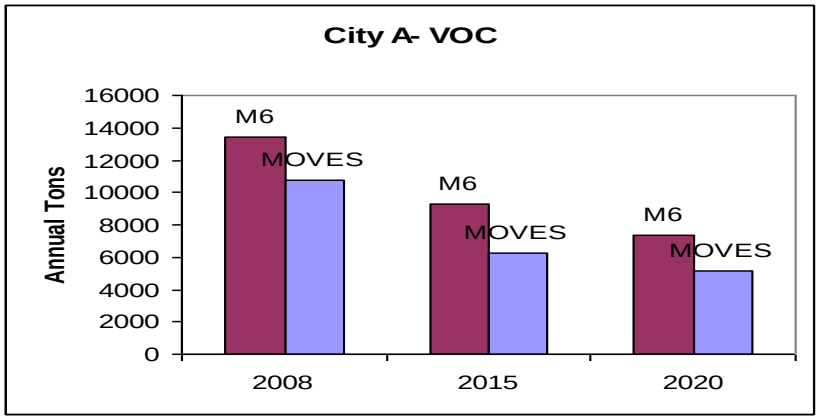


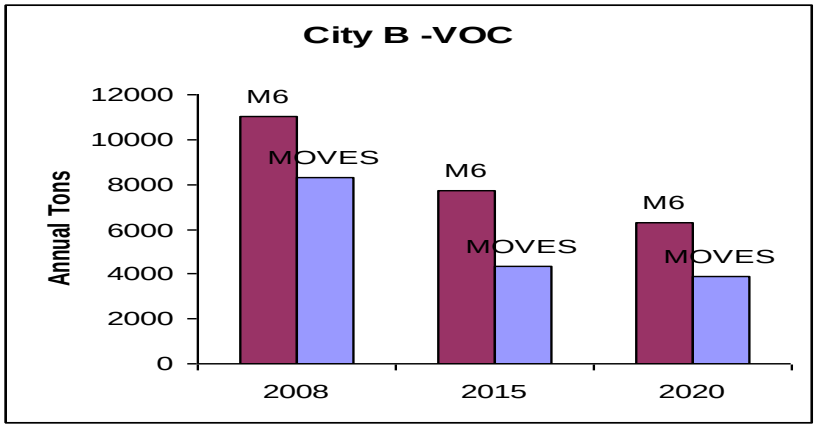
MOVES

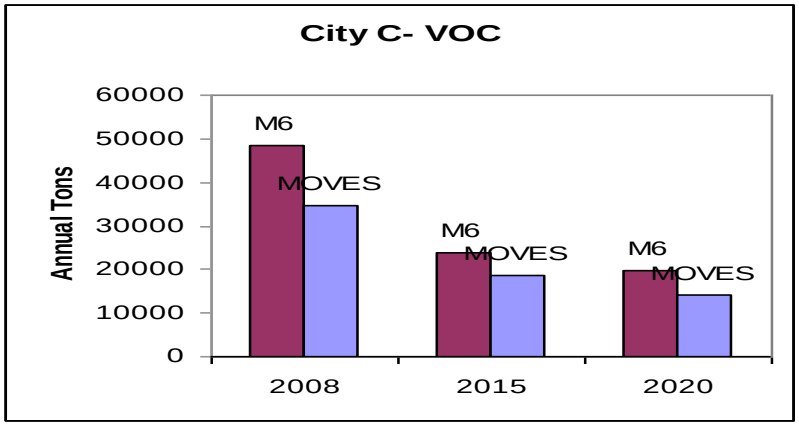
How does MOVES Change our Understanding of On-road Emissions?

