Travel Activity Data for MOVES Regional Analysis

NTAQS

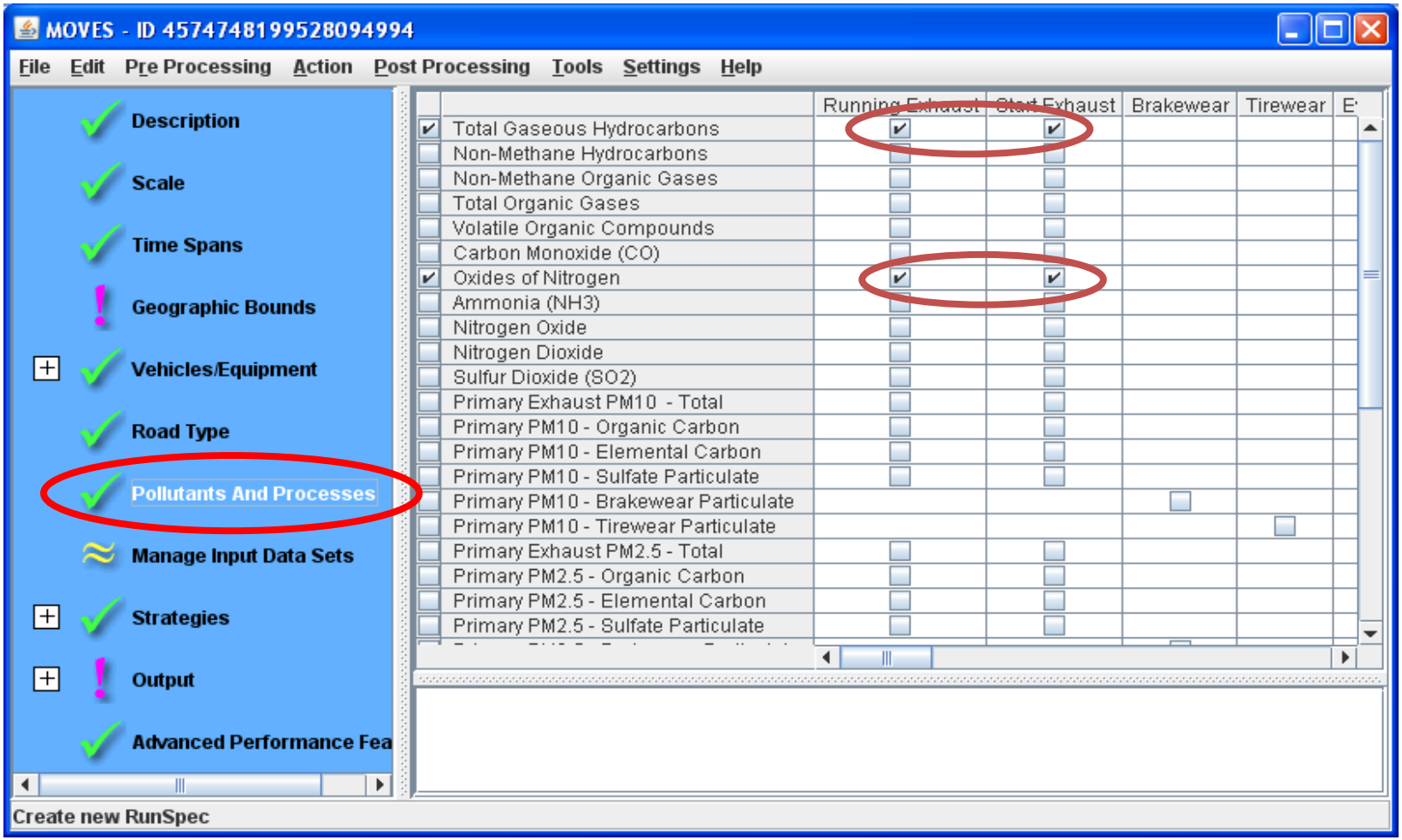
Cambridge, MA
August 24 – 26, 2010

John Byun, Ph.D.
Air Quality Modeling Specialist
Resource Center, FHWA

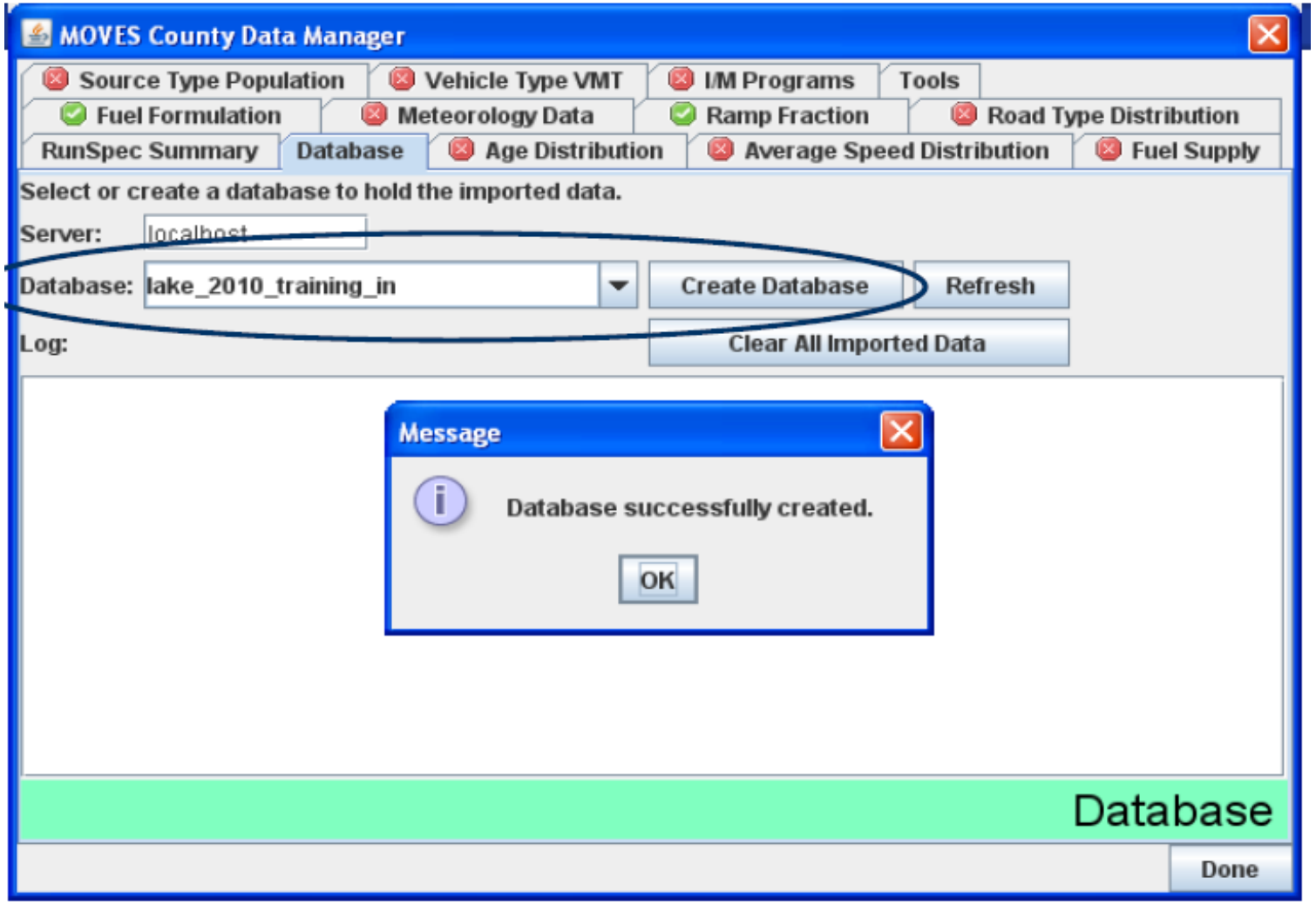
Emissions in MOVES

Emission Processes	Travel Activities
Running, Tire/Break Wear, Running Loss, Crankcase, Extended Idle	Source Hours of Operation (VHT)
Start Exhaust	Number of Vehicles (starts)
Diurnal, Hot Soak	Source Hours Parked (SHP)
Refueling Loss	Source Hours

