Emission Rate Approach for Evaluating the Differences in Emissions Between CNG and Diesel Busses

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Background Information

(MOBILE vs. MOVES)

MOBILE6.2 Modeling Approaches HC Curve

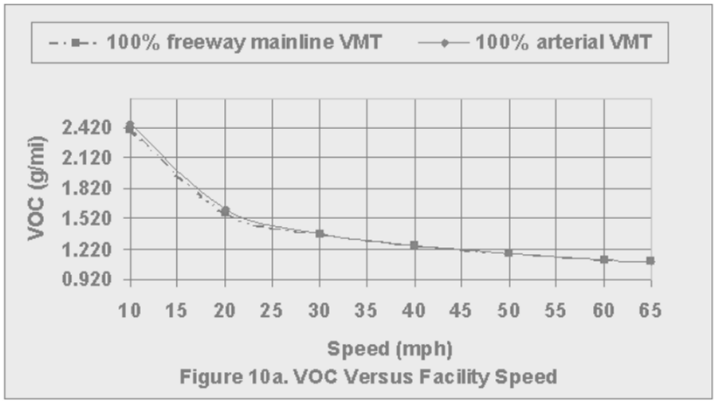

Figure 10a. VOC Versus Facility Speed

Source: Tianjia Tang, Ph.D., FHWA

MOBILE6.2 Modeling Approaches NOx Curve

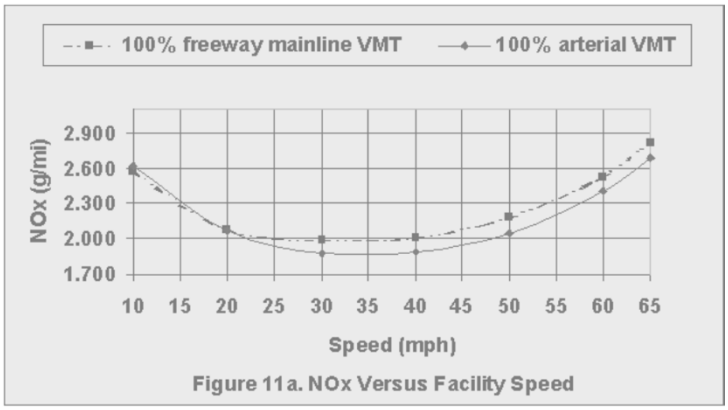

Figure 11a. NOx Versus Facility Speed

Source: Tianjia Tang, Ph.D., FHWA

MOBILE6.2 Modeling Approaches
CO Curve

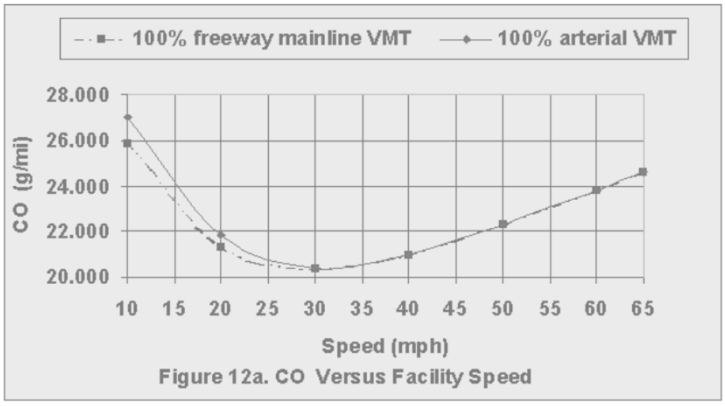

Figure 12a. CO Versus Facility Speed

Source: Tianjia Tang, Ph.D., FHWA

How About
Start & Evaporative Emissions?