- **Compared MOVES2010 and MOBILE6 estimates for three sample urban counties**
  - O_3 and $PM_{2.5}$ nonattainment areas
  - Different climates, LD/HD mix
  - Used NMIM inputs rather than full SIP-level analysis
- **Results show MOVES has:**
  - Higher NOx
  - Higher PM
  - Lower HC
  - Often greater percent reduction over time

MOVES vs. MOBILE6.2 Example Cities: VOC



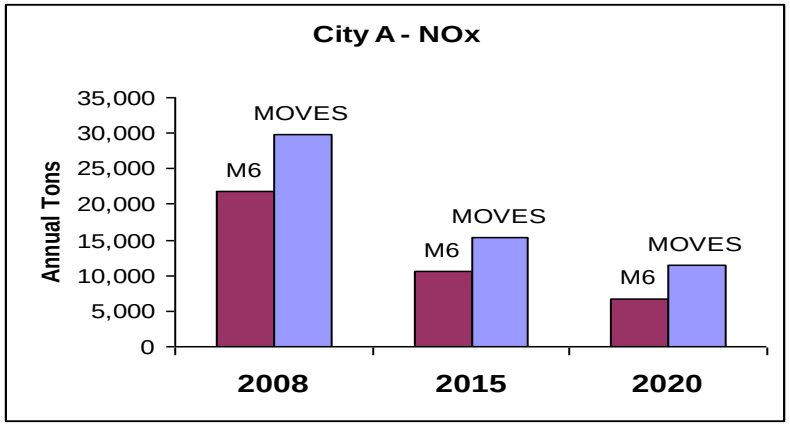


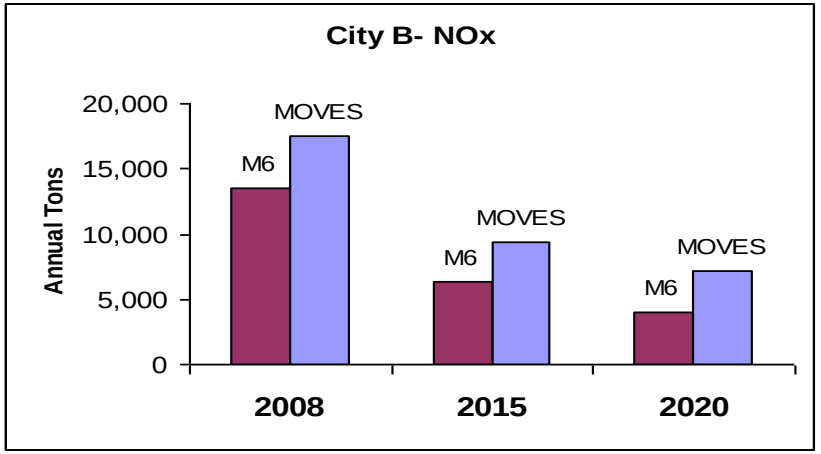


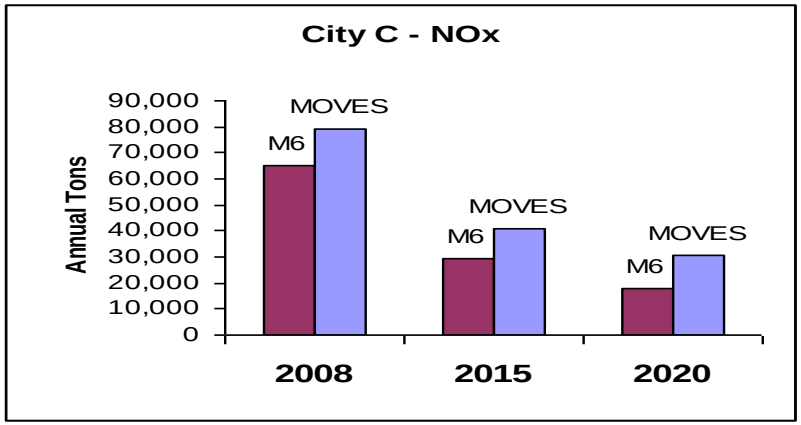
Percent Change 2008-2015

	M6	MOVES
City A	-31%	-42%
City B	-31%	-48%
City C	-50%	-46%

MOVES vs. MOBILE6.2
Example Cities: NOx



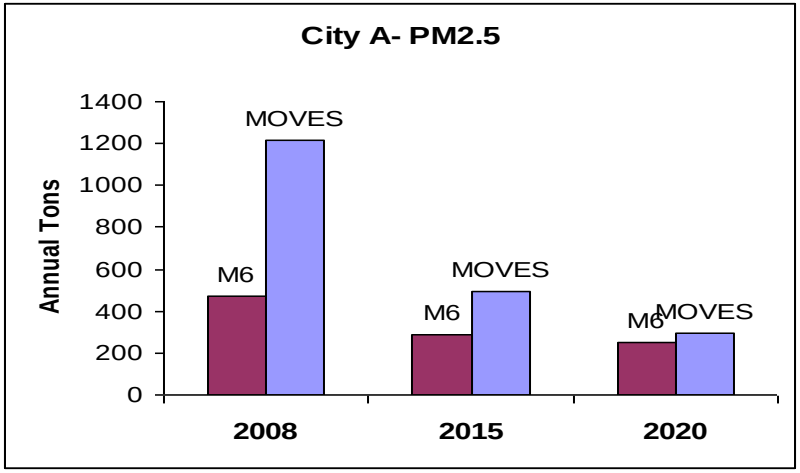