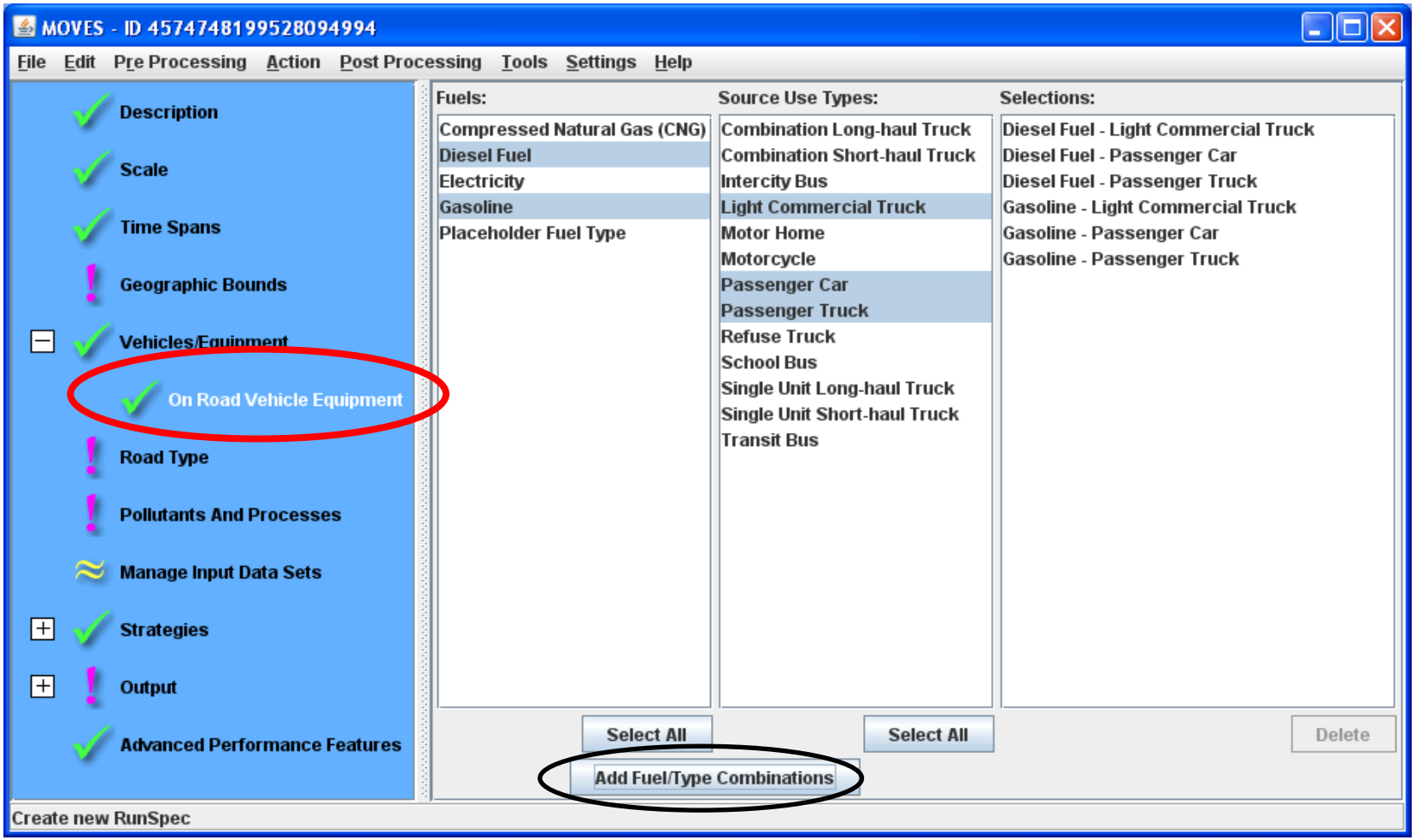
Pollutants & Processes



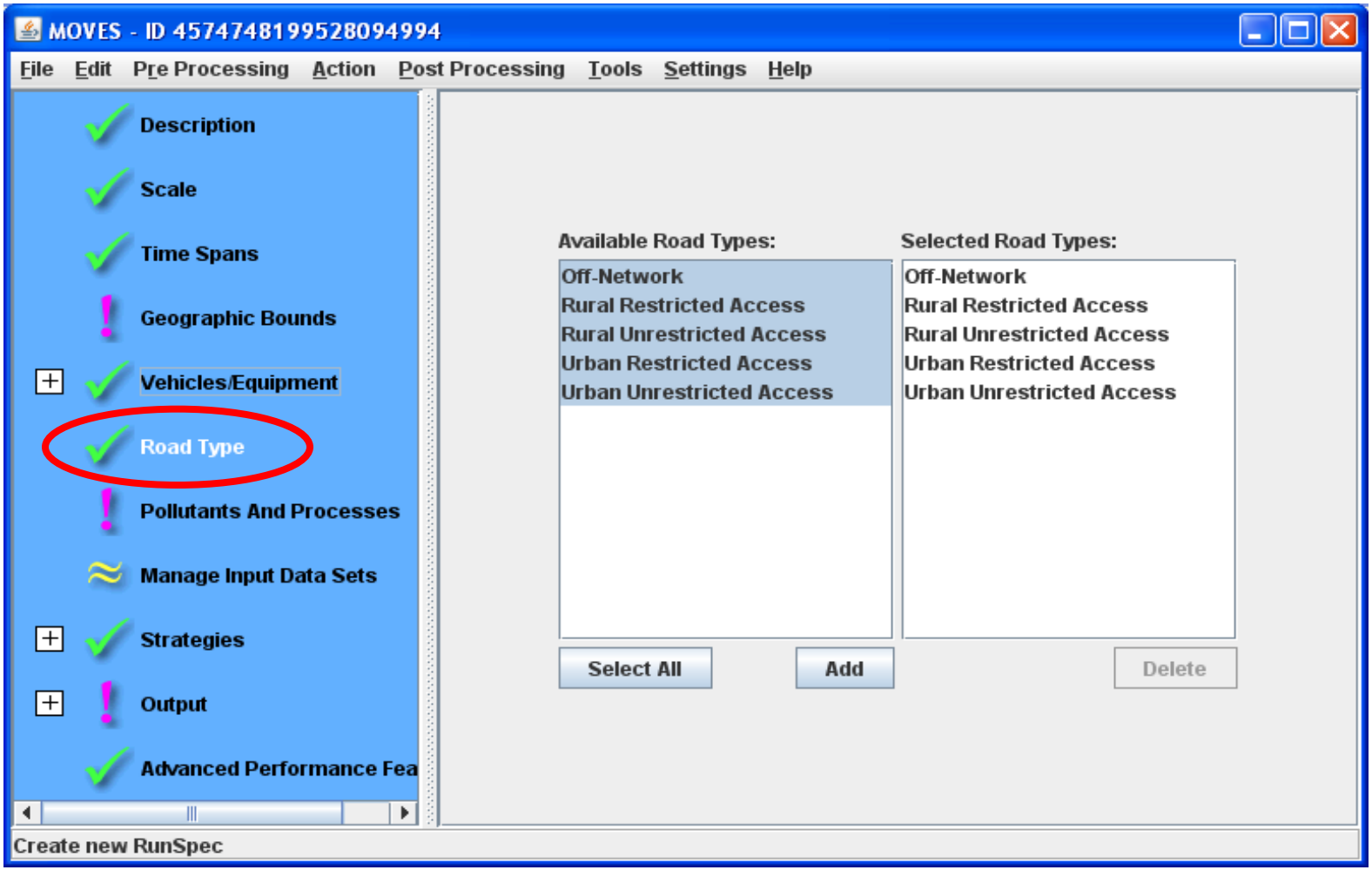
County Data Manager for Travel Activities



Vehicles/Equipment



Road Types

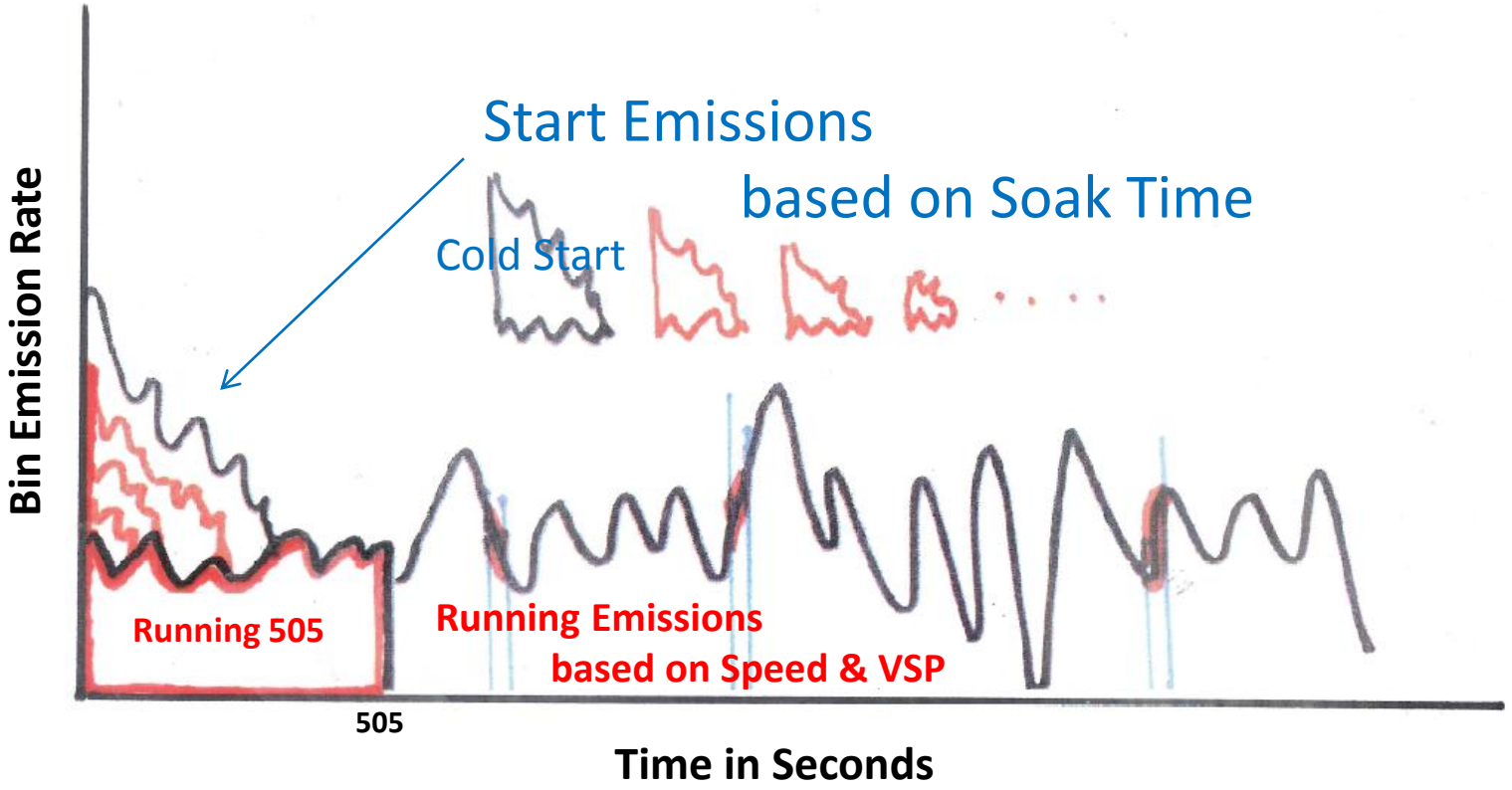

MOVES - ID 4574748199528094994
File Edit Pre Processing Action Post Processing Tools Settings Help
Description
Scale
Time Spans
Geographic Bounds
Vehicles/Equipment
Road Type
Pollutants And Processes
Manage Input Data Sets
Strategies
Output
Advanced Performance Fea
Available Road Types:
Off-Network
Rural Restricted Access
Rural Unrestricted Access
Urban Restricted Access
Urban Unrestricted Access
Selected Road Types:
Off-Network
Rural Restricted Access
Rural Unrestricted Access
Urban Restricted Access
Urban Unrestricted Access
Select All
Add
Delete
Create new RunSpec

MOVES Modeling Approaches
(Emission Processes)