- Grams per VMT (Vehicle Miles Traveled)
- Grams per engine starts
- Default: combination of both (g/mile)
- Higher the VMT, higher the start & evaporative emissions

MOVES Modeling Approaches
(Emission Processes)

- Running
- Start
- Evaporative Processes
- Crankcase
- Tire Wear
- Brake Wear
- Extended Idle
- Life Cycle Processes

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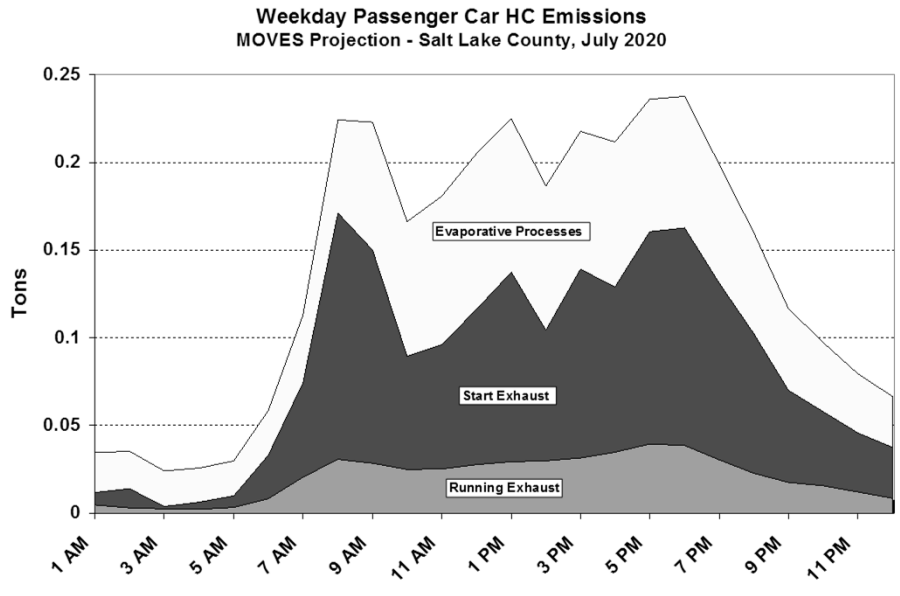

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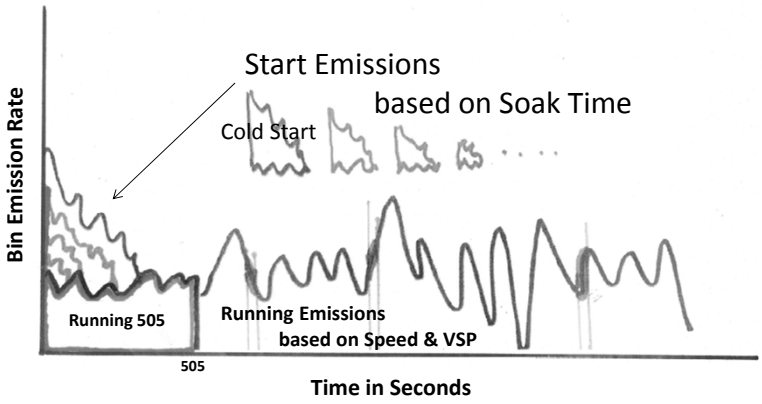
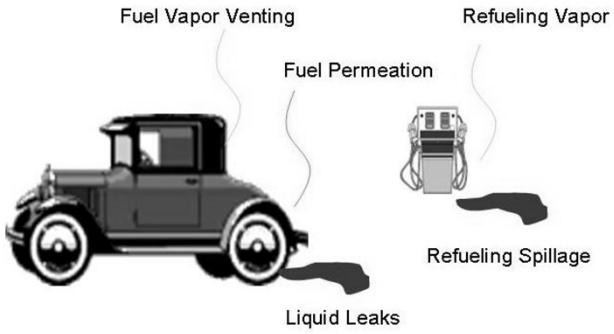
Source: John Koupal, EPA

MOVES Modeling Approaches
(Start and Running Emissions)



MOVES Modeling Approaches
(Evaporative Emissions)



Source: US EPA

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Emission Processes and Mobile Source Activities

Emission Process	Activity Basis
Running Exhaust, Brake Wear, Tire Wear, Running Loss, Crankcase, Extended Idle	Source Hours Operating (SHO)
Start Exhaust	Number of Starts
Diurnal, Hot Soak	Source Hours Parked (SHP)
Resting Loss, Manufacture/Disposal	Source Hours (SH)
Refueling, Well-To-Pump	Energy (Fuel) Used