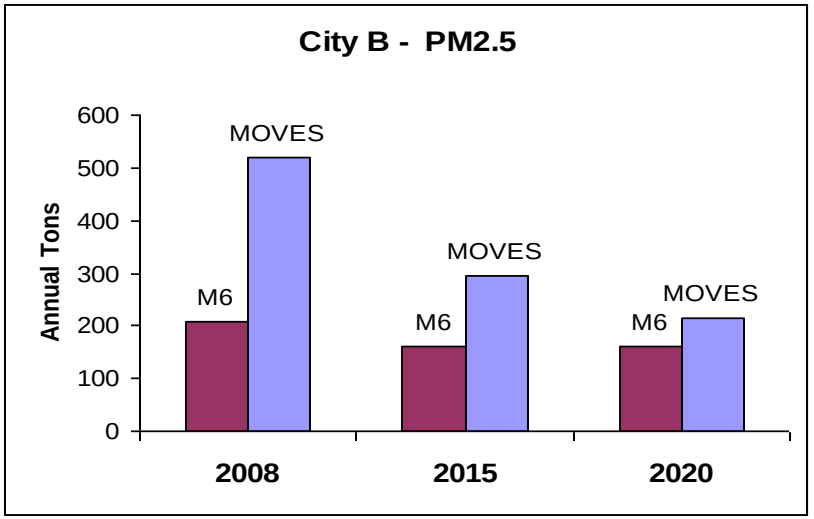


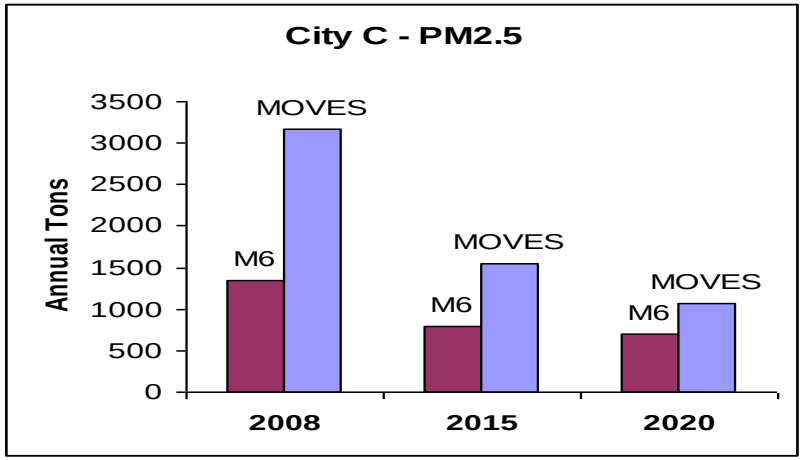
Percent Change 2008-2015

	M6	MOVES
City A	-52%	-49%
City B	-53%	-46%
City C	-56%	-49%

MOVES vs. MOBILE6.2
Example Cities: PM2.5







Percent Change 2008-2015

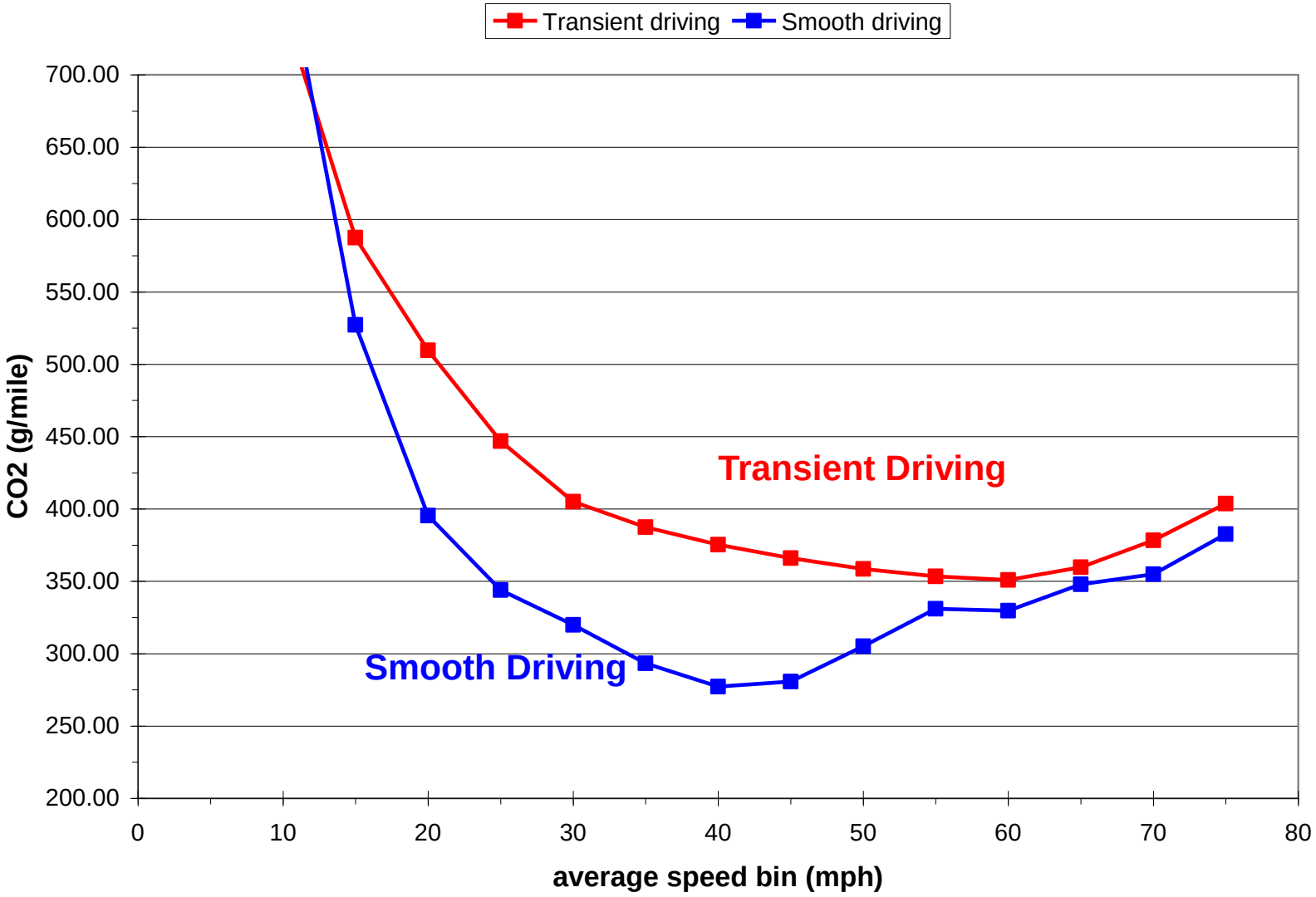
	M6	MOVES
City A	-40%	-59%
City B	-23%	-44%
City C	-40%	-51%