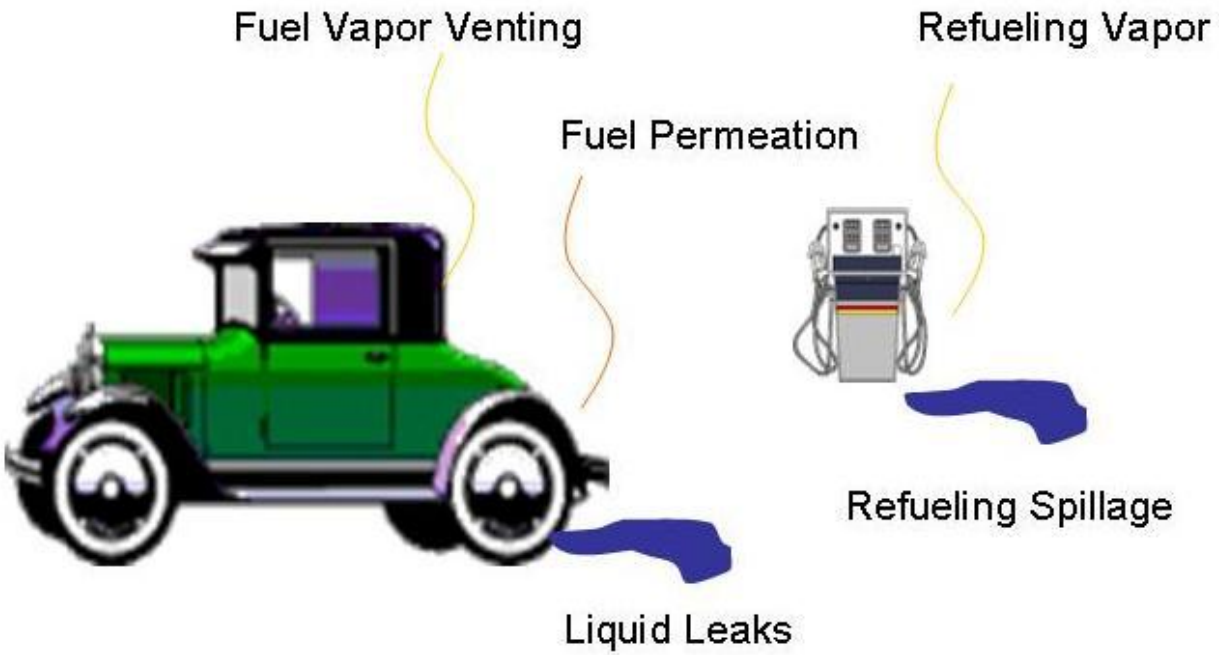
- ✓ Running
- ✓ Start
- ✓ Evaporative Processes
- Crankcase
- Tire Wear
- Brake Wear
- Extended Idle
- Life Cycle Processes

MOVES Modeling Approaches

(Start and Running Emissions)



MOVES Modeling Approaches
(Evaporative Emissions)



Source: US EPA

VOC & NOx

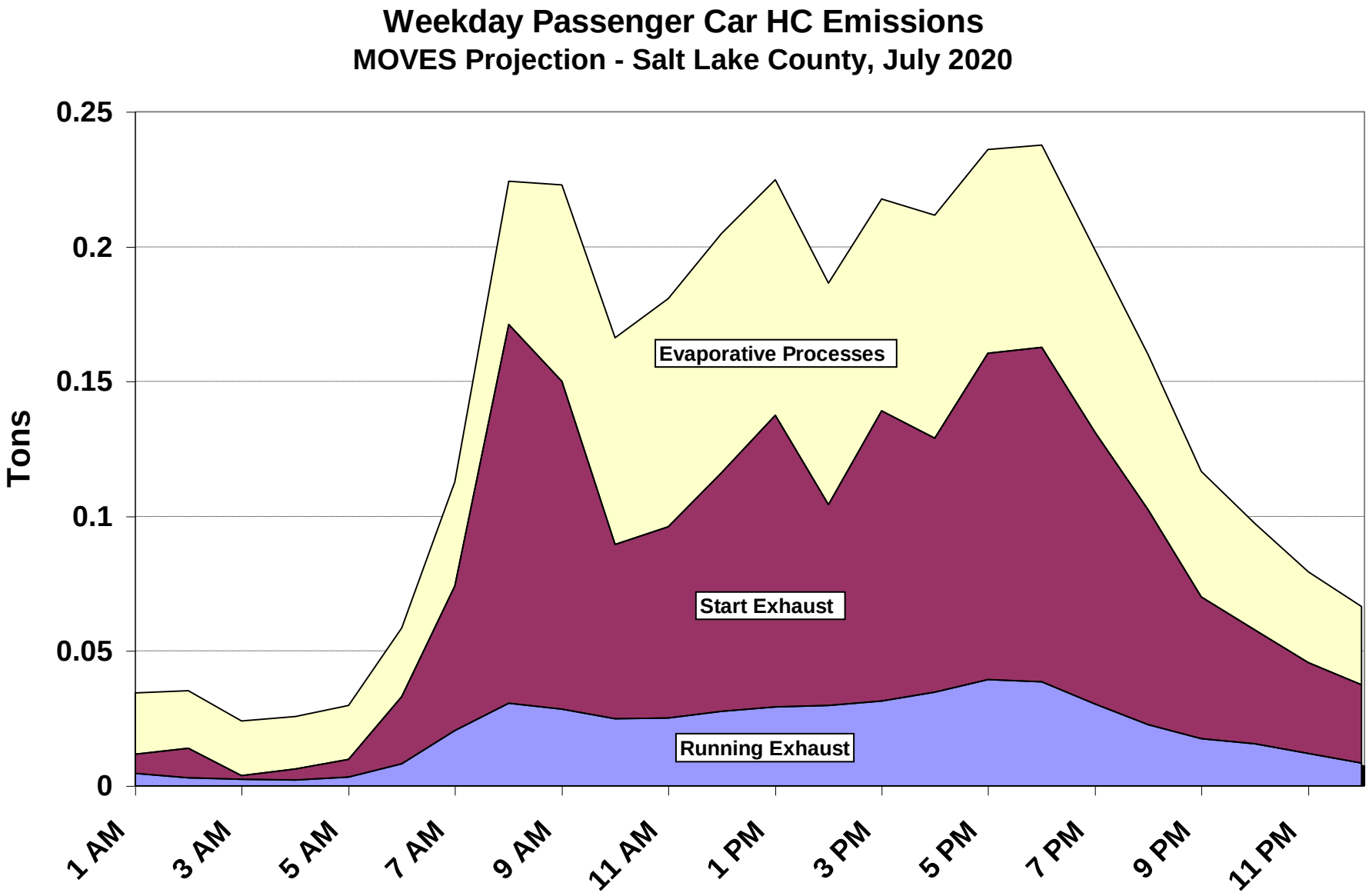
(MOBILE6.2 vs. MOVES)

Table 7 2030 Montgomery County VOC and NOx Emissions (Daily)

	Mobile6		MOVES_Local		MC_Local & ZEV	
	VOC	NOx	VOC	NOx	VOC	NOx
Start	1.25	0.36	3.25	2.03	2.57	2.03
Running	4.67	4.72	1.62	10.14	1.32	10.14
Start & Running	5.92	5.08	4.87	12.16	3.89	12.16
Vehicle Related	0.56	0.00	3.26	1.17	2.75	1.17
Bus, Transit, and Auto	0.13	0.24	0.00	0.00	0.00	0.00
Total	6.61	5.32	8.13	13.34	6.63	13.34

Note: AQ modeling environment is changing significantly with MOVES

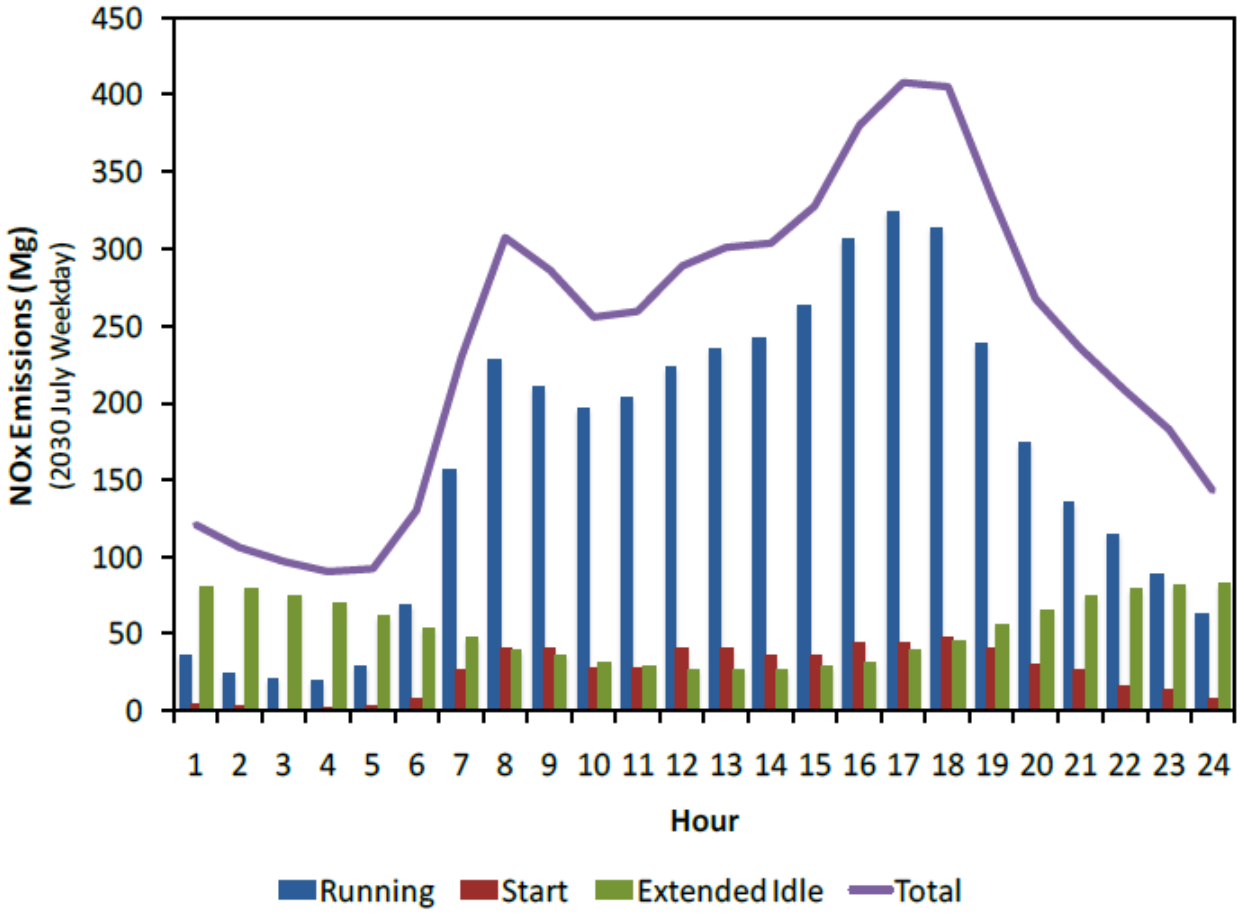
Source: Eulalie Lucas, Dept of Transportation Planning, MWCOG., May, 2010