Emission Processes vs. Rates (MOVES vs. MOBILE6)

	MOVES			MOBILE6
Emission Processes	Rates/Distance	Rates/Vehicle	Rates/Profile	Rates/Distance
Running Exhaust	Grams/Mile			Grams/Mile
Start Exhaust		Grams/Vehicle		Grams/Mile
Evap Permeation	Grams/Mile	Grams/Vehicle		Grams/Mile
Evap Fuel Vapor Venting	Grams/Mile		Grams/Vehicle	Grams/Mile
Evap Fuel Leaks	Grams/Mile	Grams/Vehicle		Grams/Mile
Crankcase Running Exhaust	Grams/Mile			Grams/Mile
Crankcase Start Exhaust		Grams/Vehicle		NA
Crankcase Extended Idle Exhaust				NA
Refueling Displacement Vapor Loss				Grams/Mile
Extended Idle Exhaust		Grams/Vehicle		Included in the HDDV8b Class

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Running Emissions

Grams/Mile by Temperature

Running Emissions

(County Data Manager)

- Facility based drive schedules (cycles)
  - Urban Freeway, Urban Non-freeway, Rural Freeway, Rural Non-freeway
- Emission rates option
  - grams/mile by temp
- Reason to believe that the drive schedules of your projects are significantly different from the MOVES default schedules, **Project Level Analyses are required**

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MOVES Drive Schedules

Drive Schedule Set	DriveScheduleName(ID)	AverageSpeed (mph)
Light-Duty Non-Freeway	Low Speed 1 (101)	2.5
	New York City (102)	7.1
	Non-Freeway LOS EF (103)	11.6
	Non-Freeway LOS CD (104)	19.2
	Non-Freeway LOS AB (105)	24.8
Light-Duty Freeway	Freeway LOS G (151)	13.1
	Freeway LOS F (152)	18.6
	Freeway LOS E (153)	30.5
	Freeway LOS D (154)	52.9
	Freeway LOS AC (155)	59.7
	Freeway High Speed 1 (156)	63.2
	Freeway High Speed 2 (157)	68.2
	Freeway High Speed 3 (158)	76
	Freeway Ramp (199)	34.6
Medium Heavy-Duty Non-Freeway	5 mph (201)	4.6
	10 mph (202)	10.7
	15 mph (203)	15.6
	20 mph (204)	20.8
	25 mph (205)	24.5
	30 mph (206)	31.5
Medium Heavy-Duty Freeway	30 mph (251)	34.4
	40 mph (252)	44.5
	50 mph (253)	55.4
	60 mph (254)	60.4
	Ramp (299)	31
Heavy Heavy-Duty Non-Freeway	5 mph (301)	5.8
	10 mph (302)	11.2
	15 mph (303)	15.6
	20 mph (304)	19.4
	25 mph (305)	25.6
	30 mph (306)	32.5
Heavy Heavy-Duty Freeway	30 mph (351)	34.3
	40 mph (352)	47.1
	50 mph (353)	54.2
	60 mph (354)	59.4
	Ramp (399)	25.3
Bus Non-Freeway	Low Speed Urban (401)	15*
	30 mph flow (402)	30*
	45 mph flow (403)	45*
Refuse Truck	Refuse Truck Urban (501)	2.2

* Speed represents average of traffic the bus is traveling in, not the average speed of the bus, which is lower due to stops.