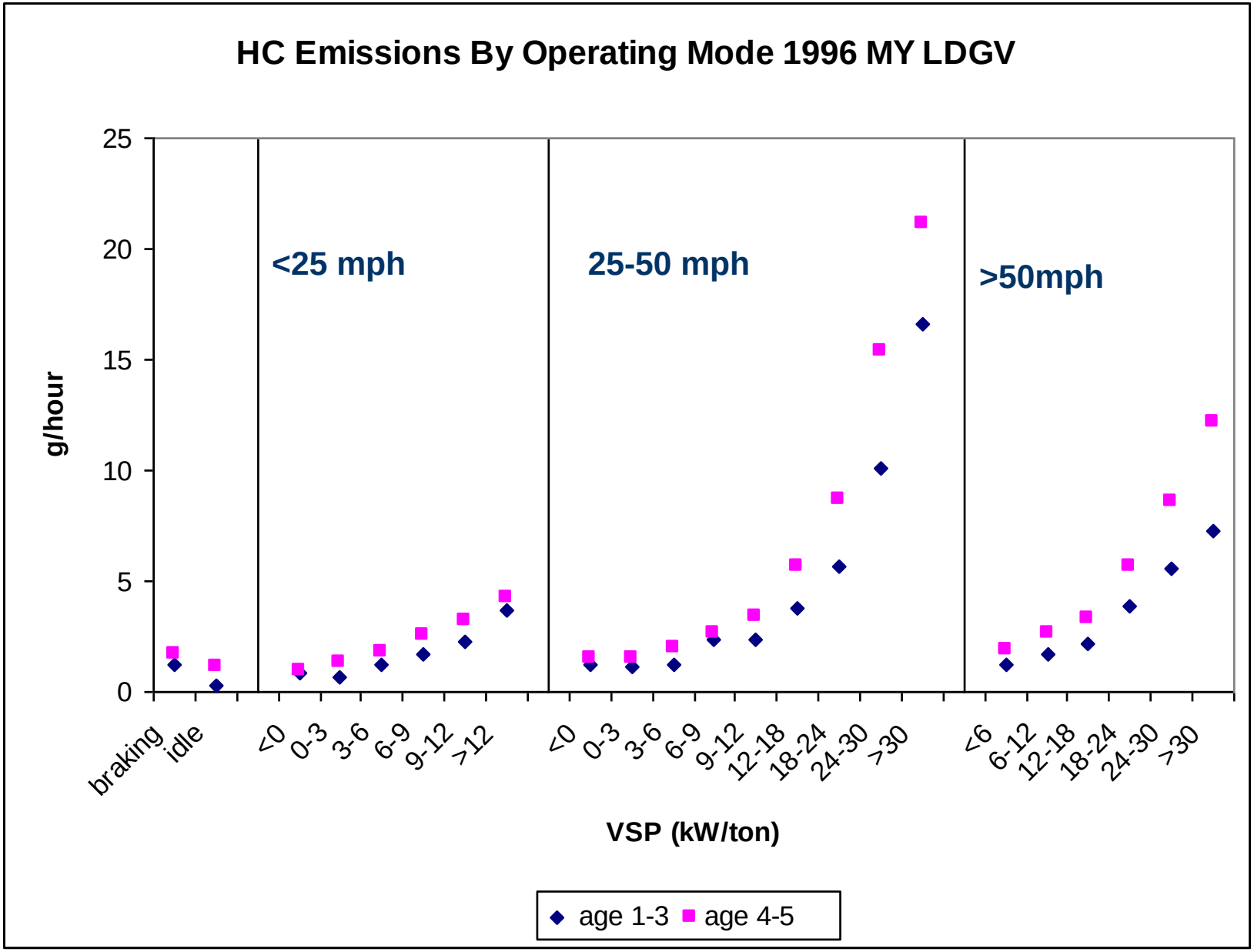
MOVES

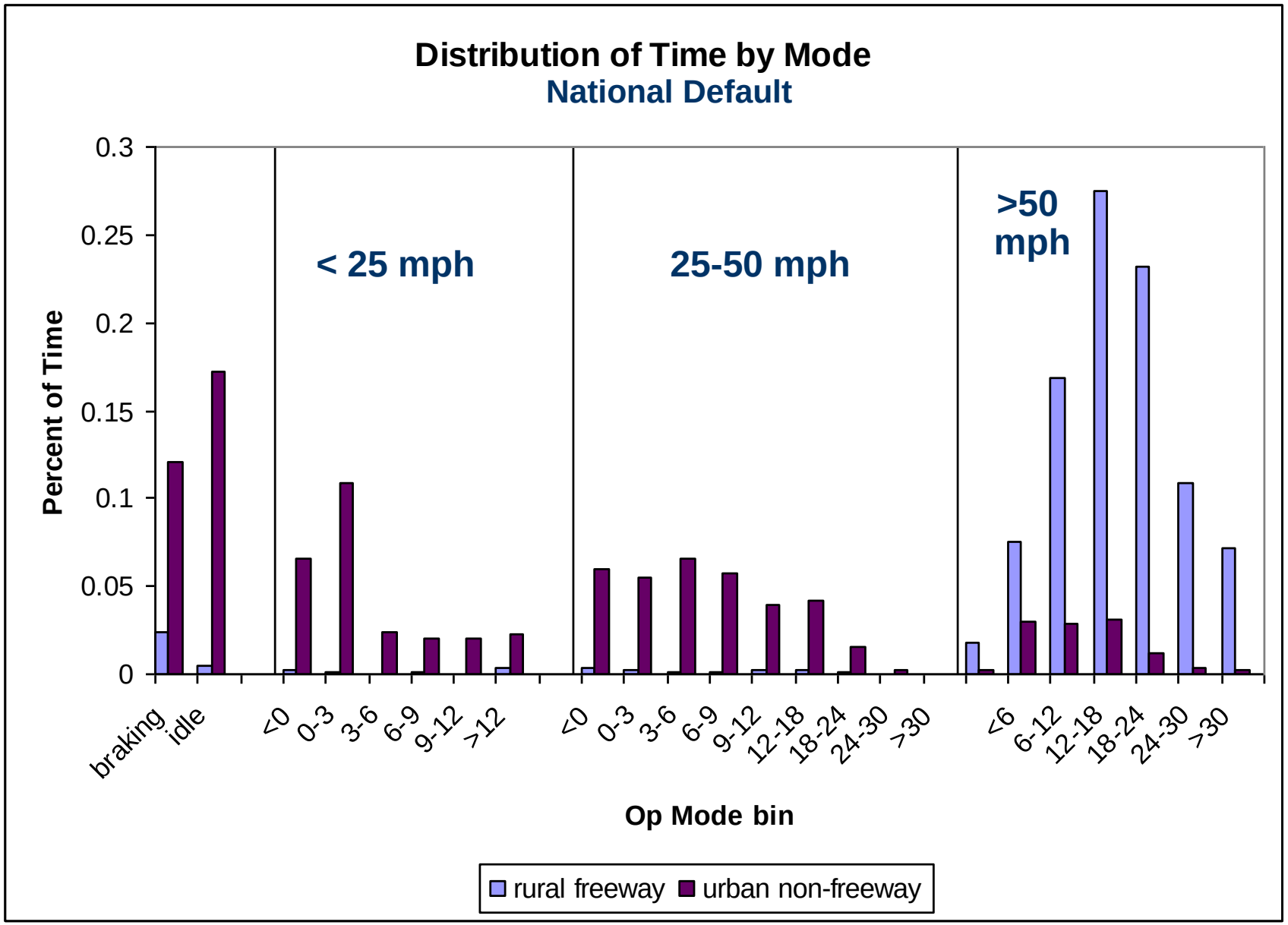
MOVES Can Better Model Emissions from Changing Driving Patterns