Source: John Koupal, EPA

NOx from Emission Processes

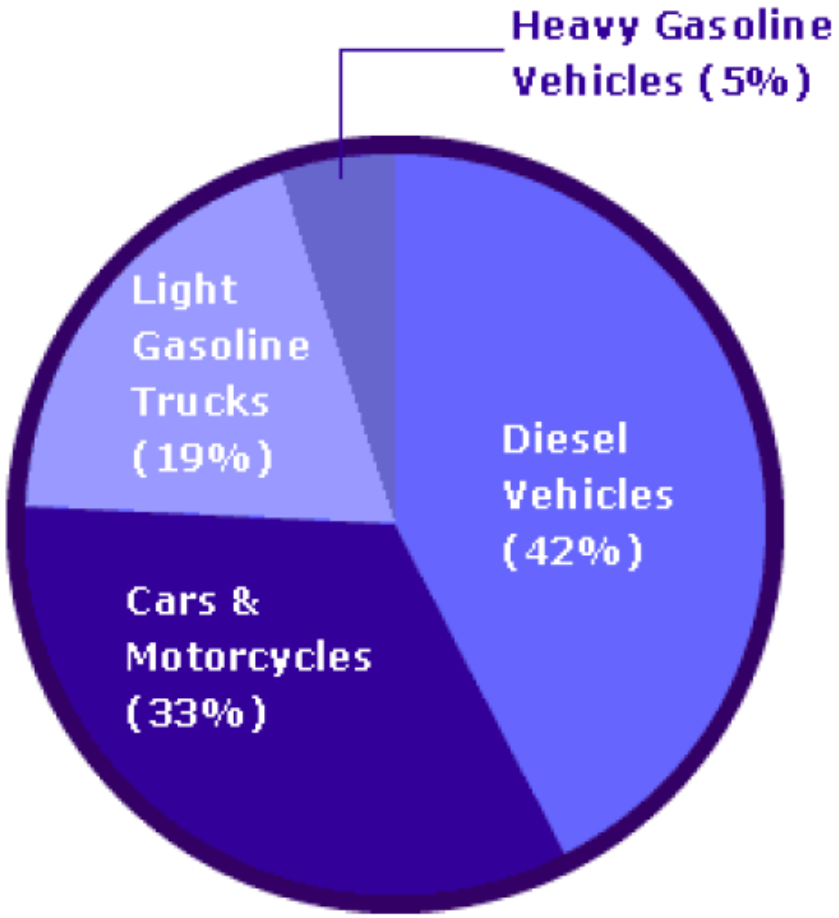
(MOVES Defaults)



Source: M. Claggett, Ph.D., Resource Center, FHWA

National NOx by Source

(On-Road Mobile, 1999)



Source: OTAQ, US EPA

Running Emissions

Rates/Distance

Running Emissions
(County Data Manager)

- ✓ Facility based drive cycles
  - Urban Freeway, Urban Non-freeway, Rural Freeway, Rural Non-freeway
- ✓ Emissions inventory (SIP)
  - VMT & Speed
    - Inventory within MOVES modeling system
  - Emission rates option
    - RatePerDistance
    - Unit: mass/distance (e.g., grams/mile)

Note:
- RatePerVehicle
  - Grams/vehicle for start emissions
- RatePerProfile
  - Grams/vehicle for temperature profile
  - Vary by day, hour, temperature, and previous hour temperature

MOVES Drive Schedules

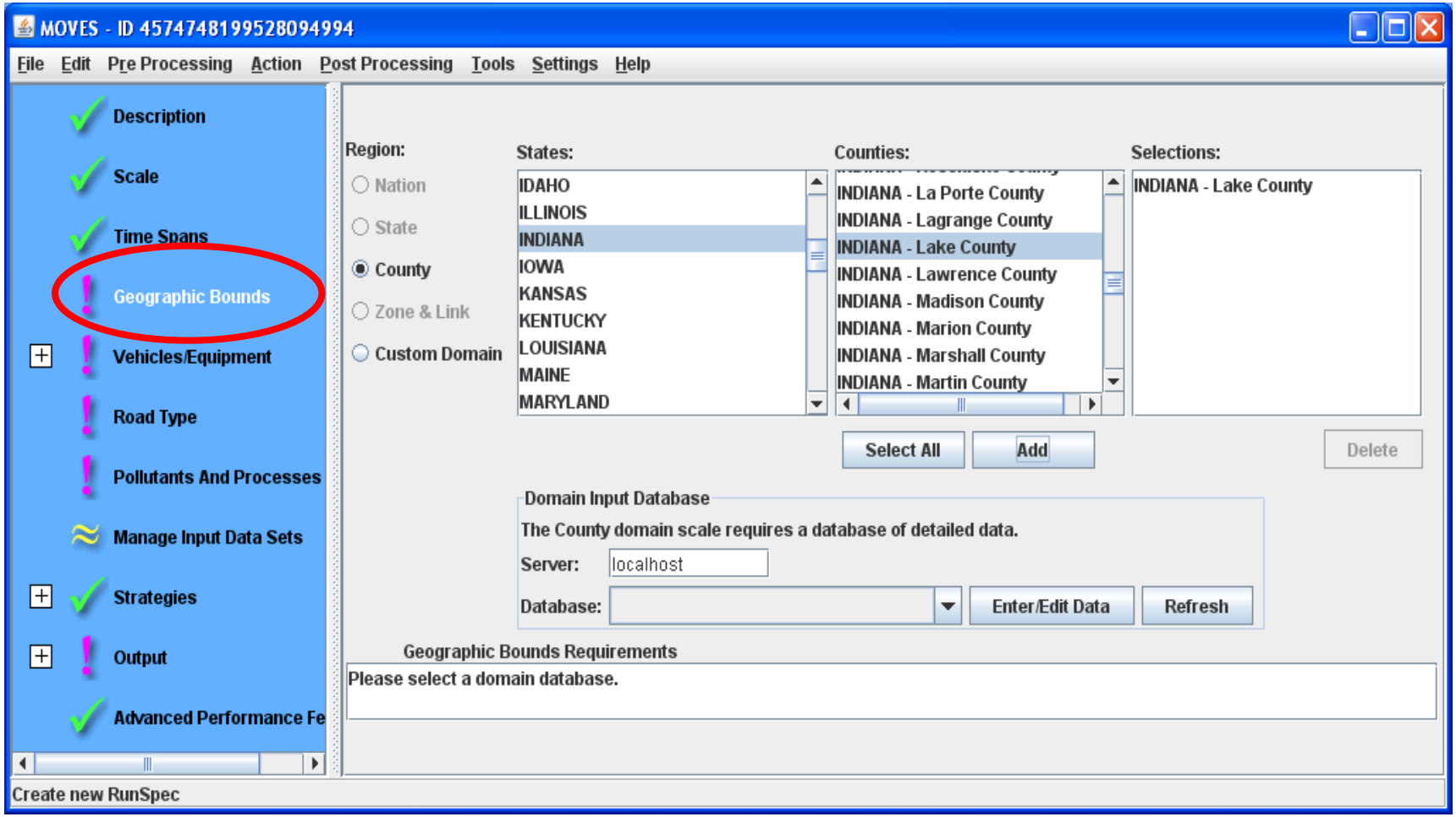
Drive Schedule Set	DriveScheduleName(ID)	AverageSpeed (mph)
Light-Duty Non-Freeway	Low Speed 1 (101)	2.5
	New York City (102)	7.1
	Non-Freeway LOS EF (103)	11.6
	Non-Freeway LOS CD (104)	19.2
	Non-Freeway LOS AB (105)	24.8
Light-Duty Freeway	Freeway LOS G (151)	13.1
	Freeway LOS F (152)	18.6
	Freeway 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.

Travel Activity Data
(Running Emissions from VMT)

- ✓ Geographic Bounds Panel
  - Choose a single county from the list
    - Allows access to the available default data
  - Create a custom domain
    - Users must provide most data (very few defaults available)

Modeling Area



Start Emissions

Rates/Vehicle

Start Emissions

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

Sample Vehicle Trip Information
(Source Data)

Study	Study Area	Study Years	Vehicle Types	Number of Vehicles
3-City	Atlanta, GA; Baltimore, MD; Spokane, WA	**1992**	**Passenger cars & trucks**	**321**
Minneapolis	**Minneapolis/St. Paul, MN**	**2004-2005**	**Passenger cars & trucks**	**133**
Knoxville	**Knoxville, TN**	**2000-2001**	**Passenger cars & trucks**	**377**
Las Vegas	**Las Vegas, NV**	**2004-2005**	**Passenger cars & trucks**	**350**
Battelle	**California, statewide**	**1997-1998**	**Heavy duty trucks**	**120**
TxDOT	**Houston, TX**	**2002**	**Heavy, heavy duty diesel dump trucks**	**4**

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."

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* ≤ soak period < *upper-bound*.