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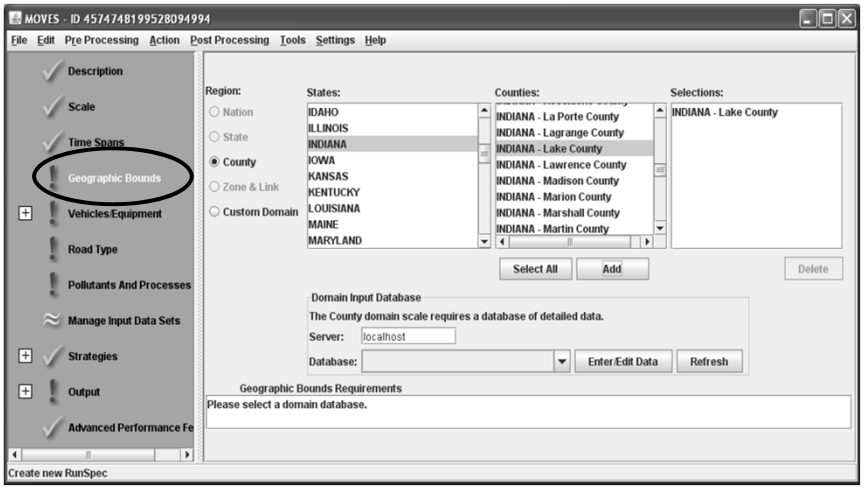
Modeling Area



Start Emissions

Grams/Vehicle by Hours

Start Emissions

- Engine Starts per day per vehicle (autos & trucks)
  - MOBILE6
    - Baltimore, Spokane & Atlanta
  - MOVES
    - Baltimore, Spokane, Atlanta, Minneapolis, Knoxville & Las Vegas
- Engine Temperatures
  - Soak Distribution
    - Differs by hour

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Start per Day by Vehicle Types
(MOVES vs. MOBILE6)

SourceType	Draft MOVES2009 Weekday	Draft MOVES2009 Weekend	MOBILE6*
Motorcycles	0.78	0.79	1.35
Passenger Cars	5.89	5.30	6.75
Passenger Trucks	5.80	5.06	7.38
Light Commercial Trucks	6.05	5.47	7.38
Intercity Buses	2.77	0.88	6.88
Transit Buses	4.58	3.46	6.88
School Buses	5.75	1.26	6.88
Refuse Trucks	3.75	0.92	6.88
Single-unit short-haul trucks	6.99	1.28	6.88
Single-unit long-haul trucks	4.29	1.29	6.88
Motor homes	0.57	0.57	6.88
Combination short-haul trucks	5.93	1.16	6.88
Combination long-haul trucks	4.29	1.29	6.88

* Note, MOBILE6 distinguished "starts" and "trips." MOVES does not, but MOVES does include some very short "trips."

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Operating-Mode Definitions for Start Exhaust Emissions

opModeID	Description	Soak Period (min)[1]
101	"hot start"	≤ 6
102		6 - 30
103		30 – 60
104		60 – 90
105		90 – 120
106		120 – 360
107		360 - 720
108	"cold start"	≥ 720

[1] Defined in terms of *lower-bound* $\leq$ soak period $<$ *upper-bound*.

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Number of Vehicle Starts

- No seasonal variations
- Default number of starts per vehicle
  - Check with local data
  - Alternative source of data

Number of Engine Starts per Day

(Local Sources of Data)

- TDF model O/D trip table
  - Provides approximate number of "engine starts"
    - Seasonal variation
    - Reflective to: annual growth, transportation projects/policies etc.
    - Number of auto trips per day < number of engine starts per day
  - Provides good information where starts are located
- O/D trip table approach may provide better local number of engine starts than the MOVES model defaults
- Regionally non-significant projects can not be modeled through TDF model. Use **project level analysis** methodologies