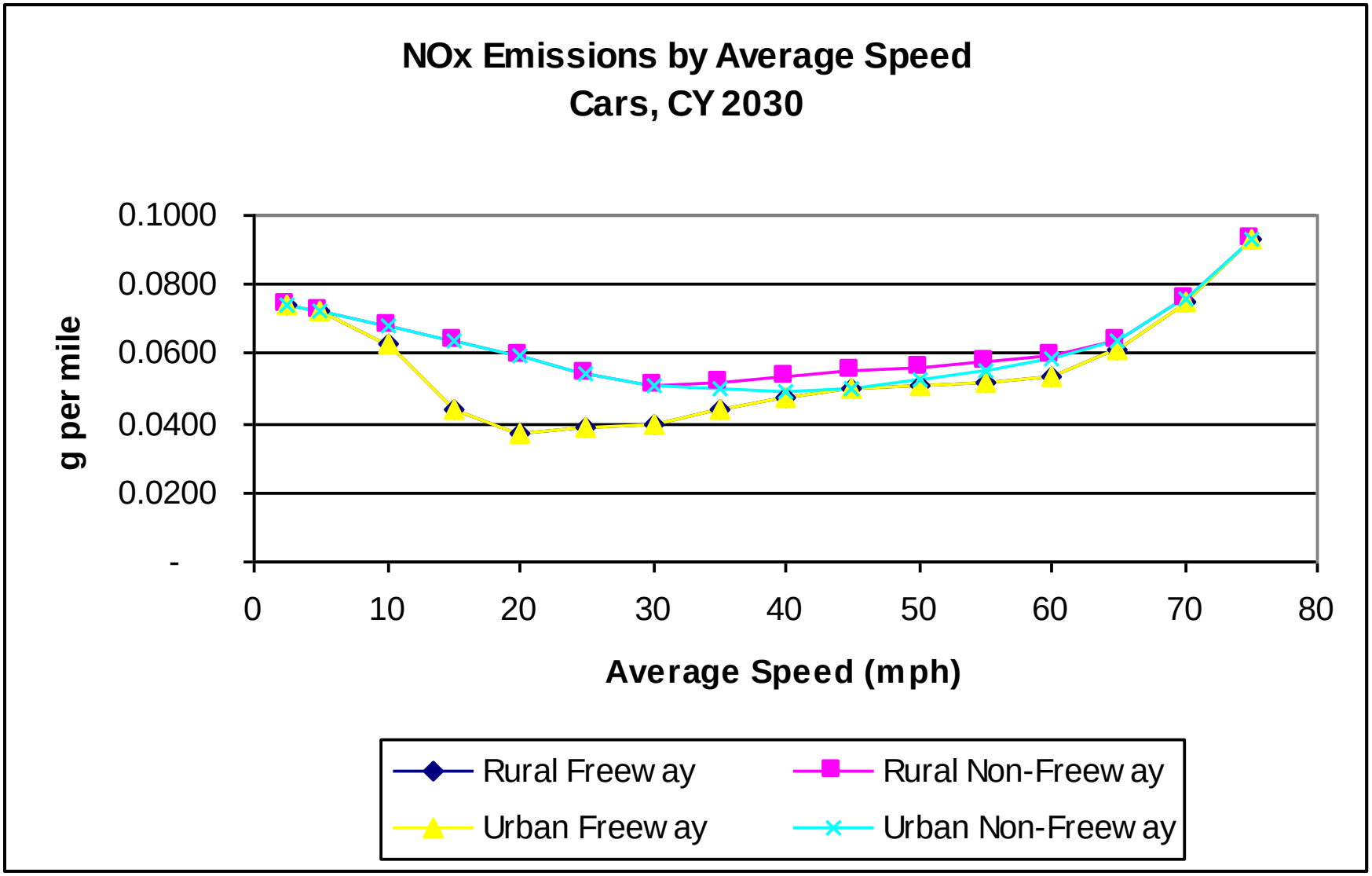
- **MOBILE6 was "driving cycle" based**
  - Emissions by speed characterized by set cycles
  - Lacked flexibility to analyze different driving patterns
- **MOVES has "modal" design**
  - Emissions stored by operating mode
  - Operating modes defined by second-by-second speed and acceleration
  - Any driving pattern can be modeled as a sum of appropriate operating modes
    - Can compare emissions data collected on different driving cycles (or even real-world driving)
    - Can estimate emissions on any defined driving pattern