Start Emissions
(County Data Manager)

- ✓ Off-network
- ✓ Incremental emissions per start
  - – Source Type Population
    - • # of vehicles in the county being modeled
  - – Grams per vehicle
    - • Soak time distribution
  - ❖ Separation of engine starts from VMT
    - ❖ Trip length issues (MOBILE6.2)
- ✓ Emissions inventory (SIP)
  - – Emissions are based on number of vehicles
    - • Inventory within MOVES modeling system
  - – Emission rates option
    - • RatePerVehicle
    - • Unit: mass/vehicle (e.g., grams/vehicle)

Note:

- RatePerProfile
  - – vehicles are at stationary (include vapor venting process)
  - – Vary by day, hour, temperature, and previous hour temperature

Number of Vehicle Starts
(in MOVES)

- ✓ Sample vehicle trace data
- ✓ No geographic bounds
  - I/I vehicle trips
  - I/E, E/I vehicle trips
- ✓ No seasonal, yearly variation
- ✓ Default number of starts per vehicle
  - Check with local data
  - Alternative source of data

Other Sources of Data
(Number of Engine Starts per Day)

- ✓ 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
- ✓ Good for cross check
- ✓ Research is needed to compare the results of instrumented vehicle study vs. trip O/Ds from TDF models
- ✓ Consult with EPA

1990 NPTS Data Reveals

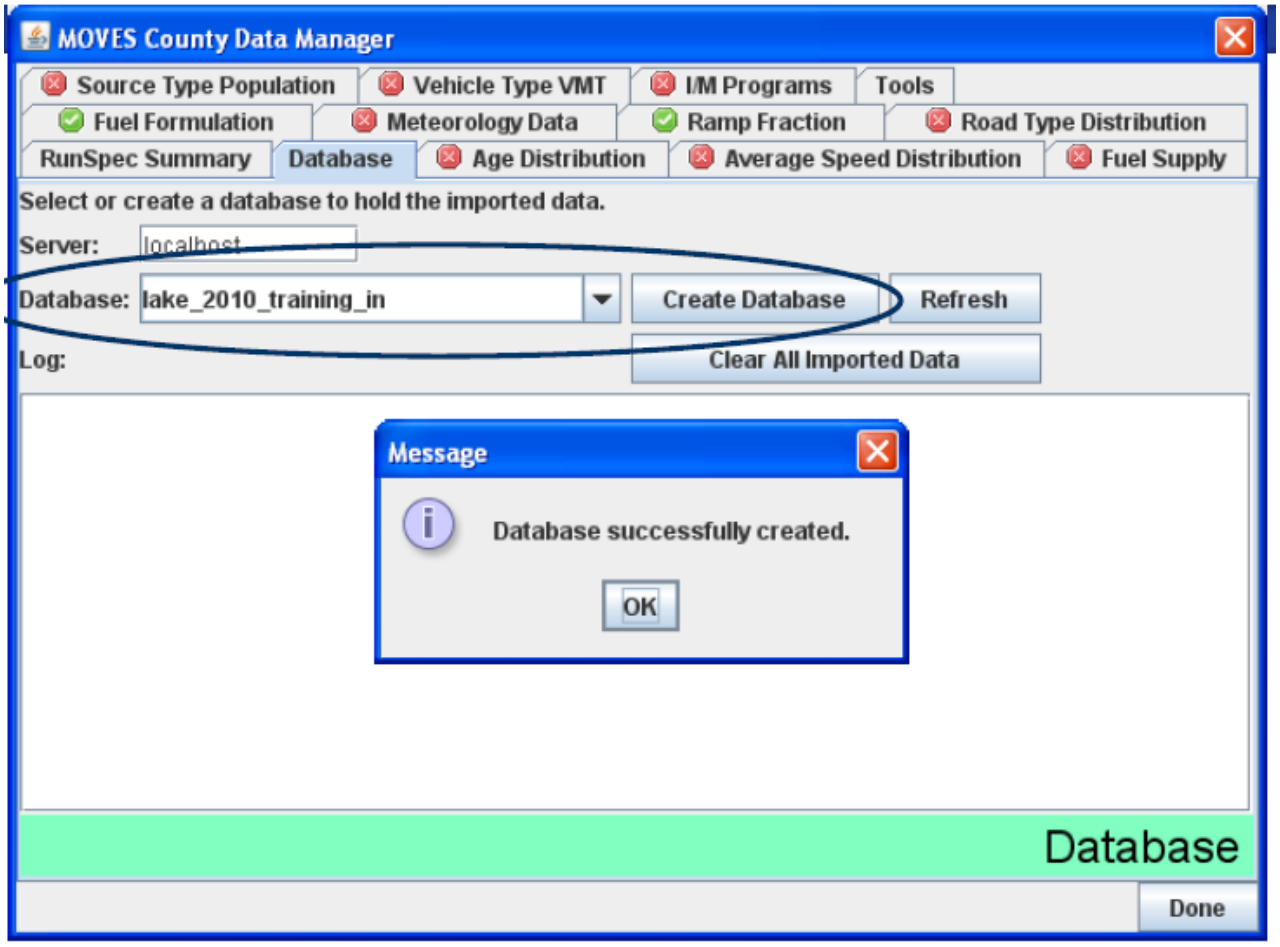
(Examples of Trip Making)

Average Daily Person Trips per Household by Number of Autos and Persons per Household in Various Transportation Studies

Household Size	Number of Autos	Mean Number of Trips												
		Nashua	Charlotte	Reno	Austin	Vancouver	Phoenix	Pittsburgh	Seattle	St. Louis	San Diego	Atlanta	New Jersey	NPTS
One Person	Zero Cars	1.00	1.55	1.79	2.12	3.29	1.56	3.32	4.08	1.70	3.27	0.78	1.38	1.47
	One Car	5.04	4.36	4.42	4.48	3.20	4.09	5.27	4.73	4.10	5.91	3.92	3.57	3.16
	Two Cars	4.00	4.43	4.97	5.33	3.52	5.22	5.00	4.34	4.16	5.79	3.62	3.84	3.51
	Three Cars Plus	0.00	3.60	3.89	4.00	4.23	4.58	0.00	4.88	6.20	8.38	4.72	2.00	3.82
Two Person	Zero Cars	0.00	2.29	2.75	2.80	2.00	3.03	4.43	4.37	5.08	7.35	2.47	3.33	3.29
	One Car	7.58	7.40	6.30	5.13	3.50	6.54	8.86	4.50	6.48	10.24	6.44	5.68	4.63
	Two Cars	7.26	7.64	7.22	7.18	4.72	7.37	7.66	4.49	7.60	10.88	7.10	6.62	5.53
	Three Cars Plus	7.60	9.43	8.21	7.96	4.87	7.39	6.75	4.77	8.02	12.31	8.61	8.29	6.00
Three Person	Zero Cars	2.67	5.43	3.67	7.25	5.00	5.75	6.40	5.60	6.09	11.40	5.62	4.50	4.82
	One Car	7.18	8.29	8.29	6.73	5.40	7.21	10.10	5.27	9.46	14.23	10.33	6.00	6.66
	Two Cars	10.02	10.45	8.38	9.19	5.82	10.21	10.88	4.76	9.52	15.80	10.08	7.76	7.53
	Three Cars Plus	10.28	11.15	11.01	10.09	7.40	10.73	11.43	4.81	12.05	16.46	10.74	10.02	8.20
Four Person Plus	Zero Cars	0.00	7.75	0.00	6.40	14.00	4.79	7.40	3.86	12.86	12.25	10.78	4.56	6.85
	One Car	10.20	12.82	10.62	10.58	7.19	10.38	12.86	4.94	10.40	20.42	14.28	7.20	9.10
	Two Cars	12.27	16.26	14.32	11.42	7.70	13.26	14.75	4.75	14.98	24.41	15.76	11.33	11.07
	Three Cars Plus	11.81	17.62	15.26	13.91	10.16	15.33	16.25	4.93	16.63	25.09	16.28	14.16	11.37
Average Rate		10.08	9.29	8.58	7.99	5.82	8.98	10.72	4.69	9.05	14.30	8.22	7.75	6.70

Nashua (may be Wausau?), Charlotte, Reno, Austin, Vancouver, Phoenix, Pittsburg, Seattle, St. Louise, San Diego, Atlanta, New Jersey, NTPS

County Data Manager



County Data Manager
(Input Data)

- ✓ Default data available
  - I/M programs
  - Fuel formulation
  - Meteorology data
  - Ramp fraction
  - Average speed distribution
  - Fuel supply
  - Month, day, and hour VMT fractions
- ✓ Source type population
- ✓ Vehicle type VMT
- ✓ Road type distribution
- ✓ Vehicle age distribution

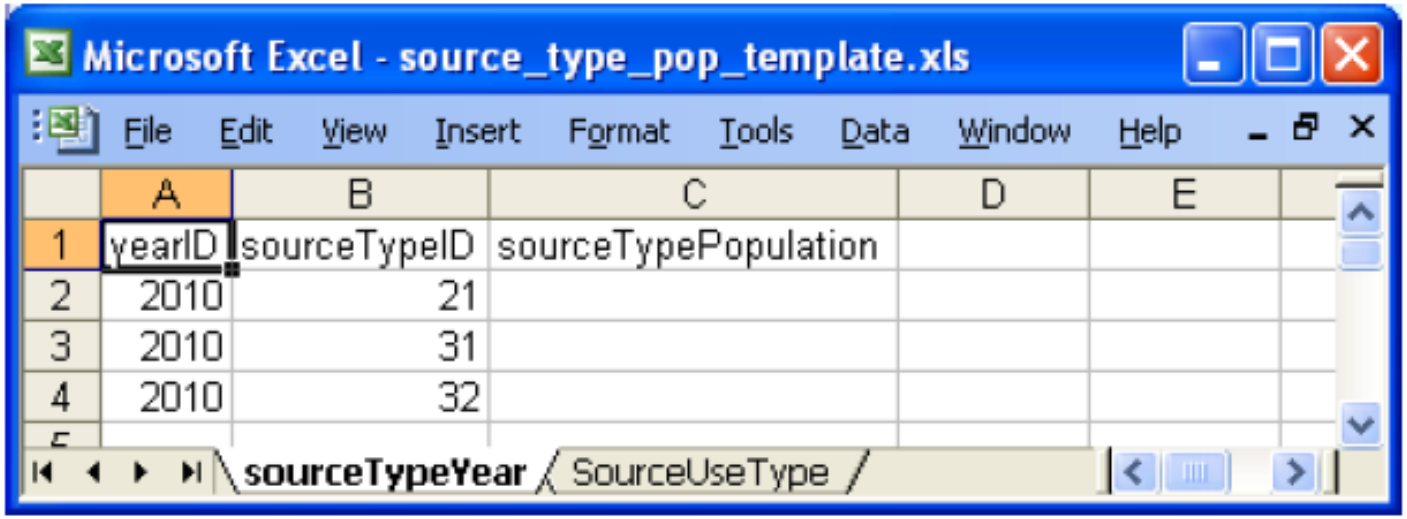
Developing Travel Activity Data
(CDM Inputs)