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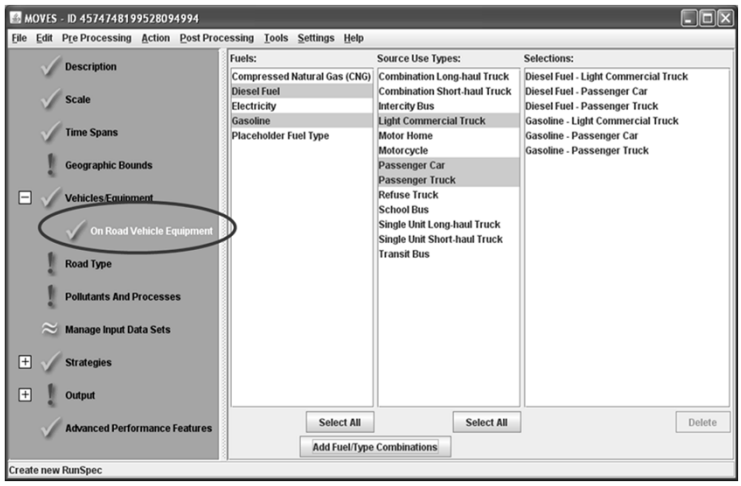
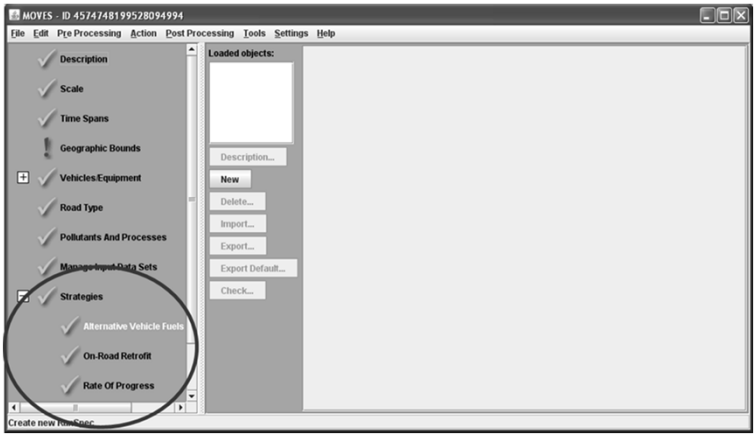
On Road Vehicle Equipment



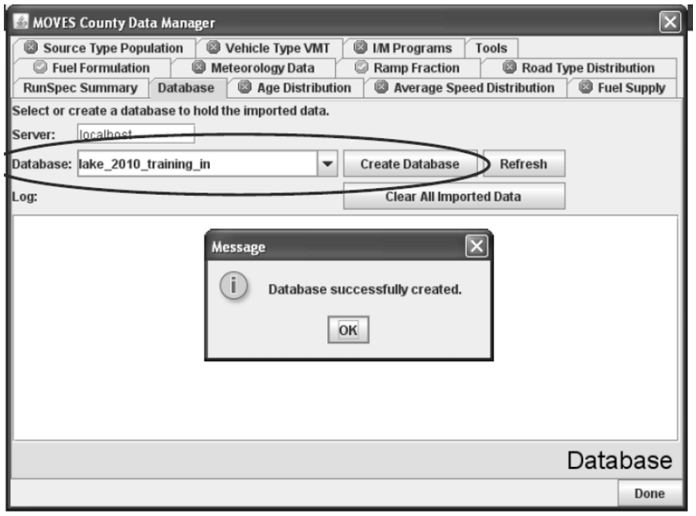
Caution

- When transit buses are selected, default database allocates some VMT to Compressed Natural Gas (CNG) transit buses
  - Therefore, users should either select the CNG transit bus combination; or
  - Edit the AVFT input (covered in later session) so that no VMT is allocated to CNG buses.
  - If one of these approaches is not used, some VMT assigned to buses (HPMS class 40) will be "lost"

MOVES Strategies Option (AVFT, Retrofit, ROP)



County Data Manager



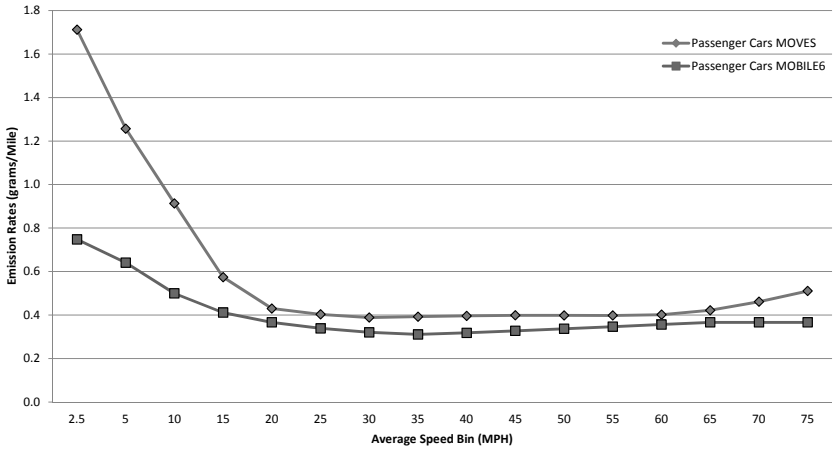
National Trend on Vehicle Age

(BTS Data)