CO_2 Impact of Traffic Smoothing




HC Emissions By Operating Mode 1996 MY LDGV
g/hour
25
20
15
10
5
0
<25 mph
25-50 mph
>50mph
braking
idle
<0
0-3
3-6
6-9
9-12
>12
<0
0-3
3-6
6-9
9-12
12-18
18-24
24-30
>30
<6
6-12
12-18
18-24
24-30
>30
VSP (kW/ton)
age 1-3
age 4-5


Distribution of Time by Mode
National Default
Percent of Time
0.3
0.25
0.2
0.15
0.1
0.05
0
< 25 mph
25-50 mph
>50 mph
braking
idle
<0
0-3
3-6
6-9
9-12
>12
<0
0-3
3-6
6-9
9-12
12-18
18-24
24-30
>30
<6
6-12
12-18
18-24
24-30
>30
Op Mode bin
rural freeway
urban non-freeway


NOx Emissions by Average Speed
Cars, CY 2030
g per mile
0.1000
0.0800
0.0600
0.0400
0.0200
-
0
10
20
30
40
50
60
70
80
Average Speed (mph)
Rural Freeway
Rural Non-Freeway
Urban Freeway
Urban Non-Freeway

New Analysis Opportunities

- **Modal emission structure allows calculation of "Project-level" emission changes**
  - Changes in operating mode distribution → changes in emissions
- **Project Domain Manager helps users input project-specific information on driving activity**
  - Users can enter average speed, operating mode distribution or driving pattern by link
- **Areas will want tools to estimate how changing road design affects operating modes**
  - Adding lanes?
  - Synchronizing signals?
  - Replacing stop signs with rotaries?
- **Creates need to better characterize driving patterns -** MOVES defaults may not characterize local patterns, esp project level

Online Resources

- **MOVES2010 model, user guide, guidance documents**
  - http://www.epa.gov/otaq/models/moves/index.htm
- **Technical reports, previous versions of MOVES**
  - http://www.epa.gov/otaq/models/moves/movesback.htm
- **Training materials**
  - http://www.epa.gov/otaq/models/moves/training.htm
- **Subscribe to MOVES email list**
  - http://www.epa.gov/otaq/models/mobilelist.htm
- **Information on Transportation Conformity policy, guidance & regulations**
  - http://www.epa.gov/otaq/stateresources/transconf/index.htm

What's next for MOVES

- **Additional user features, performance improvements**
- **Adding nonroad equipment**
- **Adding more air toxics**
- **Continuous improvement to emission rates**
  - Incorporate final GHG rules (proposed in 2009)
  - Update fuel effects if needed
  - Additional research ongoing