- ✓ MOVES Technical Guidance
- ✓ EPA developed tools
  - Convert MOBILE6-based input to MOVES input
  - SPEED VMT => AvgSpeedDistribution

- ✓ Source Type Population (SourceTypeYear)
- ✓ Ramp Fraction (RoadType) (optional)

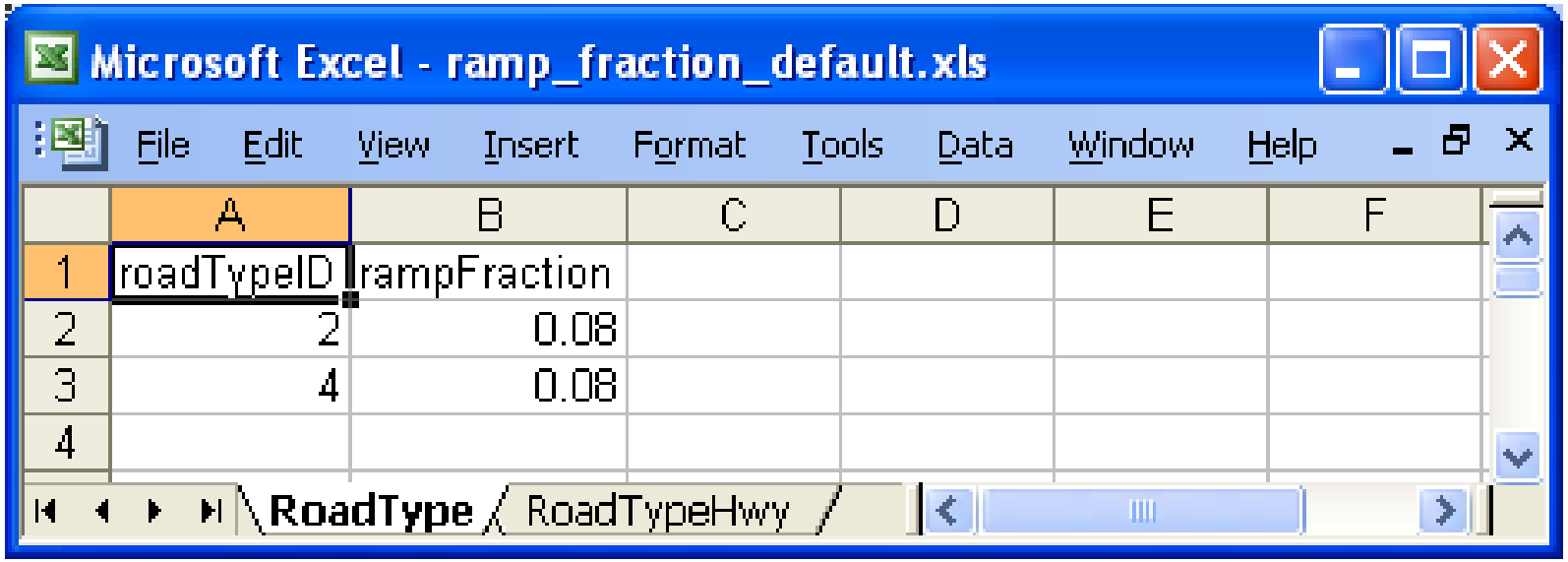
Source Type Population
(Start Emissions)

- ✓ Source Type Population is the actual number of vehicles within a source type in the county being modeled



Ramp Fraction (RoadType)

- ✓ Fraction of Time (VHT not VMT)
- ✓ Default fraction (0.08)



Ramp Fraction

Table 1

2005 Montgomery County Ozone Day Emission Comparison for Ramp Scenarios

Restricted Access Facilities

		Default	VMT Approach		Difference	
		VHT=8%	Non_ramp	Ramp	Absolute	%
VMT			7,930,289	207,983 (2.6%)		
VOC T/d	Running	1.83	1.66	0.08 (5.1%)		
	Total	1.83	1.75		-0.09	-4.7%
NO x T/d	Running	13.03	12.12	0.52 (4.3%)		
	Total	13.03	12.64		-0.38	-3.0%

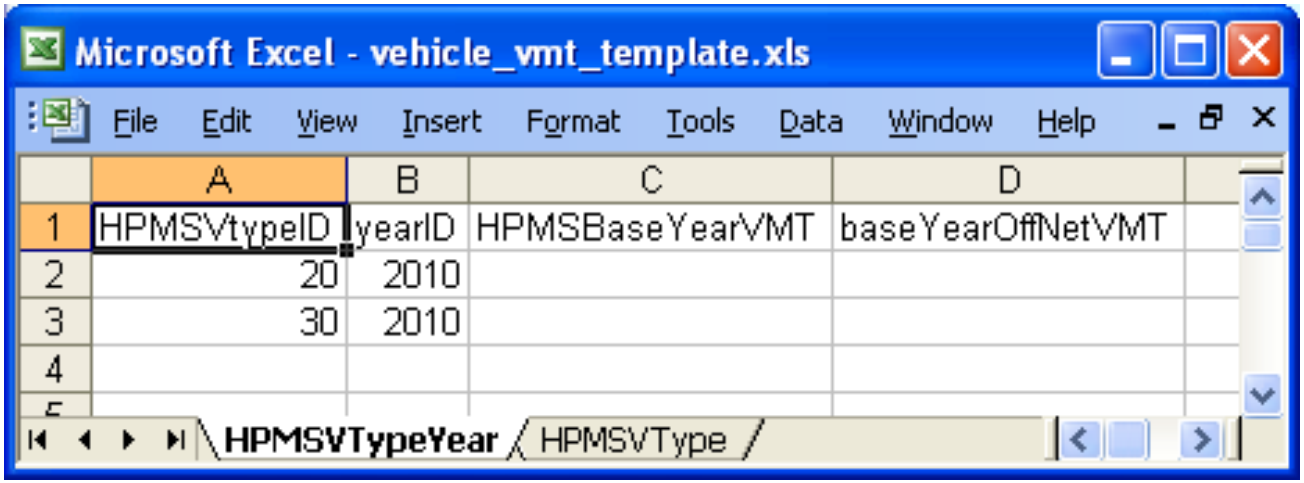
Source: Eulalie Lucas, Dept of Trans. Planning, MWCOG

Developing County Inputs (Cont'd)

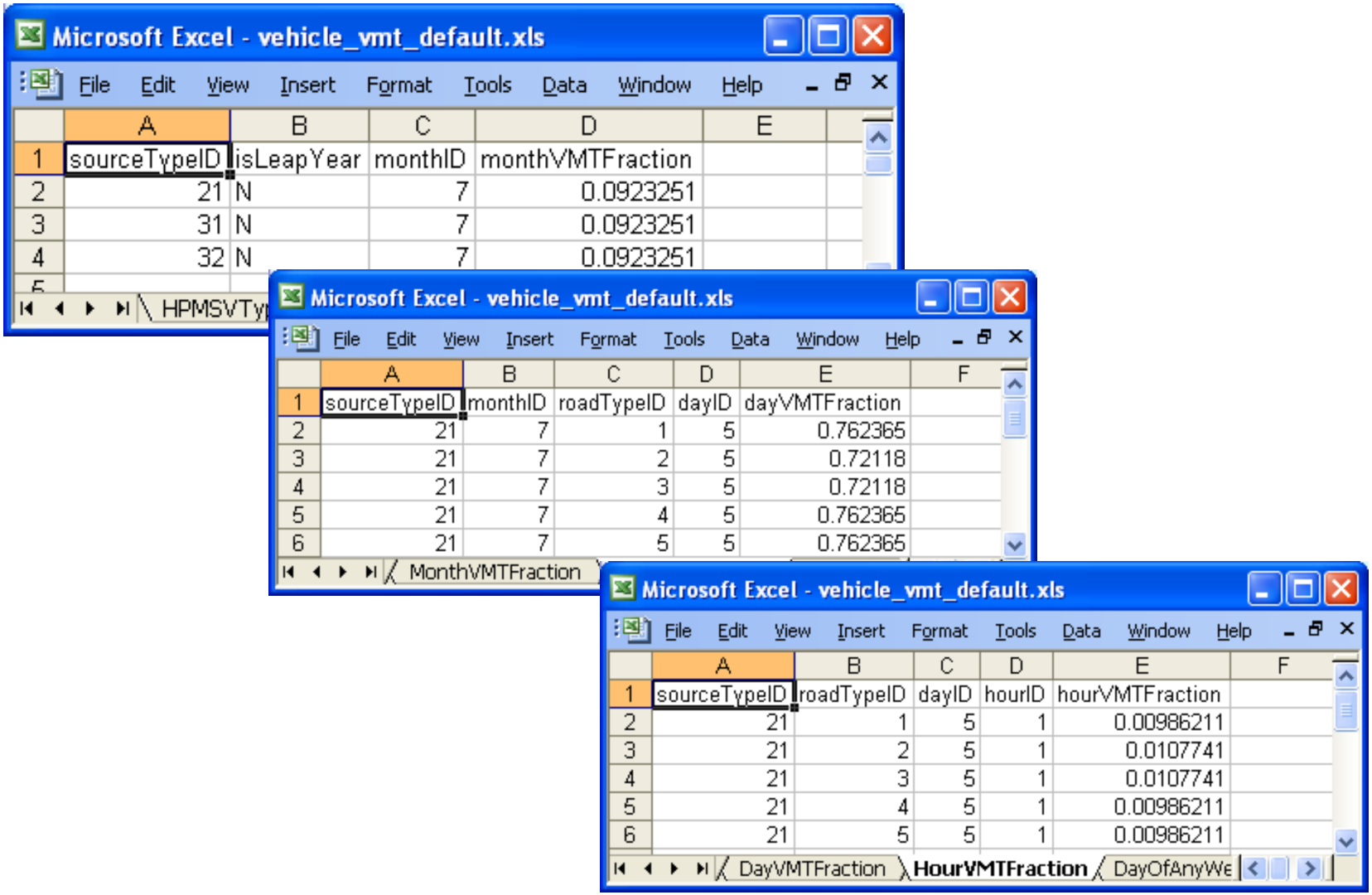
- ✓ Vehicle Type VMT (HPMSVTypeYear)
  - Total annual VMT by HPMS vehicle type
- ✓ Month VMT Fraction, Day VMT Fraction, Hour VMT Fraction
  - Allocate annual VMT by month, day (weekday vs. weekend), and hour