- In 2007 the median age for automobiles was 9.2 years, a significant increase over 1990 (6.5 years)
- As SUVs are part of a relatively new consumer trend originating mostly in the 1990s, SUVs had the lowest mean age of any body style (6.1 years in 2007).
- Between 2007 to 2008 alone, the median age of passenger cars increased to 9.4 years, and that the median age for light trucks increased from 7.1 years in 2007 to 7.5 years in 2008 (RL Polk, March 2009)

NOx Emission Rates for Passenger Vehicles

(MOVES vs. MOBILE6)



Source: Madhusudhan Venugopal, North Central Texas Council of Governments

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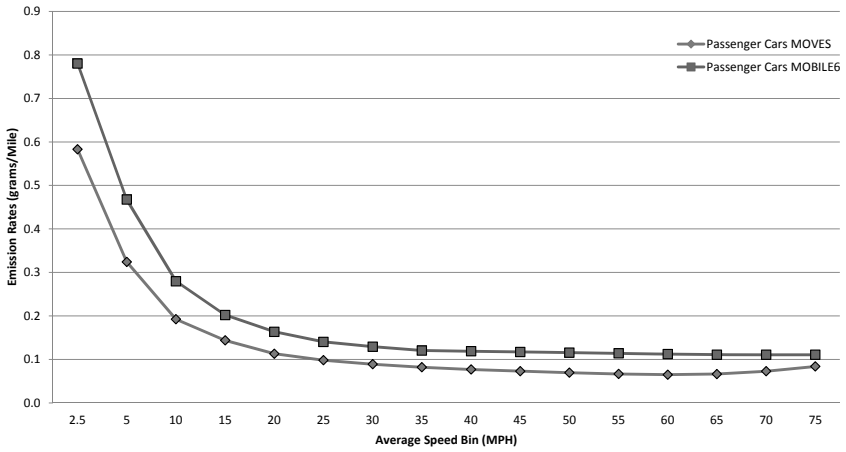
VOC Emission Rates for Passenger Vehicles
(MOVES Vs MOBILE6)



Source: Madhusudhan Venugopal, North Central Texas Council of Governments

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Evaporate Emissions Only for HC

Grams/Profile

Modeling Emissions
CNG vs. Diesel Buses

Replace old technology vehicles with new technology vehicles:

Often this is a replacement of urban diesel buses with cleaner fuel vehicles such as CNG buses.

Add new CNG Vehicles

1) Determine the daily bus service frequency (F: one-way) and route length (L)
2) Run MOVES by using Alternative Fuel Option initiating with base (before) conditions: no CNG Buses
3) Run MOVES by using Alternative Fuel Option initiating with after conditions: with CNG Buses

Conventional bus emission factor = CBEF in grams/mile
CNG bus emission factor = CNGBEF
Emission benefits = F x L x (CBEF-CNGBEF)

Add new CNG Vehicles

1) Determine the daily bus service frequency (F: one-way) and route length (L)
2) Allocate F into hourly bases: f
3) Allocate L into hourly bases: l
4) Run MOVES by using Alternative Fuel Option initiating with base (before) conditions: no CNG Buses
5) Run MOVES by using Alternative Fuel Option initiating with after conditions: with CNG Buses

Conventional Bus Emission factor = CBEF in grams/mile
CNG bus emission factor = CNGBEF

Daily Running Emission benefits = $\sum f \times l \times$ (CBEF-CNGBEF)
How about start emissions?