Vehicle Type VMT (HPMSVTypeYear)

- ✓ VMT for each HPMS vehicle class
- ✓ Converters can be used to map VMT from MOBILE vehicle classes to HPMS vehicle classes
- ✓ AADVMT Calculator can be used to scale daily VMT up to yearly VMT



Month, Day, and Hour VMT Fraction

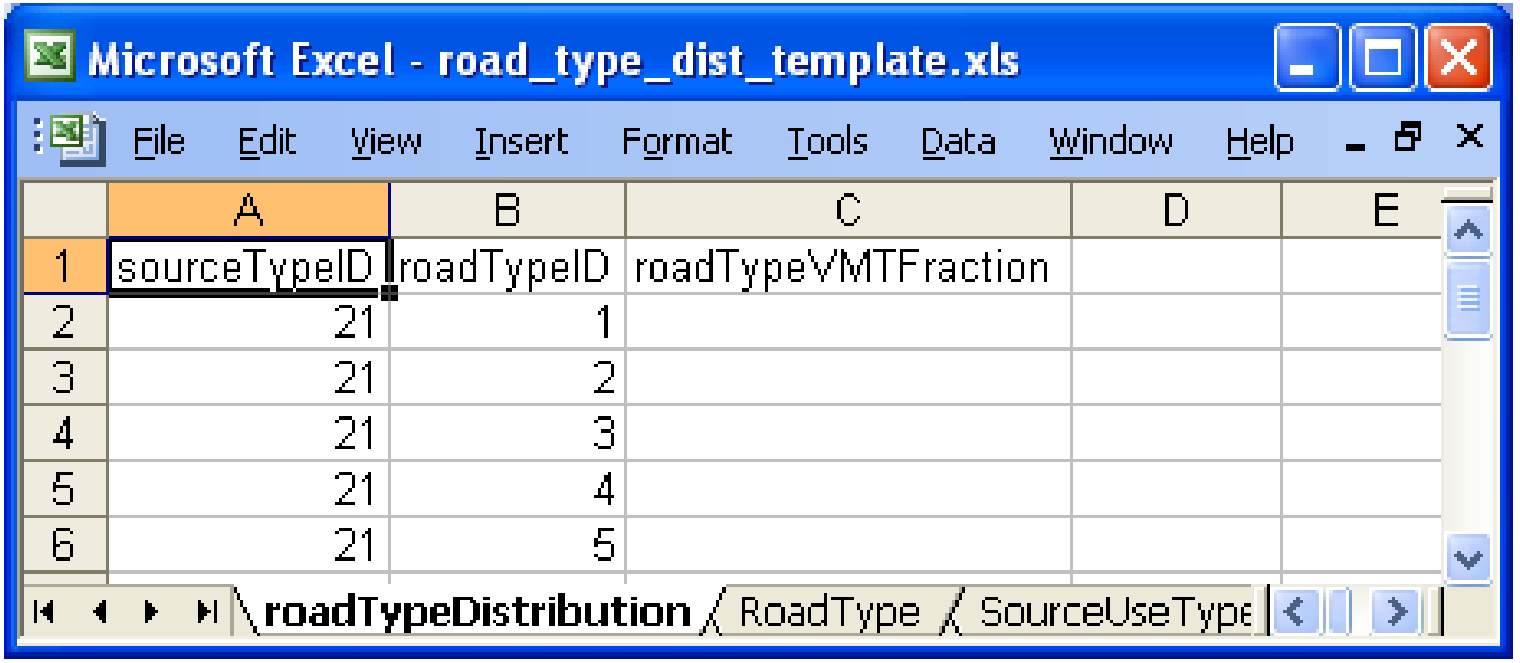


Developing County Inputs (Cont'd)

- ✓ Road Type Distribution
  - Similar to MOBILE6.2 "VMT BY FACILITY"
- ✓ Age Distribution
  - Similar to MOBILE6.2 "REG DIST"
- ✓ Average Speed Distribution
  - Similar to MOBILE6.2 "SPEED VMT"

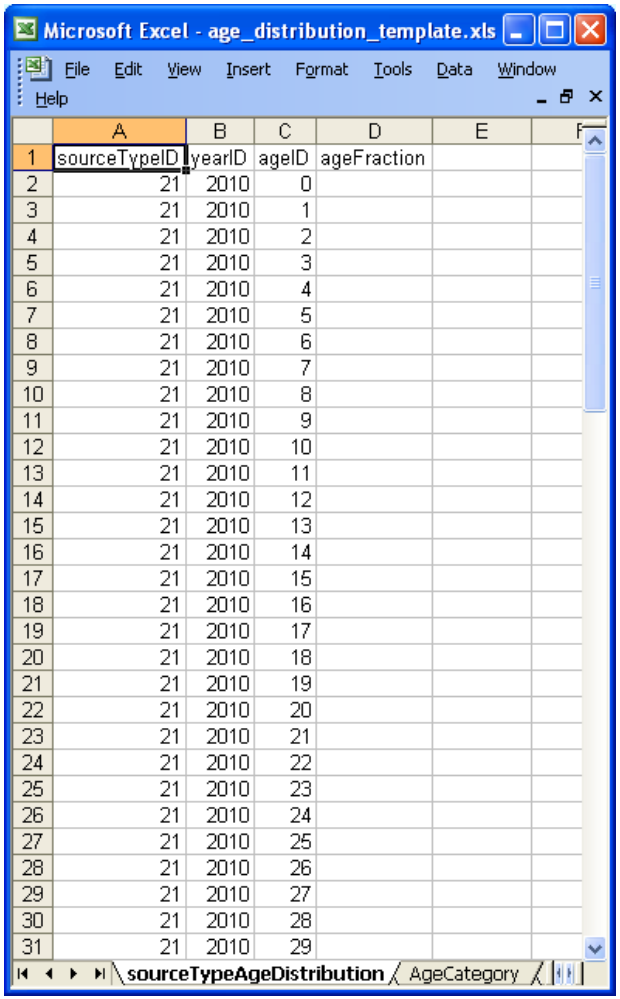
Road Type Distribution
(RoadTypeDistribution)

- ✓ For each source type VMT fraction should sum to 1
- ✓ Always “0” for road type “1”



	A	B	C	D	E
1	sourceTypeID	roadTypeID	roadTypeVMTFraction		
2	21	1			
3	21	2			
4	21	3			
5	21	4			
6	21	5			

SourceTypeAgeDistribution

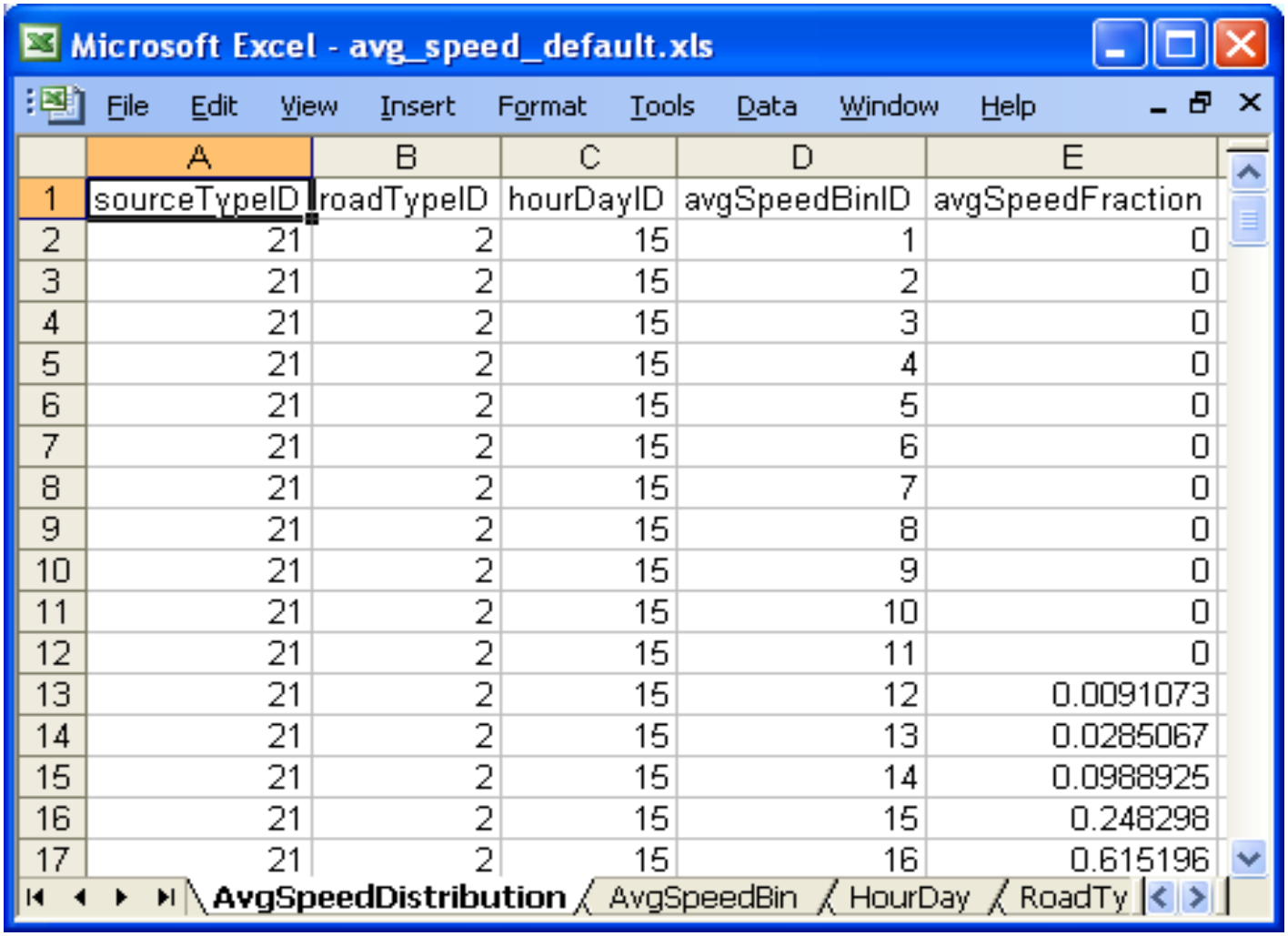


	A	B	C	D	E
1	sourceTypeID	yearID	ageID	ageFraction	
2	21	2010	0		
3	21	2010	1		
4	21	2010	2		
5	21	2010	3		
6	21	2010	4		
7	21	2010	5		
8	21	2010	6		
9	21	2010	7		
10	21	2010	8		
11	21	2010	9		
12	21	2010	10		
13	21	2010	11		
14	21	2010	12		
15	21	2010	13		
16	21	2010	14		
17	21	2010	15		
18	21	2010	16		
19	21	2010	17		
20	21	2010	18		
21	21	2010	19		
22	21	2010	20		
23	21	2010	21		
24	21	2010	22		
25	21	2010	23		
26	21	2010	24		
27	21	2010	25		
28	21	2010	26		
29	21	2010	27		
30	21	2010	28		
31	21	2010	29		

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)

AvgSpeedDistribution

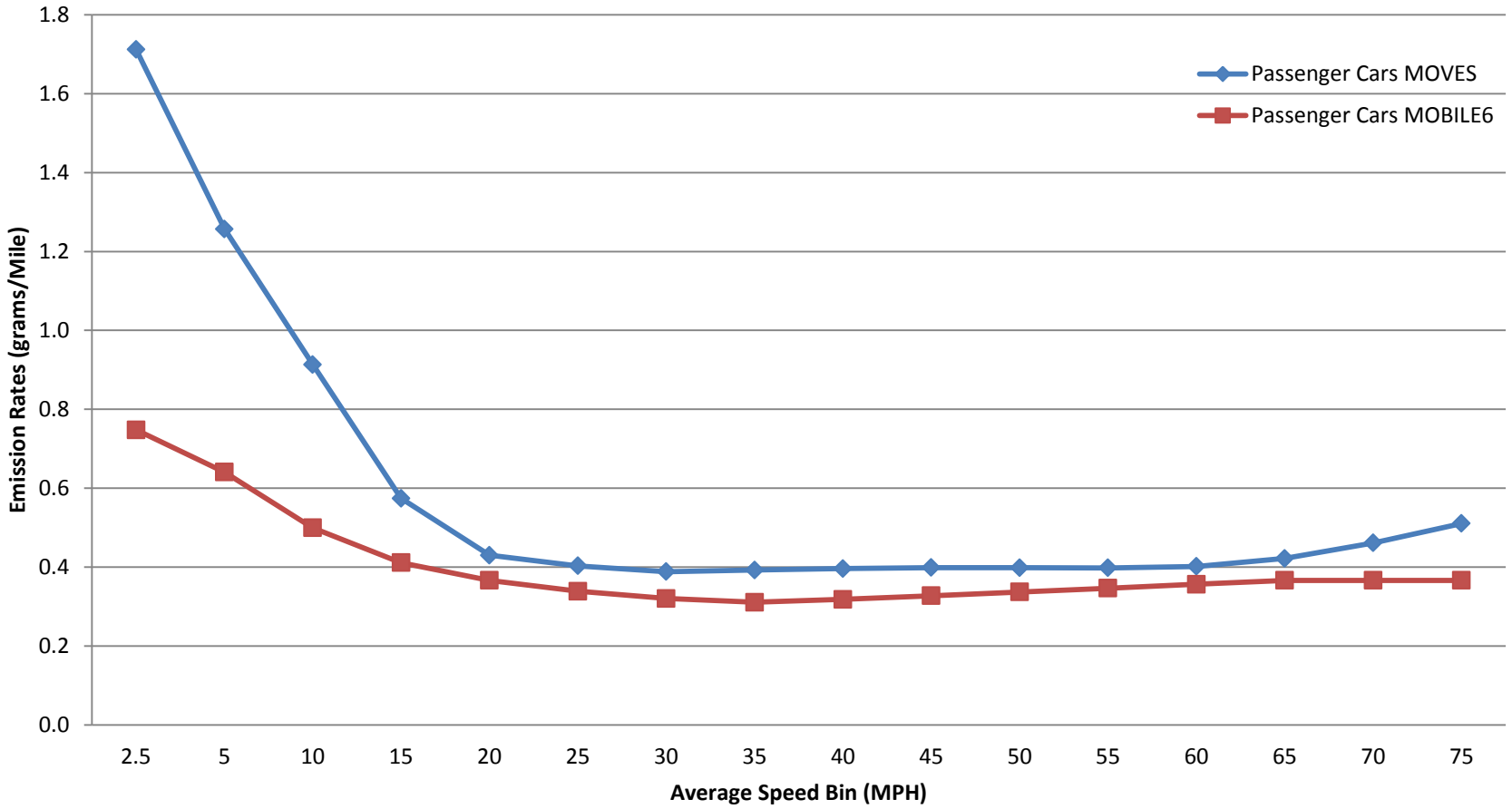

Microsoft Excel - avg_speed_default.xls

File Edit View Insert Format Tools Data Window Help

	A	B	C	D	E
1	sourceTypeID	roadTypeID	hourDayID	avgSpeedBinID	avgSpeedFraction
2	21	2	15	1	0
3	21	2	15	2	0
4	21	2	15	3	0
5	21	2	15	4	0
6	21	2	15	5	0
7	21	2	15	6	0
8	21	2	15	7	0
9	21	2	15	8	0
10	21	2	15	9	0
11	21	2	15	10	0
12	21	2	15	11	0
13	21	2	15	12	0.0091073
14	21	2	15	13	0.0285067
15	21	2	15	14	0.0988925
16	21	2	15	15	0.248298
17	21	2	15	16	0.615196

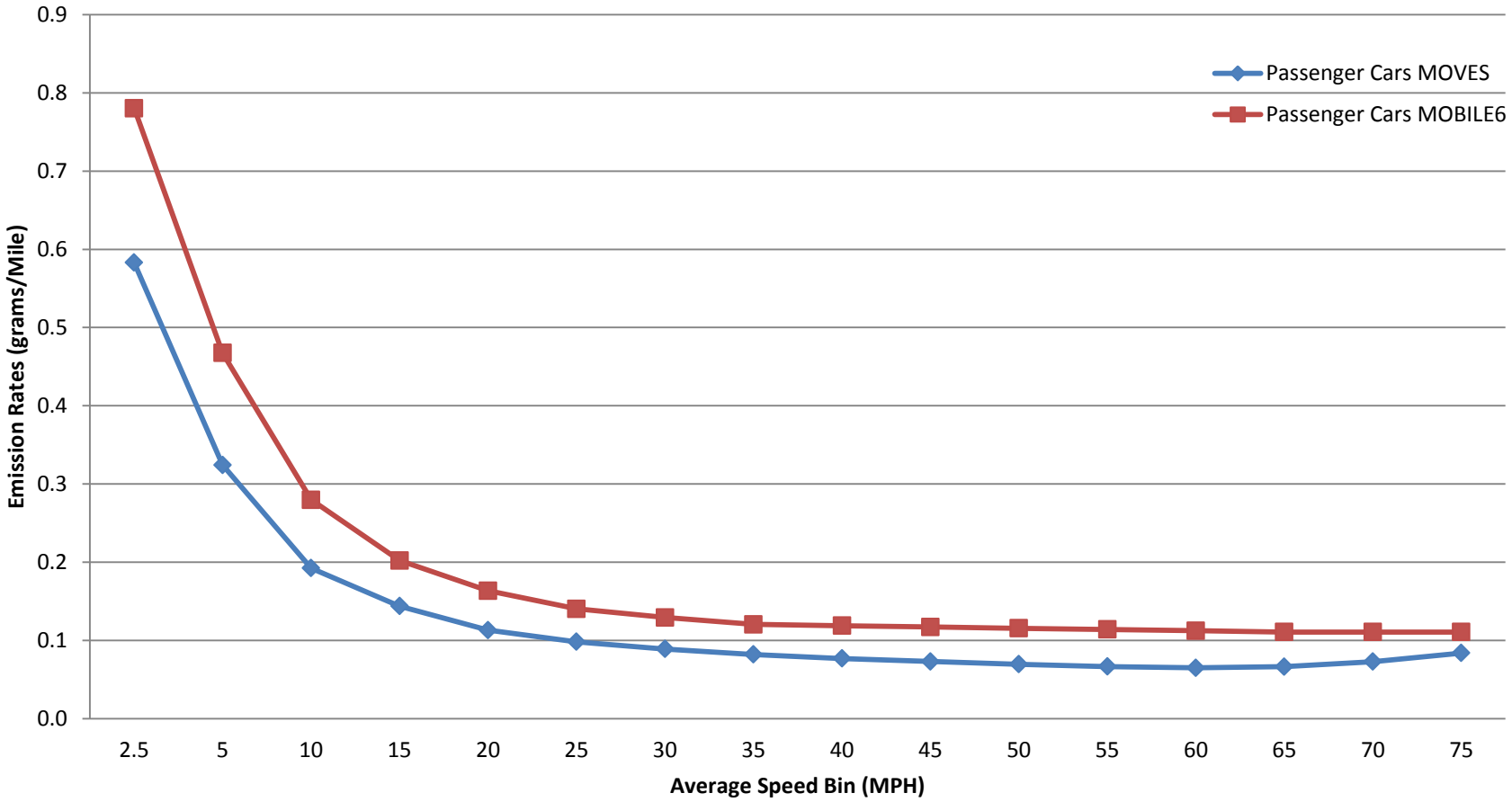
AvgSpeedDistribution | AvgSpeedBin | HourDay | RoadTy

NOx Emission Rates for Passenger Vehicles
(MOVES vs. MOBILE6)



Source: Madhusudhan Venugopal, North Central Texas Council of Governments

VOC Emission Rates for Passenger Vehicles
(MOVES Vs MOBILE6)



Source: Madhusudhan Venugopal, North Central Texas Council of Governments

Closing Remarks

- ✓ Source Type Population
  - Start & evaporative emissions
  - Impacts on (HC vs. NOx)
- ✓ Ramp Fraction
  - VHT fraction
  - VMT fraction (MOBILE6.2)
- ✓ Vehicle Age Distribution
  - Vehicle ages increased significantly in recent years
- ✓ Average Speed Distribution
  - ❖ NOx on low operating speeds (congestion management)

The End

Reference Materials

Not for Presentation

Emission Processes

(MOVES vs. MOBILE6)

Emission Processes	MOVES			MOBILE6
	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